tumi
E-Bus Mission

Supporting and Building Capacity in Monitoring and Evaluating Pilot E-Bus Implementations

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Prepared by ITDP

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ICLEI Local Governments for Sustainability
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Executive summary

In Indonesia, the transport sector contributed around 27% of national GHG emission in 2019, there is no time to delay taking actions to decarbonize motorized vehicles. As the first city in Indonesia piloting e-buses, Jakarta has started e-bus trials using different bus models since 2019, Transjakarta operated 2 e-buses without carrying any passengers as a trial. After this, the formal pilot was carried out in March 2022, equipped with 30 brand new BYD K9 e-buses running on routes 1P and 1N. However, facing the new challenges of operating e-buses, Transjakarta and its operators need support to fill skill gaps and settle into the system.

ITDP together with TUMI E-bus Mission developed a technical assistance plan to support the pilot e-bus monitoring and evaluation in Jakarta. The team has set up an evaluation methodology consisting of four areas: vehicle performance, operating performance, environmental performance, and social and gender performance. Using the data provided, the team analyzed the vehicle performance on different days, months, and routes. Although results showed superior vehicle performance despite a few variations in different conditions, e-buses are running 19.5 kilometers invalid operating distance from terminus to depot. The team also conducted Training Needs Assessment with stakeholders involved in the electrification process. The survey outcomes revealed the urgent priority to upskill e-bus monitoring and Intelligent Transport Management Systems, along with limited technical and financial support from Transjakarta and government officials.

Based on these analyses, the team proposed five recommendations for larger-scale e-bus deployment in Jakarta:

- Provide both technical and fiscal support on e-bus operations and charging infrastructure
- Incorporate detailed data collecting and sharing mechanism
- Upgrade the e-bus control center and build capacity on Intelligent Transportation System
- Develop a long-term sustainable business model
- Summarized experiences gained and lessons learned from the pilot project

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Contents

Section Three: Recommendations

List of figures

List of tables

Section One:

Project overview

1. Project background

Jakarta transport system

Jakarta is a metropolitan city located in the northern part of the island of Java with an area of 661.5 km^2. While the immediate metro area has an estimated 10 million residents, the Greater Jakarta (also known as “Jabodetabek”) increases that number. The population of the Jakarta metropolitan area, with an area of 6,437.68 km2 (2,485.60 sq mi), is 31.24 million according to the Indonesian 2020 Census. This high population number is the result of the high rate of urbanization and as a result, is the second largest megacity in the world.

Today, Jakarta has several mass public transportation systems operating, i.e. the road-based bus rapid transit (Transjakarta), MRT, LRT, and commuter rail. In addition, there are also the airport train connection and regular buses operating outside the Transjakarta system. However, the use of private vehicles remains high and causes various mobility and environmental issues, such as traffic congestion and worsening air quality.

Private vehicle usage only increased during the COVID-19 pandemic. Prior to the pandemic, the use of public transportation in Jakarta reached 9.86% and decreased to 4.21% during the pandemic (April-December 2020). The increasing number of private vehicles on the road further exacerbated existing issues, especially tailpipe greenhouse gas and air pollutant emissions.

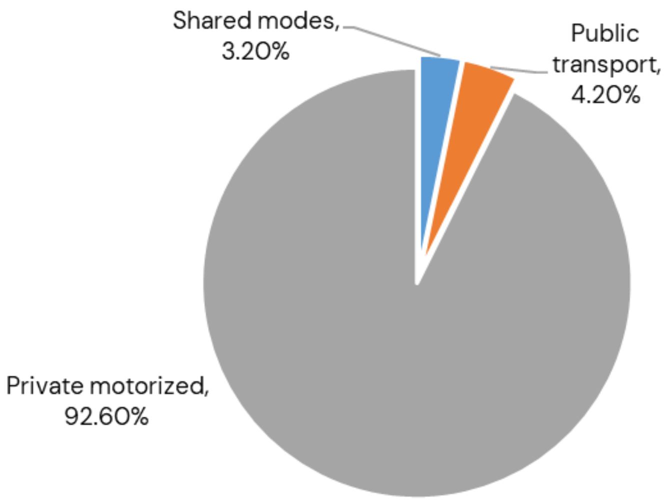

Figure 1 Jakarta modal split during the pandemic (April to December 2020)

Given the high use of motorized vehicles, the transport sector’s contribution to GHG emission and air pollution, as well as energy consumption, is enormous: the sector contributed around 27% of national GHG emission in 2019 and more than 40% of national energy consumption. Similar conditions are also happening in Jakarta. The current bus fleet, in particular, is a significant GHG emitter in the city.

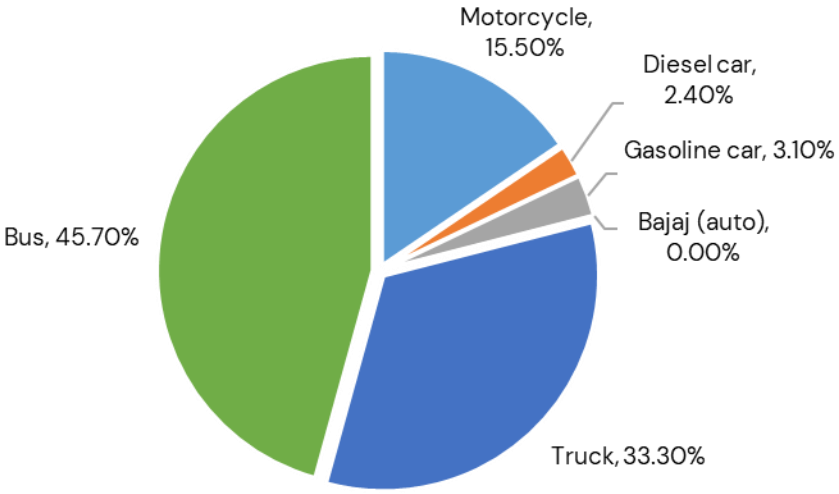

Figure 2 GHG emission by transport mode in Jakarta in 2019

Fortunately, the national government has acknowledged the need to reduce GHG emissions and air quality at the national and local levels. As a result, Indonesia has committed to reducing greenhouse gas emissions to 29% by 2030. At the local level, there is an Air Quality Control policy that includes instructions to accelerate public transport fleet renewal and to implement a more stringent emission standard for public transport fleets. Moreover, based on the Jakarta Transportation Master Plan, as stated in Presidential Regulation No. 55/2018, Jakarta targets 60% of public transport mode share in the Greater Jakarta area by 2030. Jakarta also plans to implement two low-emission zones as well as other “push” policy measures such as increased parking fares and congestion pricing.

As part of the efforts to reduce the GHG emissions from the transport sector, the government envisioned a national transition to electric mobility, which was kickstarted through the Battery Electric Vehicle Acceleration Program. In particular, for the public transport segment, Indonesia set the targets to have 10% electric public transport fleet by 2025 and 90% by 2030, according to the Ministry of Transport’s public transport electrification roadmap.

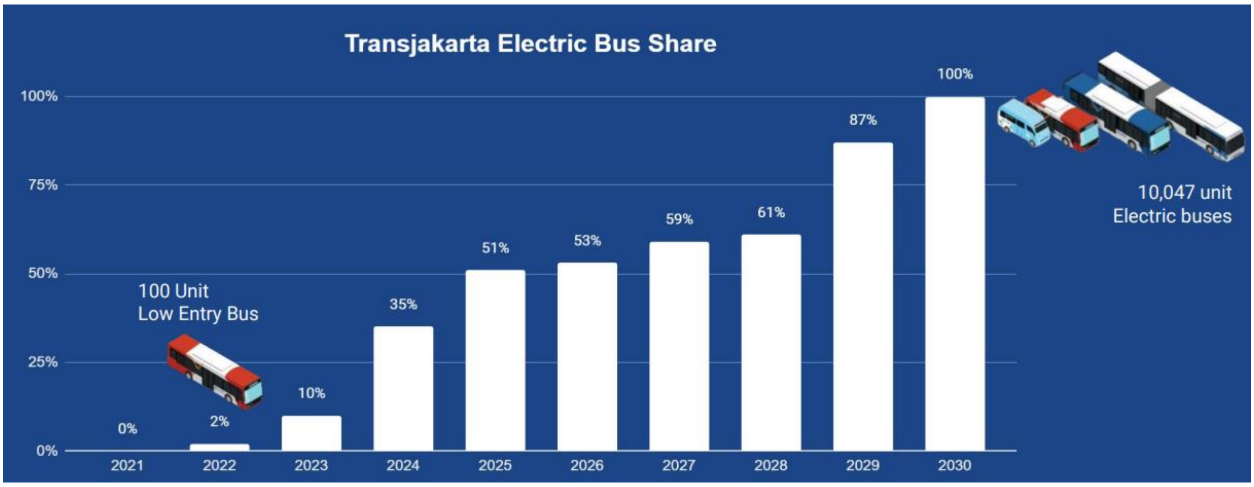

Figure 3 Transjakarta's target on e-bus share

In Jakarta, Transjakarta also has already stated its ambitious plan to deploy 10,047 electric bus fleets, or 100% of its fleets, by 2030 in their Long-term Corporate Plan 2020-2030. As baseline information, the current fleet of Transjakarta by 2020 can be segmented as follows, based on the type of bus and propulsion technology:

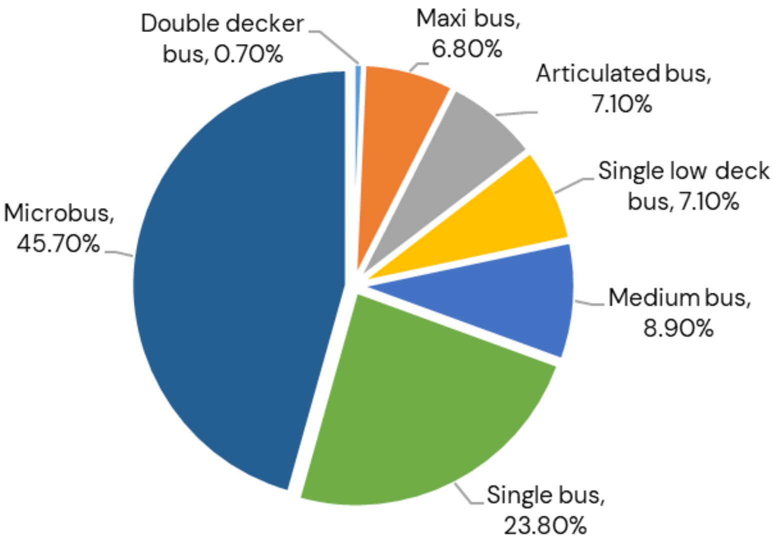

Figure 4 Number of Transjakarta buses unites by vehicle type in 2020

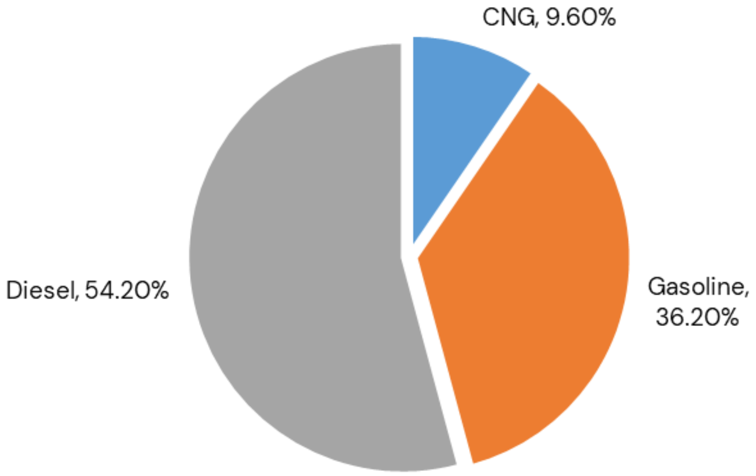

Figure 5 Number of Transjakarta buses by vehicle technology (2020)

TUMI E-bus Mission

On behalf of the German government, German technical cooperation (GIZ), together with the partners C40 Cities, The International Council on Clean Transportation (ICCT), The Institute for Transportation and Development Policy (ITDP), ICLEI – Local Governments for Sustainability, The International Association of Public Transport (UITP) and World Resource Institute (WRI) is implementing the TUMI E-Bus Mission until the end of 2025.

The aim of the Transformative Urban Mobility Initiative (TUMI) E-Bus Mission is to establish a broad coalition of public- and private-sector organizations to help accelerate the procurement and transition of e-buses within 20 "deep dive cities" and to scale this further in 100 additional cities by 2025. The project is part of the German government's Action towards Climate-friendly Transport (ACT)-Initiative, launched at the UNSG Summit in September 2019.

Jakarta is one of the selected deep-dive cities to receive technical assistance support from this initiative. The goal of the TUMI E-bus Mission in Jakarta will continue the pathway to achieve Transjakarta's target of 10,000 electric buses by 2030 and achieve greater impacts on greenhouse gas emissions through assisting the pilot electric bus program and future potential electrification of additional BRT corridors. The technical assistance provided by ITDP focused on supporting and building the capacity of Transjakarta in monitoring and evaluating its pilot e-bus implementations.

2. Current Initiatives for Transjakarta Electric Bus Deployment

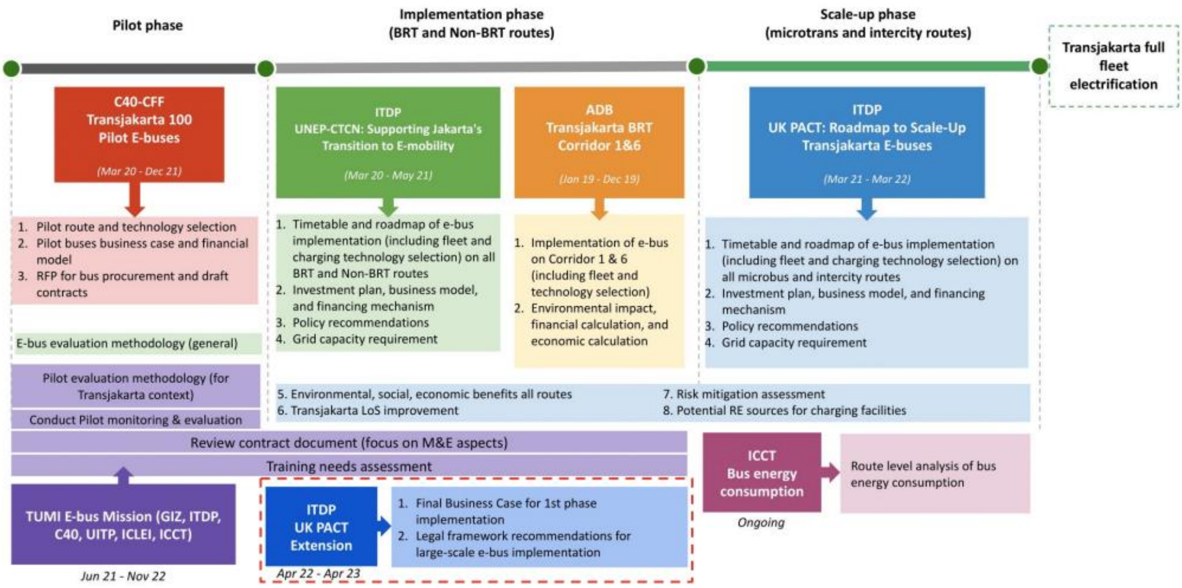

Figure 6 Initiatives for Transjakarta e-bus deployment

Since 2019, there have been a number of technical assistance programs supported and implemented by various institutions such as C40-CFF, UNEP, CTCN, ADB, UK PACT, and ITDP Indonesia. The programs mostly focus on the initial planning of the electric bus deployment, to reach the goal of 10,000 e-buses by 2030. An illustration of the scopes of the programs is shown above, dividing various technical assistance programs in the pilot phase, the implementation phase of BRT and non-BRT routes, and the scaled-up implementation phase of Mikrotrans (microbus) services and intercity routes.

3. The Progress of Jakarta Pilot E-bus Project

The Jakarta pilot e-bus project is the first electrification project in Indonesia. Due to the lack of strong policy support and domestic implementation experiences, the launch of the e-bus pilot faces significant challenges and difficulties, resulting in a severe lag in the pilot's progress. Since the pilot project was put forward in 2021, the operators purchased 30 electric buses in August 2021 and built an electric bus charging station with 10 charging piles from January to June 2022. Although it was expected that the pilot would get started later due to the lack of availability of charging infrastructure and vehicles at the end of 2021, by March 2022, only 4 e-buses had been put into operation. All 30 e-buses were parked at the depot for seven months without any utilization during this time. In June 2022, the rest of the 26 e-buses were on the road after staying at the depot for ten months.

The significant delay in the pilot project greatly impacted the project monitoring and evaluation. Since there was not enough data collected during the TUMI project period, the project team could not carry out comprehensive data analysis.

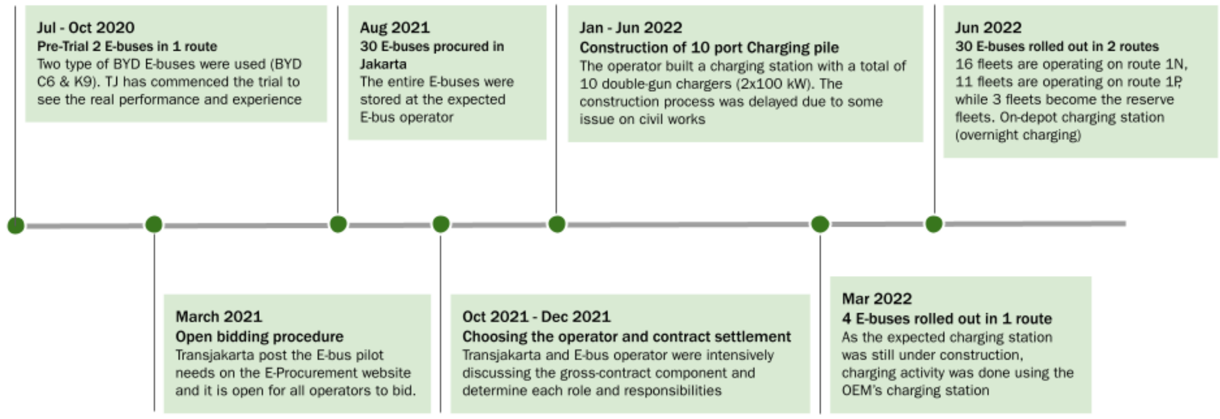

Figure 7 The pilot e-bus project timeline

Table 1 The pilot e-buses

Operating time	March to May 2022	June 2022 onward
Operator	Mayasari Bakti	
Contract	Gross-Cost Contract	
Bus model	BYD K9 (12m low deck, 324 kWh)	
Route and fleet quantity	4 units only at 1P (Bundaran Senayan – Terminal Senen)	11 units at 1P (Blok M – Terminal Senen); 16 units at 1N (Blok M – Tanah Abang)
Trip/day	Up to 7 – 8 Roundtrip	

Under the current operational model, 27 e-buses are in operation and 3 e-buses used as reserved fleet daily. At the end of 2022, it was planned that 100 e-buses will be operated on 3 routes: 1P (Blok M - Terminal Senen), 1N (Blok M - Tanah Abang), 6D (Stasiun Tebet - Bundaran Senayan).

Figure 8 Pilot e-buses parked in the depot

Figure 9 Pilot e-buses in operation

Figure 10 Charging station for pilot e-buses

4. TUMI E-bus Mission Project Scope and Methodology

The activities proposed for TUMI E-bus Mission will continue to support Transjakarta's target of 10,000 electric buses by 2030 and achieve greater impacts on greenhouse gas emissions through assisting the upcoming pilot electric bus program and future potential electrification of additional BRT corridors. The technical assistance provided by TUMI-GIZ and ITDP will focus on supporting and building the capacity of Transjakarta in monitoring and evaluating their pilot e-bus implementations. The detailed activities and outputs are as follows:

- **Activity 1**: Reassess and reaffirm evaluation methodology with Jakarta Transport Agency and Transjakarta
  Outputs:
  - Updated evaluation methodology for pilot electric bus implementation
  - Document and outline the importance of pilot project monitoring and evaluation
- **Activity 2**: Ensure readiness for pilot project monitoring and evaluation
  Outputs:
  - Develop pilot implementation monitoring and evaluation forms
  - Staff training on data recording and collection
  - A shared data collection platform
  - Review on the contract documents focusing on enabling pilot monitoring and evaluation
- **Activity 3**: Pilot project monitoring and evaluation
  Outputs:
  - A coordination protocol with Transjakarta for regular e-buses and chargers performance monitoring and data collection
  - Report on pilot e-buses real-world performance data analysis
  - Recommendations on e-bus technology specification, operation, and procurement for larger-scale e-bus implementation
- **Activity 4**: Training needs assessment (TNA)
  Outputs:
  - Training needs assessment survey questionnaire
  - Capacity improvement plan for electric bus implementation
- **Activity 5**: Capacity-building sessions for pilot project monitoring
  Outputs:
  - Capacity building workshop
- **Activity 6**: Document lessons learned from Transjakarta pilot e-bus deployment
  Outputs:
  - Documentation of lessons learned from Transjakarta pilot
  - Dissemination of lessons learned to other cities through mentee cities network

Section Two:

Technical assistant activities

1. Reassess and reaffirm evaluation methodology with Jakarta Transport Agency and Transjakarta

1.1 The importance of pilot project monitoring and evaluation

A pilot project is the starting point for larger-scale deployment of e-buses. It could help Transjakarta and other stakeholders to better understand the process and requirements of electrifying the bus system and prepare for the transition in the future. Therefore, e-bus pilots are crucial when cities are unfamiliar with e-bus technologies. It is even more important for these cities to monitor and evaluate the pilot performance by collecting and analyzing the real-world performance data of e-buses.

E-bus implementing entities could benefit from learning the energy consumption characteristics under different geographical regions, weather, and road conditions and recognizing the positive environmental impacts that e-buses bring to the city. Furthermore, by comparing the TCO of e-buses with ICE buses, the results from the monitoring and evaluation could guide the city in choosing the most cost-effective vehicle models and charging infrastructure from various OEMs, this will also provide reference information to other cities when launching e-bus projects.

For Transjakarta, the pilot monitoring and evaluation process is an opportunity to establish the e-bus performance data collection, sharing, and analysis mechanism in the future. Transjakarta could adopt the methodology proposed in the project as the framework for the preparation of future long-term monitoring and evaluation. The suggested raw data needed would help formulate the data-sharing agreements between Transjakarta and operators when signing contracts.

From the perspective of OEMs, pilot monitoring and evaluation have the potential to improve and upgrade their technologies to suit the needs of the city best. E-bus operators could work with the manufacturer to find out the issues in the vehicle design by analyzing the e-bus operational and failure data. The example from Shenzhen shows that the collaboration between operator and manufacturer can vastly improve the quality of e-bus and the efficiency of e-bus operation.

Government authorities will also benefit from e-bus performance monitoring and evaluation results. Because of the high capital cost of e-buses, financing the large-scale implementation of e-buses still relies on the subsidies provided by the local and national governments. Monitoring the performance of electric vehicles will help with planning the investment in electrification and deciding the amount of subsidies, thus formulating effective policies and reducing the financial burden of e-bus operators.

As the first e-bus pilot project in Indonesia, Jakarta's e-bus pilot findings are valuable for other organizations and City Network looking to accelerate the transition to electric buses. Lessons learned from the whole process could also be summarized and disseminated, making a useful reference for implementing e-buses in the future.

1.2 Pilot monitoring and evaluation methodology

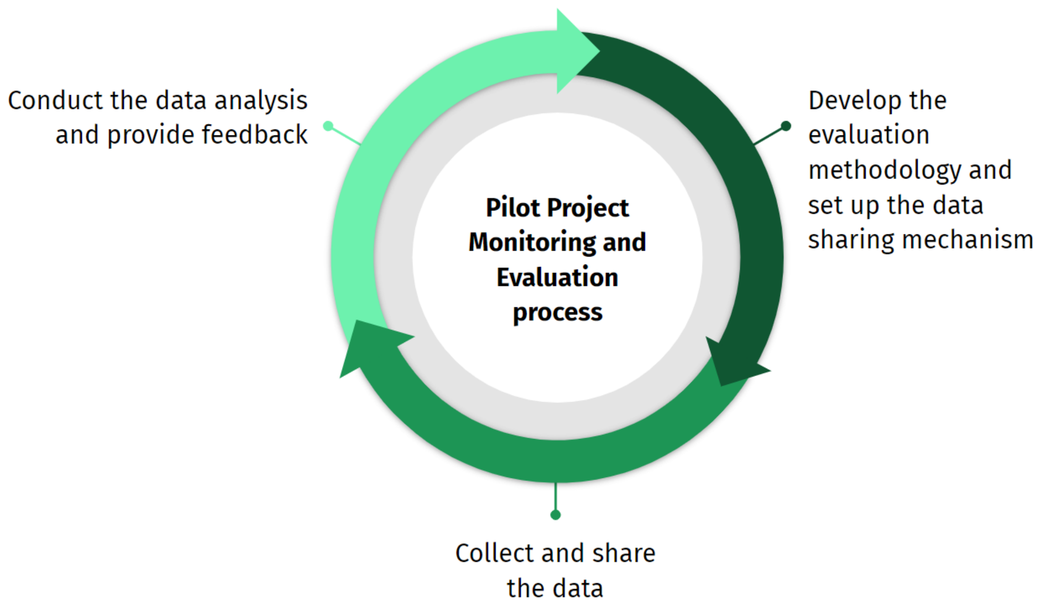

Figure 11 Pilot project monitoring and evaluation process

The monitoring and evaluation process for the e-bus pilot project should start with setting up the data sharing mechanism, which requires Transjakarta to first develop the data management strategy and the evaluation methodology. As a result, Transjakarta could reach an agreement with operators and e-bus manufacturers regarding what kinds of data are needed, the quality of data, the frequency of collecting and sharing data, and to share through which channel. They also should set up regular meetings to discuss the issues existing in the data and ensure the data verification is incorporated into the process. In this TUMI project, an updated evaluation metric will be proposed in 1.3, and the explanations of the data-sharing requirements will be discussed in chapter 2.

After the mechanism is established, operators or e-bus manufacturers could conduct the data collection and share based on the requirements of Transjakarta. And Transjakarta could use the data to further analyze the evaluation methodology. It should be noted the importance of giving feedback to the data provider in a timely manner, which could help Transjakarta to improve the evaluation methods and ensure the requirements are met, otherwise the efficiency of the whole process will be affected.

1.3 Pilot monitoring and evaluation metric

In order to help Transjakarta to conduct the pilot monitoring and evaluation, the project team developed a comprehensive pilot monitoring and evaluation metric based on experiences from China and other countries. The metric considers the daily operations and the sustainability aspects of the pilot project, including the operational efficiency, and economic, environmental, social and gender impacts. It is made up of 4 categories and 23 indicators, which are:

- Vehicle Performance, 7 indicators
- Operating Performance, 9 indicators
- Environment Impacts, 5 indicators
- Social and Gender Impacts, 2 indicators

Monitoring and Evaluation Metric	Vehicle Performance	• Energy consumption per km traveled • Seasonal variation rate of energy consumption per km traveled • Ratio of actual range to nominal range • Battery degradation rate per 10,000km traveled • Proportion of total failure durations to operating time • Failure rate per 10,000km traveled • Average action time
	Operating Performance	• Vehicle attendance rate • Average daily travel distance • Proportion of valid operating distance • Proportion of peak-hour charging duration • Average proportion of out-of-service vehicles • Maintenance cost per km traveled • Energy cost per km traveled • Operating cost per km traveled • Total cost of ownership per km traveled
	Environment Impacts	• Energy saved per e-bus per year • CO2 emission reduction per e-bus per year • Other pollutants emission reduction per e-bus per year • Carbon emission per passenger per km traveled • Other pollutants emission per passenger per km traveled
	Social and Gender Impacts	• Total number of PwD passengers using TransJakarta e-buses per year • Total numbers of TransJakarta e-buses drivers and maintenance staffs segregated by sex, age, and PwD status

Figure 12 Pilot monitoring and evaluation metric

This section will elaborate on indicators included in each category, and for each indicator, the primary data needed and frequency of collection for calculating each indicator within the metric will be explained. It should be noted that the data related to some indicators may not be available within the timeframe of the TUMI E-bus Mission, some indicators can only be obtained after e-buses are operated for a period of time, such as the seasonal variation rate of energy consumption per km traveled, and battery degradation rate per 10,000km traveled. But these aspects should be reviewed in future evaluations.

1.3.1 Vehicle Performance

The vehicle performance category focuses on efficiency and safety indicators. Through energy consumption per km traveled, specifically on seasonal variation of energy consumption, and battery degradation rate, the operators will understand better about the bus and the battery quality, thus conducting route plans, dispatching plans, and charging plans accordingly. The failure rate is a primary indicator reflecting the safety of the e-bus. The action time for dealing with the failure event will showcase the maintenance team's capability and the difficulty level of the event. The experience gained from failure data collection and analysis will be used to improve maintenance skills and shared with OEMs to enhance their vehicle technology.

Table 2 Vehicle Performance evaluation metric and data requirements

Indicator		Unit	Primary data needed	Frequency of Collection
Efficiency	Energy consumption per km traveled	kWh/km	Distance traveled per trip, SOC when trip begins and ends	Per trip
	Seasonal variation rate of energy consumption per km traveled	%		Per trip
	Ratio of actual range to nominal range	%		Per trip
	Battery degradation rate per 10,000km traveled	%		Per trip
Safety	Proportion of failure duration to operating time	%	Failure types and durations	Per event
	Failure rate per 10,000km traveled	%		Per event
	Average action time	hour	Failure types and action time	Per event

1.3.2 Operating Performance

Indicators included in the operating performance category reflect the operational efficiency, reliability, and costs. The operational efficiency indicators will provide operators data to understand better daily driving distance, whether the charging location is reasonable, and whether the charging time is suitable for the operation, analyzing these indicators will provide evidence to operators to further improve the routes plan and charging plan. Conducting an analysis of operational costs will be necessary for operators to review and reassess the contracts with Transjakarta or with charging service providers.

Table 3 Operating performance evaluation metric

Indicator		Unit	Primary data needed	Frequency of Collection
Efficiency	Vehicle attendance rate	%	Number of vehicles in operation	Per day

Indicator		Unit	Primary data needed	Frequency of Collection
	Average daily travel distance	km/day	Distance traveled per day	Per day
	Proportion of valid operating distance	%	Distance traveled per trip and per day	Per day
	Proportion of peak-hour charging duration	%	Charging time and duration per day	Per day
	Failure rate of charging infrastructure	%	Failure types and durations	Per day
	Average action time	%	Failure types and action time	Per day
Reliability	Average proportion of out-of-service vehicles	%	Number of vehicles in operation	Per day
Cost	Maintenance cost per km traveled	USD/km	Total maintenance cost	Per month
	Energy cost per km traveled	USD/km	Total energy cost	Per month
	Operating cost per km traveled	USD/km	Total operation cost	Per month
	Total cost of ownership per km traveled	USD/km	Total cost	Per month

1.3.3 Environment Impacts

Indicators included in the environmental impact will calculate the fossil fuel saved by using e-buses and the CO_2 and pollutants emissions reduction by e-buses. Energy saved, CO_2, and reduced pollutants will be calculated by the pilot phase and projected by the larger phase.

Table 4 Environmental impacts evaluation metric

Indicator		Unit	Primary data needed	Frequency of Collection
Energy saving	Fuel saved per e-bus per year	liter/vehicle /year	Fuel usage of ICE bus	Per year
Emission reduction	CO_2 emission reduction per e-bus per year	ton/vehicle /year	CO_2 emission of ICE bus	Per year
	Other pollutants emission reduction per e-bus per year	kg/vehicle/year	Other pollutants emission of ICE bus	Per year
	Carbon emission per passenger per km traveled	g/passenger /km	Number of passengers	Per year
	Other pollutants emission per passenger per km traveled	g/passenger /km	Number of passengers	Per year

1.3.4 Social and Gender Impacts

Indicators related to social and gender will showcase the inclusion and equity of Jakarta E-bus project. The number of PwD passengers, drivers/managers/maintenance staff by gender, age, and PwD status will be calculated.

Table 5 Social and gender impacts evaluation metric

Metric	Unit	Primary data needed	Frequency of Collection
Total number of People with Disabilities passengers using TransJakarta e-buses per year	no. of passengers/year	Annual passenger survey on TransJakarta E-buses accessibility report (the data should be disaggregated by sex, age, and PwD status)	Per year
Total numbers of TransJakarta e-buses drivers and maintenance staffs segregated by sex, age, and PwD status	no. of staff	TransJakarta Annual report with additional and specialized section of TransJakarta e-buses (segregated by sex, age, and PwD status)	Per year
Total numbers of TransJakarta staff (including maintenance staffs) who participated in any trainings emanating from e-buses deployment organized by TransJakarta (segregated by sex, age, and PwD status)	no. of staff per year	TransJakarta Annual report with additional and specialized section of TransJakarta e-buses (that should be disaggregated by sex, age, and PwD status)	Per year

After the discussion with Transjakarta, the table below summarizes all the raw data that should be collected and the people who should be responsible.

Table 6 Raw data required for the evaluation metric

Metric	Raw data required				Frequency of collection	Collected by
Vehicle and operating performance	**For each bus:** - Bus route - Bus type - Start location - End location - Plate No. - Depot location - Date	**For each trip:** - Origin - Destination - Start time - Start mileage - Start SOC - End time - End mileage - End SOC	**For each charging event:** - Start time - Start SOC - End time - End SOC - Electricity charged	**For each vehicle failure event:** - Duration - Failure description - Action time	Daily at each bus/trip/ charging event/ vehicle failure event	Operator (by their drivers)
	For each charging infrastructure failure event: - Depot name - Charging infrastructure Number - Date				Daily at each charging infrastructure failure event	Operator (by charging maintenance staff)

Metric	Raw data required	Frequency of collection	Collected by
	- Duration - Failure description - Action time		
Operating performance	CAPEX and OPEX (includes staff cost, spare parts cost, maintenance cost, electricity cost, and other costs)	Monthly	Operator
Environment impacts	Ridership numbers	Monthly	Transjakarta
Social and gender impacts	Number of PwD passengers	Yearly	Operator
	Numbers of Transjakarta e-buses drivers and maintenance staffs segregated by sex, age, and PwD status		
	Numbers of TransJakarta staff (including maintenance staffs) who participated in any training emanating from e-buses deployment organized by TransJakarta (segregated by sex, age, and PwD status)		Operator and Transjakarta

Conduct monitoring and evaluation for pilot projects is essential for e-bus implementation entities including Transjakarta, OEMs, government authorities to understand the performance of electric vehicles and make plans in the future. They should especially acknowledge that this first e-bus pilot in the country has profound impacts on other cities to learn from.

Since Transjakarta is responsible for coordinating operators for data collection, they should establish the monitoring and evaluation strategy at an early stage, develop the methodology, set up the data collection and sharing mechanisms, and allow data verification. Transjakarta should also communicate with operators and e-bus providers about the feasibility of data collection and ensure this agreement is incorporated into the contracts.

To help Transjakarta to conduct the pilot monitoring and evaluation, a comprehensive metric is developed, considering the vehicle performance, operating performance and environmental impacts, and social and gender Impacts. There are a total of 23 indicators in the metric. For each indicator, the meaning and calculation methods are explained. Transjakarta could use this metric as the template to learn what raw data should be collected and what analysis could be done with these data.

2. Ensure readiness for pilot project monitoring and evaluation

2.1 Data collection preparation

ITDP conducted a dedicated meeting with Transjakarta to explain the pilot e-bus monitoring and evaluation metric and requirements for data collecting. Monthly coordination meetings were also arranged to track the project's progress and tackle issues existing in data sharing and collection. Compared to ICE buses, operators do not have extensive experience in e-bus operations. It is suggested that Transjakarta should conduct training on data collection for the operators, the participants should include the management team, drivers, and technicians who deal with chargers and provide guidance on data collection at the site if necessary. Therefore, operators could collect and record required raw data daily and share the data with Transjakarta promptly.

Data collection forms for gathering primary data are designed and trained in Transjakarta with monitoring and evaluation metrics and data collection methods. It is recommended that the operators or OEM provide access for e-buses to be integrated into the Transjakarta bus control center, where they can automatically receive operational data and analyze the data. The vehicle performance data can be easily obtained from the dashboard on e-buses, where the dashboard will show information about SOC, battery voltage, battery electric current, maximum and minimum voltage, maximum and minimum temperature, electric current under high voltage and low voltage, motor speed (in rpm), mileage traveled, etc.

Figure 13 Dashboard on Yutong e-bus[1]

[1] Source: http://www.yutong.com/products/U12.shtml

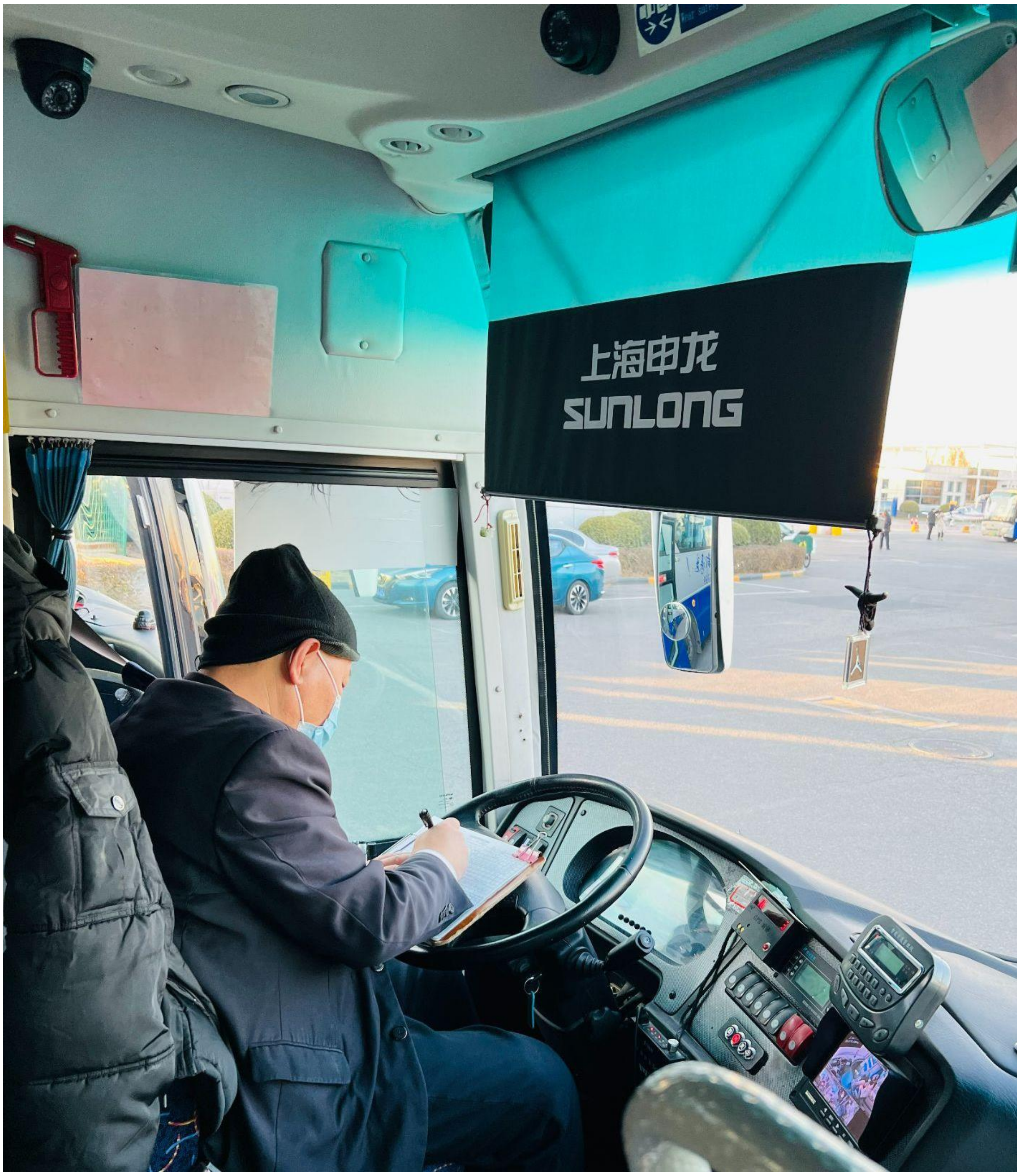

Figure 14 Driver recording the data in China

The driver can manually record the information from each trip in the datasheet that the project team provided. Each failure event of the e-bus and charging infrastructure should be clearly recorded, including the failure type, duration, and action time.

E-bus operational data collection

Bus route: Bus type: Start location: End location:
Bus plate No.: Depot location:
Date:
Weather and temperature:

Note: Charging event includes midday charge events and overnight charge events

Trip	Origin (station name)	Destination (station name)	Trip start			Trip end			Charging event				
			Time (e.g. 9.30 AM)	Mileage (in km)	SOC (in %)	Time (e.g. 9.35 AM)	Mileage (in km)	SOC (in %)	Start time (e.g. 12.00 PM)	Start SOC (in %)	End time (e.g. 14.00 PM)	End SOC (in %)	Electricity charged (in kWh)
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													

Figure 15 E-bus operational data collection form sample

Failure event							
No.	Bus plate No.	Route No.	Date	Start time (e.g. 9.30 AM)	Duration (in hours)	Description of the failure	Action time (in hours)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Figure 16 E-bus failure event data collection form sample

Failure event								
No.	Depot name	Charging infrastructure No.	Date	Start time (e.g. 9.30 AM)	Duration (in hours)	Weather condition	Description of the failure	Action time (in hours)
1								
2								
3								
4								
5								
6								
7								
8								
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Figure 17 Charging infrastructure failure event data collection form sample

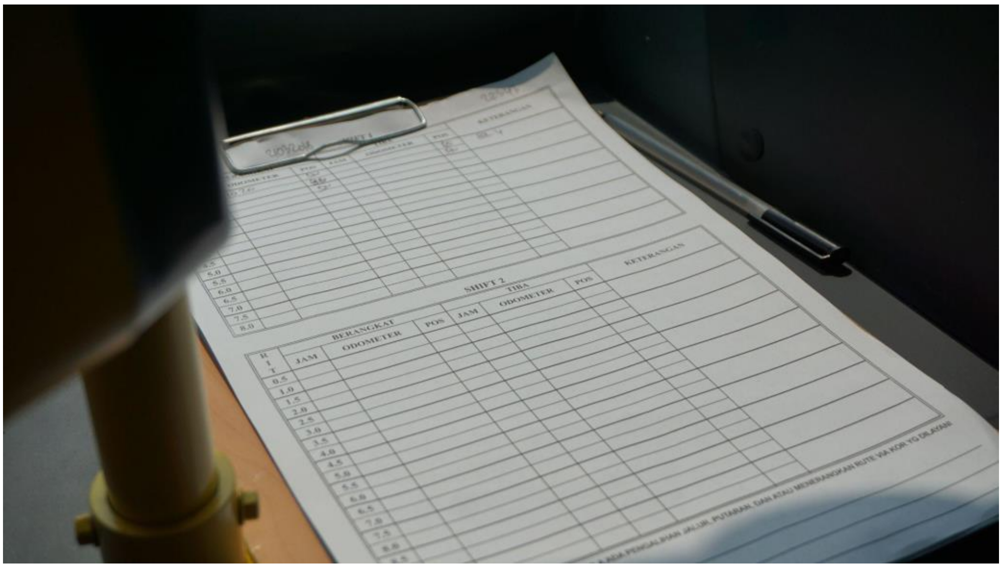


Figure 18 Data collection forms that are ready to be used by drivers

2.2 Data sharing mechanism

Establishing a data collection and sharing mechanism should consider the roles and responsibilities among Jakarta Transport Agency, Transjakarta, operators, OEMs, and the consulting team. If the charging service will be outsourced to a third party in the future, the charging service provider should be included in the data-sharing loop as well.

Through data analysis and evaluation, Transport Agency and Transjakarta can understand the real-world e-bus performance information and take action on the optimization of operational plans and charging plans to achieve operational and economic efficiency. Transjakarta will regularly share the monitoring and evaluation results with operators and OEMs for operational adjustments and improvement of the vehicle technologies accordingly.

The first and foremost consideration in the data sharing mechanism is to **identify the roles and responsibilities** of data collecting and sharing between Transjakarta and operators/OEMs. Transjakarta needs to train operators on data collection, sharing, verification, and explain the data monitoring and evaluation results, and provide guidance to operators once issues are identified in the operations. Operators/OEMs are obliged to collect and share real-world data with Transjakarta and work with them to find solutions to operational problems.

Transjakarta should also **reach an agreement with operators on the data sharing requirements** and ensure they fully understand. Transjakarta should decide the type of data and the format needed and provide guidance on how to obtain the data for operators. The frequency of data collection and sharing should be decided before the operation starts.

Regular **meetings and communications** among Jakarta Transport Agency, Transjakarta, operators, OEMs, and the consultant team are crucial during the process. This will help to check on data quality, verify data accuracy and find out problems existing through the data sharing process. Also, frequent communication is beneficiary for building trust among stakeholders, thus formulating a sustainable environment for data access in the future.

A data-sharing platform should be established. Since Transjakarta doesn't have an upgraded control center, there is no integration for e-buses to get connected to the current control center, so a data-sharing platform should be built between Transjakarta, operators and other partners. It can be as simple as a shared drive document or folder, every stakeholder can access the data and provide inputs.

The data verification process should be included. Since the e-buses are not integrated into the control center, it is necessary to verify the data occasionally.

Sharing the data analysis results is an important step. Transjakarta should analyze the data in a timely manner and share it with operators and OEMs to help operators understand the issues and find solutions.

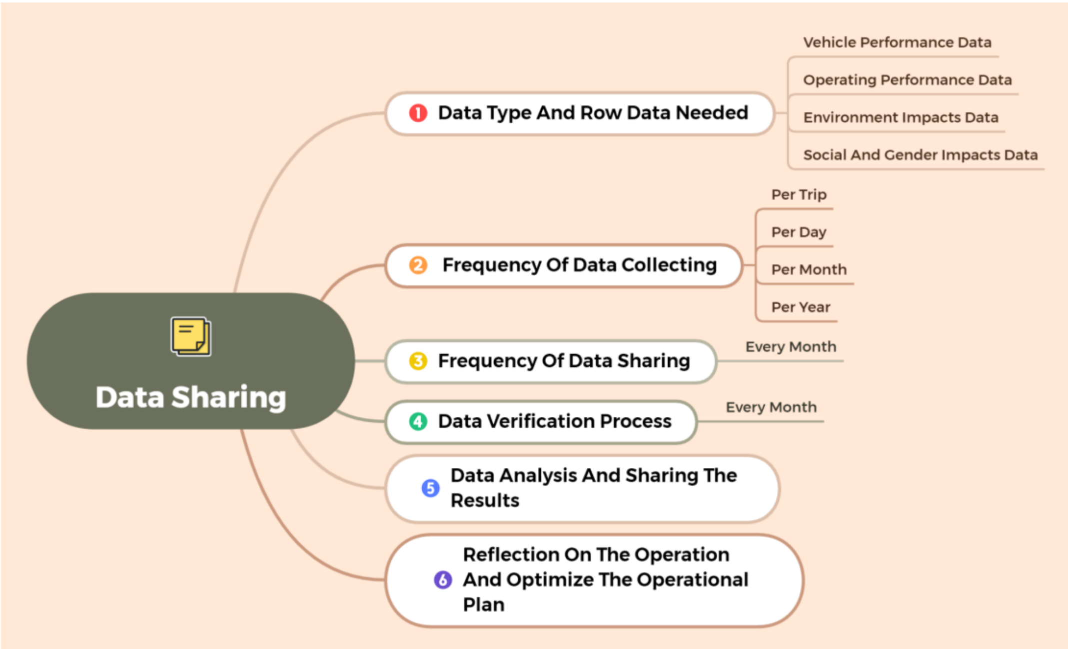


Figure 19 Data sharing considerations

2.3 Contract documents reviewing

To ensure the sustainability of the evaluation process, cooperation both for Transjakarta and operators is mandatory to enable the data recording, data keeping, and sharing process. This is due to the data collection could not be done single-handedly by Transjakarta, as in this case Transjakarta is not operating the e-bus by itself but they have chosen the operator through the bidding process. So, in this case, Transjakarta does not own the entire data unless with the operator's support and cooperation. This form of coordination has to be bound by the contract documents and needs to be clear and agreed upon by both parties. Transjakarta should define which data can be collected by Transjakarta and which data should be done by the operator. In that manner, the contract could have stated the operator's obligations to provide.

Considering that the contract between Transjakarta and its operators is confidential, all of the stated information could not be disclosed to the general public. Therefore our approach to collecting and elaborating on the idea of the contract is by interviewing Transjakarta's staff responsible for formulating and negotiating the contract details. The focus of the reviewing contract activity is limited to the effort on enabling pilot monitoring and evaluation.

Based on the Transjakarta statements, the contract has pointed out the obligations that the operator and the latest status from the contract statement actualization must carry out.

Figure 20 Operator obligation related to monitoring and evaluation

No	Contract Statements	Status
1	Provides monitoring equipment and systems and integrates with Transjakarta's command center	Dashboard data could be obtained by extracting data from the bus manufacturer's server yet still not integrated with Transjakara's command center
2	Permit and provide access to Transjakarta, other authorized agencies, and/or independent auditors appointed and approved by Transjakarta to obtain all forms of information relating to the implementation of this agreement	All data requests must go through a formal letter request and it takes a long time to get data from the operator as the consequence of the detailed data needed was not stated in the contract
3	Supervise the implementation and get the widest possible access to documents and information regarding the results of the recorded activities of the bus operator	All data requests must go through a formal letter request and it takes a long time to get data from the operator as the consequence of the detailed data needed was not stated in the contract
4	Bus operators are required to submit a monthly report containing at least: ● Daily operation orders ● Bus kilometers traveled ● Periodic and non-periodical	Daily operation order and bus kilometer traveled data has been submitted to Transjakarta. However, maintenance activity and bus breakdown data have not been

No	Contract Statements	Status
	maintenance activity reports ● Bus breakdowns, and other flaws that need repair or adjustment	received yet by Transjakarta
5	The bus operator agrees to provide real-time data monitoring and provide Transjakarta access to a monitoring system relating to the performance of the bus operator under this Agreement. The bus operator further agreed to install a device on the bus to allow Transjakarta to access the location and status of the Bus in real-time.	Real-time location and bus status could be obtained by the dashboard data from the bus manufacturer's server, yet it is still not integrated with Transjakara's command center

Transjakarta has determined the role of the bus operator to enable monitoring and evaluation by pointing out the bus operator's obligation, as shown in the table above. However, what has been stated in the contract is quite general and needs to be clarified by stating the specific data details needed by Transjakarta. At the status quo, Transjakarta owns all the documents and information generated by the e-bus pilot implementation, but it requires a formal letter to be sent to the bus operator, which is potentially time-consuming, inefficient, and repetitive activities.

On the other hand, in the monthly report, operators are obligated to provide regular updates on Daily operation orders, Bus kilometers traveled, Periodic and non-periodical maintenance activity reports, Bus breakdowns, and other flaws that need repair or adjustment. Even though the pilot has been rolled out for almost five months, Transjakarta still doesn't have complete data from the operator, notably on maintenance activity and bus breakdown data. Strengthening the coordination between Transjakarta and bus operators is crucial in the process of monitoring and evaluation and if the bus operators are still not showing any good intentions, Transjakarta may need to take further actions as stated in the contract to cut down or withhold payment of part or all of the Bill and/or performs, confiscate and withdraw the Performance Guarantee if the bus operator commits a Default.

Besides strengthening the coordination between Transjakarta and bus operators, Transjakarta should have given out the details of data that need to be provided by bus operators along with the time frame of data submission. The table in the last chapter, raw data required for the evaluation metric, indicates the suggestions of what specific data should be provided by the bus operator.

2.4 International E-bus monitoring and evaluation examples

This section will introduce the practices of e-bus monitoring and evaluation in Chinese cities: how do they apply the big data from the daily operations of e-buses at the national and city levels, what policies and regulations should be considered and developed, and how the data should be presented to make it easy to understand.

E-buses in China overview

In China, New Energy Vehicles (NEVs) is a term used by the Chinese government to represent battery electric vehicles, hybrid vehicles, and fuel cell vehicles. By the end of June 2022, the total number of NEVs has reached 10 million. Among the total of 709400 buses operated in China by the end of 2021, 59.1% of them are BEBs[2]. Looking at the e-bus deployment at the provincial level, the average proportion of BEBs was 61.9% in 2020. Six provinces have more than 80% of BEBs within their entire bus fleets. By far, China has achieved the large-scale implementation of e-buses in cities, with over 98% of the e-buses inventory worldwide.

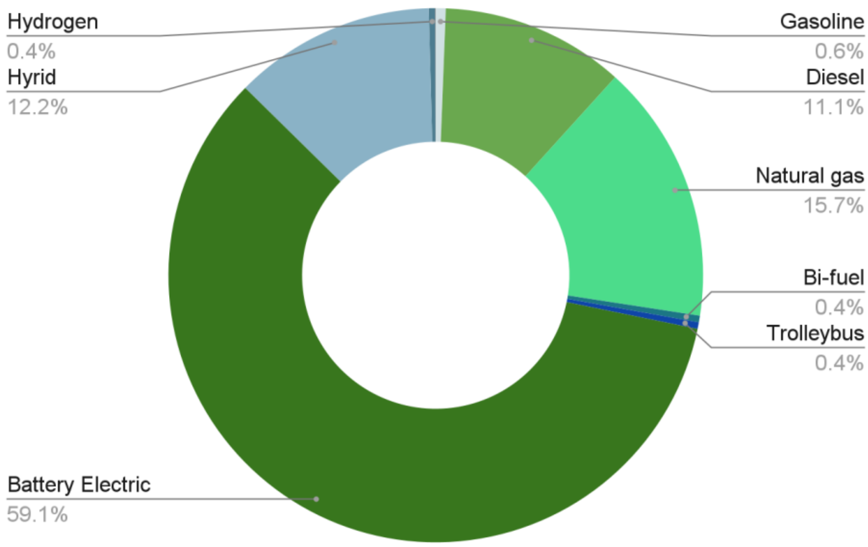


Figure 21 Energy types of the total bus fleets by the end of 2020 in China

[2] http://www.gov.cn/shuju/2022-05/25/content_5692174.htm

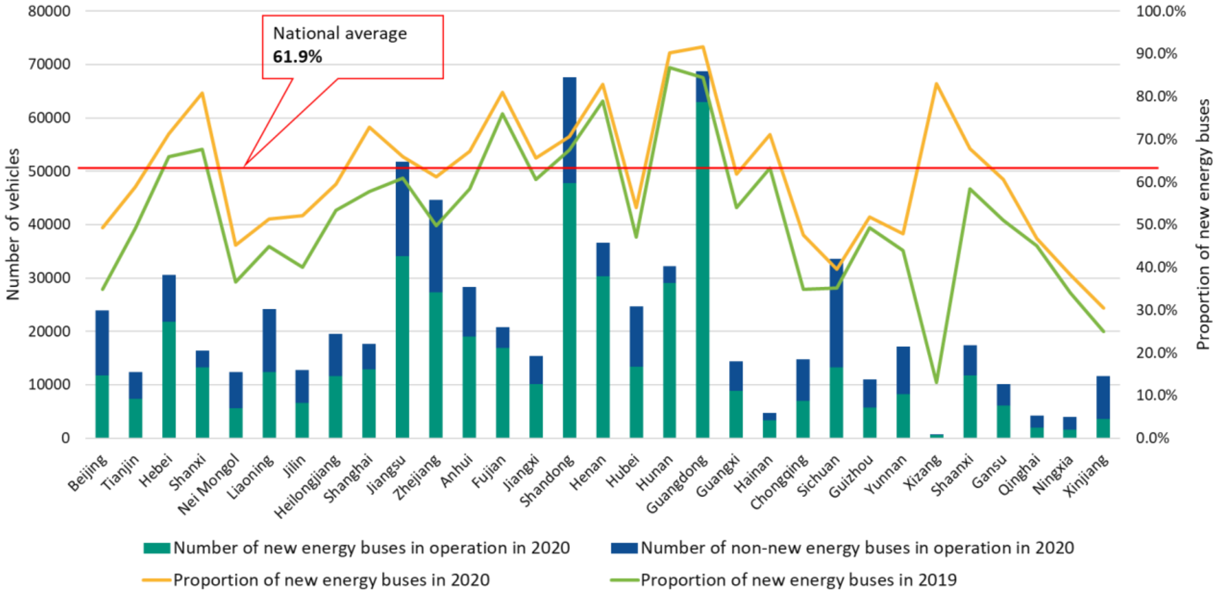


Figure 22 New energy buses by the province in 2020

The importance of data for electric vehicles

Compared with ICE buses, e-buses have the inherent advantage of data collection because of the high level of intelligence and the large number of sensors that are installed in the vehicle. The automobile terminals could collect the data generated from the sensors and Battery Management Systems and then transmit it to the cloud or the data management platform. These data could be used to monitor operation activities, check battery health, predict battery degradation, and detect safety risks.

Regulations on monitoring and evaluation

According to the "*Notice on Further Improving the Promotion and Application of New Energy Vehicles Safety Supervision and Management*" released by the Ministry of Industry and Information Technology (MIIT) in 2016, New Energy Vehicles must install onboard terminals that have the functions of collecting, storing, transmitting vehicle running status, and alarming, charging and positioning data. The "*National Monitoring and Management Platform for New Energy Vehicles*" was established in the same year. The data is collected by OEMs and must be uploaded to this platform in accordance with the requirements at "*Electric Vehicle Remote Service Specifications and Management System Technical Specifications" (GB/T 32960)*. There are a total of 61 data items on the list, including vehicle data, driving motor data, vehicle location data, alarm data, etc. The detailed requirements regarding the data types and collection frequencies are summarized in the appendix. Up to July 2022, there are a total of 9.27 million NEVs with 300 billion kilometers of operating mileage data that have been connected to this national platform. The platform is managed by the Beijing Institute of Technology[3], and they publish a brief on vehicle connectivity information and data quality each week.

Figure 23 National Monitoring and Management Platform for New Energy Vehicles

The multi-level New Energy Vehicles monitoring and evaluation system

Since different entities have different needs for data, the monitoring, and evaluation system is divided into three tiers from macroscopic to microscopic levels. For the national government, the platform will support policy-making, investment planning, and budgeting, as well as deciding the number of subsidies that should be provided for NEVs. Therefore, the data needed is the number of NEVs, their utilization, traveling mileage, safety status, etc. The data monitoring platform at the province level has similar functionality, but it needs more detailed information from each city. And for enterprises, OEMs need real-time vehicle technical performance data to upgrade their vehicle products and detect any failure event warnings to ensure the safety of e-buses. Bus operating companies need battery and vehicle performance data, vehicle failure events, operation status, overall costs, and charging and maintenance data. The data will be used to optimize vehicle scheduling and make plans for charging and maintenance. Based on this framework, the data collected by the terminals installed in the vehicle will be transmitted to different parties with their specific requirements.

[3] Source: http://www.bitev.org.cn/achieve/48.html

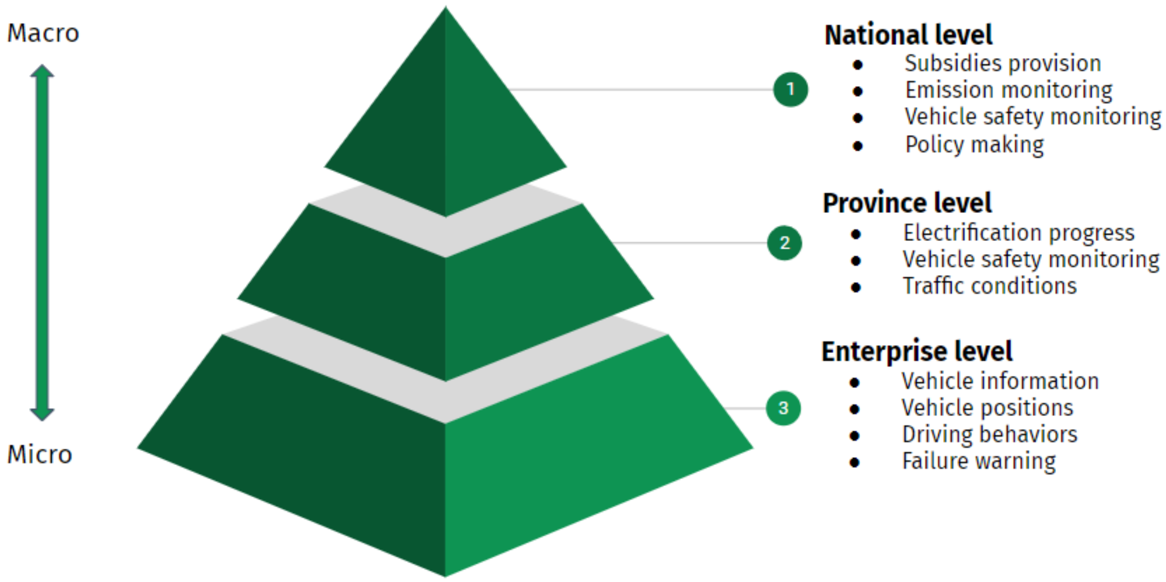


Figure 24 The Multi-level New Energy Vehicles monitoring and evaluation system

Data visualization

The data will be visualized on the screen in the bus company's operating center. The smart screen is a helpful tool to visualize such a huge amount of data collected from e-buses. It has the feature of dynamically displaying the data on a large screen so that administrators can easily find out the patterns existing in the data and detect any outliers. The layout is flexible and straightforward to use, components that are shown on the screen can be added and deleted by drag-and-drop. They can also use the filter function and draw charts to discover the relationships between each parameter.

The figures below are the screens at Guangzhou Bus Group. The screen displays the total number of charging piles and their availability, the number of routes and the route types, the total number of ridership, the total driver attendance, and vehicle attendance. In the middle of the screen is the map of the e-bus operating area, where selected figures can be presented on the map in real time. Operating staff can use this screen to allocate buses to different routes based on vehicle and personnel availability to even out the ridership and provide better passenger service. The screen is also used to check the scheduling of each bus and receive alerts of long waiting times, overspeeding, low power, etc.

Figure 25 Guangzhou bus monitoring platform

Shenzhen Bus Group, which has a fully electrified bus fleet, adopted the smart screen for bus planning and scheduling, as well as safety management.

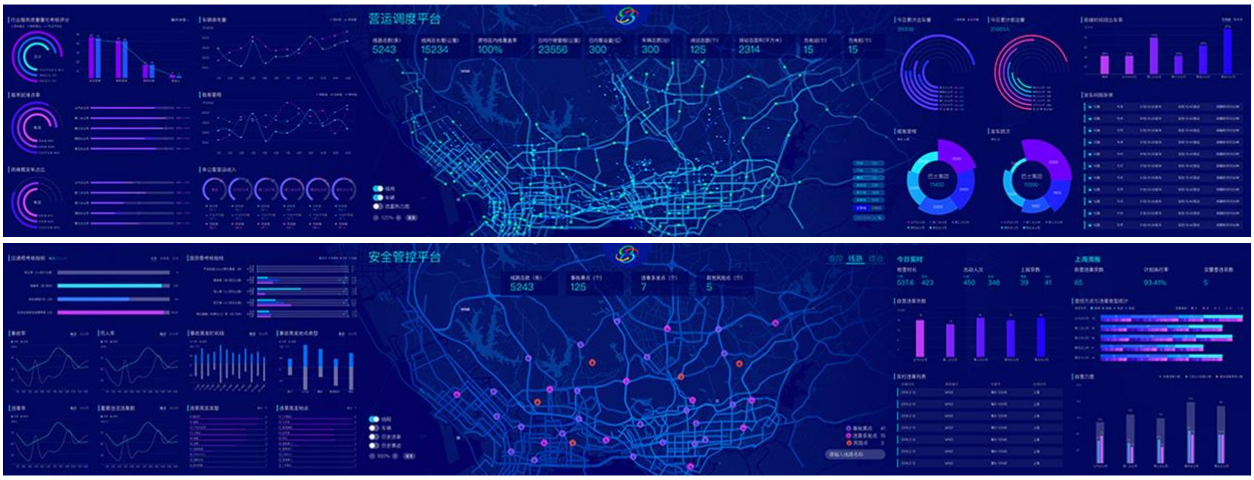


Figure 26 Shenzhen Bus Group bus scheduling and safety monitoring platform

The application of e-buses data

Apart from monitoring the operations, e-bus data can be further utilized for carbon emissions calculation, vehicle risk warming, battery degradation forecast, market analysis, risk evaluation for insurance companies, and battery recycling tracing and tracking, etc. The following figure is the carbon emission management platform used by Fujian province in China. The platform can trace the emission reductions by NEVs that are contributed by different companies and different cities in the province.

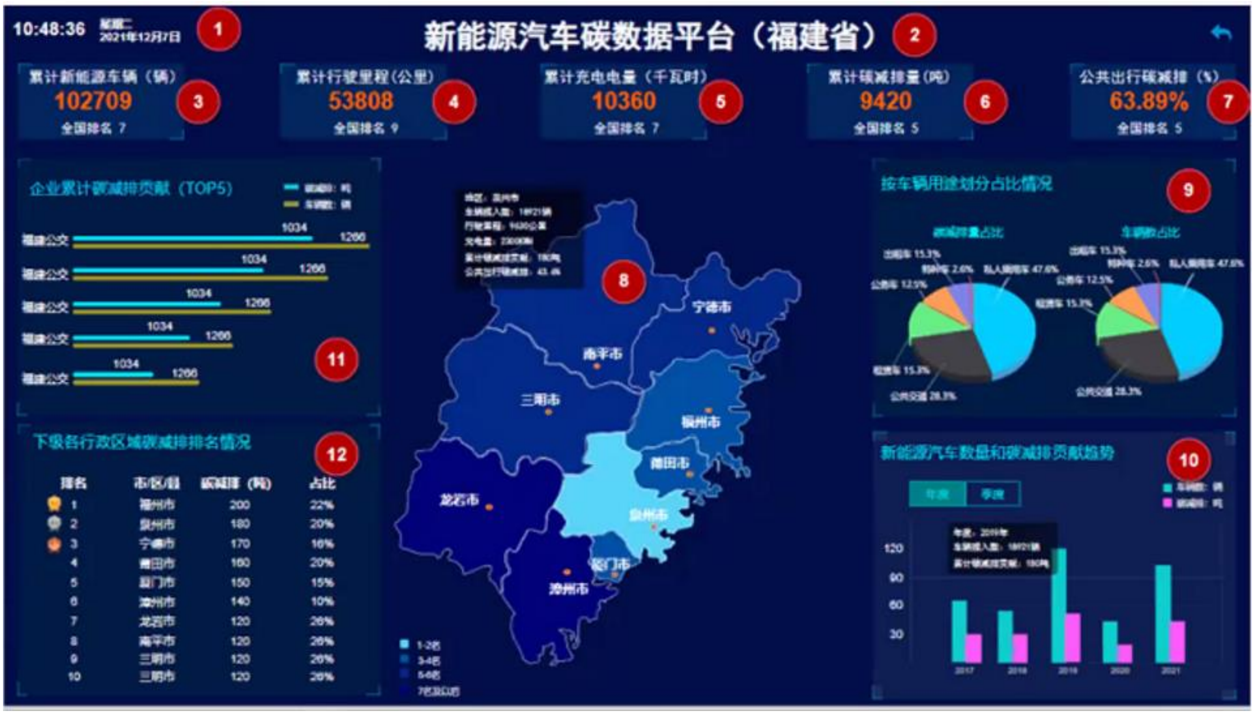


Figure 27 New energy buses carbon data management platform in Fujian Province in China

2.5 Findings and recommendations

Before collecting data, Transjakarta should understand the preliminary source of the data and train operators on how to record using the pre-designed forms. Transjakarta should also explain the evaluation methodology and the reason why these data should be collected. The data-sharing mechanism requires a comprehensive overview of the whole process, beginning with identifying the roles and responsibilities of each stakeholder.

From the contract agreements between Transjakarta and operators, although it is stated that operators are obligated to provide e-bus operational data to Transjakarta at certain frequencies, the level of detail is not provided, which may result in misunderstandings by operators. Transjakarta should incorporate the detailed data requirements within the contract, and specify the penalties if not compliant. Also, communication and coordination on performance monitoring and evaluation should be strengthened.

The e-bus monitoring and evaluation experience from China showed its strong emphasis on e-bus data, with the release of the national policy and the establishment of a multi-level monitoring and evaluation system for New Energy Vehicles. The data is visualized on the large screen and applied not only to monitor the performance of e-buses but also to manage safety and track emissions in the region.

3. Pilot project monitoring and evaluation

3.1 Raw data overview

After communicating with Transjakarta to set up a coordination protocol for regular performance monitoring and data collection of e-buses and chargers, Transjakarta committed to requiring e-bus operators to record the data and share it with Transjakarta and the project team on a monthly basis. Using the data collected, the team analyzed the pilot e-bus performance, as well as monitored and recorded operational and maintenance issues. Passenger surveys on pilot e-bus deployment are also conducted to understand passengers' needs and ensure the level of service is achieved.

By the end of January 2023, Transjakarta provided a total of 10-month operational data from March 4 2022 to December 31, 2022. The dataset consists of the start and end SOC, and the mileage traveled for each vehicle on each day, and there are 5814 valid records in total. The following table summarized the vehicle information from the data. Currently, the operator runs 30 e-buses, serving routes 1N, 1P, and 6D, as well as special routes (Requested by Jakarta Province/National to provide temporary service for a certain event or delegation, so the bus was not operating at the normal routes): 4 e-buses that started operating on March 4, 23 e-buses from 7 June, 1 bus started on 9 March, and the other 2 e-buses started on 10 March 2022.

Table 7 The number of records on each month

Month	No. of records	Total mileage traveled (km)
March	58	12957
April	60	13641
May	62	14342
June	660	150851
July	837	198954
August	836	198572
September	812	188820
October	839	193798
November	812	193223
December	838	198272
Total	5814	1363430

Since there are four vehicles (MYS-22334, MYS-22335, MYS-22336, MYS-22343) that have significantly higher mileage traveled (over 30,000 km) than other vehicles, some analysis is only based on these four vehicles.

Despite the amount of available data, the quality of this data is still poor with missings and mistakes caused by human errors. For example, the operational data recorded on 9 July did not have the end SOC; vehicle MYS-22343 had the same start and end mileage on 30 July; the end mileage of vehicle MYS-22341 did not meet the start mileage on the next day… these problems all influences the quality of analysis results. Apart from this, the level of detail is not met as well. It is required to record the data for each trip rather than once daily. Because of this, the analysis may not represent the real pilot performance.

3.2 Vehicle performance

Based on the available data, the following table summarizes the performance of all vehicles and the four most used vehicles. These measurement indicators show little differences among each vehicle, indicating that hardly any failures happened during the operation. Specifically, vehicle MYS-22361 has slightly higher efficiency than other vehicles, which could have more distance traveled with the same amount of energy consumption. The performance of other vehicles is all around the average level.

Table 8 Daily average values on vehicle performance

Plate number	Consumed SOC (%)	Consumed kWh (kWh)	Mileage Travelled (km)	Travelled Distance Per SOC (km/SOC)	Travelled Distance per kWh (km/kWh)	Consumed per km (kWh/km)
MYS-22334	0.70	225.54	235.26	3.40	1.04	0.96
MYS-22335	0.69	224.23	235.52	3.41	1.05	0.95
MYS-22336	0.69	224.06	232.70	3.38	1.04	0.97
MYS-22337	0.73	236.28	237.39	3.26	1.00	1.00
MYS-22338	0.75	241.95	234.45	3.14	0.97	1.03
MYS-22339	0.73	236.22	231.42	3.19	0.98	1.02
MYS-22340	0.67	217.99	235.09	3.50	1.08	0.93
MYS-22341	0.72	232.58	233.84	3.27	1.00	1.00
MYS-22342	0.74	240.52	238.57	3.24	1.00	1.01
MYS-22343	0.71	228.58	234.13	3.34	1.02	0.98
MYS-22344	0.74	238.49	235.04	3.20	0.98	1.02
MYS-22345	0.71	230.95	235.05	3.31	1.02	0.98
MYS-22346	0.72	232.57	236.49	3.31	1.02	0.98
MYS-22347	0.72	231.67	233.47	3.27	1.01	0.99
MYS-22348	0.72	232.26	234.77	3.29	1.01	0.99
MYS-22349	0.68	221.91	239.82	3.51	1.08	0.93
MYS-22350	0.72	232.26	237.77	3.33	1.02	0.98
MYS-22351	0.73	235.06	232.10	3.21	0.98	1.01
MYS-22352	0.75	243.71	231.53	3.09	0.95	1.06
MYS-22353	0.69	223.14	232.97	3.39	1.04	0.96
MYS-22354	0.71	228.63	231.95	3.30	1.02	0.99
MYS-22355	0.71	231.02	236.24	3.32	1.02	0.98
MYS-22356	0.70	227.48	235.24	3.36	1.03	0.97

MYS-22357	0.71	231.29	233.81	3.28	1.00	0.99
MYS-22358	0.73	238.00	228.98	3.13	0.97	1.04
MYS-22359	0.74	238.89	233.95	3.19	0.98	1.02
MYS-22360	0.71	229.90	233.56	3.30	1.01	0.99
MYS-22361	0.66	214.57	237.21	3.60	1.10	0.91
MYS-22362	0.71	231.52	234.43	3.29	1.01	0.99
MYS-22363	0.71	229.54	232.57	3.30	1.02	0.99
Total	0.71	230.80	234.51	3.31	1.02	0.99

Energy consumption per km traveled (kWh/km)
In general, e-buses MYS-22340, MYS-22349, and MYS-22261 have relatively lower energy efficiency than other e-buses (less than 0.93 kWh/km), and the e-buses MYS-22352, MYS-22338, and MYS-22358 have relatively higher energy efficiency (equal or larger than 1.03 kWh/km).

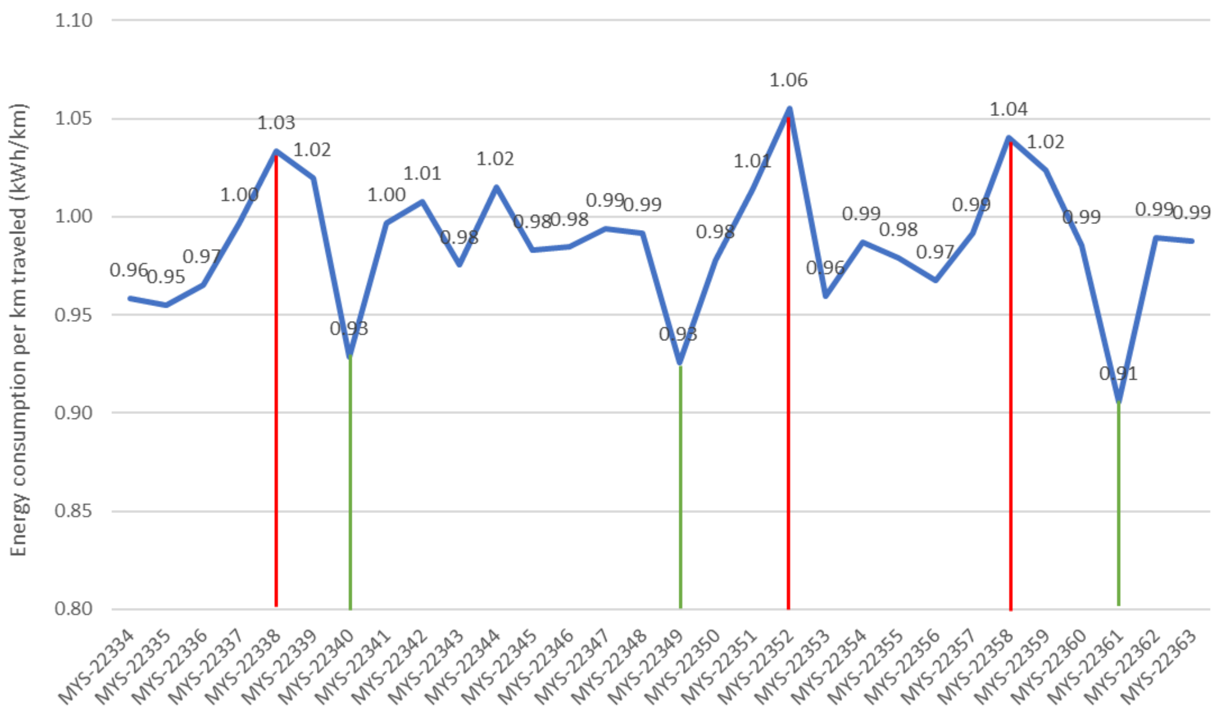


Figure 28 Energy efficiency (kWh/km) of all buses

The following figure analyzes the energy utilization efficiency of different vehicles from June to September respectively (all 30 buses are on road since June). By comparison, we can clearly identify the buses and months with low energy utilization, and find out the reasons behind it. For example, the energy efficiency of **e-bus MYS-22359 in June, MYS-22352 in August is obviously lower** than that of other e-buses, and the **energy efficiency of MYS-22361 is much higher than other e-buses**. Looking back at the raw data, it was found that **there were only two pieces of record for MYS-22361 in June**, and **there is no record for the e-bus MYS-22363 in August**, it is unclear whether because of the failure events or the operation setting. Transjakarta should assist operators to find out the reasons for the low utilization rate of vehicles and find solutions together with operators.

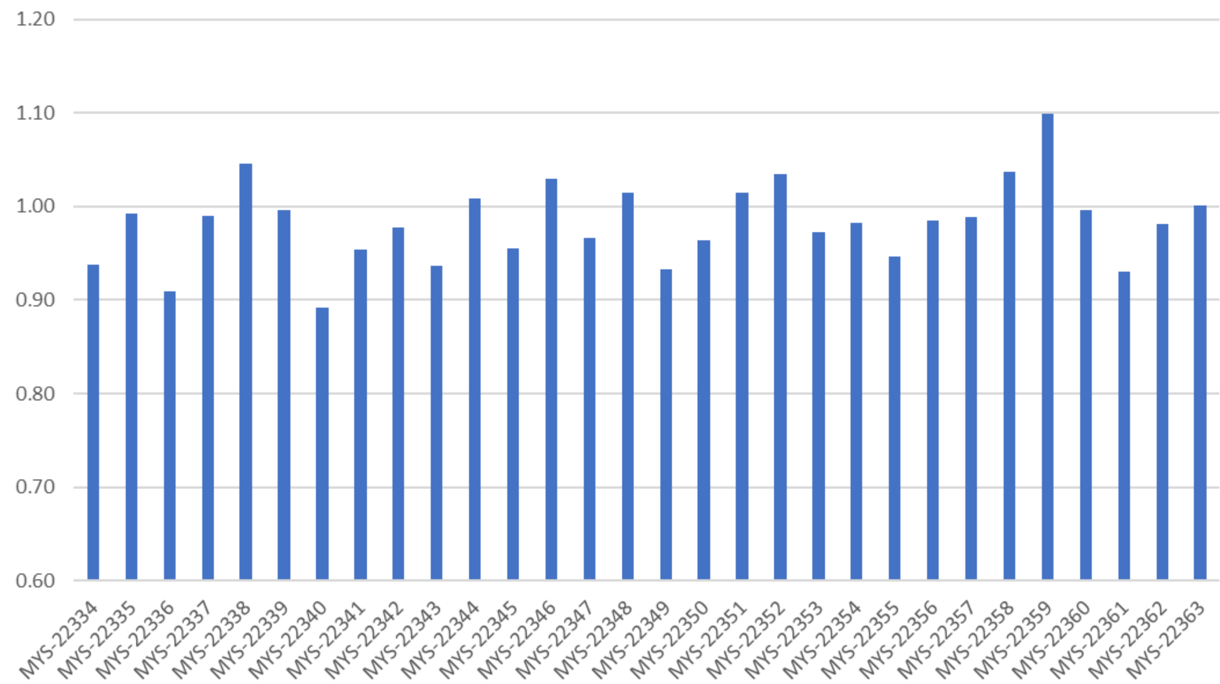


Figure 29 Average energy efficiency (kWh/km) in June

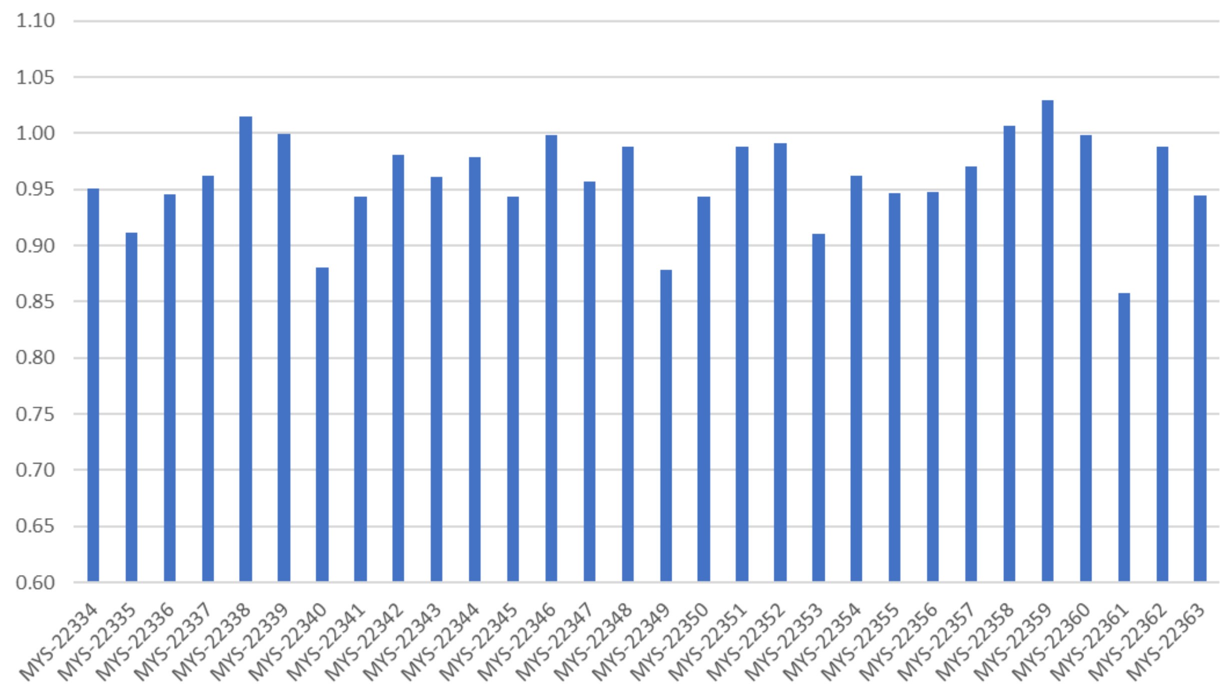


Figure 30 Average energy efficiency (kWh/km) in July

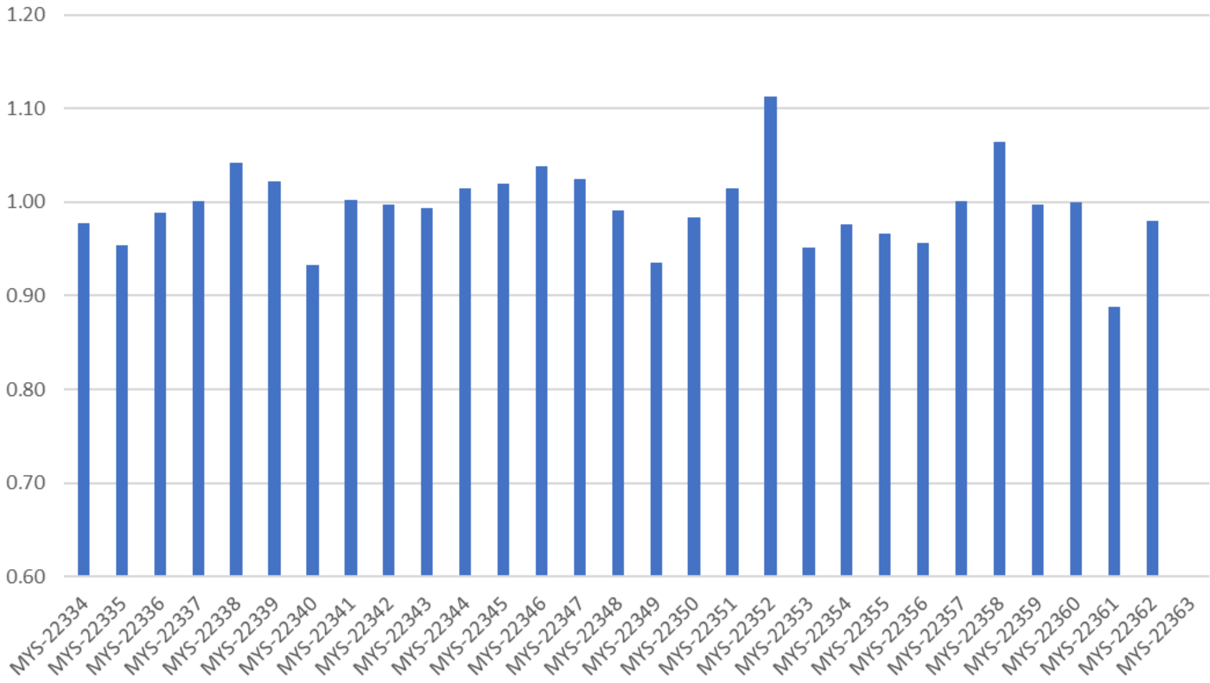


Figure 31 Average energy efficiency (kWh/km) in August

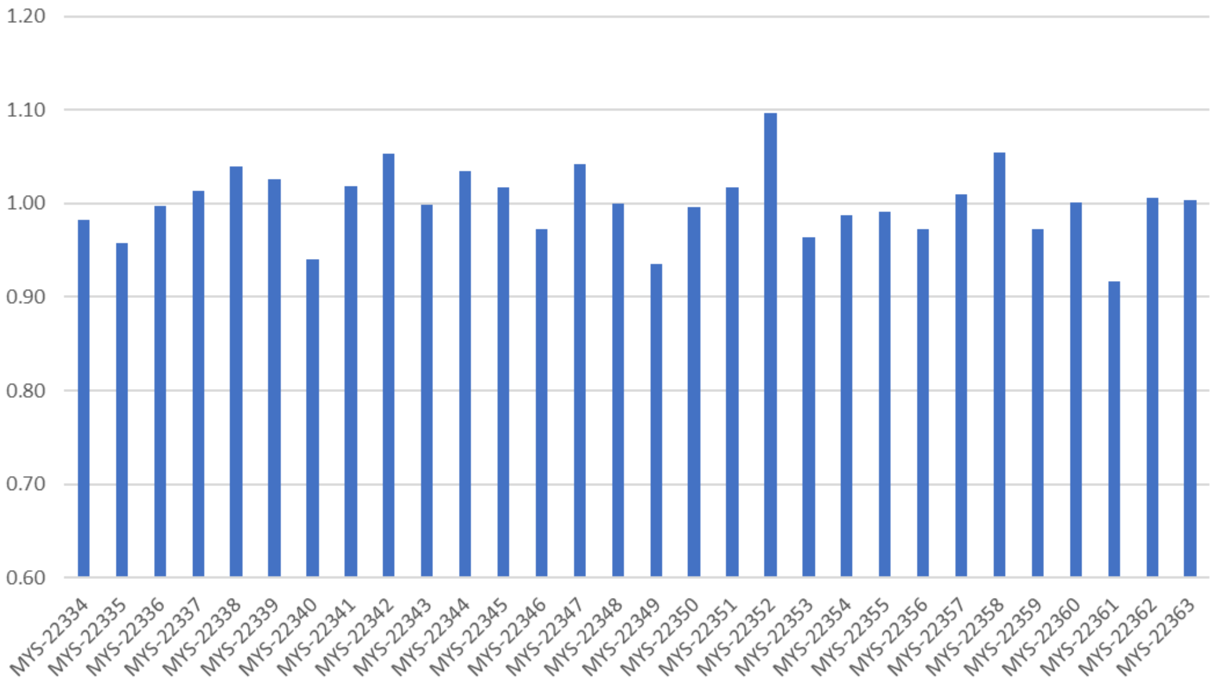


Figure 32 Average energy efficiency (kWh/km) in September

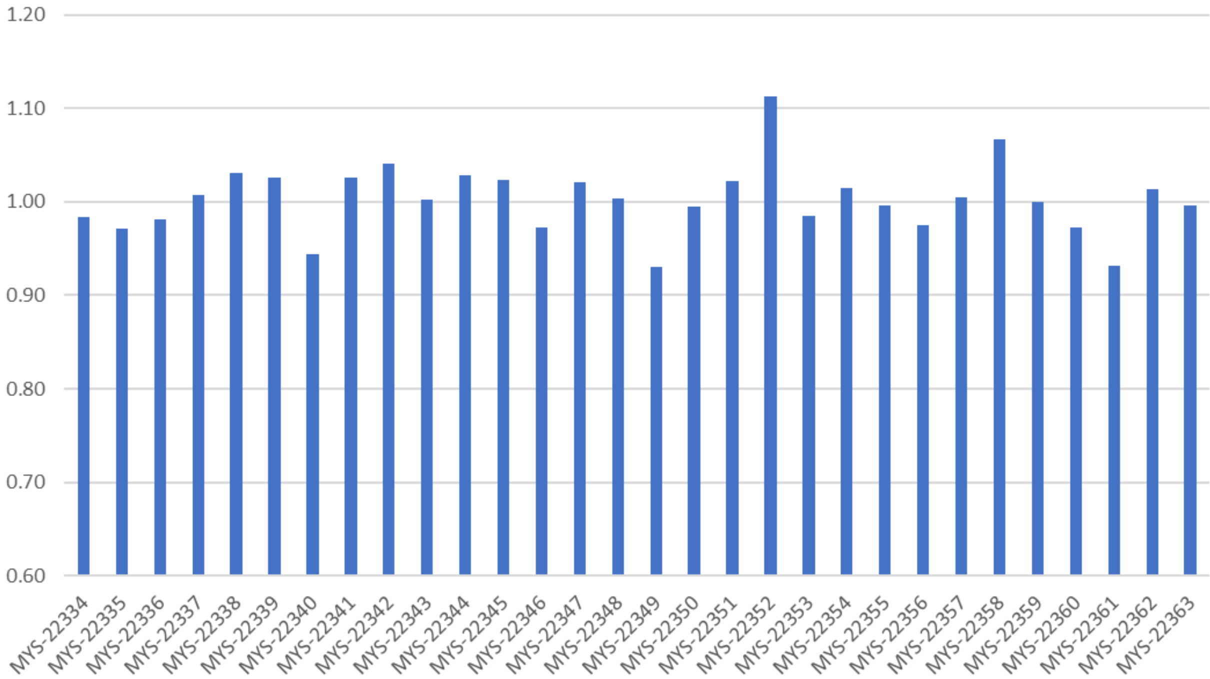


Figure 33 Average energy efficiency (kWh/km) in October

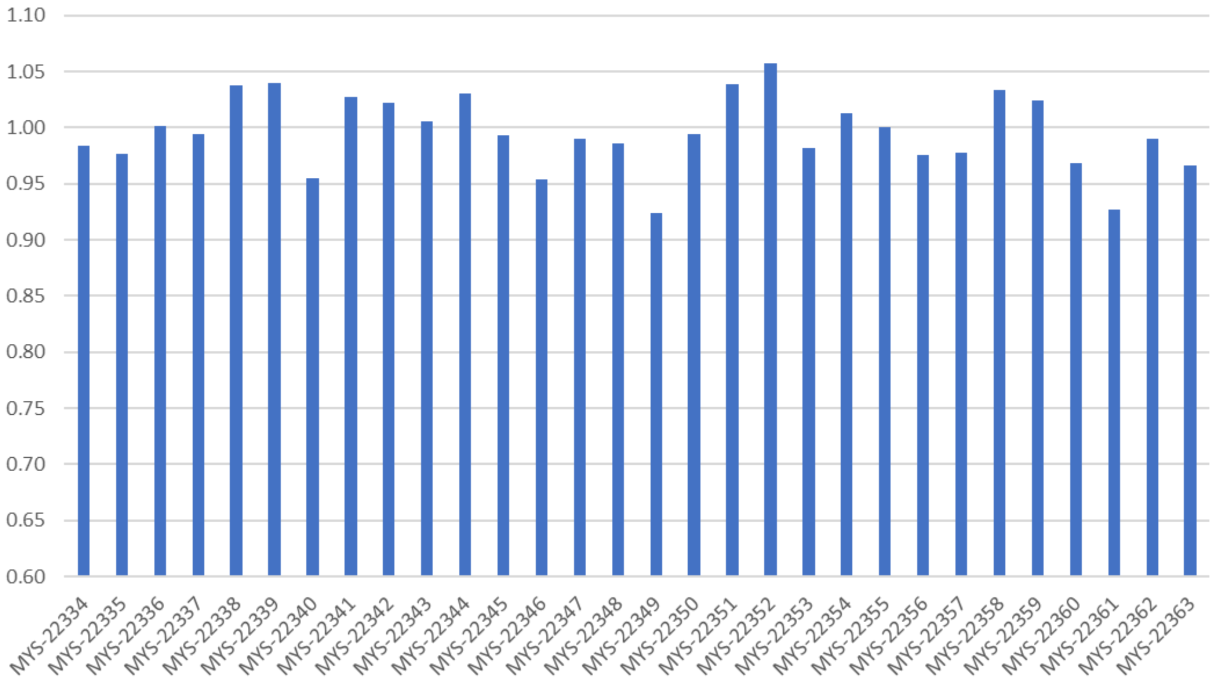


Figure 34 Average energy efficiency (kWh/km) in November

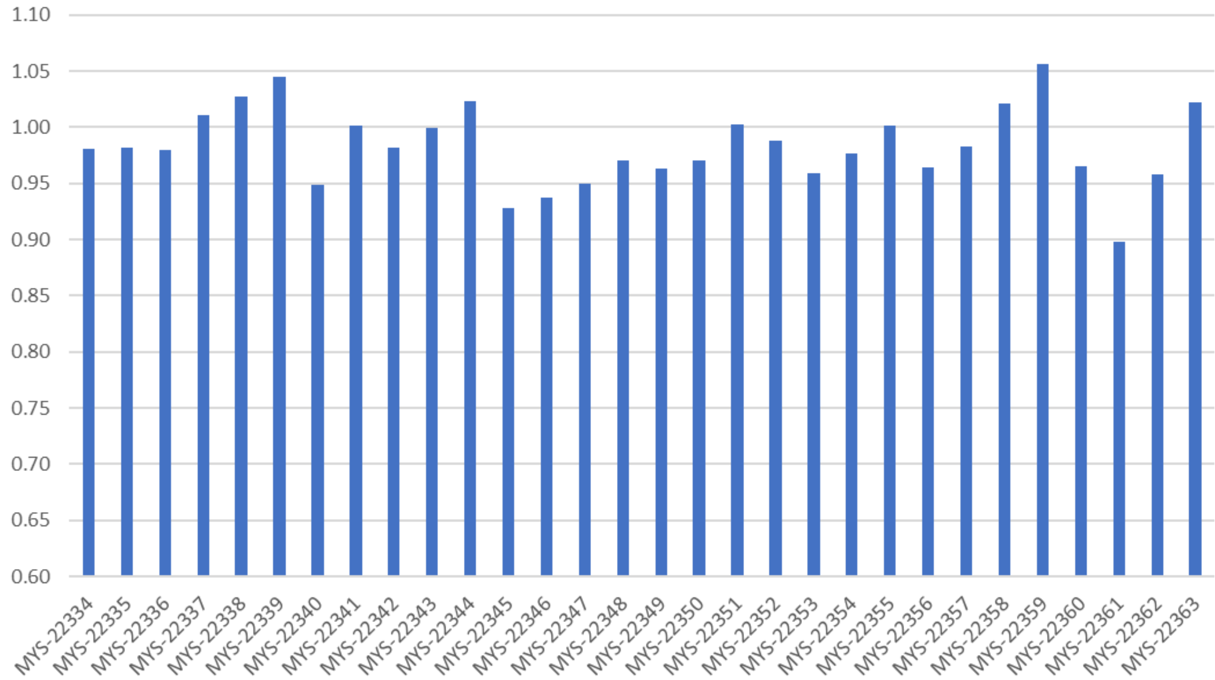
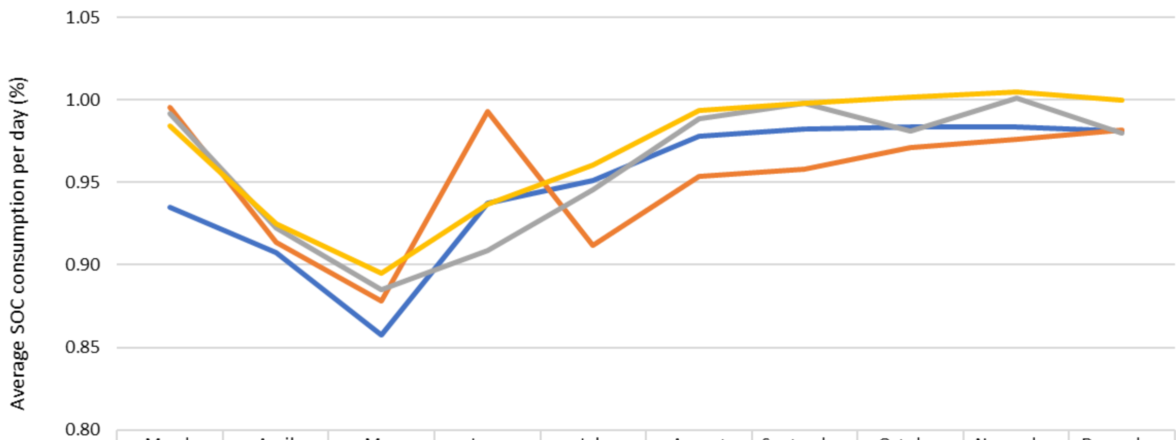


Figure 35 Average energy efficiency (kWh/km) in December

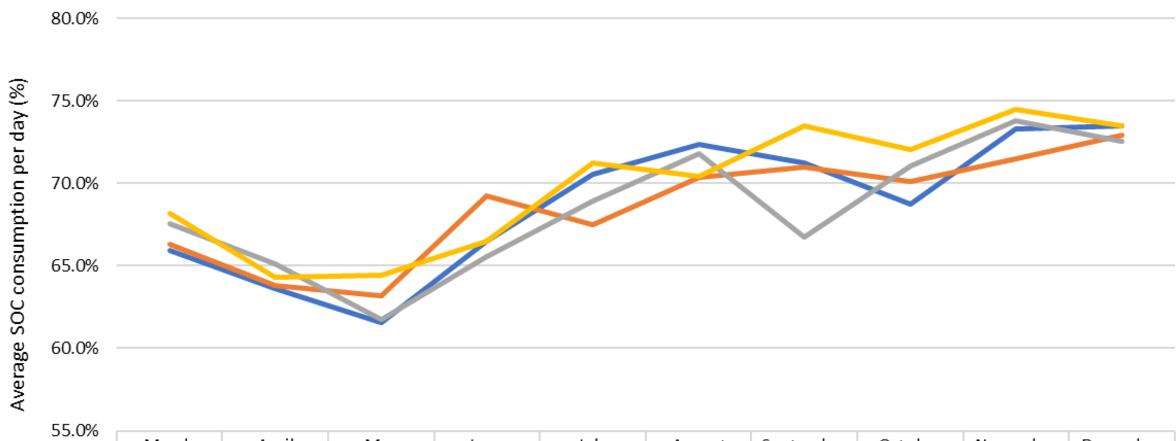
Looking into the energy efficiency of four buses with the most travel mileage, it is found that all of them have the lowest energy consumption per kilometer traveled in May compared with other months, with only 0.88 kWh electricity consumed per kilometer traveled. But this figure is around 0.95 in other months. This is because of the low level of average energy consumed per day, which is resulted from the lower start SOC but higher end SOC. Transjakarta needs to reevaluate what specifically happened during the month, whether there are operating changes or errors in recording the data. Besides this notable pattern, it can also be seen an increasing trend in the kWh consumed for one kilometer traveled when vehicles are traveling more mileages, indicating a decrease in battery efficiency with more usage.



	March	April	May	June	July	August	September	October	November	December
MYS-22334	0.94	0.91	0.86	0.94	0.95	0.98	0.98	0.98	0.98	0.98
MYS-22335	1.00	0.91	0.88	0.99	0.91	0.95	0.96	0.97	0.98	0.98
MYS-22336	0.99	0.92	0.88	0.91	0.95	0.99	1.00	0.98	1.00	0.98
MYS-22343	0.98	0.92	0.90	0.94	0.96	0.99	1.00	1.00	1.01	1.00

MYS-22334 MYS-22335 MYS-22336 MYS-22343

Figure 36 Energy consumption per km traveled (kWh/km) by month and vehicle



	March	April	May	June	July	August	September	October	November	December
MYS-22334	66.0%	63.6%	61.5%	66.5%	70.5%	72.4%	71.3%	68.8%	73.3%	73.5%
MYS-22335	66.3%	63.8%	63.2%	69.2%	67.5%	70.4%	71.0%	70.1%	71.5%	72.9%
MYS-22336	67.5%	65.1%	61.7%	65.5%	69.0%	71.8%	66.7%	71.1%	73.8%	72.5%
MYS-22343	68.2%	64.3%	64.4%	66.5%	71.2%	70.4%	73.5%	72.1%	74.5%	73.5%

MYS-22334 MYS-22335 MYS-22336 MYS-22343

Figure 37 Average energy consumption per day (kWh)

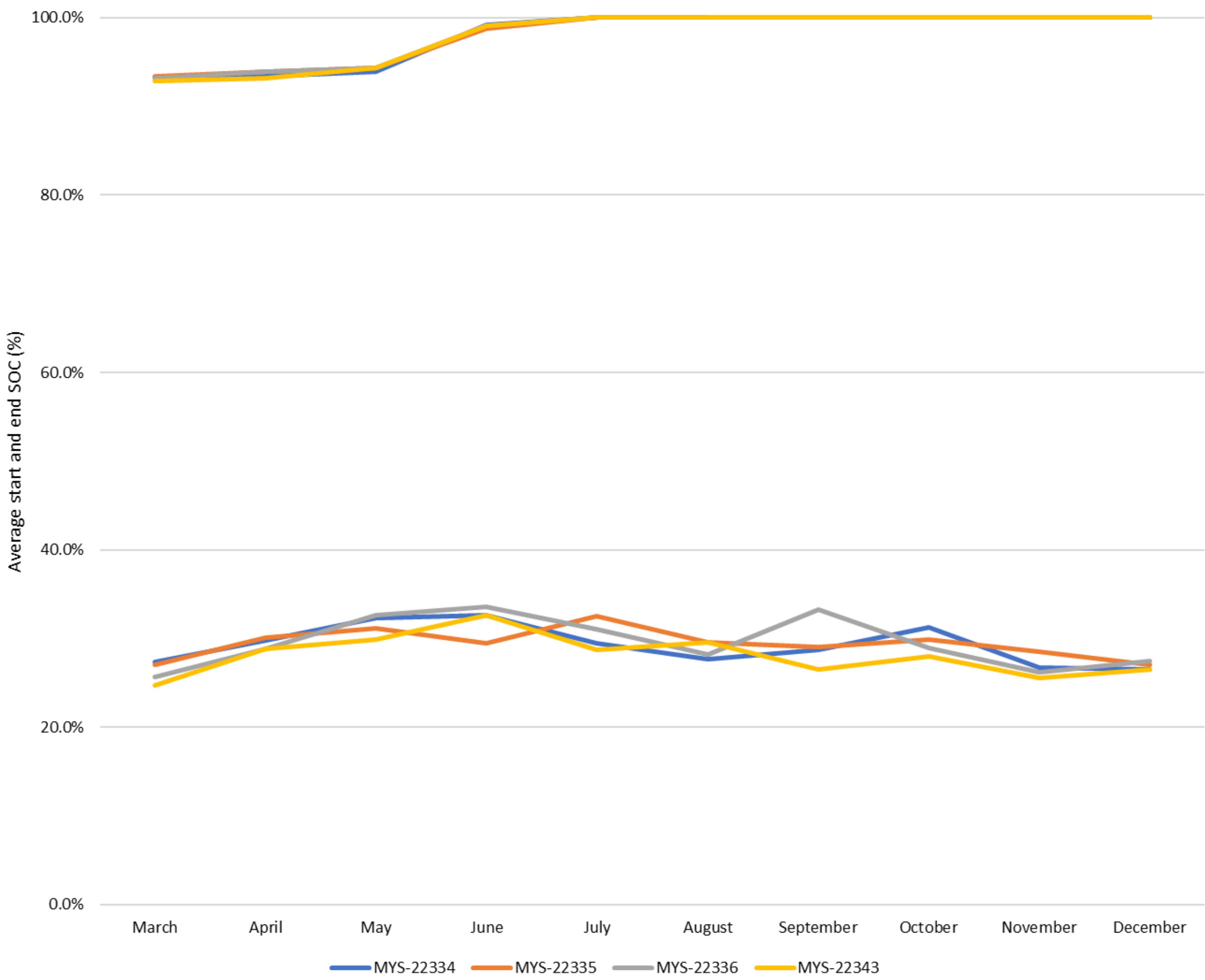


Figure 38 Average start and end SOC by month (%)

Since the energy consumed by electric vehicles could be affected by various factors including external temperature, weather conditions, road conditions, inclinations, traffic conditions, driving behaviors, vehicle load, etc.[4] It is necessary to discover the energy consumption variations in different routes, weekdays and weekends. As shown in the figure below, for most vehicles, route 1P requires less energy consumption than route 1N. Since there are only four records on route 6D, the result of significant high energy consumption may not be reliable. It is also found the energy efficiency of e-buses may be decreased on weekdays compared to weekends. This may be caused by more passenger attendance on working days.

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[4] Iopscience.iop.org. 2022. *ShieldSquare Captcha*. [online] Available at: <https://iopscience.iop.org/article/10.1088/1757-899X/1247/1/012001> [Accessed 13 October 2022].

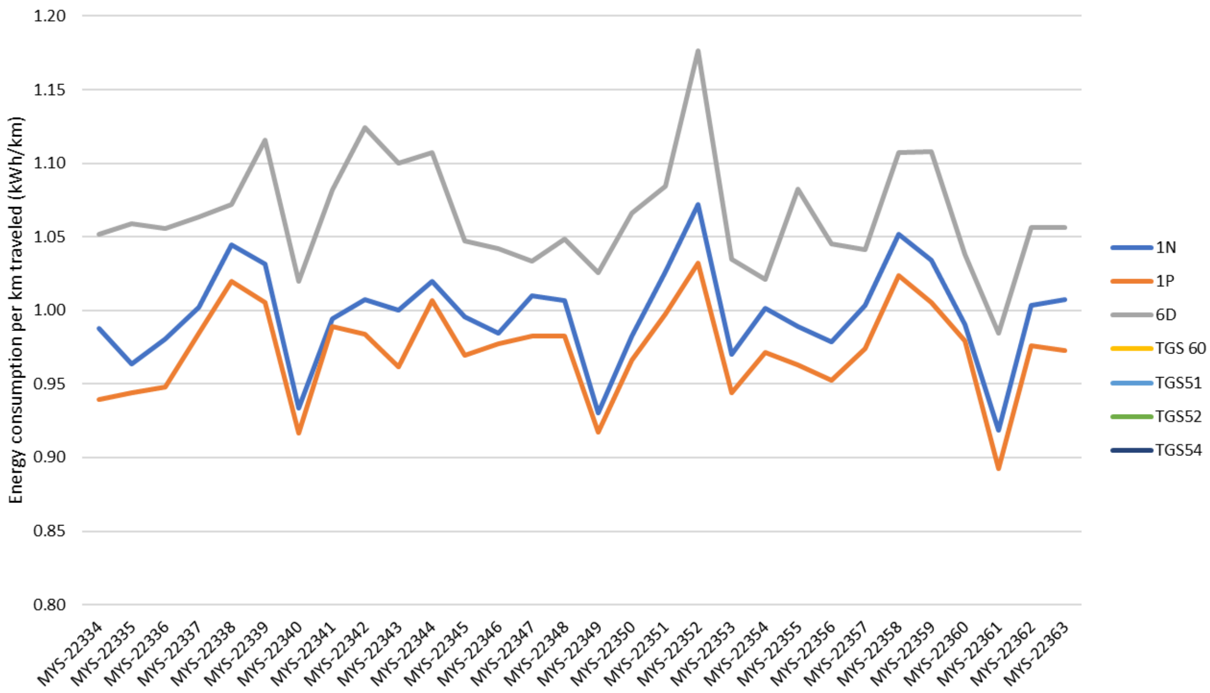


Figure 39 Energy consumption per km traveled by route

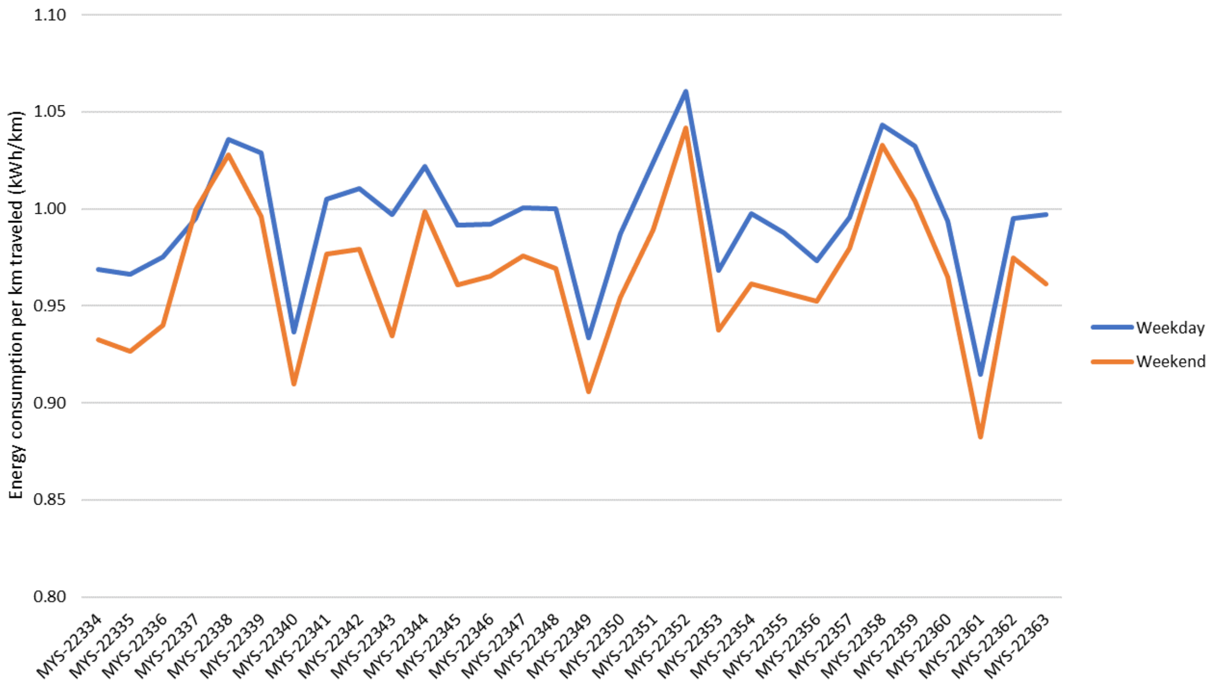


Figure 40 Energy consumption per km traveled by weekdays and weekends

Traveled distance per SOC (km/SOC)

Table 9 Traveled distance per SOC of all vehicles in each month

Plate number	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trend
MYS-22334	3.47	3.58	3.78	3.47	3.42	3.32	3.31	3.30	3.30	3.32	
MYS-22335	3.29	3.55	3.69	3.34	3.57	3.41	3.38	3.34	3.33	3.31	
MYS-22336	3.29	3.54	3.70	3.59	3.44	3.29	3.26	3.31	3.25	3.33	
MYS-22337				3.28	3.37	3.26	3.20	3.22	3.27	3.22	
MYS-22338				3.11	3.20	3.11	3.12	3.15	3.13	3.17	
MYS-22339				3.28	3.25	3.18	3.17	3.17	3.13	3.11	
MYS-22340				3.65	3.69	3.48	3.46	3.44	3.40	3.43	
MYS-22341				3.40	3.50	3.24	3.19	3.17	3.16	3.26	
MYS-22342				3.33	3.31	3.41	3.09	3.13	3.18	3.33	
MYS-22343	3.31	3.51	3.63	3.48	3.38	3.20	3.26	3.24	3.24	3.26	
MYS-22344				3.22	3.33	3.20	3.14	3.15	3.16	3.18	
MYS-22345				3.40	3.44	3.19	3.19	3.18	3.28	3.50	
MYS-22346				3.16	3.25	3.14	3.34	3.35	3.41	3.47	
MYS-22347				3.37	3.40	3.17	3.12	3.19	3.28	3.42	
MYS-22348				3.21	3.34	3.28	3.25	3.23	3.31	3.37	
MYS-22349				3.50	3.70	3.47	3.47	3.49	3.53	3.38	
MYS-22350				3.37	3.44	3.30	3.26	3.27	3.27	3.35	
MYS-22351				3.21	3.29	3.20	3.19	3.18	3.13	3.25	
MYS-22352				3.15	3.28	2.92	2.98	2.94	3.08	3.29	
MYS-22353				3.39	3.57	3.41	3.37	3.31	3.31	3.39	
MYS-22354				3.31	3.38	3.32	3.30	3.20	3.21	3.33	
MYS-22355				3.46	3.43	3.36	3.28	3.27	3.25	3.25	
MYS-22356				3.30	3.43	3.39	3.34	3.34	3.33	3.38	
MYS-22357				3.29	3.35	3.25	3.22	3.23	3.34	3.32	
MYS-22358				3.14	3.23	3.06	3.08	3.05	3.15	3.20	
MYS-22359				2.97	3.17	3.31	3.34	3.25	3.17	3.09	
MYS-22360				3.27	3.26	3.25	3.24	3.34	3.35	3.38	
MYS-22361				3.51	3.80	3.67	3.56	3.49	3.51	3.63	
MYS-22362				3.30	3.28	3.31	3.23	3.21	3.29	3.40	
MYS-22363				3.25	3.44		3.25	3.27	3.37	3.19	
Total	3.34	3.55	3.70	3.33	3.40	3.28	3.25	3.25	3.27	3.32	

The table above marked the cells that have the least and the most values of traveled distance per SOC in each month. It can be seen vehicle MYS-22334 has the best performance at first three months; but vehicle MYS-22352 always has inferior performance. Transjakarta needs to further investigate the worst performed vehicles and check the reasons. There is also a trend that vehicles all performed distinctly well in May and then decreased after.

Battery degradation

A more detailed analysis of the four electric buses with the longest operating time is conducted and it is found that with the increase of the total operating mileage, the battery efficiency decreased. These four electric buses operated for about 35,000 kilometers respectively, all of which showed the trend of decreasing battery efficiency. The overall battery efficiency needs to be verified by longer operation and more data. At present, the research group has only conducted a preliminary study and provided an analysis method.

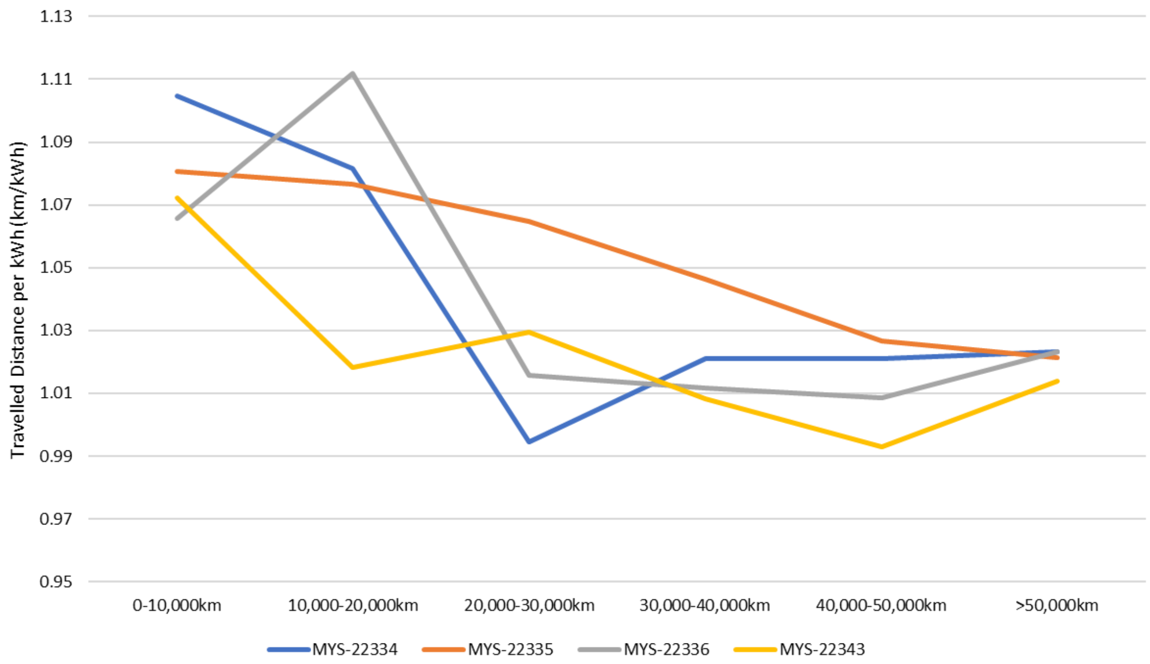


Figure 41 Travelled distance per kWh by different travel mileage (km/SOC)

Observing all vehicles, there is an overall decreasing trend on the distance traveled for every kWh consumed, despite the vehicle 'MYS-22359', where the traveling distance per energy consumed is raised when more accumulated mileage is traveled, more data needs to be collected to verify the trend of battery degradation for the all the vehicles, especially for the vehicle 'MYS-22359'.

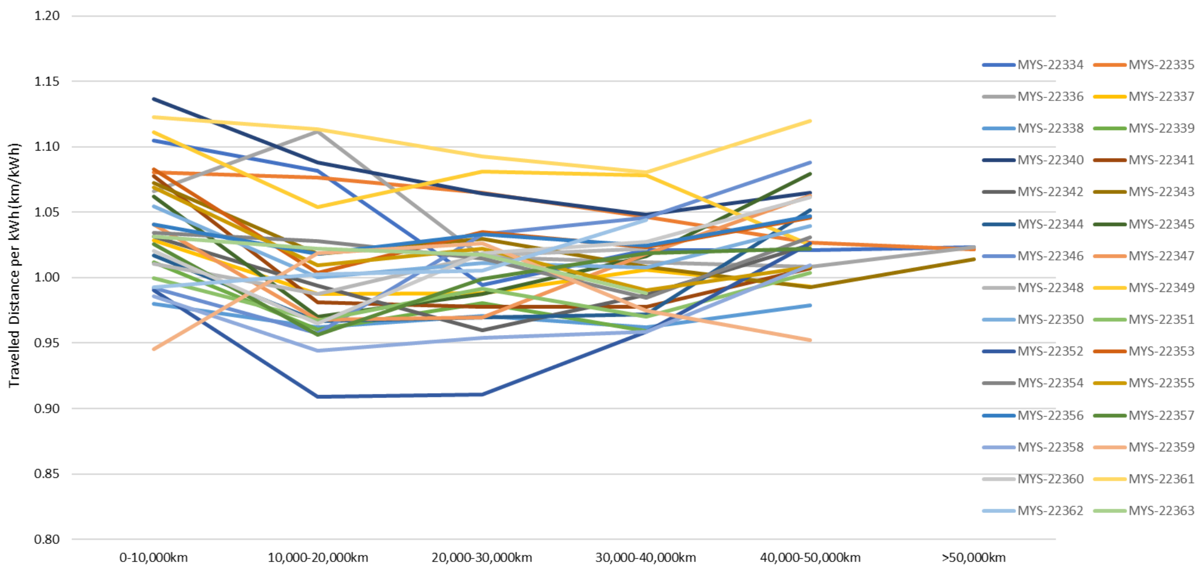


Figure 42 Traveled distance per kWh of all vehicles by different travel mileage (km/kWh)

3.3 Operating performance

Vehicle attendance

From March 2, 2022, there are four e-buses that are operating at route 1P only. When more buses are ready on June 7, 2022, Transjakarta added route 1N with e-buses. The operating route for each bus is not fixed, all vehicles are allocated to two or three routes and the route may vary on different days. The total number of buses operating on the same route every day is not fixed as well, but the variations are one or two vehicles per day. These adjustments might be made based on the vehicle availability and the external environment conditions on the day. Although both routes 1P and 1N are fully electrified, around 5 more buses are needed for route 1P every day.

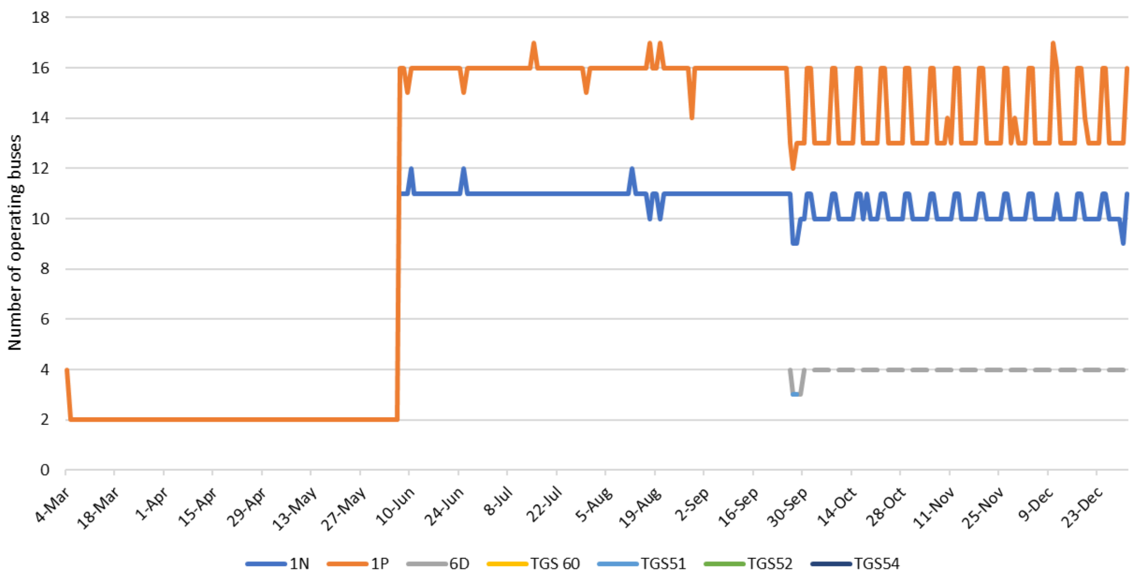


Figure 43 The number of operating buses on each day by routes

Table 10 Vehicle operating records

Plate Number	Operation start from	Operating route								Total operating mileage (km)
		1N	1P	6D	TGS 60	TGS51	TGS52	TGS54	total	
MYS-22334	4 March 2022	73	162	11				1	247	58108
MYS-22335	4 March 2022	72	151	10					233	54876
MYS-22336	4 March 2022	80	152	10		2	1		245	57012
MYS-22337	7 June 2022	94	95	8					197	46765
MYS-22338	7 June 2022	88	94	10					192	45014
MYS-22339	7 June 2022	70	89	5					164	37953
MYS-22340	7 June 2022	74	111	7		2			194	45607
MYS-22341	7 June 2022	84	101	12	1				198	46300
MYS-22342	7 June 2022	76	98	10		1			185	44136
MYS-22343	4 March 2022	81	148	10					239	55958
MYS-22344	7 June 2022	79	92	4					175	41132
MYS-22345	7 June 2022	69	111	10					190	44660
MYS-22346	7 June 2022	63	114	15					192	45407
MYS-22347	7 June 2022	60	122	11					193	45059
MYS-22348	7 June 2022	44	120	7					171	40145
MYS-22349	7 June 2022	56	110	7					173	41489
MYS-22350	7 June 2022	75	106	10					191	45415
MYS-22351	7 June 2022	78	108	11					197	45723
MYS-22352	7 June 2022	78	103	9					190	43991
MYS-22353	7 June 2022	89	98	8					195	45429
MYS-22354	7 June 2022	86	101	10					197	45695
MYS-22355	7 June 2022	80	104	9					193	45595
MYS-22356	7 June 2022	78	108	10					196	46107
MYS-22357	7 June 2022	91	96	10					197	46061
MYS-22358	10 June 2022	79	101	10		1			191	43735
MYS-22359	10 June 2022	80	97	11					188	43982
MYS-22360	9 June 2022	76	106	6					188	43910
MYS-22361	7 June 2022	63	120	10					193	45782
MYS-22362	7 June 2022	50	96	9					155	36336
MYS-22363	7 June 2022	51	97	7					155	36048
Total		2217	3311	273	1	6	1	1	5814	1363430

Because ensuring all vehicles are used for a certain amount of mileage is beneficial to test the vehicle performance, the total mileage traveled by each vehicle is evenly distributed to buses that started operating in June, ranging from 22035 to 25642 kilometers during the recorded operating period. But the one exception is MYS-22348, the operating days given to this bus dropped remarkably in September, despite its high usage from June to August.

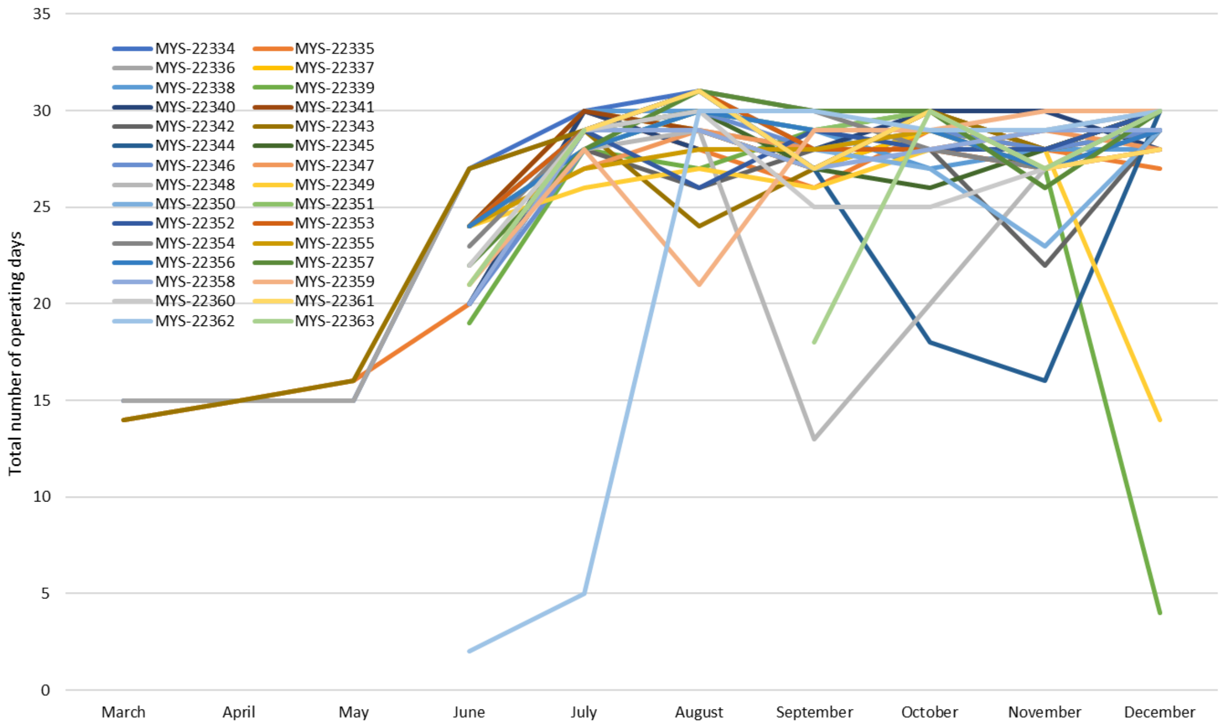


Figure 44 Operating days of each vehicle by month

Table 11 Vehicle operating days by month

Month	3	4	5	6	7	8	9	10	11	12	Total
MYS-22334	15	15	15	27	30	31	27	29	28	30	247
MYS-22335	14	15	16	20	30	28	26	29	28	27	233
MYS-22336	15	15	15	27	29	29	28	28	29	30	245
MYS-22337				24	30	29	27	29	28	30	197
MYS-22338				20	30	30	29	27	28	28	192
MYS-22339				19	28	27	29	30	27	4	164
MYS-22340				20	30	28	28	30	30	28	194
MYS-22341				24	30	29	27	30	28	30	198
MYS-22342				24	28	26	28	28	22	29	185
MYS-22343	14	15	16	27	29	24	27	30	28	29	239
MYS-22344				24	29	31	27	18	16	30	175
MYS-22345				20	29	30	27	26	28	30	190
MYS-22346				20	28	30	28	29	28	29	192
MYS-22347				24	27	29	28	28	29	28	193
MYS-22348				24	28	29	13	20	27	30	171
MYS-22349				24	26	27	26	28	28	14	173
MYS-22350				24	29	31	28	27	23	29	191
MYS-22351				24	28	30	29	30	26	30	197
MYS-22352				20	29	26	29	28	28	30	190
MYS-22353				24	29	31	28	28	27	28	195
MYS-22354				23	29	31	30	28	27	29	197
MYS-22355				24	27	28	28	29	27	30	193
MYS-22356				24	28	30	29	29	27	29	196
MYS-22357				22	28	31	30	30	26	30	197
MYS-22358				20	29	29	27	28	29	29	191

Month	3	4	5	6	7	8	9	10	11	12	Total
MYS-22359				21	28	21	29	29	30	30	188
MYS-22360				22	29	30	25	25	27	30	188
MYS-22361				21	29	31	27	30	27	28	193
MYS-22362				2	5	30	30	29	29	30	155
MYS-22363				21	29		18	30	27	30	155
Total	58	60	62	660	837	836	812	839	812	838	5814

Vehicle attendance rate

Vehicle attendance rate is calculated by the number of vehicles in operation over all available vehicles. It could be used to measure operating efficiency: the higher the proportion is, the more vehicles are utilized and the more efficient the system is. Only 50% of buses were utilized when only 4 buses were available in the depot, but the figure went up to 90% after more e-buses were deployed. Beginning from 7 June when all 30 buses are on road, 3 out of 112 days have lower vehicle utilization. These unexpected changes should be further observed.

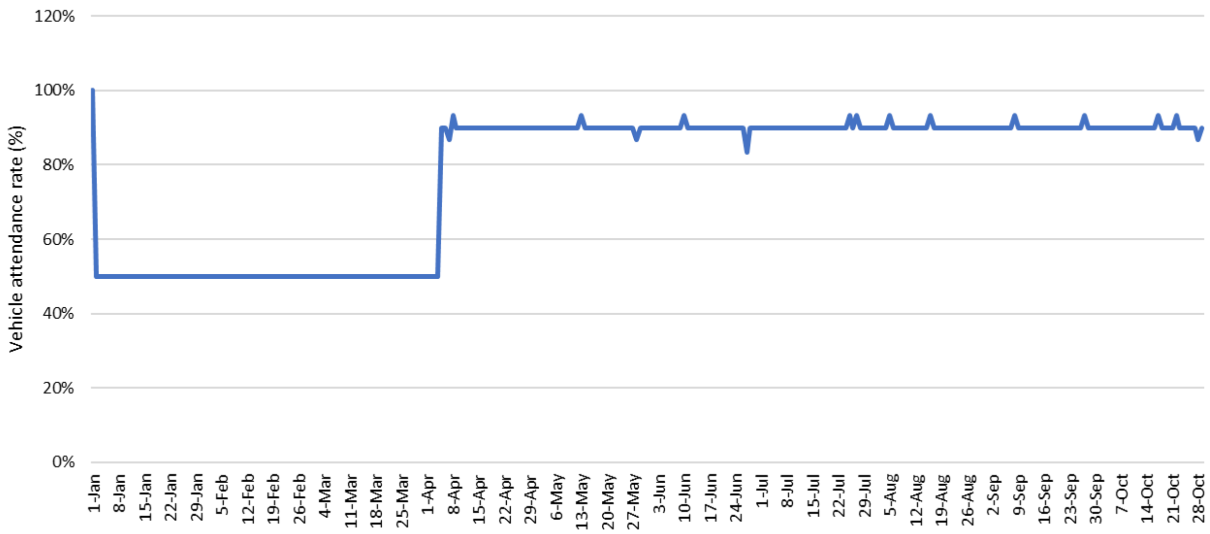


Figure 45 Vehicle attendance rate at each day

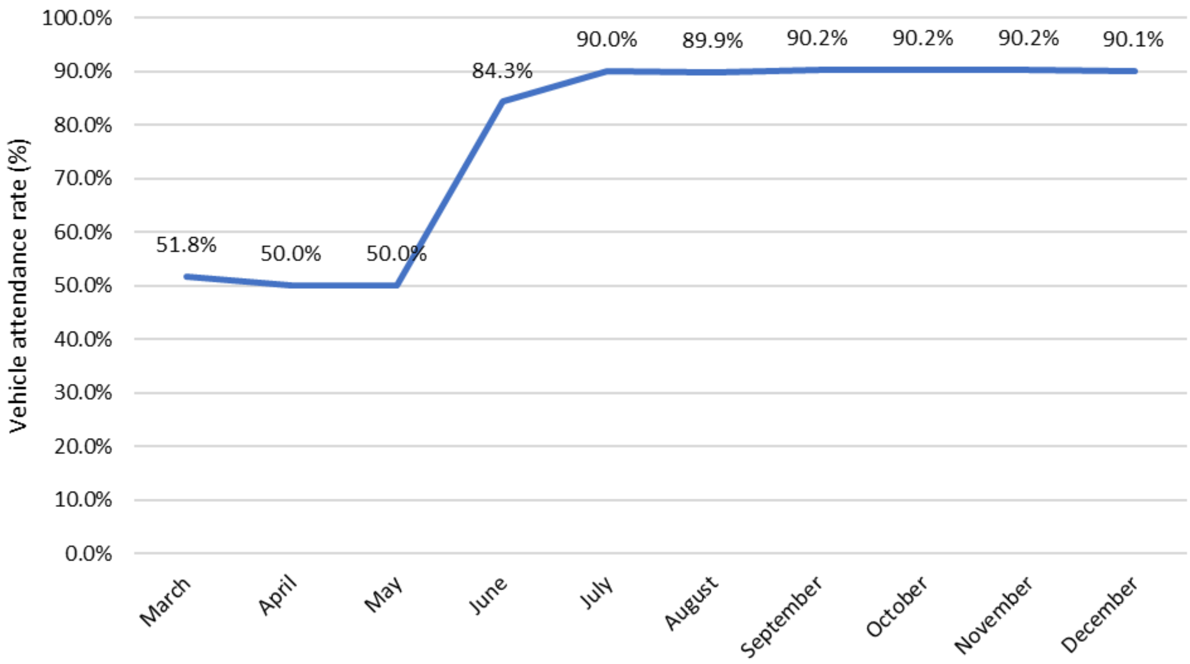


Figure 46 Vehicle attendance rate at each month

Average daily travel distance

The average daily driving distance for the 30 e-buses are quite even, the e-buses MYS-22342 and MYS-22349 have higher daily driving distance than other e-buses, the e-buses MYS-22354 and MYS-22362 have the lower daily driving distance than other e-buses. On average, the buses travel 234.2 km per day.

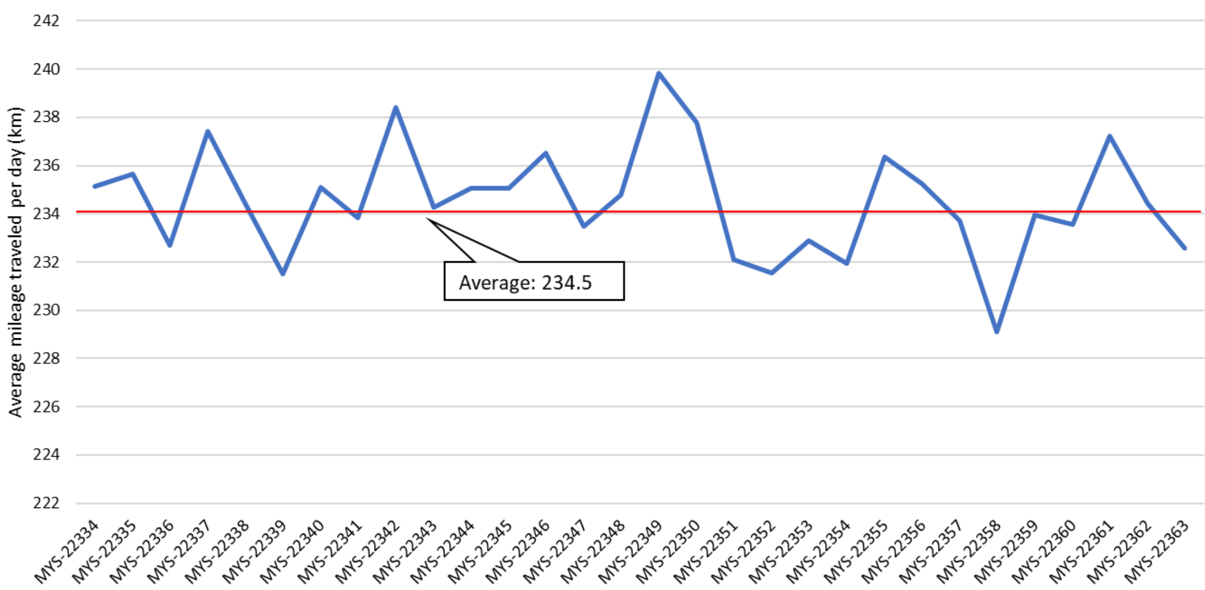
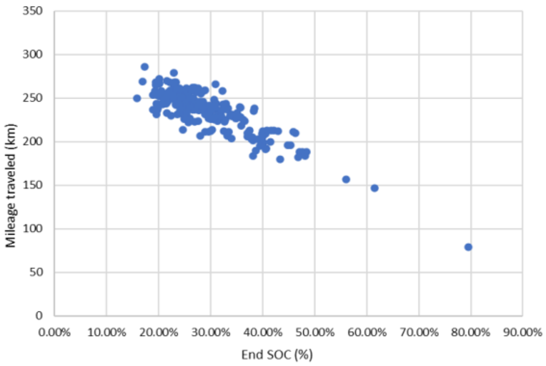


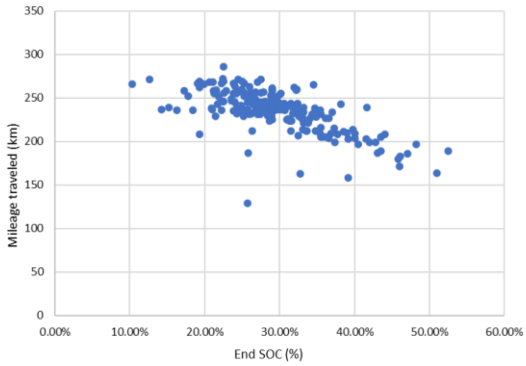
Figure 47 Average daily driving distance of all vehicles

Relationship between the end SOC and mileage traveled

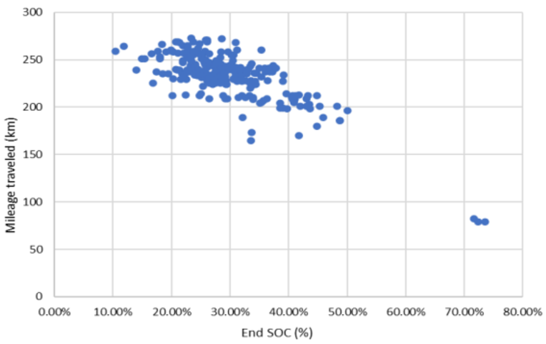
The team has analyzed the use characteristics of these four electric buses. The overall operation of electric buses is relatively stable, with an average daily mileage of about 230 km, but it has not fully exerted its efficiency. According to the data of daily operation, in many cases, the operation of electric buses is finished when the SOC is 40%. The vehicles could have been used for longer-distance operations, and the performance advantages of electric buses can be better exerted through more reasonable route settings.



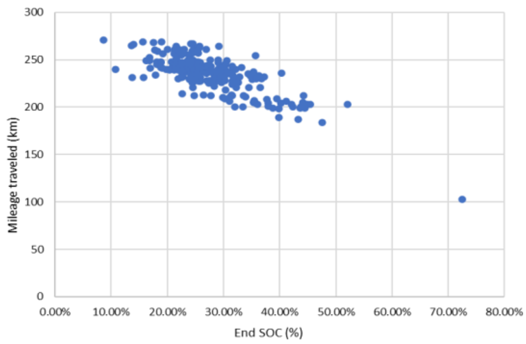
MYS-22334



MYS-22335



MYS-22336



MYS-22343

Figure 48 End SOC and mileage traveled

Dead kilometers

Dead kilometer refers to the distance the bus traveled from the depot to the first stop of the operational trip and the distance from the last stop to the depot. Dead kilometers need to be minimized by allocating buses to suitable depots to increase operational efficiency. The picture below shows

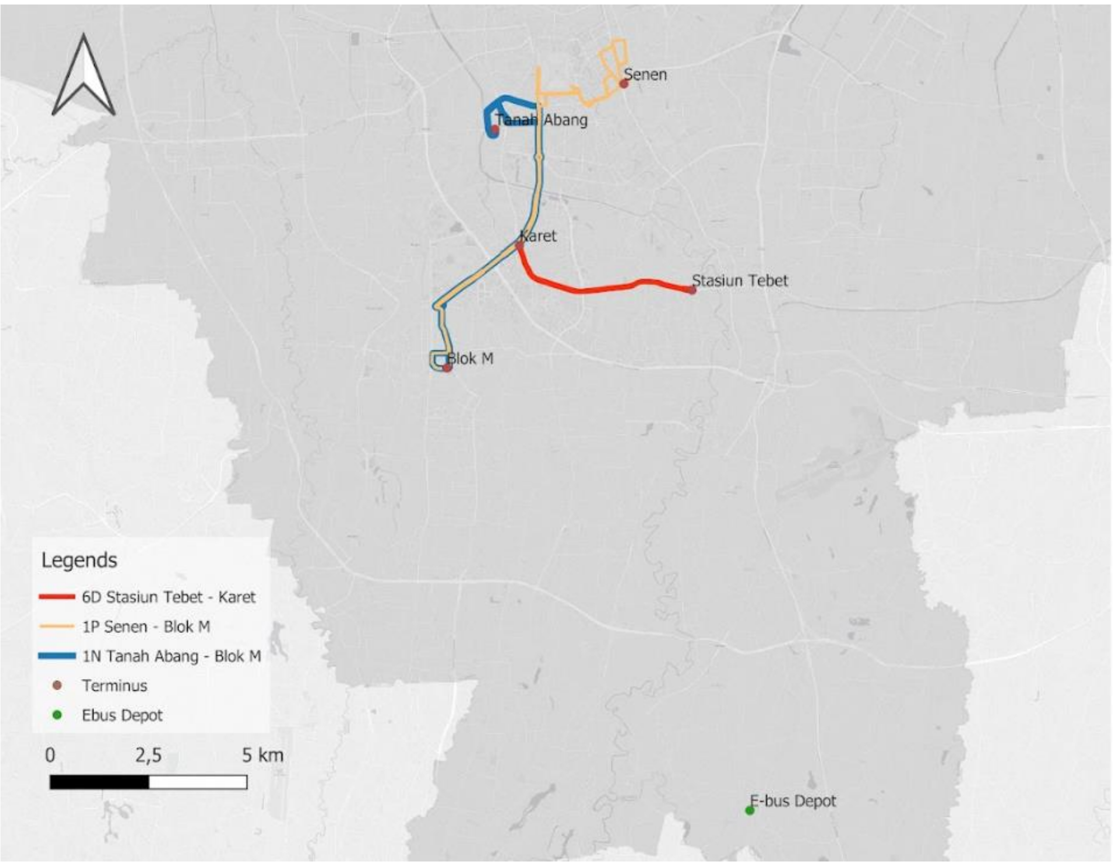


Figure 49 E-bus route map

Since the actual traveling distance is not provided by Transjakarta, the dead kilometers are computed through the distance obtained from Google Maps. The table below summarized the length and dead kilometers for each route. The average dead kilometers is 19.1 km, whereas the route length is 20 km on average. Although route 6D only has a length of 10.12km, the bus has to run 18.3 km to get back to the depot. More depots with charging infrastructure need to be constructed in the long term to minimize the dead kilometers.

Table 12 Route information

Route		Length (km)	Distance from terminus to depot (km)
1P	Senen - Block M	29.13	19.5
1N	Tanah Abang - Block M	20.8	19.5
6D	Stasiun Tebet - Bundaran Senayan	10.12	18.3

Charging efficiency and average charging time

Charging efficiency is measured by the energy added to the e-bus over the energy used by the charger at each charging event. This indicator reflects the energy lost during the charging process. Based on the one-day charging data provided by Transjakarta, the following figure shows the charging durations and efficiency for each charging session on Jul 11, 2022. The average charging time is 92 minutes, and the charging efficiency reached over 95%, despite several human recording errors with over 100% of efficiency.

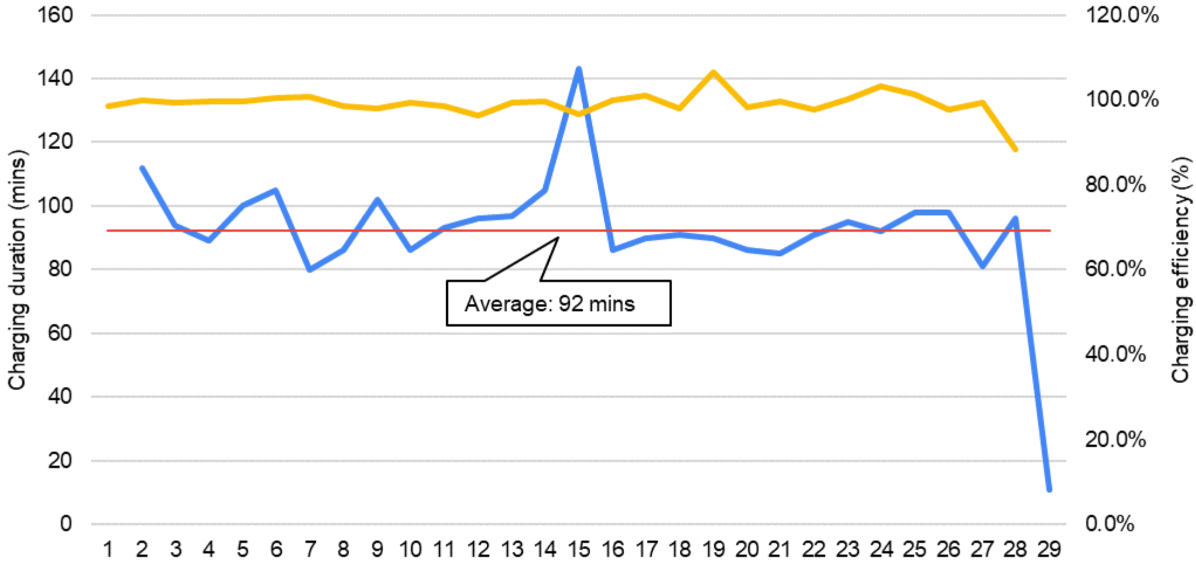
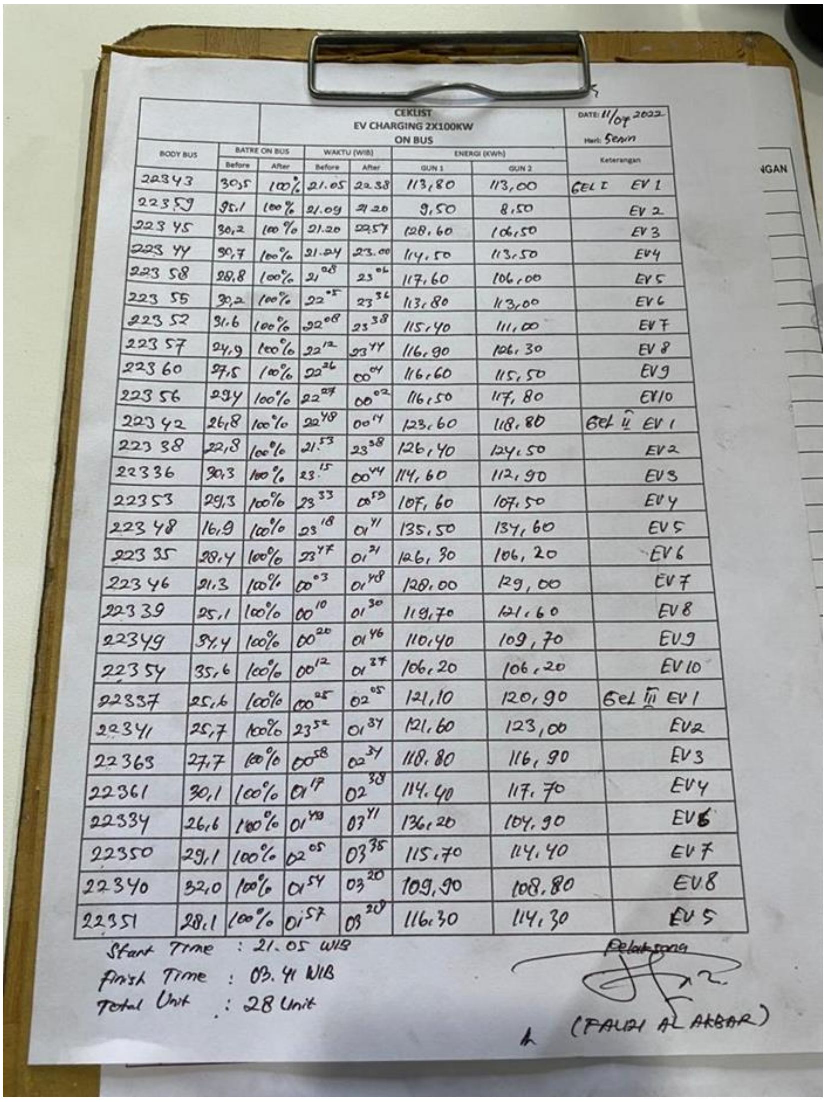


Figure 50 Charging duration and efficiency for each charging event on Jul 11, 2022

Figure 51 Double charging gun

Figure 52 The surface screen of the charging Infrastructure

Figure 53 Staff is charging the e-bus



CEKLIST
EV CHARGING 2X100KW
ON BUS

DATE: 11/07 2022
Hari: Senin

BODY BUS	BATRE ON BUS Before	BATRE ON BUS After	WAKTU (WIB) Before	WAKTU (WIB) After	ENERGI (KWh) GUN 1	ENERGI (KWh) GUN 2	Keterangan
22343	30,5	100%	21.05	22.38	113,80	113,00	GEL I EV 1
22359	95,1	100%	21.09	21.20	9,50	8,50	EV 2
22345	30,2	100%	21.20	22.57	128,60	106,50	EV 3
22344	30,7	100%	21.24	23.00	114,50	113,50	EV 4
22358	28,8	100%	21^{08}	23^{06}	117,60	106,00	EV 5
22355	30,2	100%	22^{05}	23^{36}	113,80	113,00	EV 6
22352	31,6	100%	22^{08}	23^{38}	115,40	111,00	EV 7
22357	24,9	100%	22^{12}	23^{44}	116,90	126,30	EV 8
22360	27,5	100%	22^{26}	00^{04}	116,60	115,50	EV 9
22356	29,4	100%	22^{27}	00^{02}	116,50	117,80	EV 10
22342	26,8	100%	22^{48}	00^{14}	123,60	118,80	Gel II EV 1
22338	22,8	100%	21^{53}	23^{38}	126,40	124,50	EV 2
22336	30,3	100%	23^{15}	00^{44}	114,60	112,90	EV 3
22353	29,3	100%	23^{33}	00^{59}	107,60	107,50	EV 4
22348	16,9	100%	23^{18}	01^{41}	135,50	134,60	EV 5
22335	28,4	100%	23^{47}	01^{21}	126,30	106,20	EV 6
22346	21,3	100%	00^{03}	01^{48}	128,00	129,00	EV 7
22339	25,1	100%	00^{10}	01^{30}	119,70	121,60	EV 8
22349	34,4	100%	00^{20}	01^{46}	110,40	109,70	EV 9
22354	35,6	100%	00^{12}	01^{37}	106,20	106,20	EV 10
22337	25,6	100%	00^{25}	02^{05}	121,10	120,90	Gel III EV 1
22341	25,7	100%	23^{52}	01^{34}	121,60	123,00	EV 2
22363	27,7	100%	00^{58}	02^{34}	118,80	116,90	EV 3
22361	30,1	100%	01^{17}	02^{38}	114,40	117,70	EV 4
22334	26,6	100%	01^{48}	03^{41}	136,20	104,90	EV 6
22350	29,1	100%	02^{05}	03^{35}	115,70	114,40	EV 7
22340	32,0	100%	01^{54}	03^{20}	109,90	108,80	EV 8
22351	28,1	100%	01^{57}	03^{20}	116,30	114,30	EV 5

Start Time : 21.05 WIB
Finish Time : 03.41 WIB
Total Unit : 28 Unit

Pelaksana

(FAUZI AL AKBAR)

Figure 54 Charging data collection form

Failure events and e-bus maintenance

E-bus failure events are recorded using the technical report. A typical report is shown below: a front tire from an e-bus was damaged because of unexpected road conditions, and a technician arrived 41 minutes after the incident was reported. The maintenance report for November 2022, was provided by Transjakarta as well, all of the grounded e-buses are due to road accidents. However, because of the lack of data, a detailed analysis of e-bus failures is not done in this report.

Transjakarta provided a 1-month maintenance report, the data provided was too broad and didn't have details, all the failure events are grounded in the 'road accident' category in the report, the project team was unable to make adequate analysis based on the raw data.

TECHNICAL REPORT

VIN	LC06S24S6M4000018	Component	Chassis
Drie Motor Code	121000610	Sub Component	Wheel/Tyre
Body Number	MYS 22351	Part Number	
Customer	PT. Mayasari Bakti	Mileage	38897
Location	Cibubur	Date	29-Nov-22

FLAT TYRE (Front left tyre)

I. Background

Odometer

Flat Tyre (Front left tyre)

Driver inform to Bus Mechanic by phone at 07.36 (location in Blok M). Mechanic arrived at Pasar Senen station at 08.17 (Information received from PLO that repairing time is up at 7.40, BA will up at 8.27, tyre replacement completed at 8.57

II. Cause analysis

a. Analyzing condition existed

Flat tyre because it was punctured by a bolt

Fleet condition after fleet replacement with the spare tyre from storing

First information received at 7.36
Travel from Blok M to Pasar Senen (7.36 - 8.17),
Tire replacement process (8.20 - 8.57), 37
Repairing time is up at 7.40 (4 minutes from the information received)

b. causal analysis

Because the fleet went through road conditions which at that time were poor, the left front tire was stuck with a bolt so there was a small leak on the tire

Conclusion & Recommendation

1. Tyre replacement on front left of the bus using the spare tyre
2. There needs to be a tolerance for repair time (more than 30 minutes) because a tyre replacement is an activity that can definitely be completed on the road (not at bus depot)

Figure 55 Example Technical report

Maintenance Report

No	Date	Total Fleet	Ready to Operate (SGO)	Grounded						TJ Operating plan	Free Unit
				Telematic	Body	Engine & Chassis	Road Accident	Administration	Others		
1	2022/11/1	30	28	0	0	0	2	0	0	27	1
2	2022/11/2	30	29	0	0	0	1	0	0	28	1
3	2022/11/3	30	28	0	0	0	2	0	0	27	1
4	2022/11/4	30	28	0	0	0	2	0	0	27	1
5	2022/11/5	30	28	0	0	0	2	0	0	27	1
6	2022/11/6	30	29	0	0	0	1	0	0	27	2
7	2022/11/7	30	29	0	0	0	1	0	0	27	2
8	2022/11/8	30	29	0	0	0	1	0	0	27	2
9	2022/11/9	30	29	0	0	0	1	0	0	27	2
10	2022/11/10	30	29	0	0	0	1	0	0	27	2
11	2022/11/11	30	28	0	0	0	2	0	0	27	1
12	2022/11/12	30	30	0	0	0	0	0	0	27	3
13	2022/11/13	30	30	0	0	0	0	0	0	27	3
14	2022/11/14	30	30	0	0	0	0	0	0	27	3
15	2022/11/15	30	30	0	0	0	0	0	0	27	3
16	2022/11/16	30	30	0	0	0	0	0	0	27	3
17	2022/11/17	30	29	0	0	0	1	0	0	27	2
18	2022/11/18	30	29	0	0	0	1	0	0	27	2
19	2022/11/19	30	29	0	0	0	1	0	0	27	2
20	2022/11/20	30	29	0	0	0	1	0	0	27	2
21	2022/11/21	30	29	0	0	0	1	0	0	27	2
22	2022/11/22	30	29	0	0	0	1	0	0	27	2
23	2022/11/23	30	29	0	0	0	1	0	0	27	2
24	2022/11/24	30	30	0	0	0	0	0	0	27	3
25	2022/11/25	30	30	0	0	0	0	0	0	27	3
26	2022/11/26	30	29	0	0	0	1	0	0	27	2
27	2022/11/27	30	30	0	0	0	0	0	0	27	3
28	2022/11/28	30	29	0	0	0	1	0	0	27	2
29	2022/11/29	30	30	0	0	0	0	0	0	27	3
30	2022/11/30	30	29	0	0	0	1	0	0	27	2
		900	874	26							

Figure 56 Example maintenance report

Cost estimates

Because the capital and operational cost data of electric buses is confidential, the research group can't get the real data on the cost from the operating company. The TCO calculation is based on the data collected by ITDP. Transjakarta and the operator can verify the results based on real cost data, to understand the true cost and difference between electric buses and ICE buses.

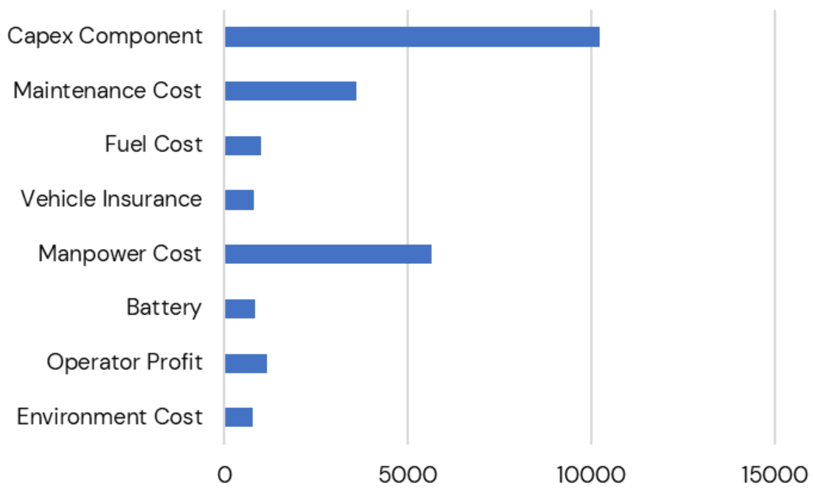


Figure 57 Single e-bus TCO components (IDR/km)

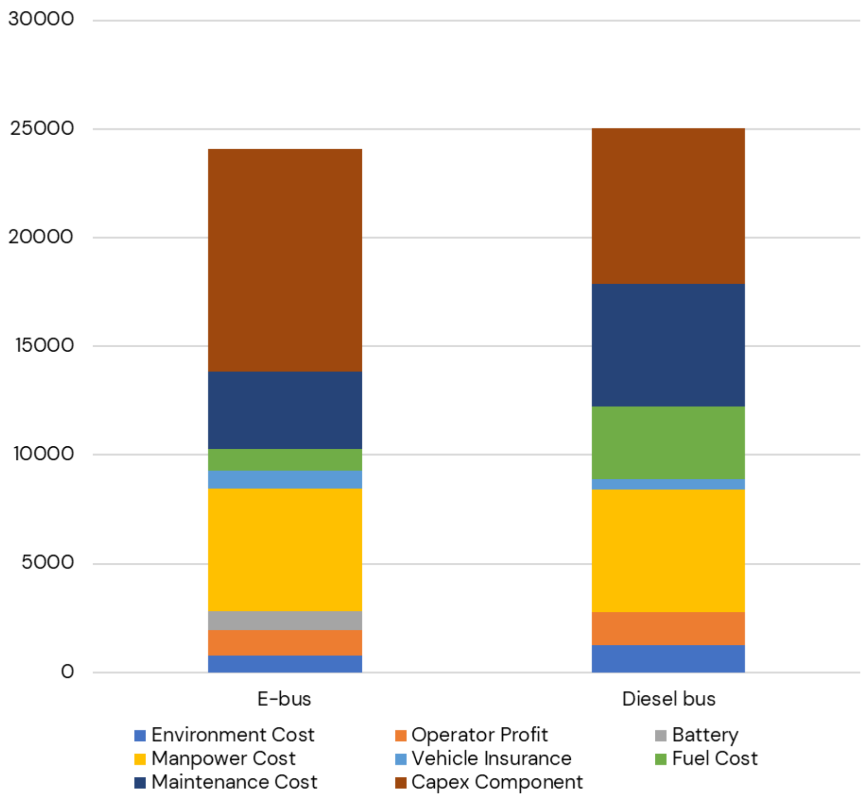


Figure 58 TCO components of single e-bus and diesel bus (IDR/km)

3.4 Environmental impacts

The calculation of environmental impacts is based on the 30 e-buses operated in Jakarta now, it is compared with the ICE buses run by the operators. Emissions including CO2, PM2.5, SO2, and NOX are being measured. The emission factors used below are based on ITDP's previous report on GHG Reduction Estimation Supporting Jakarta's Transition to E-Mobility[5].

Figure 59 Emission factors

Emission factors	ICE buses	E-buses
WTW CO2 Emissions (kg CO2eq/km)	1.94	0.88
PM2.5 (g/km)	0.63	0
SO2 (g/km)	0.4	0
NOX (g/km)	14	0

The total emission reductions are related to the total mileage traveled of each e-bus. Since only the operational data from March to December is available, the results in the table below reflect only the emission avoided during this period. And the reductions refer to the differences compared with ICE buses that are operated before.

[5] GHG Reduction Estimation Supporting Jakarta's Transition to E-Mobility, ITDP, 2020

Table 13 Emissions saved from pilot e-buses from March to December 2023

Pollutant	Total emission reduced (kg)	Emission reduced per bus (kg)
CO2eq	1445235.8	48174.5
PM2.5	859.0	28.6
SO2	545.4	18.2
NOX	19088.0	636.3

The figure below compares the CO2 and pollutant emissions reduced by each vehicle. Bus MS-22334, which was one of the first operated buses, has the largest amount of emission savings.

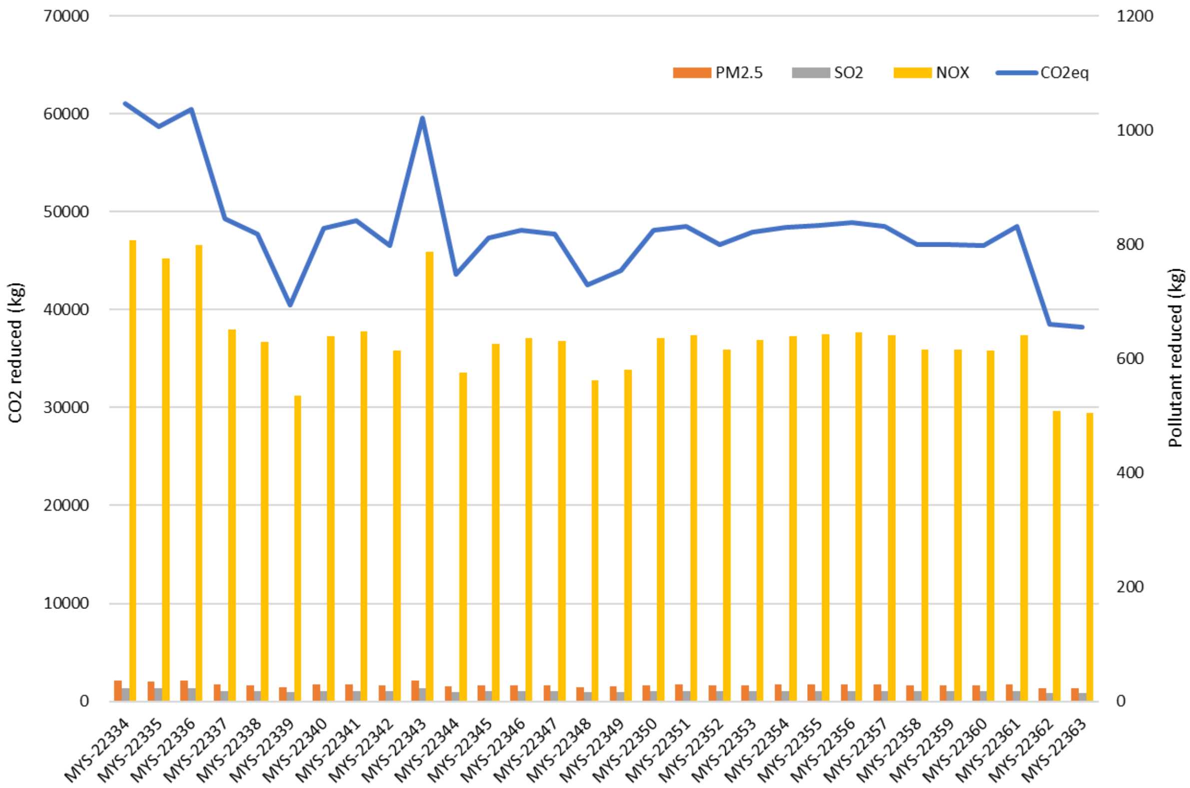


Figure 60 CO2 emission reduction of each vehicle (kg)

3.5 Social and gender impacts

Total number of People with Disabilities passengers using TransJakarta e-buses
Since Transjakarta did not collect detailed information on disabled passengers that used the pilot e-buses, these figures are estimated based on the passengers used the whole Transjakarta system.

There are a total of 14353269 passengers who used Transjakarta services during May 2022, of which the proportion of vulnerable passengers (including elderly, low-income, and children) is 1.4% and the proportion of disabled passengers is 0.04%. In the vulnerable group, elderly people took up the largest proportion, and then children. Therefore, it can be estimated that there are 390 vulnerable passengers and 10 disabled passengers.

Table 14 Total number of disabled passengers who used Transjakarta services in May 2022

Group		No. of passengers	Proportion
Vulnerable	Elderly	157,494	1.10%
	Low-income	31,696	0.08%
	Children	11,948	0.22%
Disability		5,439	0.04%
Total		206,577	1.44%

Table 15 Total number of e-bus passengers in April, May, and June 2022

Route	April	May	June	Total
1P	22438	26967	71536	120941
1N	17983	144	56923	75050
Total	40421	27111	128459	195991

Total numbers of TransJakarta e-buses drivers and maintenance staffs

Transjakarta's e-bus drivers are made of 95.5% of male, only three drivers are female. In the e-bus technician team, all of the staff are male; three of them have ages ranging from 20 to 30, and others are between 30 and 50.

Table 16 Total number of e-bus drivers

Gender	People	Proportion
Male	64	95.5%
Female	3	4.5%
Total	67	100%

Table 17 Total number of e-bus technicians

Gender	People	Proportion
Male	7	100.0%
Female	0	0%
Total	7	100%

Table 18 Age range of e-bus technicians

Age Range	People
20 - 30	3
30 - 50	4
Total	7

3.6 Passenger satisfaction survey

To better understand passengers' needs and the level of service provided by pilot e-buses, passenger satisfaction surveys are distributed through interviews with passengers. There are a total of 105 valid respondents, with 53% of them female. Their ages are also distributed evenly, with the majority of e-bus users above 40 and between 21-25 years old.

Figure 61 Respondents' gender distribution

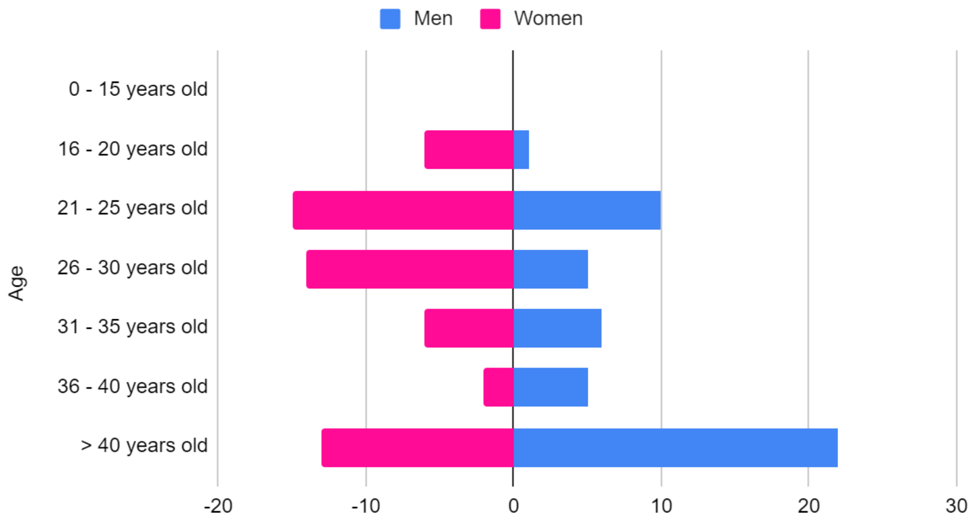


Figure 62 Respondents' age distribution divided by gender

There was no significant difference between male and female satisfaction levels. On average, the respondent's satisfaction levels are in between "satisfied" and "very satisfied" levels which indicates the positive result of Transjakarta's operational performance that is perceived by passengers. Specifically, over half of the respondents rated the on-bus environment as very satisfied, but only 42.9% and 30.5% of the passengers respectively felt the noise level and comfortability very satisfied. Overall, more than half felt satisfied with the pilot e-buses and 38.1% said they were very satisfied.

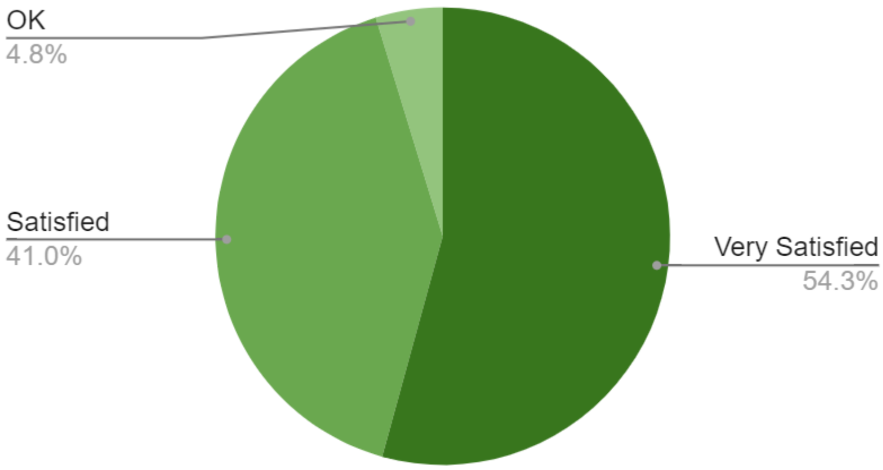


Figure 63 On-bus environment

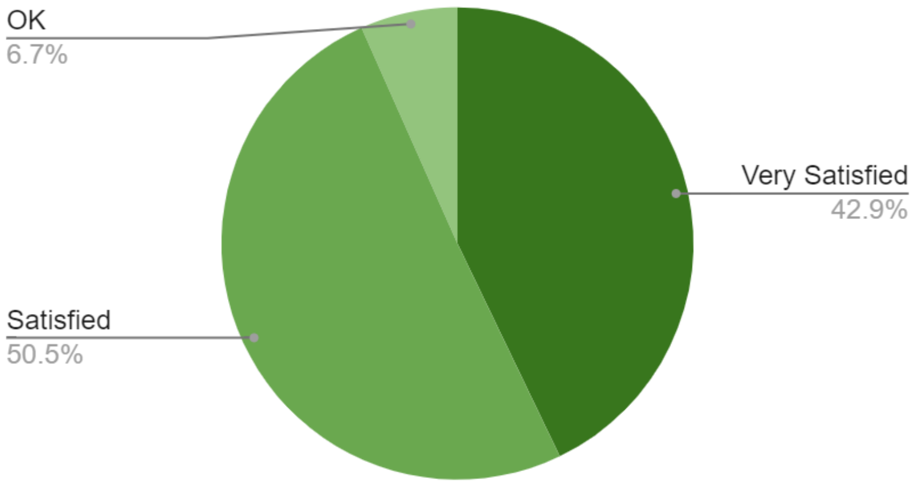


Figure 64 Noise level

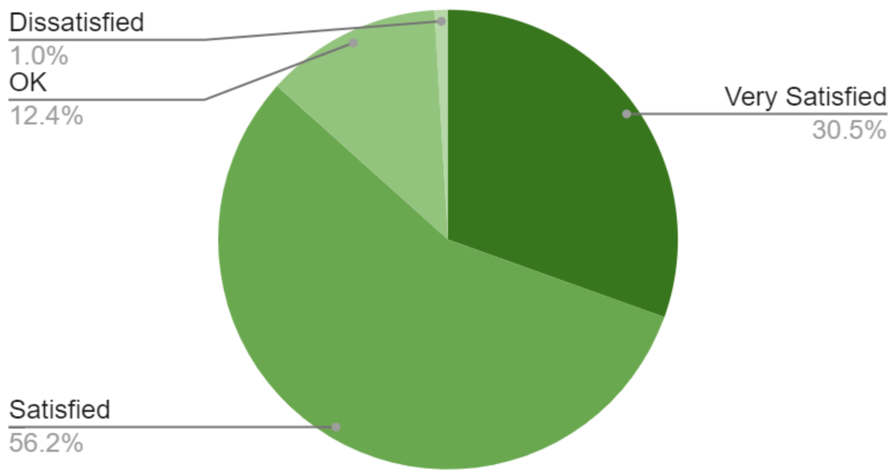


Figure 65 Comfortability

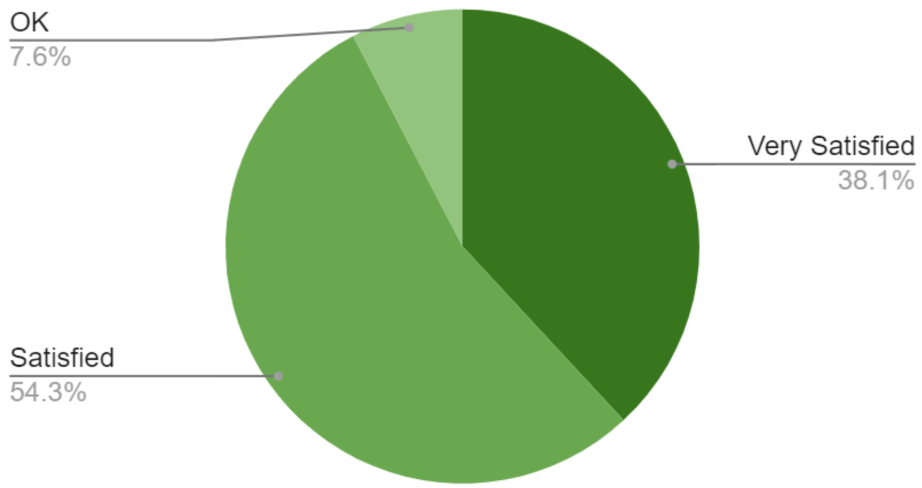


Figure 66 Overall satisfaction

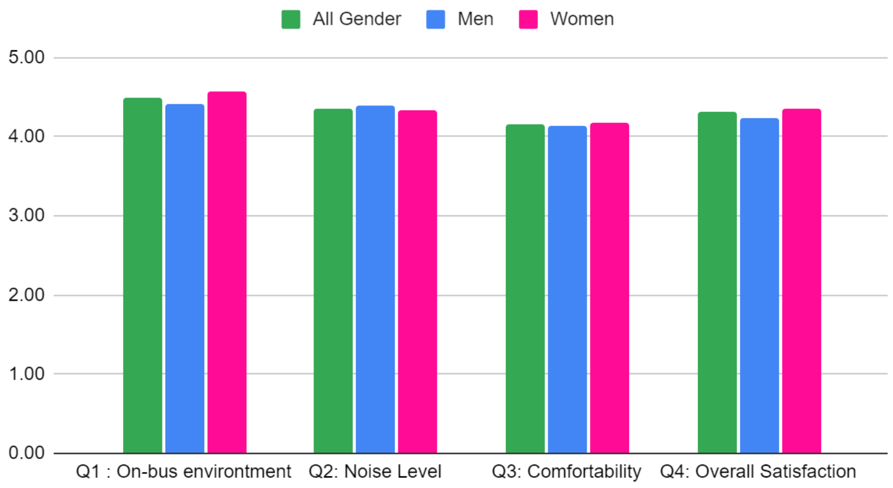


Figure 67 All Gender, Men, and Women Satisfactory Comparison

At the end of the questionnaire, the areas of improvement for e-bus operations in the future are asked. Fleet quantity is the most frequently mentioned suggestion. Since the survey was conducted when only four buses were available, passengers hope to see more e-buses on the road and reduce the waiting time.

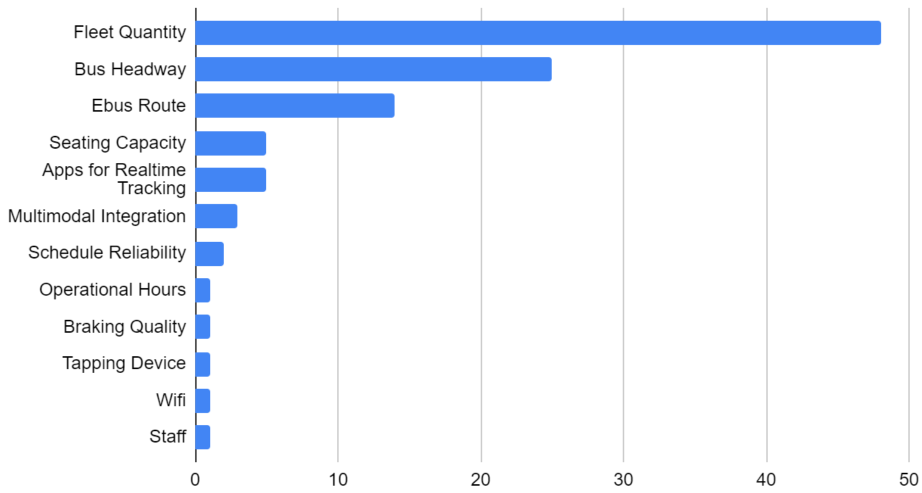


Figure 68 Area of improvements

Figure 69 Word Cloud on the area of improvements

3.7 Findings and recommendations

Data is the foundation for performance evaluation. Transjakarta is still collecting the e-bus operational data manually by asking the driver to transcript the data on an application installed in the phone. This method could reduce the efficiency of transmitting the data in real time. On the other hand, the data collected is also lacking details. Although the project team specified the requirements and data collection forms beforehand, the operators did not record the data with the required frequency: the operational data should be recorded every trip rather than every day.

With the operational data provided by Transjakarta, the team analyzed the vehicle performance and operating performance, and also conducted the passenger satisfaction survey.

- Since all e-buses are new and there are few failure events recorded during the observation period, on average the energy efficiency of all vehicles has superior performance with 0.95 kWh/km on average. Considering the seasonality and potential ridership and topography variations, energy efficiency is calculated under different routes, months, days, weekends, and weekdays. Results showed slight differences, despite the slow decline in the km traveled per SOC consumed, indicating the existence of battery degradation. Despite this, it is suggested to closely monitor the bus performance and pay more attention to particular vehicles and routes that have the worst energy efficiency.
- More charging data, detailed failure data is needed to conduct more comprehensive analysis. Transjakarta should verify the data received from the operators before the control center is upgraded and the e-buses are integrated.
- The operating performance is not stable, notably in the first stage of the implementation phase due to the issue of the readiness of the charging station. Only half of the vehicles were operating during the first three months, but the rate went up to more than 90% later.
- Dead kilometers are too long, Transjakarta needs to set up more depots and terminals with charging infrastructure to minimize the invalid operating distance and ensure the overnight charging for e-buses.
- Feedback from passengers showed that Transjakarta needs to increase bus quantity and reduce headways, thus improving the level of service.

4. Training Needs Assessment

4.1 Aim of Training needs assessment

The aim of conducting Training Needs Assessments is to identify Transjakarta's current skills and knowledge gaps through face-to-face interviews with Transjakarta and various stakeholders involved in the e-bus implementation process. The interviews are based on well-designed questionnaires to have a comprehensive understanding of what challenges Transjakarta is facing from the perspectives of e-buses operators, the local OEM, the grid company, the local government, industrial experts, etc. Interviewees range from top management to grassroots, the questions also cover all key stages during the e-bus deployment process. Therefore, the survey results could be used to prioritize the training needs modules and help with developing future capacity-building programs.

4.2 Methodology

Training Needs Assessments are conducted through face-to-face interviews using pre-designed questionnaires. Considering the similar electrification stage of Jakarta and Indian cities, the questionnaires used by this project are modified from the report that is published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH[6]. Targeted interviewees include Transjakarta, which manages the overall process of implementing e-buses, the local e-bus manufacturer, which supplies the e-bus units, the operator, who is in charge of the e-bus daily operations, the local grid company, who provides electricity connection for charging electric vehicles, local government, who makes the e-bus-related policies and supports Transjakarta during the process, and the facilitating organization, who conducts research and provides technical assistance with professional experiences. The list of interviewees is shown in the table below. Specifically, considering the important roles Transjakarta and the operator play, we selected four interviewees from each organization, ranging from the management team to the drivers, who take on-the-ground actions to make the electrification happen. Also, both female and male drivers are interviewed in order to understand the gender issues that may exist in e-bus operation and knowledge training activities.

Table 19 List of interviewees conducted the Training Needs Assessment

No	Interviewee Company and Position	Classification
1	Transjakarta – Head Department of Operator Integration	Transjakarta – Middle Management
2	Transjakarta – Head of Fleet Engineering Division	Transjakarta – Middle Management
3	Transjakarta – Head of Maintenance Verification Department	Transjakarta – Middle Management
4	Transjakarta – Head Division of Fleet	Transjakarta – Senior Management

[6] Training Needs Assessment for Electric Buses in India, GIZ, 2021

No	Interviewee Company and Position	Classification
	Integration	
5	Transjakarta – Director of Technical and Digital	Transjakarta – Top management
6	PT. Bakrie Autoparts – President Director & CEO	E-bus OEM
7	Mayasari Bakti – Kepala Operasi Bus Listrik	Operator – Management
8	VKTR – E-bus Trainer	Operator – Technician
9	Mayasari Bakti – E-bus Driver	Operator – Male driver
10	Mayasari Bakti – E-bus Driver	Operator – Female driver
11	PLN – Marketing Strategy Manager	State Electric Company
12	Jakarta Transport Agency – Head of Land Transport Division	Local Government
13	Jakarta Transport Agency – Head of Routed Transportation & Terminal Section	Local Government
14	ITDP – Transport Assistant	Facilitator

Figure 70 Face-to-face interviews with stakeholders

The survey questionnaire is divided into four major sections. It starts with a brief introduction to the aim of this interview and the role the interviewee plays during the e-bus implementation process. Then, the first section asks about the key challenges faced by their organization and Transjakarta. The second section rates Transkalarta's current skills levels and the level of importance for each key function that needs to be considered during the e-bus implementation process. As shown in figure X, all stages of the lifecycle of e-buses are included, from the procurement process to disposal and recycling. Under each key function, there are also sub-functions to specify what detailed skills are needed to evaluate. And the next section is about changes due to deploying e-buses, including changes in people, processes, and systems. At last, interviewees should give suggestions on the overall area of improvement in the future. The full questionnaire could be found in the Appendix.

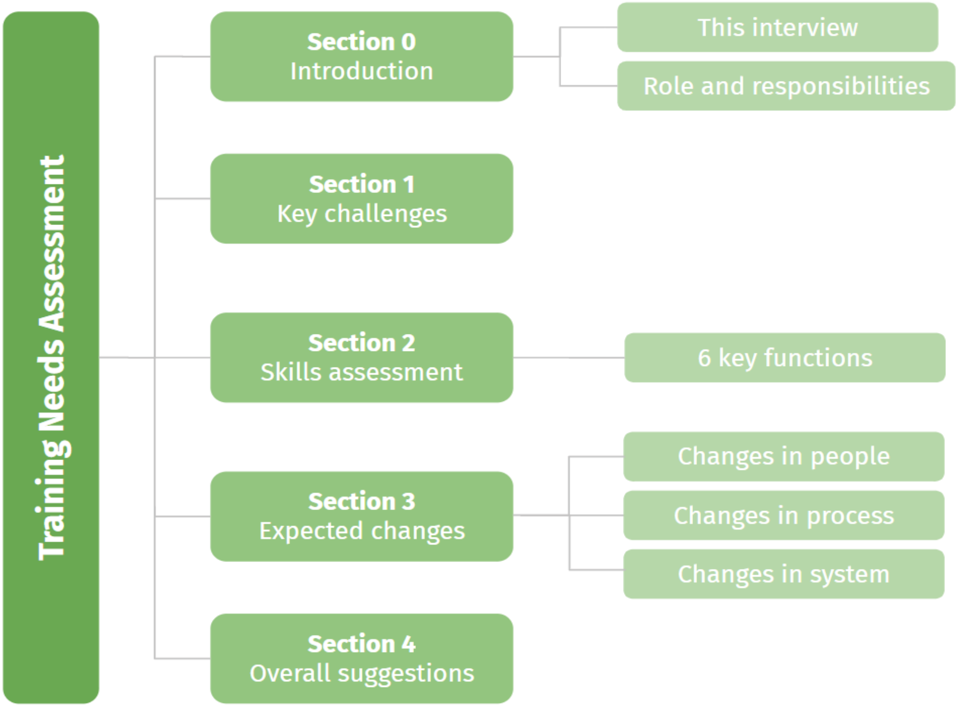


Figure 71 Survey questionnaire design

1	**Technical Specification Design**	• Power requirement • Range requirement • Battery selection and sizing • Charging and electrical high voltage systems selection and sizing • Depot and terminal infrastructure requirements • Spare parts specification • ITMS specification
2	**Procurement**	• E-bus purchase specification • Contracts and performance documentation • Define quality assurance • After-sale service
3	**Operations**	• E-bus route network and operations planning • E-bus driving • Monitoring, ITMS & MIS
4	**Repair and maintenance**	• E-bus charging • Preventive, maintenance, breakdown, repairs and overhauling • Batteries and BMS • Thermal management system of batteries • Electronics, sensors, wiring, fuses etc. • Air conditioning
5	**Monitoring and control**	• ITMS (Integrated Transportation Management System) and MIS (Management Information System)
6	**Scrapping and recycling**	• End-of-Life definition and tracking

Figure 72 Key functions to evaluate

4.3 Assessments result

Based on the answers from interviewees, they all have a clear understanding of their roles and responsibilities during the e-bus pilot phases.

Table 20 Roles and responsibilities by each interviewee

Interviewee company and position	Roles and responsibilities
Transjakarta – Head Department of Operator Integration	● Prepare the working reference framework, owner estimate, and procurement documents ● Generate operational report ● Make sure the procurement is in a timely manner as the planned schedule ● Negotiate with the operator
Transjakarta – Head of Fleet Engineering Division	● Prepare the e-bus specifications and ensure the fleet and charging stations are technically ready
Transjakarta – Head of Maintenance Verification Department	● Verify all maintenance processes for e-buses, ensure the buses are maintained and repaired according to the applicable contract ● Ensure the verification of the kilometer number and maintenance information
Transjakarta – Head Division of Fleet Integration	● Handle the contract with the operator, communicate with the operator's stakeholders ● Evaluate the service route, recommend modifying the route to Jakarta Transport Agency, verify traveled distance, deal with payment invoice ● Commission the operation and route, conduct proceedings, write violation reports and give sanctions
Transjakarta – Top Management	● Determine e-bus specification, as well as the location and facilities of charging infrastructures ● Evaluate e-bus maintenance ● Monitor the e-buses risk study
PT. Bakrie Autoparts (OEM) – President Director & CEO	● Supply the e-bus unit with a Full Maintenance Contract (FMC) for 10 years with Transjakarta
Mayasari Bakti (Operator) – Kepala Operasi Bus Listrik	● Check the fleet readiness for daily operation and the traveled kilometers for every E-Bus unit ● Ensure the charging process with the coordination with VKTR company
VKTR – E-Bus Trainer	● Train how to drive safely and efficiently ● Give safety introduction to the drivers and technicians from the basic to the

Interviewee company and position	Roles and responsibilities
	advanced level of knowledge ● Train Transport Agency in several cities and Transjakarta's Maintenance Verification Team
Mayasari Bakti (Operator) – Female driver	● Carry passengers according to the specified route and schedule ● Check the vehicle (Battery, Tires, Body, Glass) before departure ● Report bus damage or failure during operation to bus mechanic
Mayasari Bakti (Operator) – Male driver	
PLN – Marketing Strategy Manager	● Support the preparation of Electric Vehicles Charging infrastructure, including power requirement, distance for electrical substation, etc.
Jakarta Transport Agency – Head of Land Transport Division	● Make the budget plan and plan the E-bus procurement
Jakarta Transport Agency – Head of Routed Transportation & Terminal Section	● Do the Monitoring and Evaluation of Transjakarta's service performance, including the operation, selection of the bus types, finance, service, and management
ITDP – Transport Assistant	● Provide technical assistance to Jakarta Transport Agency, Transjakarta, and related stakeholders, including developing the roadmap, technical support, and business model for e-buses

The next section of the questionnaire identified key challenges their organizations or Transjakarta is facing. The following summarized the most frequently mentioned issues:

a) **Insufficient knowledge** on:

- Calculating the cost per kilometer traveled for e-buses, which could be used to estimate the infrastructure requirements
- Various financial technologies and their different characteristics
- E-bus maintenance, especially on hazard mitigation, such as flooding

b) **Lack of standardization and public socialization** on:

- Charging port nozzled
- E-bus Standard Operational Procedures (SOP)
- Operation manuals that have been specifically designed for Transjakarta

c) **Policy gaps** on:

- Electric vehicle tax regulation, while the current policies still differ for every region (province/city)
- Different manpower price of e-buses and ICE buses because of the risk of handling E-Bus is larger compared to the ICE Bus

- Proactive policies and regulations for e-buses

d) **Lack of assistance to operators** regarding:

- Preparing for implementing e-buses
- Understanding every aspect of the Standard Operational Procedures (SOP), thus ensuring the compliance

e) **Other problems** during the e-bus implementation:

- Authorized local resellers are not well-established, resulting the poor after-sale services
- The availability of charging infrastructure is not sufficient
- Contract design should be improved, where the battery has an 8-year warranty while the contract duration is 10 years
- Lack of a comprehensive training program, right now the training contents are limited to only what Transjakarta asked
- Insufficient communication with stakeholders
- Technicians' awareness to use the APD (Personal Protective Equipment) is still deficient. As handling the high electrical voltage is very dangerous
- Insufficient public engagement about e-buses
- During the procurement process: lack of e-bus information to be used as the specifications benchmark in the procurement process
- No evidence state explicitly that the benefits of e-buses regarding air pollution and fuel-saving

To sum up, filling up the knowledge gaps on e-buses is an urgent need for Transjakarta's internal team. Transjakarta needs to be able to analyze and estimate costs of e-buses, thus to differentiate the payment to operators who operate e-buses and ICE buses and incentivize the electrification process. Also, because of the special weather conditions in Indonesia, where heavy rains and floods happen frequently in the city, electric vehicles are more likely to be soaked in water and break down. It is essential for Transjakarta to formulate emergency action plans and train operators on the e-bus maintenance skills before the e-buses are adopted. This may require assistance from bus manufacturers, who know best about e-buses and provide after-sale services. Moreover, the lack of standards on e-bus and charging infrastructure would create barriers for operators to understand the requirements from Transjakarta and affect the overall working efficiency. After the standards are developed, education and training are important to ensure compliance.

The next questionnaire section is designed to have a competitive assessment of all the core skills needed for e-bus implementations. The following table shows the methods to evaluate which key functions should be prioritized for training. Functions that are classified as having high training needs are those rated with high importance and low skill level; while low training needs functions are those rated with low importance and high skill level.

Table 21 Extend of training needs evaluation card

		Importance level (1 being least important and 5 being very important)				
		1	2	3	4	5
Current skill level	High	Low	Low	Medium	Medium	Medium
	Medium	Low	Medium	Medium	Medium	High
	Low	Medium	Medium	Medium	High	High

Based on the rating results by interviewees, **spare parts specification**, which requires to estimate the overall requirements of e-bus spare parts, and **ITMS specification**, which requires Transjakarta having the ability to understand the overall process of estimating requirements of the Integrated Transportation Management System, have high training priority than other sub-functions under the technical specification design function. The overall current skill level of the spare parts specification is 55% while the importance level is rated as 82%; the ITMS specification has the skill level and the importance level of 45% and 87% respectively.

Table 22 Training needs evaluation result

Founction		**Skill level**	**Importance level**
Technical Specification Design	Power requirement	78%	100%
	Range requirement	81%	100%
	Battery types and performance characteristics	78%	97%
	Battery operating model	75%	97%
	Charging and electrical high voltage systems selection and sizing	72%	97%
	Depot and terminal infrastructure requirements	67%	91%
	Spare parts specification	55%	82%
	ITMS specification	45%	87%
Procurement	E-bus purchase specification	70%	96%
	Contracts and performance documentation	80%	96%
	Define quality assurance	63%	86%
	After-sale service	57%	86%
Operations	E-bus route network and operations planning	72%	91%
	E-bus driving	64%	92%
	Monitoring, ITMS & MIS	49%	85%
Repair and maintenance	E-bus charging	59%	85%
	Preventive, maintenance, breakdown, repairs and overhauling	51%	86%
	Batteries and BMS	51%	89%
	Thermal management system of batteries	51%	88%
	Electronics, sensors, wiring, fuses etc.	59%	83%
	Air conditioning	67%	83%
Monitoring and control	ITMS and MIS	51%	91%
Scrapping and recycling	End-of-Life definition and tracking	52%	93%

Extent of training needs: High Medium Low

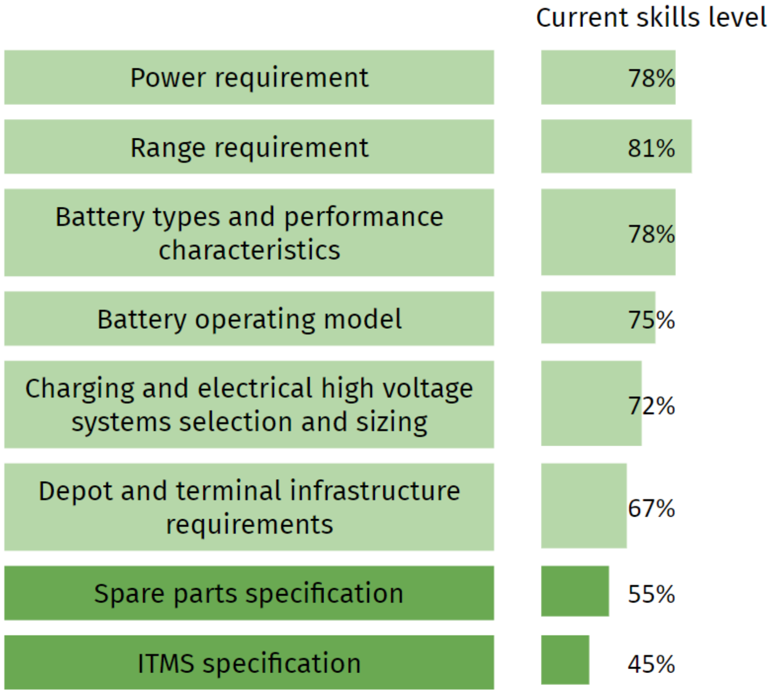


Figure 73 Technical specification design

Under the procurement function, Transjakarta has a high training need in **defining quality assurance** (skill level is 63% and importance level is 86%) and **after-sale service** (skill level is 57% and importance level is 86%). These two themes should all be specified in detail in contracts signed with OEMs and operators. Transjakarta should define the quality of e-buses and their spare parts that should be received based on the domestic EV standards, thus ensuring vehicle repair and maintenance in the future. In Shenzhen, China, the bus provider, BYD, provides the warranty for the BEB's battery, motor, and electronic control system during the whole lifetime of the e-buses, which helped the bus company with reducing the maintenance cost to a large extent.

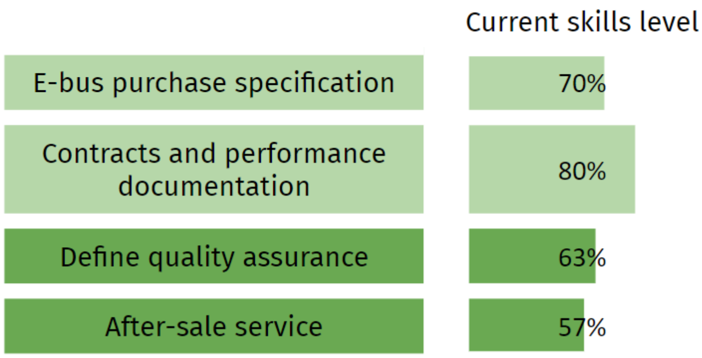


Figure 74 Procurement

For the operation function, **e-bus driving, monitoring, and ITMS&MIS** have high needs for training (skills levels are 64% and 49%, importance levels are 92% and 85%). In contrast, the e-bus route network and operating planning skills have medium improvement needs. Compared with ICE buses, the driving behavior of e-buses may affect energy consumption and operating range, and the late detection of vehicle failure events may also result in severe fire risks. Therefore, drivers should be trained in new skills on how to save energy, report hazards, and precautionary measures on emergency handling procedures.

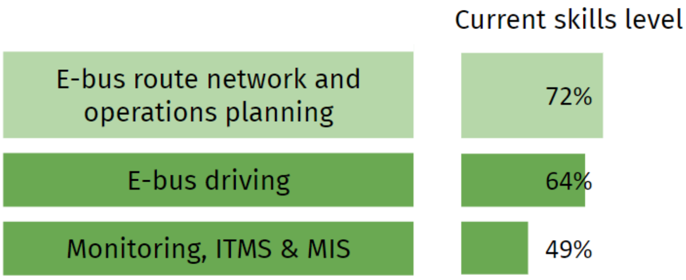


Figure 75 Operations

Repair and maintenance function is the most needed to have the training, where every aspect except air conditioning is rated as having low skills (between 49% and 64%) and high importance (above 83%). Despite whether the vehicle repair and maintenance are done in-house or outsourced, Transjakarta should have basic knowledge of the EV system and develop regular maintenance plans with the OEMs or the outsourcing company.

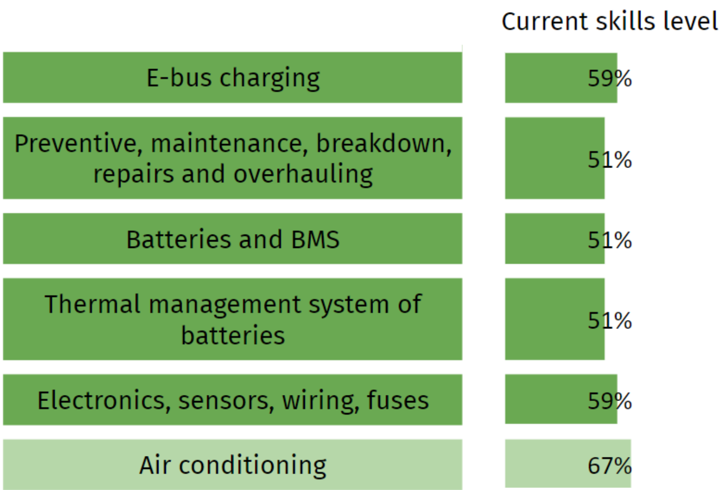


Figure 76 Repair and maintenance

The last two functions are **monitoring and control**, and **end-of-life definition and tracking**. Transjakarta needs to have priority training needs on both functions (skills levels are 51% and 52%, importance levels are 91% and 93%). Although Jakarta is in the early stage of implementing e-buses and not facing vehicle disposals and recycling, they still need to acknowledge the potential environmental and health risks that may be caused by the mishandling of batteries. Transjakarta should also make plans on the battery handling procedures to mitigate the risks.

Figure 77 Monitoring and control

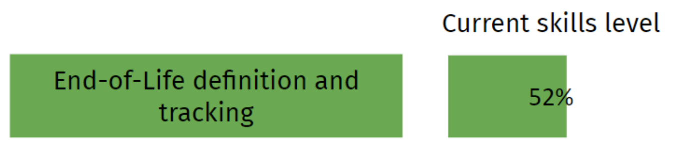


Figure 78 Scrapping and recycling

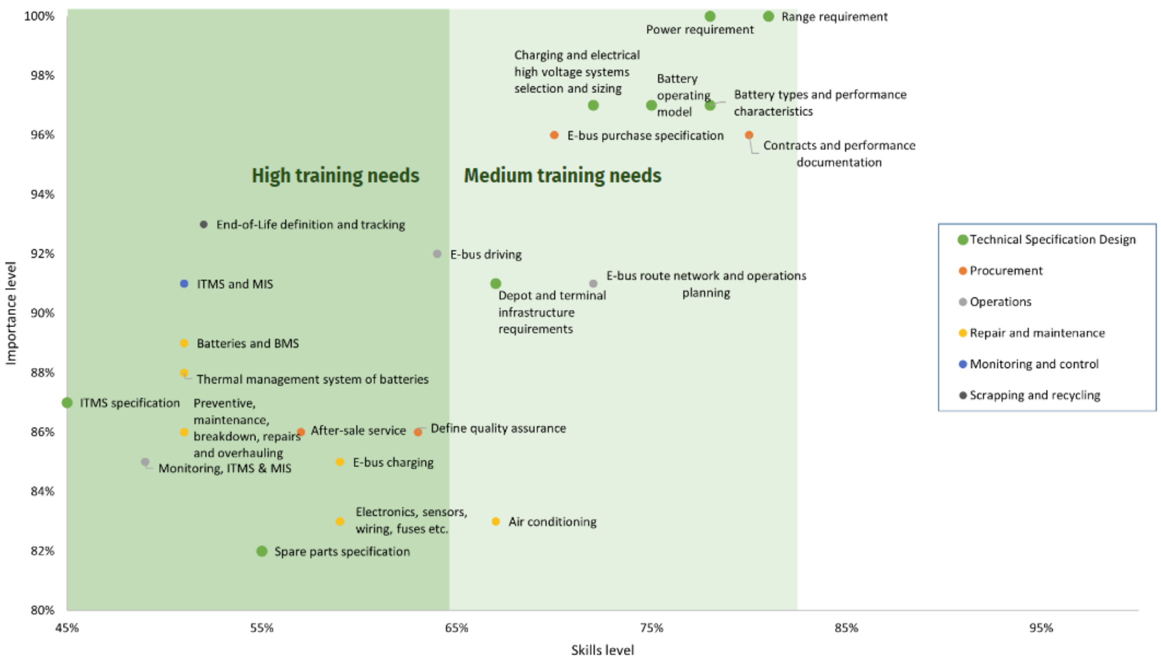


Figure 79 Skill assessment summary

As summarized above, most of the high training needs skills are under repair and maintenance function. Transjakarta should build more strength and develop training programs for both its own staff and operators. Especially, ITMS specification is the most urgent training module that has the lowest skill level.

For the next section of the survey, the expected changes are summarized as follows:

a) **Expected changes in people**:

- More well-trained staff who have knowledge and skills in cost estimation, electricity network installation, and e-bus maintenance
- Raise the awareness across Transjakarta's all departments

b) **Expected change in process:**
- Operator selection process
- Vehicle procurement model
- Operation process
- Contracting with operators

c) **Expected change in the system:**
- Modified command system for e-buses
- Brand selection process in the e-catalog system

On the last section, the overall suggested areas of improvements are summarized as follows:

a) **Suggestions for OEMs:**
- Capacity building on the technical skills, including vehicle maintenance, e-bus specifications
- Ensure the after-sale in the future
- Establish the electric vehicle industry ecosystem as soon as possible, including spare parts, vehicle manufacturers

b) **Suggestions for operators:**
- Driver management: working schedule and payment
- Expand knowledge on charging, vehicle specification, driver's driving techniques, attitudes, and troubleshooting

c) **Suggestions for Transjakarta:**
- E-bus data management: operational data accessibility, storage, analysis
- Contracting with operators: supplemental agreements on the data requirements
- Corporate and Financial Planning Division should have more knowledge on the business models
- Educate and train operators on the minimum service standards and Standard Operational Procedure (SOP), to avoid misunderstandings by operators

d) **Suggestions for government:**
- Updated regulations: the vehicle lifetime considering the differences between ICE buses and e-buses
- Financial incentives by the provincial government: value should be adjusted based on the contract value between Transjakarta and operators
- Tax reduction incentives by the national government: E-bus tax of Completely Knocked Down (CKD) should be cheaper than Complete Built-Up (CBU)
- Trade agreements to lower the e-bus price
- Simplify the process of procuring e-buses

- Provide supportive policies for charging infrastructure
- Develop policies for retrofitted buses

4.4 Findings and recommendations

Training Needs Assessment is designed for identifying Transjakarta's knowledge and skills gaps regarding e-buses implementation. The team conducted 14 interviews to Transjakarta and related stakeholders. The following recommendations are developed based on the survey results.

- Develop training programs for the systematic study on e-buses:
  - Prioritize training on e-bus repair and maintenance, and ITMS specification
  - Train operators on the required service levels and SOP, as well as the preparations to shift to electric buses
  - Train drivers on troubleshooting process, that is, how to detect the vehicle failure events and make prompt response
  - Train technicians on the maintenance skills
  - Train Transjakarta staff on the e-bus specifications, cost estimation, potential business models at deeper levels
- Provide strong financial incentives:
  - Tax reduction for electric vehicles
  - Adjusted payment to operators that differ from ICE buses
  - Subsidies for charging infrastructure
- Fill policy gaps:
  - Establish standards on e-bus Standard Operational Procedures and operation manuals
  - Provide policy supports to accelerate the formulation of domestic electric vehicles industries
  - Develop supplemental agreements with Operators regarding the data collection and sharing

5. Capacity-building activities

5.1 Workshop on Lessons learned from China and India

Background
Jakarta, as one of the deep dive cities under TUMI E-bus Mission, has already stated its ambitious plan to deploy 10,000 electric bus fleets, or 83% of its fleets, by 2030 in its Long-term Corporate Plan 2020-2030. To support the electrification of Transjakarta's bus project, ITDP proposed a sharing session with international best practices to increase the capacity of the various stakeholders who are involved in the electrification of Transjakarta's bus project including Transjakarta, city officials, original equipment manufacturers (OEMs), and e-bus operator. The workshop was held online via Zoom on September 29, 2022, from 14:30 to 16.00 (Jakarta Time). It consists of various speakers presenting their topics, followed by a Q&A session led by the moderator.

Objectives
This sharing session is designed to share the international experience on how to implement pilot e-buses, the key objectives are as follows:

- Disseminate the lessons and experiences learned from Chinese and Indian cities on how to implement pilot e-buses successfully, including setting up strategic goals, selecting e-bus types and routes for the pilot, formulating supportive policies, identifying stakeholder, collecting data to monitor and evaluate the pilot e-buses performance.
- Discuss and Identify the challenges that exist during e-bus pilot phase in Jakarta

Expected outcomes

- Understand the importance of e-bus pilot and how it helps with larger-scale e-bus deployment in the future
- Identify the current challenges and policy gaps during e-bus pilot in Jakarta
- Being able to plan a successful e-bus pilot strategically with the lessons learned from Chinese and Indian cities
- Being able to monitor and evaluate the pilot performance
- Identify stakeholders that are involved in the pilot stages and being able to coordinate different roles they play

Table 23 Workshop agenda

Time	Duration	Content	Speaker
14:30 - 14:35	5 mins	TUMI e-Bus Mission Introduction & Welcoming Remarks	Shanshan Li – Director of ITDP South-East Asia
14:35 - 15:00	25 mins	Lessons learned from Shenzhen	Hallie Liao - Deputy General Manager at Shenzhen Bus Group
15:00 - 15:25	25 mins	Lessons learned from Mumbai	Lokesh Candra - General Manager at BEST Undertaking

Time	Duration	Content	Speaker
15:25 - 15:55	30 mins	Q&A	Moderator (Gonggomtua Sitanggang)

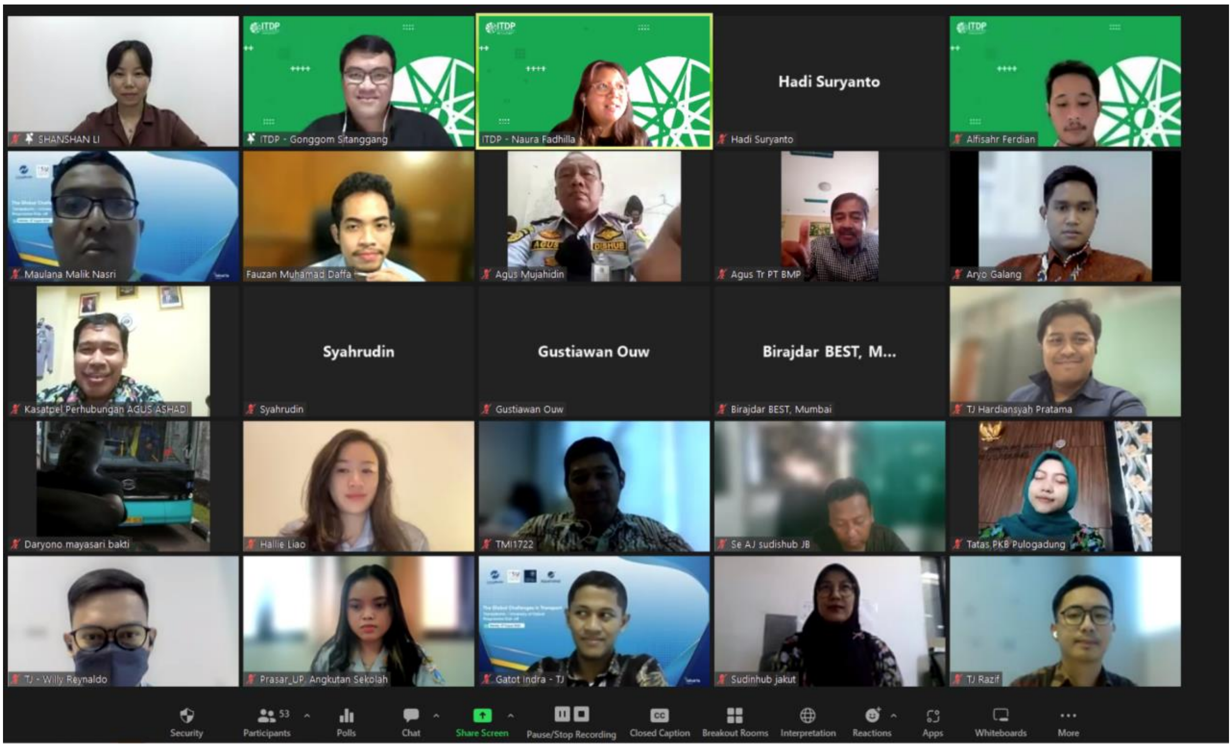


Figure 80 Workshop participants group photo

Participants

Transjakarta:

- Director of Technical and Digital
- Director of Operations and Safety
- Head of Bus Operation Division
- Head of Fleet Engineering Division
- Head of Transjakarta Subsidiary Business Division
- Head of Design, Engineering Standardization, and Electric Bus Department
- Head of Operator Integration Department
- Head of Operation Planning and Evaluation Department
- Head of Operation Department
- Head Of Department Legal Business
- Head of Control Center Operation Department
- Public Transport Integration & Vendor Management Supervisor
- Coordinator of Bus Integration and Operator Relations
- Analyst of Operator Integration and Relation

Bus Operator:

- Mayasari Bakti

- Bianglala Metropolitan
- Sinarjaya Megahlanggeng

Jakarta Transport Agency:

- Head of Land Transport Division
- Head of Routed Transportation and Terminal Section
- Head of Safety and Road Based Traffic Safety Section
- Head of Service Unit of Mampang Prapatan

Workshop findings:

Lessons learned from Chinese cities:

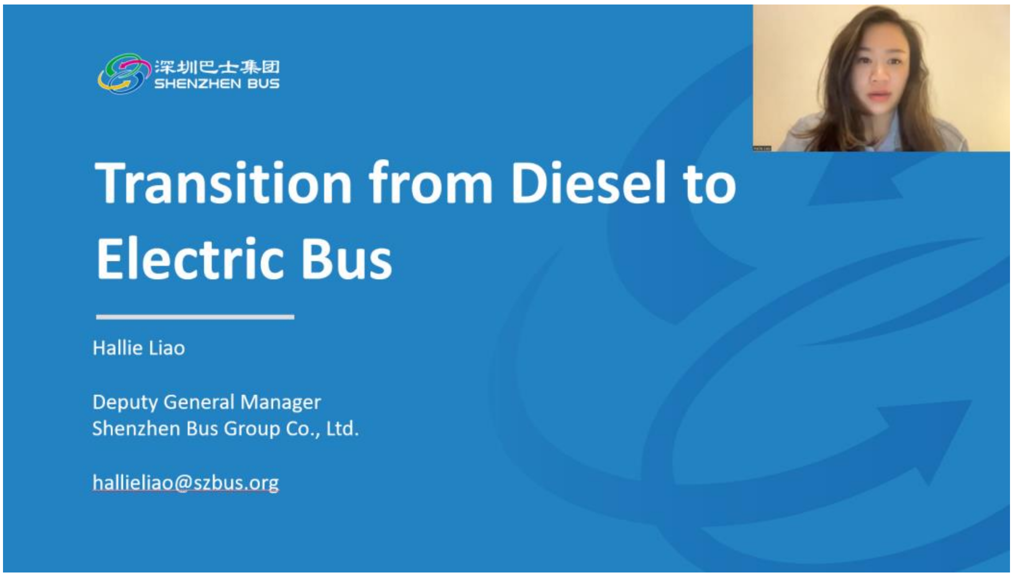


Figure 81 Hallie Liao from Shenzhen Bus Group making the presentation

- Operators need to have negotiating power with OEMs to reduce the procurement cost of e-buses.
- Since the need to closely monitor the SOC of each bus, Shenzhen Bus Group has already upgraded and retrofitted the monitoring system.
- Charging skills are needed to optimize battery degradation. Strategic charging plans also helps with saving operational cost by charging during the low electricity price time (electricity price during the night is only 1/5 of the day price).
- Local bus manufacturers have the benefits of easily sending vehicles back to the factory and communicating technical issues. It is also easy to get staff trained by OEMs. In the past year, BYD received over 900 technical feedback from Shenzhen Bus Group and 700 of them are adopted for upgrading the e-buses.
- Shenzhen Bus Group constructed a large amount of charging infrastructure in the city and opens up the chargers to the public during certain times, this could also encourage the public to adobe electric vehicles.

Lessons learned from Indian cities:

Figure 82 Lokesh Candra from BEST Undertaking marking presentation

- For e-buses at BEST Undertaking, the operating range is the major challenge. Traffic congestion also causes problems in maintaining the operation schedule and increasing the operation cost because of the low vehicle utilization. Operators are reluctant to operate e-buses in flooding seasons.
- During the tendering process, many OEMs request for low operating range. Operators need to insist on opportunity charging time, higher assured kilometers, and a 100% rate for underutilized and excess distance.
- BEST Undertaking used the e-bus pilot project to improve battery health with M/s-Nunam Technology. The battery data will be remotely available and can be monitored battery state (individual cell), thus enabling identifying potential faults at the cell level and battery level.
- The monitoring results helped with avoiding costly downtime and protects the business from loss. It increases the life span of the battery and reduces the maintenance replacement cost. It also helps to maintain the safety of the operation and avoid the overcharging and over-discharging of the battery.

5.2 Workshop on E-bus Financing

The Indonesia E-bus Roadmap & Financing Strategy Workshop was organized by all TUMI E-bus Mission Deep Dive Jakarta Partners, including WRI, ICLEI, ITDP, UITP, C40, and ICCT. These activities include a capacity-building agenda and dialogue on regulations, planning and development strategies, stakeholder engagement, and financing strategies.

The event was attended by various stakeholders, such as Representatives of the Network City Regional Government, Bali Province, West Java Province, South Sumatra Province, Bandung City, Medan City, Pekanbaru City, and Other stakeholders like the Ministry of Finance, Ministry of Transportation, DKI Jakarta Transportation Service, Bali Provincial Transportation Service, PT Transjakarta, PT Penjaminan Infrastruktur Indonesia (PII), PT Sarana Multi Infrastructure (SMI), World Bank, KfW Development Bank, electric bus manufacturers

The workshop will be held for 3 days from 17-19 October 2022 with the following agenda per day as below:

- Day 1 (October 17th, 2022)
  The Morning Session: The title of the event is "City Dialogue: The Role of Local Governments in Accelerating the Transition Towards Electric-Based Public Transportation" delivered by representatives from DKI Jakarta Province, Bali Province, Ministry of Transportation, Transjakarta.

  Noon Session: The theme of the event is “Panel Discussion on Procurement and Financing Options for E-buses” delivered by representatives from the Ministry of Finance, Millennium Challenge Corporation (MCC), ITDP, PT Sarana Multi Infrastructure (SMI), World Bank, PT Penjaminan Infrastruktur Indonesia (PII), KfW Development Bank.

  Afternoon Session: Headline of the Event “Market Dialogue: OEM and Electric Bus Operators” delivered by representatives from PT Industri Kereta API (INKA), PT Mobil Anak Bangsa (MAB), and Start-up Company “Transition”.

Figure 83 Day 1 Workshop on Indonesia E-Bus Roadmap & Financing Strategy

- Day 2 (October 18th, 2022)
  The Morning Session presentations from WRI DC's E-Mobility Manager, WRI Finance Expert, ICCT, and C40 Cities who sequentially discussed how to adopt electric buses in urban areas, electric bus business models, the total cost of electric bus ownership, and legal aspects of electric buses.

  Afternoon Session: The theme of the event is “Workshop - World Cafe on the development of electric bus roadmaps and financing strategies”. Each city will be asked to develop a strategy to improve the implementation phase of electric buses in their city.

  The afternoon session was allocated for facilitators and city representatives to present the results of the world cafe discussion.

Figure 84 Day 2 Workshop on Indonesia E-Bus Roadmap & Financing Strategy

- Day 3 (October 19th, 2022)
  Study tour to an electric bus depot which belongs to the electric bus operator who had under contract with Transjakarta. On this day, participants were demonstrated by the e-bus operator on the charging activity, safety features, and a brief explanation of daily maintenance.

Figure 85 Day 3 Workshop on Indonesia E-Bus Roadmap & Financing Strategy

5.3 Workshop on Findings Dissemination

As one of the themes identified in the needs assessment, a finance and technical workshop were held in March 2023, organized by TUMI E-bus Mission Deep Dive Jakarta Partners, including WRI, ICLEI, ITDP, C40, and ICCT. The workshop will bring together both local and international stakeholders to share lessons learned and best practices with TransJakarta to assist them to overcome the barriers they are facing in their e-bus deployment and operation. The workshop held was in the form of a roundtable discussion in which each stakeholder not only explains the conditions and solutions they offer but there is also a two-way discussion that ends with a conclusion and follow-up. The agenda is shown as follow:

Table 24 Findings Dissemination and Capacity Building Workshop agenda

Time	Duration	Topic	Organization
08:00 - 08:30	30 mins	Registration	WRI
08:30 - 08:40	10 min	Opening and safety induction by MC	WRI
08:40 - 08:50	10 min	Welcome Remarks from Jakarta Transport Agency	Jakarta Transport Agency
08:50 - 09.:00	10 min	Welcome Remarks from TUMI Coalition	Rohan Shailesh Modi
09:00 - 09:10	10 mins	Brief Introduction of TUMI E-Bus Sub-Coalition Program in Jakarta	C40
09:10 - 09:20	10 mins	Jakarta Coalition Needs and Takeaways of Stakeholder Meetings	WRI
09:20 - 09:40	20 mins	Topic 1: Transjakarta E-Bus Vision and Current Progress Q&A: 5 minutes	TransJakarta
09:40 - 09:50	10 mins	Topic 2: TUMI Need Assessment Result-Financial Constraints in Jakarta's E-Bus Ecosystem Q&A: 5 minutes	C40

Time	Duration	Topic	Organization
09:50 - 10:10	20 min	Topic 3: Findings Dissemination on TUMI e-bus Mission Technical Assistance in Jakarta Q&A: 5 minutes	ITDP
10:10 - 10:30	20 min	Topic 4: Ebus route level total cost of ownership technical assistance findings Q&A: 5 minutes	ICCT
10:30 - 10:50	20 mins	Topic 5: Lesson Learned from other Cities on Finding the Right E-Bus Business Model (Case Study:Bogota) Q&A: 5 minutes	Transmilenio
10:50 - 11:10	20 mins	Topic 6: Lesson Learned from other Cities on Finding the Right E-Bus Business Model (Case Study: India) Q&A: 5 minutes	WRI India
11:10 - 11:30	20 mins	Topic 7: Capacity Building Session based on Training Needs Assessment Result (Case study: China) Q&A: 5 minutes	Shenzhen Bus Group
11:30 - 12:20	50 mins	Roundtable Discussion with Participants	C40 and WRI
12:20 - 12:25	5 mins	Summary	C40 and WRI

The event was opened by welcoming remarks by the Head of Jakarta Transport Agency (Dr. Syafrin Liputo, A.T.D, M.T) The event was attended by various stakeholders, such as head of Road-based transport division, TransJakarta, World Bank, KfW IPEX-Bank, PT Bank Syariah Indonesia (BSI), Shenzhen Bus Group Company Limited, PT VKTR (BYD local e-bus distributor), PT Penjaminan Infrastruktur Indonesia (PT.II), PT Sarana Multi Infrastruktur (PT SMI), PT Steady Safe, PT Mayasari Bakti, PT Bianglala Metropolitan, Perum PPD.

The workshop brings together several international case studies from other countries, such as TUMI Coalition cities in India, e-bus uptake in Columbia (Bogota by Transmilenio), and capacity building from China (Shenzhen by Shenzhen Bus Group Company), showcasing successful models for e-bus deployment, operation, and finance.

In this particular workshop, ITDP also has the opportunity to disseminate the findings on Technical Assistance on TUMI e-Bus Mission in Jakarta. It covered the entire activities during the past year towards the monitoring and evaluation of e-Bus pilot deployment and operation in Jakarta thas was managed by Transjakarta since March 2022. In this dissemination, ITDP presents the findings on the evaluation of the operational data, battery efficiency, vehicle attendance, results from the passenger satisfaction survey, training needs assessment (TNA), and the overall recommendations throughout the whole process of the e-bus pilot in Jakarta.

Figure 86 Findings dissemination on the e-Bus pilot in Jakarta by ITDP

Besides the dissemination of the findings, a capacity building session was conducted in response to the result of the Training Needs Assessment activities (TNA). Based on the TNA analysis, Integrated Transportation Management System (ITMS) specification, e-bus repair, and maintenance were included in the list of Transjakarta's knowledge and skills gap regarding e-buses implementation. Hence, we provide capacity building by inviting Dr. Yi Guo (Managing Director, GST Institute, Shenzhen Bus Group Co. Ltd) to share their experiences on digital transformation, and repair & maintenance optimization.

Figure 87 Capacity building session by Shenzhen Bus Group

On the next day, the team took the e-buses to the Low Emission Zone (LEZ) located in Kota Tua Tourism Area (KTTA) in Jakarta. The KTTA LEZ is an area where access is restricted for certain types of polluting vehicles to improve air quality in the area and the odd-even restrictive driving policy is implemented on several roads around the

KTTA to support the LEZ. Later, the team visited Transjakarta's office and discussed the e-bus financing issues with Yoga Adiwinarto, Director of Engineering and Facilities at Transjakarta.

Figure 88 Discussion with Transjakarta's staff

Figure 89 Visit to Transjakarta's office

Section Three:

Recommendations

1. Recommendations

1.1 Provide more support to e-bus operators

There are many challenges when operating e-buses, especially for the first adopters. According to the Training Needs Assessment survey results and discussions with stakeholders, e-bus operators are experiencing various difficulties but did not receive enough support from Transjakarta and Transport Authorities. Although there is no significant failure and all buses had high-level energy efficiency during the pilot, it is still necessary to put more effort into guiding operators on how to run e-buses more efficiently and offering preferential financial policies.

Operators don't have enough knowledge and experience in operating e-buses and have limited access to information such as emerging technologies and business models. It is hard for operators to coordinate with energy sectors or acquire the space for charging infrastructure. Currently, the guidance and support from Jakarta Transport Agency and Transjakarta are not enough. Based on the experiences gained from the current 30 e-buses operation, Jakarta Transportation authorities, and Transjakarta should review the Gross-cost contract, recalculate the CAPEX and OPEX for the operator, and set up a more attractive payment per kilometer. Jakarta Transportation Agency and Transjakarta should help operators to tackle charging infrastructure installation and grid connection issues, which were the major reasons that had caused long delays in the pilot project operation. Also, they should take on the role of coordinating with operators and bus manufacturers in order to better understand the vehicle specifications and maintenance requirements.

As for now, there is no direct communication channel among major stakeholders. Establishing an operational task force and tackling the problems operators faced in operation will be helpful. The task force should include the transportation authority, Transjakarta, the operator, OEM, and the consultant team. The task force should have regular meetings to discuss problems, vehicle performance, failure events, charging related issues. Jakarta Transportation Agency and Transjakarta could understand the real-world performance of e-bus and operational situations, and then provide support and help operators find solutions regularly. The TUMI E-bus Mission has set up monthly meetings with Transjakarta, and operational issues have been discussed at the meeting, but a formal operational task force still needs to be created.

1.2 Incorporate detailed data collecting and sharing mechanism

It is important to set up a data sharing mechanism among Transjakarta, operators, and OEMs, therefore, they can understand the real-world e-bus performance information and take action on optimization of the operational plan to achieve operational efficiency. Transjakarta will regularly share the monitoring and evaluation results with operators and OEMs for operational adjustments and also improve the e-bus vehicle technologies accordingly. The first thing to set up the data-sharing mechanism is to identify the responsibilities of data collecting and sharing between Transjakarta, operators, and OEMs, and charging providers if applicable, along with setting up a platform for data transmitting. Google Drive shared files can be an option, Jakarta Transportation Agency, Transjakarta, and consultants can provide prompt comments in terms of the data shared by the operators, identify issues and find out solutions, and operators can take actions to make adjustments. During this process, regular meetings and communication are needed. In the contract, it is suggested to specify the following elements:

- Data types and raw data needed
- Frequency of data collection
- Frequency of data sharing
- Data verification process
- Data analysis and results sharing
- Reflection on the operation

However, after reviewing the contract, it is found that the detailed data collection and sharing mechanism between operators and Transjakarta, including data type and the submission timeframe, is not clearly stated in the contract. This leads to difficulties in acquiring enough data from the operator. Even Transjakarta could not get enough data and quality data to analyze the operational performance so far. It was recommended that before the upgraded bus control center is installed and the e-bus data is integrated, Transjakarta should have full access to all the data collected by the operators and the OEMs, and regularly verify the data to ensure accuracy.

1.3 Upgrade the e-bus control center and build capacity on Intelligent Transportation System

Based on the discussion with stakeholders, the data collection highly relies on the operators, and drivers manually recording the data is the major way to collect the data, which is inefficient and prone to data errors. The e-buses should be integrated with the Transjakarta control center. This could help Transjakarta automatically receive the operational data and understand the e-bus real-world performance. The present Transjakarta control center needs to be upgraded, and it should have the capacity to accommodate large-scale electrification and conduct data analysis. Jakarta Transportation Agency should provide support for Transjakarta to develop the software.

The results from Training Needs Assessment showed the urgency to enhance staff training on e-bus repair and maintenance and ITMS specification. The information system will not work solely without human resources capacity. At the present, Transjakarta is doing basic statistics on monitoring the e-bus performance with limited data. Transjakarta should prioritize upskilling staff’s capabilities on utilizing the data and applying it in optimizing e-bus performance.

ITDP has forwarded Transjakarta an online course on Digitalizing E-bus Projects developed by GIZ under TUMI E-bus Mission. This course is delivered by experts in the field, focusing on data management strategies at different stages of e-bus projects, which is exactly what Transjakarta needs. Besides this course, more training opportunities should be provided to staff.

Figure 90 Digitalization E-bus Projects course poster

1.4 Develop a long-term sustainable business model

The business model adopted by the pilot e-buses is not verified to be applied for future larger-scale e-buses deployment. But even for a pilot project, the operators need to bear the high capital cost of procuring e-bus and building the charging infrastructure, which is a huge burden for pilot project operators. Jakarta Transportation Agency and Transjakarta should provide help to operators to develop a suitable business model to purchase and operate e-buses, such as a leasing model, or provide guarantees to help operators to get loans from banks.

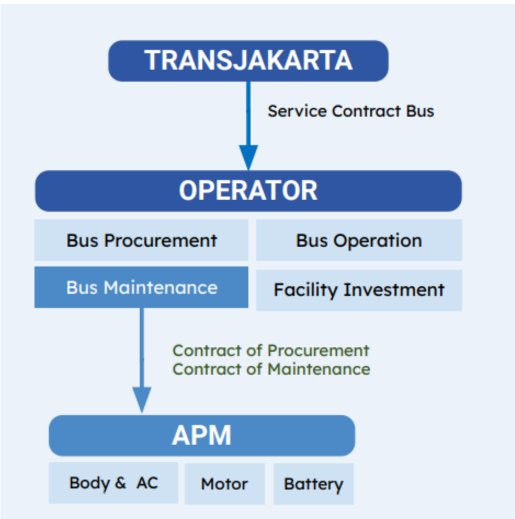


Figure 91 Pilot E-bus operator service contract structure

A sustainable business model could boost the motivation of operators. It was planned to operate 100 e-buses in the pilot project, but at the moment, only 30 e-buses are in operation, and the progress of the pilot project is lagging behind. Based on the gross-cost contract signed by Transjakarta and the operator, there are no incentives and motivation for attracting operators to bid for the e-bus pilot project and operating e-buses. The operators are paid based on the total kilometer traveled. However, this cost does not vary much between e-buses and ICE buses, despite the capital cost of an e-bus being more than double of ICE buses. Transjakarta needs to reevaluate the total cost for operators and adjust the payment. The local government also needs to consider financial instruments, such as tax reductions and subsidies for e-buses and charging infrastructure.

1.5 Summarize experiences gained and lessons learned from the pilot project

The success of a pilot project is the key to large-scale electrification. And conducting monitoring and evaluation for e-bus pilot projects is crucial for cities that are in the early stage of implementing electrification. As the capital city of Indonesia and also the pioneer of electrification, Jakarta needs to realize the value of pilot projects and take on the responsibility to summarize experiences gained and lessons learned from the pilot e-bus project and avoid the problems that existed in the pilot.

ITDP has collaborated with Transjakarta and many partners to conduct a series of workshops to share the international experience and disseminate the findings from monitoring and evaluating pilot e-buses. Next, after completing the e-bus pilot, Transjakarta should further document the pilot experience to incentivize other City Network, therefore achieving the collective outcome and realizing the ultimate goal of decarbonization in the country.

Appendix A: Passenger satisfaction survey forms

e-Bus Passengers Satisfaction Survey

GENERAL INFORMATION	Form Number	
	Surveyor Name	
	Days and Date	
	Route	

RESPONDENT PROFILE	What is the age of the respondent?	
	Respondent Gender Identity?	◯ Male ◯ Female
	Does the respondent have any disability?	◯ Yes, ... ◯ No

Filling Instruction:
Provide your level of satisfaction with the performance of the e-bus

PASSENGERS SATISFATION DATA	On-bus environment (cleanliness, AC temperature, tapping device, stop button, ramp, USB Charging)	◯ Very Satisfied ◯ Satisfied ◯ OK ◯ Dissatisfied ◯ Very Dissatisfied
	Bus Noise Level:	◯ Very Satisfied ◯ Satisfied ◯ OK ◯ Dissatisfied ◯ Very Dissatisfied
	Comfortability (Smoothness and free of jolting):	◯ Very Satisfied ◯ Satisfied ◯ OK ◯ Dissatisfied ◯ Very Dissatisfied
	Overall satisfaction with your journey	◯ Very Satisfied ◯ Satisfied ◯ OK ◯ Dissatisfied ◯ Very Dissatisfied
	In which area you think we can further improve?	

Appendix B: Training Needs Assessment survey forms

Interviewee profile

Interviewer	
Interview date	
Interviewer	
Interviewee name	
Interviewee company and position	
Interviewee contact number	
Interviewee contact email	

Section 0

What is your role during the (pilot) e-bus implementation process?

Section 1

What are the **key challenges** faced from e-Bus deployment?

For your organization or department	
For Transjakarta	

Section 2

Give importance on a scale of 0 – 5 with '0 being Least Important' and '5 being Very Important' of each 'skill attribute' for your department

Please select one option among Low (L), Medium (M), High (H) based on your seen skill assessment of Transjakarta

Instruction:

If the skill is assessed as **high-level**, it means Transjakarta could **fully** understand and meet the requirements at all cases.

If the skill is assessed as **medium-level**, it means Transjakarta **partly** understands the requirements, and could meet the requirements at **over 50% of cases** (e.g. for the

If the skill is assessed as **low-level**, it means Transjakarta **barely** understand the requirements, and could meet the requirments at **less than 50% of cases**.

		Importance	Skill		
			Low	Medium	High
Technical Specification Design					
Power requirement	Overall process of estimating power for e-buses				
Range requirement	Overall process of estimating range for e-buses				
Battery selection and sizing	Overall process of selecting **battery types and performance characteristics** (including energy density, charging/ discharging rate, end-of-life cycles, safety hazards, etc.)				
	Overall process of selecting **battery operating models** for e-buses (includes fast charging, slow charging, battery swap)				
Charging and electrical high voltage systems selection and sizing	Overall process of selecting charging models and charging infrastructure requirements (includes overnight charging, depot charging, opportunity charging)				
Depot and terminal infrastructure requirements	Overall process of estimating depot and terminal infrastructure requirements (including number of chargers, land size, resilience design and planning)				
Spare parts specification	Overall process of estimating requirments of spare parts				
ITMS specification	Overall process of estimating requirments of Integrated Transportation Management System				
Procurement (drivers, technicians, OEM, PLN could skip this skill)					
E-bus purchase specification	Define electric bus, its business models, aggregates specifications and operational plans				
Contracts and performance documentation	Detail performance service level agreements, associated incentives and disincentives				
Stores and purchases	Define quality assurance parameters and their standards, spare parts inventory				
	Mention supply of user service, repair, spare parts manuals and necessary training to PTA staff				
Operations					
E-bus route network and operations planning	Plan e-bus fleet operations, charging, scheduling, maintenance, parking, and monitoring in-sync with the existing ICE buses fleet				
E-bus driving	Driving behaviours impact on energy consumption and range reduction/enhancement; Operational hazards, safety and precautionary measures, emergency handling procedures				
Monitoring, ITMS & MIS	ITMS system for e-bus fleet and charging, and its integration with legacy IT system; Collection and storage of data points (through ITMS and manually) for e-bus fleet and charging operations; Analysis and production of standard MIS reports; Audit of non-conformance and drive co-ordination and resolution for smooth operations				
Repair and maintenance					
E-bus charging					
Preventive, maintenance, breakdown, repairs and overhauling					
Batteries and BMS					
Thermal management system of batteries					
Electronics, sensors, wiring, fuses etc.					
Air conditioning					
Monitoring and control					
ITMS and MIS	Collect data and analyse at all levels (include e-uses, batteries, charging systems etc.) with reference to physical and financial performance, energy efficiency, safety, service quality, SLAs and contract enforcement, and overall system monitoring of PTA performance				
Scrapping and recycling					
End-of-Life definition and tracking	Understand and define end-of-life for electric buses and different sub-systems (to execute timely replacements), their associated inventory planning and accounting of asset depreciation to arrive at right TCO; Disposal of batteries through certified centres to avoid environmental hazards, and capture economic value in its residual life through reuse and or recycling				

Section 3
What expected change in **People** at Transjakarta due to e-bus deployment?
What expected change in **Process** at Transjakarta due to e-bus deployment?
What expected change in **System** at Transjakarta due to e-bus deployment?

Section 4
What are your suggestions for overall improvement of e-bus adoption at Transjakarta coming from below stakeholders?

For OEM (Cost, Performance, Safety, Timely Delivery, Postsales Support, Operating Range, Operational Reliability)	
For Private Operator (Fleet/ Depot Mgmt., Contracting, Services, Integration)	
For Transjakarta Departments (Planning, Operations, Repairs & Maintenance, Operational Reliability, Safety & Emergency Handling, ITS/ MIS, Procurement/ Contract)	
Government (including City Authority, Discom, etc.)(Policy & Guidelines, MCA changes, Fund Allocation, Timely Disbursement)	

Appendix C: Data upload requirements in China

Data representation	Length/byte	Data type	Description and requirements
Vehicle data			
Vehicle condition	1	BYTE	0x01: vehicle start status; 0x02: flameout; 0x03: other status; 0xFE: abnormal; 0xff: invalid
Charging state	1	BYTE	0x01: parking charging; 0x02: driving charging; 0x03: non-charging state; 0x04: charging completed; 0xFE: abnormal; 0xff: invalid
Operation mode	1	BYTE	0x01: pure electric; 0x02: hybrid; 0x03: fuel; 0xFE: abnormal; 0xff: invalid
Speed	2	WORD	Valid range: 0 ~ 2200 (0km/h~220km/h),minimum measurement unit:0.1km/h; 0xFE:abnormal; 0xff: invalid
Accumulated mileage	4	DWORD	Valid range: 0-999999 (0km-999999.9km), minimum measurement unit: 0.1km/h; 0xFE:abnormal; 0xff: invalid
Total voltage	2	WORD	Valid range: 0 ~ 10000 (0V ~ 1000V), minimum measurement unit: 0.1V; 0xFE: abnormal; 0xff: invalid
Total current	2	WORD	Valid range: 0 ~ 20000 (offset: 1000A, -1000A~ 1000A), minimum measurement unit: 0.1A; 0xFE: abnormal; 0xff: invalid
SOC	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, 0xFE: abnormal; 0xff: invalid
DCDC state	1	BYTE	0x01: working; 0x02: disconnected; 0xFE: abnormal; 0xff: invalid
Gear	1	BYTE	Bit7: reserved. The reserved bit is represented by 0. Bit6: reserved. The reserved bit is represented by 0. Bit5: 1 for driving force; 0 for no driving force Bit4: 1 for braking force; 0 for no braking force Bit3 ~ bit0: 0000 for neutral gear; 0001 for first gear; 0010 for 2nd gear; 0011 for 3rd gear; 0100 for 4th gear; 0101 for 5th gear; 0110 for 6th gear; 1101 for reverse gear; 1110 for automatic D gear; 1111 for parking P gear
Insulation resistance	2	WORD	Valid range: 0 ~ 60000 (0k Ω ~ 60000 K Ω, minimum measurement unit: 1K Ω
Accelerator pedal travel value	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, 0xFE: abnormal; 0xff: invalid
Brake pedal state	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, "0" indicates the status of brake switch; "0x65" or "101" indicates valid brake status in case of no specific travel, 0xFE: abnormal; 0xff: invalid
Driving motor data			

Data representation	Length/byte	Data type	Description and requirements
Driving motor serial number	1	BYTE	Driving motor sequence number, valid range 1-253
Drive motor state	1	BYTE	0x01: power consumption; 0x02: power generation; 0x03: off state; 0x04: preparation state; 0xFE: abnormal; 0xff: invalid
Driving motor controller temperature	1	BYTE	Valid range: 0 ~ 250 (value offset: 40 ℃, -40 ℃~210 ℃), minimum measurement unit: 1 ℃; 0xFE: abnormal; 0xff: invalid
Driving motor speed	2	WORD	Valid range: 0 ~ 65531 (value offset: 20000, -20000r / min ~ 45531r / min), minimum measurement unit: 1r / min; 0xFE: abnormal; 0xff:invalid
Driving motor torque	2	WORD	Valid range: 0 ~ 65531 (value offset: 20000, -2000N. m~ 4553.1rn. m), minimum measurement unit: 0.1N. M; 0xFE: abnormal; 0xff: invalid
Driving motor temperature	1	BYTE	Valid range: 0 ~ 250 (value offset: 40 ℃, -40 ℃~210 ℃), minimum measurement unit: 1 ℃; 0xFE: abnormal; 0xff: invalid
Motor controller input voltage	2	WORD	Valid range: 0 ~ 60000 (0V ~ 6000V), minimum measurement unit: 0.1V, 0xFE: abnormal; 0xff:invalid
DC bus current of motor controller	2	WORD	Valid range: 0 ~ 20000 (value offset: 1000A, -1000A ~ +1000A), minimum measurement unit: 0.1A, 0xFE: abnormal; 0xff:invalid
Extreme value data			
Maximum voltage battery subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum voltage battery cell code	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum cell voltage	2	WORD	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Minimum voltage battery subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Minimum voltage battery cell code	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Minimum cell voltage	2	WORD	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Maximum temperature subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum temperature probe No.	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid

Data representation	Length/byte	Data type	Description and requirements
Maximum temperature	1	BYTE	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Vehicle location data			
Positioning state	1	BYTE	Bit0:0 for valid positioning; 1 for invalid positioning; Bit1: 0 for north latitude; 1 for south latitude Bit2:0 for east longitude; 1 for west longitude Bit3 ~ 7: reserved
Longitude	4	DWORD	Dimension value in degrees multiplied by to the nearest millionth of a degree.
Dimension	4	DWORD	Dimension value in degrees multiplied by to the nearest millionth of a degree
Alarm data			
Maximum alarm level	1	BYTE	It is the highest level of current faults, with a valid range of 0 ~ 3, and "0" for no fault; "1" for level 1 fault, which does not affect the normal driving of the vehicle; "2" for level 2 fault, which affects the performance of the vehicle and requires the driver to limit driving; "3" for level 3 fault, which is the highest level fault, which means the driver should stop the vehicle immediately or ask for assistance. the fault content corresponding to the specific level is defined by the manufacturer; "0xFE": abnormal; "0xff": invalid

Data representation	Length/byte	Data type	Description and requirements
General alarm marks	4	DWORD	Bit0:1 for temperature difference alarm; 0 for normal Bit1: 1 for high battery temperature alarm; 0 for normal Bit2: 1 for overvoltage alarm of the on-board energy storage device; 0 for normal Bit3:1 for under-voltage alarm of the on-board energy storage device; 0 for normal Bit4: 1 for low SOC alarm; 0 for normal Bit5:1 for overvoltage alarm of single battery; 0 for normal Bit6:1 for under voltage alarm of single battery; 0 for normal Bit7: 1for high SOC alarm; 0 for normal Bit8: 1 for jumping SOC alarm; 0 for normal Bit9:1 for mismatch alarm of the rechargeable energy storage system; 0 for normal Bit10:1 for inconsistent alarm of single battery; 0 for normal. Bit11:1 for insulation alarm; 0 for normal Bit12:1 for DCDC temperature alarm; 0 for normal Bit13:1 for brake system alarm; 0 for normal Bit14:1 for DCDC status alarm; 0 for normal Bit15:1 for temperature alarm of driving motor controller; 0 for normal Bit16:1 for high voltage interlock status alarm; 0 for normal Bit17:1 for temperature alarm of driving motor; 0 for normal Bit18:1 for overcharge alarm of on-board energy storage device; 0 for normal Bit19-31: reserved
Total failures of rechargeable energy storage device N1	1	BYTE	N1 rechargeable energy storage device failures, valid range: 0 ~ 252, "0xFE": abnormal; "0xff": invalid
Fault code list of rechargeable energy storage device	4xN	DWORD	Expansibility data, defined by the manufacturer; the number of failures of rechargeable energy storage device is equal to the total number of failures of rechargeable energy storage device N1
Total failures of driving motor N2	1	BYTE	N2 driving motor failures; valid range: 0 ~ 252, "0xFE": abnormal; "0xff": invalid
Fault code list of driving motor	4xN2	DWORD	As defined by the manufacturer, the number of driving motor failures is equal to the total number of driving motor failures N2.
Other failures N4	1	BYTE	N4 other failures; valid range: 0 ~ 252; "0xFE": abnormal; "0xff": invalid

Data representation	Length/byte	Data type	Description and requirements
Fault code list of other failures	4xN4	DWORD	Defined by the manufacturer, the number of faults is equal to the total number of faults N4

Appendix D: Communication meetings

No	Stakeholder	Discussion	Date
1	Transjakarta	Project activities and scope of work	January 13, 2022
2	Jakarta Transport Agency	Training Needs Assessment Interview	January 28, 2022
3	Transjakarta	Operational plan and ebus field survey	April 11, 2022
4	Transjakarta	Training Needs Assessment Survey Plan	May 13, 2022
5	Transjakarta	Survey methods and potential sources to be surveyed	May 19, 2022
6	Ministry of Transportation	Event preparation for TUMI E-bus Mission City Network Indonesia dan City Dialogue	June 06, 2022
7	Ministry of Transportation, TUMI City Network	TUMI E-bus Mission City Network Indonesia dan City Dialogue	June 16, 2022
8	Transjakarta	Training Needs Assessment Interview	June 29, 2022
9	Transjakarta	Monthly coordination meeting	July 27, 2022
10	E-bus Operator, E-bus OEM	Training Needs Assessment Interview	August 25, 2022
11	Transjakarta	Monthly coordination meeting	August 31, 2022
12	E-bus Operator	Training Needs Assessment Interview	September 01, 2022
13	PLN UID Jakarta	Training Needs Assessment Interview	September 19, 2022
14	Transjakarta, E-bus operator, Jakarta Transport Agency	Lessons learned from e-bus pilots in Chinese and Indian cities	September 29, 2022
15	Transjakarta	Monthly coordination meeting	September 28, 2022
16	Jakarta Transport Agency	Video shoot for TUMI in Jakarta	October 10, 2022
17	Transjakarta	Monthly coordination meeting	November 02, 2022
18	Transjakarta	Maintenance and failure on ebus fleet	January 26, 2023
19	E-bus Operator	Data associated to maintenance, charging activities, and Social & Gender impact	January 26, 2023
20	Transjakarta	Ebus monitoring and evaluation findings	April 06, 2023

Appendix E: Communication publications

"Jakarta's TUMI #eBusMission" series were released regularly to report the progress of efforts and the latest news regarding bus electrification in Jakarta and Indonesia.

Jakarta's TUMI #eBusMission Series November Issue

Access link: https://itdp-indonesia.org/publication/jakartas-tumi-ebusmission-series-november-issue/

Jakarta's TUMI #eBusMission Series September Issue

Access link:
https://itdp-indonesia.org/publication/zine-jakartas-tumi-ebusmission/