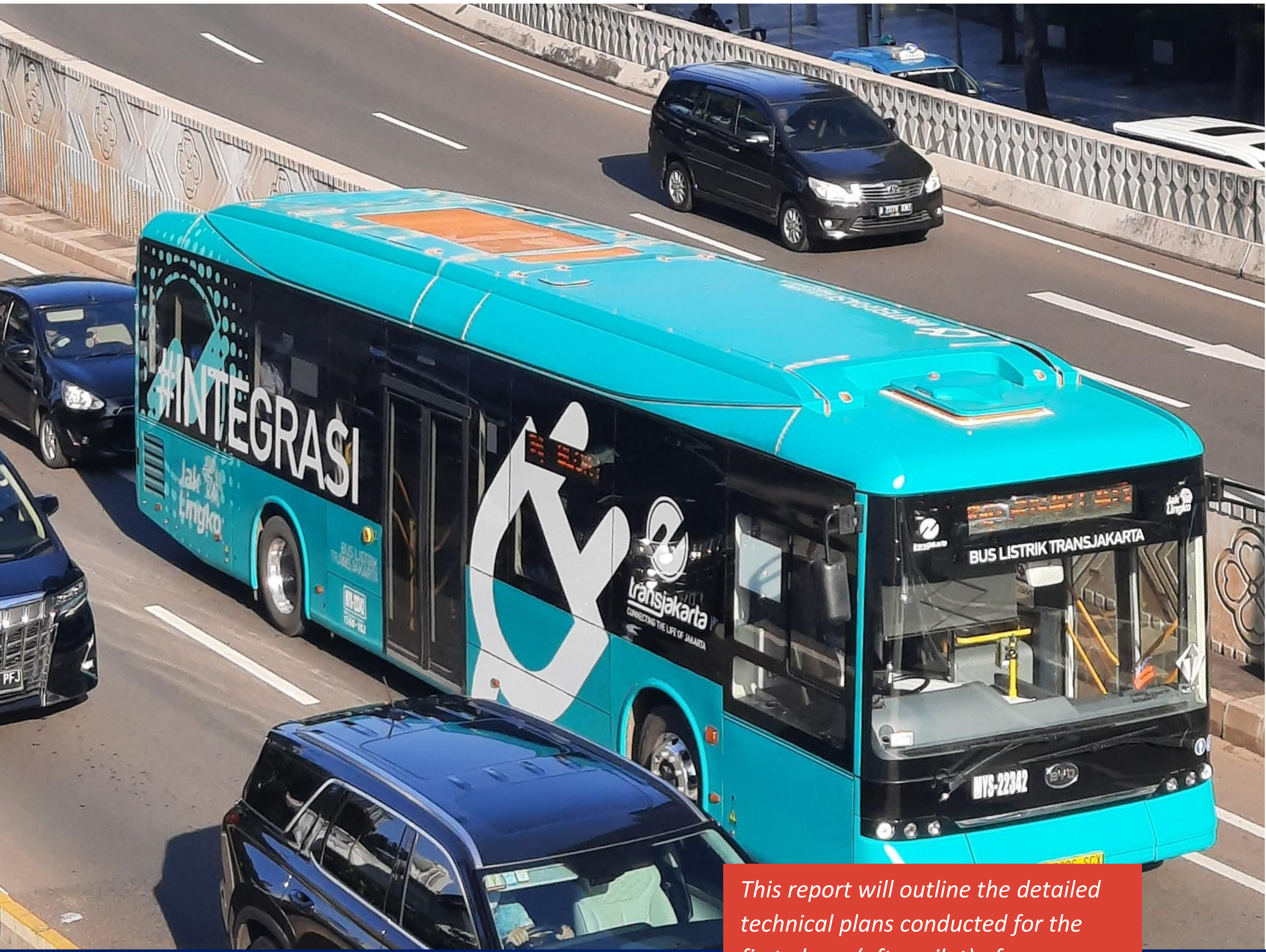


This report will outline the detailed technical plans conducted for the first phase (after-pilot) of Transjakarta's large scale electrification.

Building a Regulatory and Financial Basis for Transjakarta's First Phase E-bus Deployment

Task 4.1. Detailed Technical Plan

January 15, 2023

Table of Contents

List of Figures

List of Tables

UK PACT

UK PACT

List of Abbreviations

AB	Articulated Bus
AC	Alternating current
BEB	Battery Electric Bus
BKO	Operational Corridor Assistance (*Bantuan Kendaraan Operasional*)
BRT	Bus Rapid Transit
CAPEX	Capital Expenditure
CBD	Central Business District
CCS	Combined Charging System
CNG	Compressed natural gas
DC	Direct current
DNO	Distribution Network Owner
EUM	Electrifying Urban Mobility
EVSE	Electric vehicle supply equipment
GESI	Gender equality and social inclusion
GVW	Gross Vehicle Weight
HV	High voltage
ICE	Internal combustion engine
IDR	Indonesian Rupiah
ITDP	Institute for Transportation and Development Policy
kg	kilogram
km	kilometre
kW	kilowatt
kWh	kilowatt per hour
LFP	Lithium Iron Phosphate

m	metre
MB	Medium Bus
NMC	Lithium Nickel Manganese Cobalt Oxide
PV	Photovoltaic
PLM	Peak load management
OEM	Original equipment manufacturer
OPEX	Operational Expenditure
RDPT	Limited Participation Mutual Funds (*Reksa Dana Penyertaan Terbatas*)
RoI	Return of Investment
SB	Single Bus
SoC	State of Charge
TCO	Total cost ownership
UNEP-CTCN	United Nations Environment Programme – Climate Technology Centre and Network

Executive Summary

Transjakarta aims to electrify 100% of its fleets by 2030, which amounts to 10,047 fleets. ITDP Indonesia has developed a long-term year-on-year electrification plan that considers factors such as technology readiness, investment needs, regulatory support, and GESI aspects. The electrification plan is divided into phases to accommodate the constraints on budget and operational changes. In addition, financing institutions have expressed interests to invest in the program hence a comprehensive implementation plan is required to inform these institutions. A business case document, including a detailed technical plan, is needed to select routes, technology, charging locations, and assess the impacts of partial electrification on Transjakarta's operations.

As part of business case development, a detailed technical implementation plan is needed to inform the financing aspects. Hence, this report evaluates these particular technical aspects of electrifying Transjakarta fleets. In order to simplify the scope, based on funding mechanism using a Limited Participation Mutual Funds/ "RDPT" issuance and discussions with investment manager, the most viable funds that can be raised in one issue of such mutual funds is equal to around 840 e-bus, which can be deployed between 2023 - 2025. As such, the detailed technical plan will cover this phase only. The plan focuses on facilities and infrastructure directly related to electrification, such as e-bus fleets, charging facilities, and charging locations. The report analyses the number of fleets based on the quota allocation for each bus type in 2030, and it assumes that the total number of fleets to be deployed based on the quota is technically feasible. The study assumes all electric bus deployed in 2023 – 2025 is for fleets replacement and no fleets augmented in the selected routes. No additional routes are assumed to be deployed for electric bus between 2023 – 2025. The study utilises the existing contractual schemes between Transjakarta and operators.

<u>Routes Selected for Electrification</u>
Routes selection was done by ranking the Transjakarta routes. The route ranking was developed for BRT routes (single and articulated bus), non-BRT medium bus, and microbus.

- All routes were ranked based on:
  - Route level TCO/km
  - Number of buses
  - Ridership or fleets visibility and usability (based on zoning from the potential traffic restriction area)
  - Charging strategy

The final selection of routes for the first phase implementation is based on all of the factors discussed above. The following table shows the total number of fleets to be electrified in each year from 2023 to 2025, based on the implementation phase developed before.

Table 1. Total number of fleet to be electrified from 2023-2025

Electric buses	Start year of Implementation		
	2023	2024	2025
Articulated Bus	0	0	111
Single Bus	100	150	31
Medium Bus	100	0	50
Microbus	0	100	200

Based on the table above, the route ranking, the routes selected for BRT, non-BRT, and microbus are as follows:

For the BRT routes with single buses and articulated buses, routes ranking from 1 to 6 have been selected. Route 19C is included in the route selection as it shares the terminal Pinang Ranti with route number 9 and route no. 13C is excluded from the selection.

Table 2. Route Selected for BRT Routes

Route Code	Route Name	Terminus 1	Terminus 2	Number of SB*	Number of AB	Start of Electrification	% Electrification
1	Blok M – Kota	Blok M	Kota	100		2023	71%
1	Blok M – Kota	Blok M	Kota	70		2024	100%
9	Pinang Ranti – Pluit	Pinang Ranti	Pluit	80		2024	65%
1	Blok M – Kota	Blok M	Kota		41	2025	100%
3	Kalideres – Pasar Baru	Kalideres	Pasar Baru	33**	24	2025	71%
9	Pinang Ranti – Pluit	Pinang Ranti	Pluit	5**	39	2025	100%
9C	Pinang Ranti – Bundaran Senayan	Pinang Ranti	Bundaran Senayan		9	2025	45%
8	Lebak Bulus – Harmoni	Lebak Bulus	Harmoni	**63****		2025	78%

**Includes number of maxi buses as an equivalent number of single buses* (conversion factor 1.3).

*** reallocated from Corridor 1 to Corridor 8 in 2025 to account for replaced articulated buses in 2024 from Corridor 1.*

For the non-BRT medium bus routes, routes ranking from 1 to 15 are chosen. The selected routes will undergo full electrification.

Table 3. Routes selected for Non-BRT Medium Bus Routes

Route Code	Route Name	Terminus 1	Terminus 2	Number of MB	Nearest Terminal	Start year of Electrification
6C	Stasiun Tebet - Karet	Stasiun Tebet	Karet	7	Kampung Melayu	2023
1E	Pondok Labu - Blok M	Pondok Labu	Blok M	10	Blok M	2023
5N	Kampung Melayu - Ragunan	Kampung Melayu	Ragunan	9	Kampung Melayu	2023
6N	Ragunan - Blok M	Ragunan	Blok M	10	Blok M	2023
1C	Pesanggarahan - Blok M	Pesanggarahan	Blok M	8	Blok M	2023
8D	Joglo - Blok M	Joglo	Blok M	8	Blok M	2023
3E	Puri Kembangan - Sentraland Cengkareng	Puri Kembangan	Sentraland Cengkareng	17	Kalideres	2023
8E	Bintaro - Blok M	Bintaro	Blok M	7	Blok M	2023
1Q	Rempoa - Blok M	Rempoa	Blok M	7	Blok M	2023

Route Code	Route Name	Terminus 1	Terminus 2	Number of MB	Nearest Terminal	Start year of Electrification
11D	Pulogebang - Pulogadung 2	Pulogebang	Pulogadung	14	Both Terminus	2023
7P	Pondok Kelapa - BKN	Pondok Kelapa	BKN	9	Kampung Melayu	2023
11Q	Kampung Melayu - Pulo Gebang	Kampung Melayu	Pulo Gebang	7	Both Terminus	2025
9H	Cipedak - Blok M	Cipedak	Blok M	15	Blok M	2025
8K	Batusari - Tanah Abang	Batusari	Tanah Abang	13	Grogol	2025
1M	Meruya - Blok M	Meruya	Blok M	13	Blok M	2025

For microbus routes, routes ranking from 1 to 15 are chosen. Routes with at least one terminal end are given priority, which results in 9 routes to be selected. The selected routes will undergo full electrification.

Table 4. Routes Selected for Microbus Routes

Route Code	No. of Buses	Terminal	Start year of Electrification
JAK.53	43	Grogol	2024
JAK.56	30	Grogol	2024
JAK.30	30	Grogol	2024
JAK.31	30	Blok M	2025

JAK.46	41	Pasar Minggu	2025
JAK.54	27	Grogol	2025
JAK.15	48	Tanjung Priok	2025
JAK.19	42	Pinang Ranti	2025
JAK.84	31	Kampung Melayu	2025

Terminals Selected for Charging Infrastructure

Based on route ranking result, routes which ranks higher will be assigned to nearest terminals to carry out opportunity charging. The selection of the terminals has principles to minimise the dead kilometres hence to increase cost-effectiveness of the electrification. Routes that can be covered with overnight charging are assumed to be charged at the depots or other locations. Given that Transjakarta already has 122 layover areas across Greater Jakarta, installing charging equipment at each one may not be necessary in the initial phase of electrification. Instead, route grouping can help ensure mileage efficiency by avoiding the need for buses to travel to the farthest depot for charging.

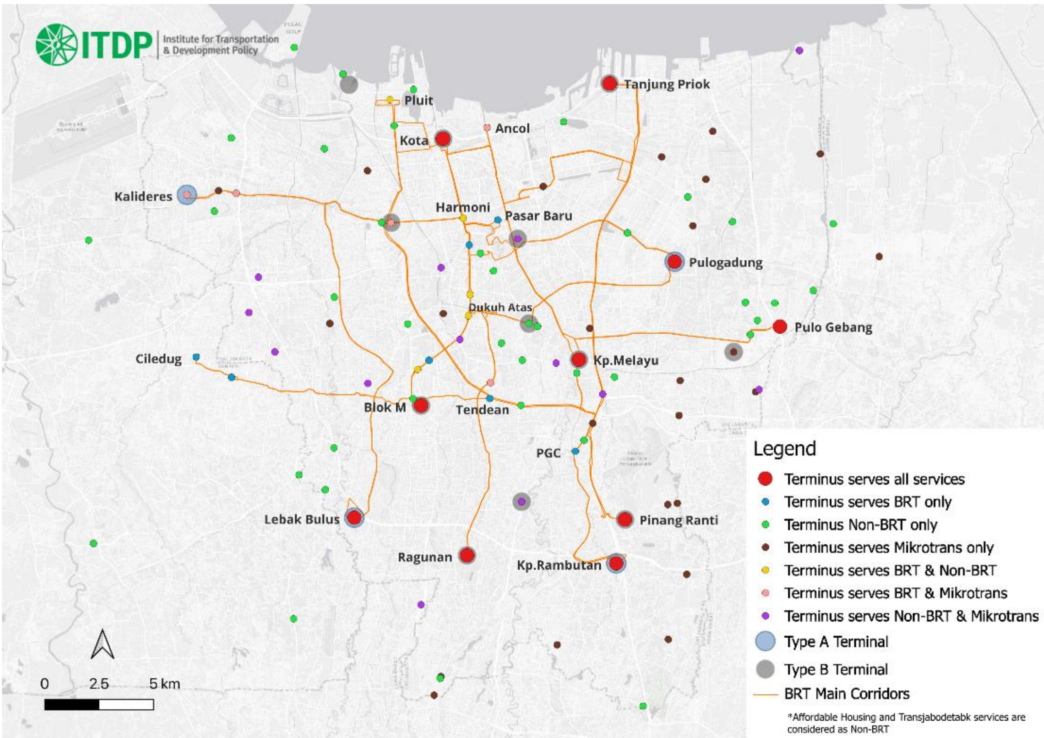


Figure 1. 112 Transjakarta layover points, divided into several archetypes

Based on BRT and non-BRT route selected, terminal charging locations are selected as follows:

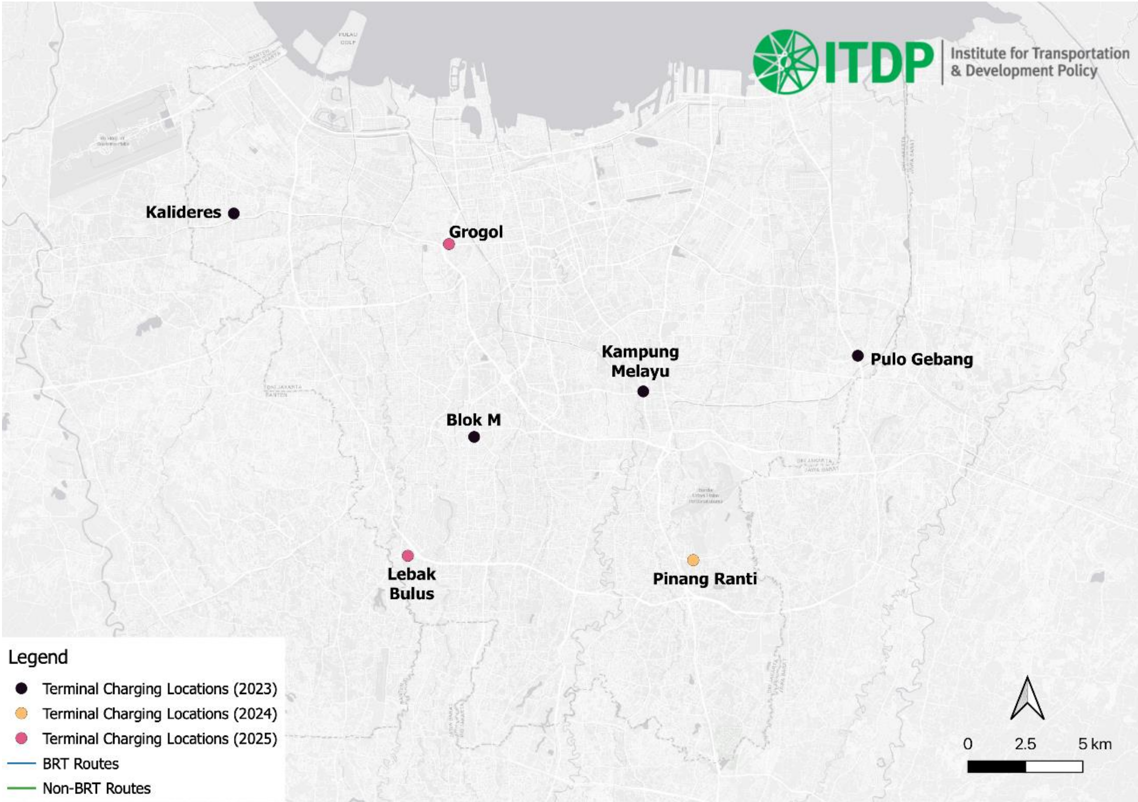


Figure 2. Terminal charging location points

Type of Technology Proposed

Fleets' Technology Readiness and Fleets Typology

Given that Transjakarta has several types of services with different bus types, typologies of electric buses need to be identified that are suitable to replace the counterpart of diesel bus types considering the bus specifications, passenger capacity and gross vehicle weight limits.

The study used market research and findings from previous studies to select bus typologies that include 12-m single buses, 12-m low entry buses, 7-m medium buses, 18-m articulated buses, and 4-m microbuses. The battery sizes were selected based on standard models available to avoid customization and longer procurement lead times. The report excludes double decker buses, Royaltrans buses, and 13.5-m maxi buses as they are not part of Transjakarta's electrification plan. Table below presents the selected bus typologies and serves as a baseline for the e-bus technology assumptions based on market availability.

Table 5. Transjakarta's fleets typology

Bus typology								
Bus Type	1	2	3	4	5	6	7	8
Type of Bus	Single Bus (12-m)		Medium Bus (7-m)		Articulated (18-m)	Low Entry (12-m)		Microbus (4-m)
Max GVW (kg)	16,000		8,000		26,000	16,000		5,000
Service Type	BRT, non-BRT		Non-BRT, affordable housing routes		BRT	Non-BRT		Mikrotrans, Transcare
Battery (kWh)	324	180*	135	150**	450	324	180*	42
Energy consumption, including factors such as AC usage (kWh/km)	1.2	1	1	1	1.8	1.2	1	0.15
Full battery range (km)	270	180	135	150	250	270	180	280
SoC reserve	20%	20%	20%	20%	20%	20%	20%	20%
Estimated range with 20 %SoC reserve (km)	216	144	108	120	200	216	144	225
Battery degradation by year 8	20%	20%	20%	20%	20%	20%	20%	20%
Range at year 8 after degradation (km)	173	115	86	96	160	173	115	180

** For single bus and low entry bus, a 324-kWh battery will be selected*
*** The 150-kWh battery has not yet met the Gross-Vehicle Weight requirement; therefore, the medium bus will use a 135-kWh battery for further analysis.*

Charger Technology Readiness & Charging Facilities

The implementation of e-buses involves several factors, such as battery technology, charging infrastructure, charger power, and fleet provision options. The report recommends LFP battery technology in the initial phases due to its availability in the Asian market, but also notes the increasing market share of advanced chemistries such as NMC. The charging technology and the number of charging stations are estimated based on the charger-to-bus ratio for each bus type and type of charging. The report provides an analysis of the charging technology, charger capacity, and the number of charging stations required for each type of electric bus, categorised based on the number of electric bus fleets. The charger-to-bus ratio serves as an initial evaluation of the required number of chargers, with further analysis required to determine the most efficient number of chargers to support the electric buses.

- 12-m single electric bus (high-deck or low entry)

The 12-m single buses both high-deck and low entry with 324 kWh LFP battery can have slow plug-in chargers up to 100 kW with a charging time of about 3.5 hours for 0% to 100% SoC and fast chargers up to 200 kW with a charging time of 1.25 hours for 10% to 80% SoC. For these bus types, double gun chargers at 200 kW recommended for overnight depot charging and terminal opportunity charging. It is assumed that each charger can charge two buses in succession for overnight charging, and the depot charger to bus ratio is estimated as 1:4. For opportunity charging, the terminal charger to bus ratio is 1:10. As battery technology improves, faster charging options may be explored in the future.

- 18-m articulated bus

The recommended charging options for articulated buses include fast charging with a charger power of up to 400 kW, taking about 1.5 hours to charge from 10% to 80% SoC, and overnight charging with 200 kW plug-in chargers, taking about 3 hours to charge from 0% to 100% SoC. The overnight charger to bus ratio is 1:2, and for terminal charging, it is estimated as 1:10, taking into account the opportunity charge requirement and fast charger power. The report highlights the potential for pantographs as an innovative solution for setting up charging infrastructure and optimising space, although further assessment is needed to determine whether pantographs or plug-in options are the best choice on a case-by-case basis from a technical and economic perspective.

- 7-m medium buses

The medium buses currently used in Indonesia are limited by the gross weight restrictions, one examples of suitable model for now is the BYD C6 with a battery size of 135 kWh. However, in future phases, buses with a higher battery capacity of 150 kWh and lighter weight may be developed. A 100-kW charger is recommended for both overnight and terminal charging, with a charging time of 1.3-1.5 hours for different battery sizes. Respectively for 135kWh and 150 kWh battery sizes, charger to bus ratios are estimated at 1:5 and 1:4 for overnight charging and 1:3 for terminal charging based on the charger power and opportunity charging requirement.

- 4-m microbuses

The Gelora EV from DFSK, equipped with a 42 kWh LFP battery and 22 kW charger, is the recommended model for electric microbuses in the current market based on TCO/km analysis conducted in the previous phase of the project. The charger to bus ratio is estimated at 1:10, with a charging time of 1.3 hours for 10% to 80% SoC, to account for opportunity charging or contingencies. The cost of each microbus includes one charger, and there will be opportunities for models with higher battery capacities and charger powers in the future as the market evolves.

Number of Chargers Needed

The report justifies the number of chargers required based on the charging scheduling at each terminal, which may result in a higher or lower number of chargers needed compared to the originally assigned charger per bus ratio, with the results are presented below:

Table 6. Number of chargers needed on each terminal

Terminal	2023		2024		2025			Total
	MB	*SB*	*MB*	*SB*	*MB*	*SB*	*AB*	
	100 kW	200 kW	100 kW	200 kW	100 kW	200 kW	400 kW	
Blok M	12	6	-	5	6	-	2	**31**
Grogol	-	-	-	-	4	-	-	**4**
Kalideres	6	-	-	-	-	3	2	**11**
Kampung Melayu	11	-	-	-	3	-	-	**14**
Pulogebang	5	-	-	-	-	-	-	**5**
Pinang Ranti	-	-	-	2	-	-	3	**5**
Lebak Bulus	-	-	-	-	-	2	-	**2**

1. Introduction

1.1 Background

Transjakarta committed to electrify 100% of its fleets by 2030. The target equals to electrifying 10,047 of its fleets in a span of 9 years. ITDP Indonesia, under the UK PACT programme, has developed a long-term year-on-year electrification plan for Transjakarta to achieve the target by integrating all Transjakarta services: BRT, non-BRT, and Mikrotrans on the plan. Aside of recommending types and number of fleets to be deployed each year, the long-term year-on-year plan also developed considering several criteria, such as technology readiness—including fleets, chargers, and batteries; charging strategy for each year of implementation; annual investment needed between 2023 – 2030; policy/ regulatory supports; and GESI (Gender Equality and Social Inclusion) aspects.

However, the electrification to 2030 shall be divided into several phase in order to comply with the budget planning, financing needed, the rapidly changing electric bus technology and its associated infrastructure, and the operational change of Transjakarta itself—including types of services, routes, and types of services.

A discussion with financing institutions highlighted their readiness to invest on the electrification program in the near future. Moreover, a business case document should be developed to the financing institutions in order to get to know better about the electrification program and their potential role on joining the electrification program based on the fund channelling schemes developed by the financing team. As a part of a business case document, there should be a detailed technical plan in order to select the routes to be deployed, the technology, terminal charging locations, charging strategy, and partial electrification impacts to the operational of Transjakarta, especially for the first phase of electrification.

1.2 Objectives of The Report

This document outlines the detailed technical plan for the first phase of Transjakarta's e-bus deployment as an integral part of Transjakarta's electrification business case document.

1.3 Scopes of The Report

Document Utilisation

This document **is not developed for feasibility study**. Since there has no signed commitment between Transjakarta and the financing institutions for the scope of the project implementation to be funded, this document will act as an "initial" business case for pre-transaction phase on the technical aspects. A comprehensive feasibility study document needs to be developed afterwards, with the scopes agreed with a financing institution.

Scopes of Time Horizon and Assumed Financing Mechanism being Used

Based on preliminary market consultations, using scheme B-2 developed by the financing team (Limited Participation Mutual Funds/ "RDPT" issuance), a fund manager willing to invest up to IDR 3 trillion for a single RDPT issuance ("**investor's market cap**"). The investment size is equivalent to electrifying around 700 – 800 fleets and its charging infrastructure. Based on the long-term electrification plan developed previously, by 2025, in cumulative, there will be 1,044 e-bus to be operated on the road. Assuming 300 fleets will be procured using business-as-usual scheme by 2023—to keep up with the yearly electrification target of 6% in the year, the rest 700 fleets in 2024 – 2025 will be procured using scheme B-2. Therefore, **the detailed technical plan will be developed for the first 1,000 e-bus to be deployed after pilot between 2023 - 2025**, consisting of 300 e-bus purchased through business-as-usual scheme and 700 e-bus secured through alternative financing mechanism, using B-2 scheme.

- With that, the detailed implementation phase will cover fleets as follows:
    - Around 100 unit of electric single high deck bus (12-m) and 100 unit of electric medium bus (7-m) in 2023;
    - Around 150 unit of electric single high deck bus (12-m) and 100 unit of electric microbus (4-m) in 2024; and
    - Around 31 unit of electric single high deck bus (12-m), 50 unit electric medium bus (7-m), 200 unit of electric microbus (4-m), and 111 electric articulated bus (18-m) in 2025.

Limiting the time horizon of the analysis to 2025 will also avoid incorporating major changes on the operation of Transjakarta that most likely will always happen with the passage of time.

Scopes of The Analysis of The Detailed Technical Plan

The detailed technical plan encompasses a range of activities, including ranking Transjakarta routes to be electrified, grouping routes for terminal charging, selecting terminal charging locations, developing a detailed charging strategy, planning charging infrastructure through conceptual designs, assessing grid impacts and renewable energy integration, and analysing partial electrification impacts. The plan only focuses on facilities and infrastructure directly related to electrification, such as electric bus fleets, charging facilities, and charging locations. BRT lines and stations, which are not directly linked to electrification, are not part of the analysis. Terminal charging is the primary focus, given that most depots are under private operators, whose selection depends on tender results. As such, dead kilometers based on depots' distance to terminus and charger power installed on the depots will be assumed rationally.

Number of Fleets and Routes Analysed

As of July 2022, Transjakarta operates approximately 3,994 fleets. The upcoming electrification programme aims not only to electrify the existing fleets but also to add around 6,000 new fleets to the Transjakarta system. The addition of new fleets will undoubtedly affect the number of fleets that can be deployed on current routes and the possibility of opening new routes. However, **this**

study only considers the current number of fleets operated on existing routes based on the July 2022 data. Therefore, the electrification in 2025 will only replace the existing fleets on selected routes and will not include the addition of new fleets. This study does not evaluate the need for additional fleets on specific routes or recommend opening new routes.

Furthermore, this study analyses the number of fleets based on the quota allocation for each bus type in 2030 as determined by the Jakarta Transport Agency. The quota allocation consists of 2,140 large buses (12-metre single bus or 18-metre articulated bus), 1,518 medium buses, and 6,360 microbuses. This study assumes that **the total number of fleets to be deployed based on the quota is technically feasible**.

Contractual Scheme Applied

The development of the detailed technical plan is closely tied to the contractual scheme that is currently in place within Transjakarta. This study utilises the existing contractual schemes between Transjakarta and operators, where tenders are issued for a specified number and type of fleets. As a result:

- The operators selected to run electric buses on particular routes remain uncertain as the operators are selected through a tendering process.
- Multiple operators may be responsible for operating a single route. For example, in July 2022, Corridor 1 (Blok M – Kota) was operated by Mayasari Bakti, PPD, and Steady Safe, while Swakelola, Transjakarta's self-owned electric bus, also served the corridor. In total, 127 fleets operated on the route. This allows a single route to be serviced by both electric and diesel buses.
- The selection of specific routes to be served by electric buses is typically determined later and is not directly linked to fleet tenders.

1.4 Outline of The Report

This report is structured into eight sections. The initial section is an introduction, which is followed by the methodology section. Prior to the analysis sections, an overview of Transjakarta services is provided. The analysis begins from section four to section eight, consecutively covering the discussion of route ranking and selection, terminal location selection and route grouping, detailed charging strategy, charging infrastructure planning, and partial electrification impacts. Finally, the report concludes with a summary and a section outlining the next steps.

2. Methodology

This section will discuss the methodology used to develop the detailed technical plan for the first phase (after-pilot) of Transjakarta e-bus implementation:

Develop the route ranking

a) The route ranking will be developed for: BRT routes (single and articulated bus), non-BRT medium bus, and microbus.
b) All routes will be ranked based on:
    i) Route level TCO/km
    ii) Number of buses
    iii) Ridership or fleets visibility and usability (based on zoning from the potential traffic restriction area)
    iv) Charging strategy
    Charging strategy will be developed on all routes, based on daily distance travelled, to determine whether the routes required overnight charging at the depots only, mid-day charging at the depots, or require opportunity charging at the terminals.

Subsequently, the routes will be chosen based on the number of fleets they are associated with, which is linked to the number of fleets deployed in 2023, 2024, and 2025, as outlined in Task 3.2. and 3.3: Report on Transjakarta E-Bus Integrated Long-Term Implementation Phase. The initial phase of electrification is expected to involve no fleet augmentation, and the electric buses will only replace the current ICE fleets.

Develop the terminal location selection and route grouping

Based on route ranking result, routes which ranks higher will be assigned to nearest terminals to carry out opportunity charging. The selection of the terminals has principles to minimise the dead kilometres hence to increase cost-effectiveness of the electrification.

Develop charging strategy and charging infrastructure provision

This analysis begins with a benchmarking of charging infrastructure provision at public depots or terminals in India, China, and Europe. It will also analyse the charging technology suitable for each type of e-bus, as discussed in Task 3.2 and Task 3 of the Transjakarta E-Bus Integrated Long-Term Implementation Phase report. Subsequently, the charging scheduling and number of EVSEs required for opportunity charging at each terminal will be preliminarily assessed through an analysis. A conceptual design will be developed for two terminals to determine the fleet flow for charging and estimate the available land for charging activity.

Analyse the partial electrification impacts

This section will carry out to examine the effects of partially electrifying certain routes. As the initial phase of electrification targets full electrification of several routes by 2025, some routes will undergo partial electrification in 2023 and 2024. An analysis of the partial electrification impact on the power grid is necessary to determine the load impact on the grid resulting from the partial electrification of specific terminals.

3. Overview of Transjakarta Services

Transjakarta is the world's most extensive Bus Rapid Transit (BRT) network, catering to the needs of the people of Jakarta and its surrounding regions. The network serves nearly 1 million passengers daily (pre-COVID 19) and covers 87.2% of the Jakarta region[1]. In addition to the BRT system, the network includes a variety of other services, such as non-BRT routes, direct services, border routes, premium routes known as Royaltrans, tourism routes, and feeder routes called Mikrotrans.

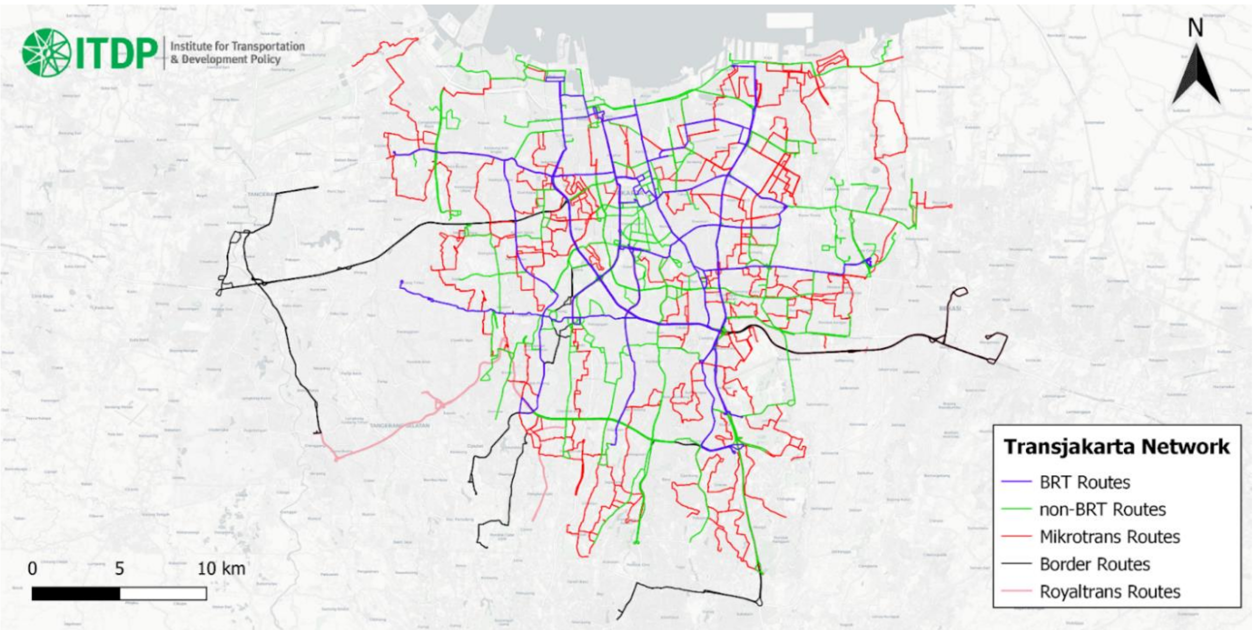


Figure 3. Transjakarta Network

Transjakarta operates a comprehensive transport system which incorporates diverse services and fleets, comprising a total of 4,413 vehicles operating on 219 routes[2]. The system operates through contractual agreements with both state-owned and private operators, which may either be in the form of companies or cooperatives.

[1] Transjakarta, November 2022.
[2] Ibid.

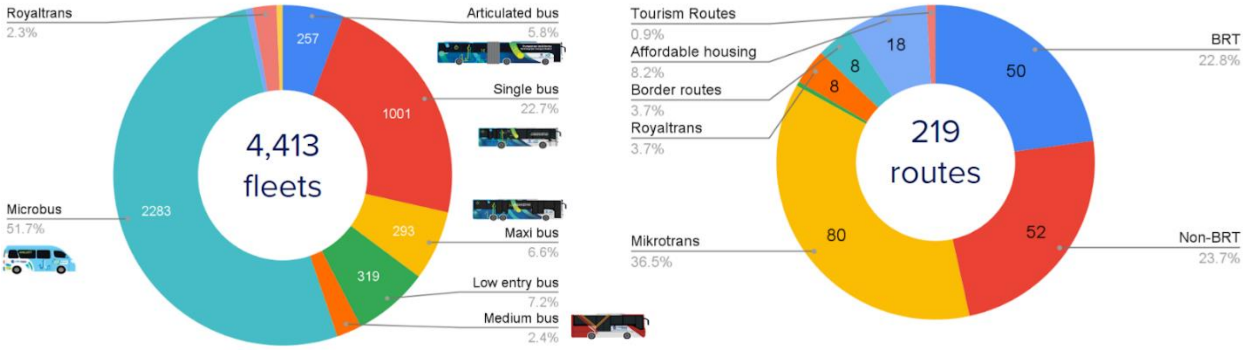


Figure 4. Transjakarta's number of fleets and number of routes, as per November 2022

This section will discuss the Transjakarta's type of fleets, type of services, and the dynamics of the operations to better understand the context for the electrification purposes.

Type of Fleets

Currently, Transjakarta operates seven different bus fleet types and eight different service categories. A few numbers of buses and are owned and run by Transjakarta, however the rest of them are owned and operated by a number of other companies. The following is a list and illustration of Transjakarta fleets:

Table 7. Transjakarta's Fleets Information.

Parameters	Single bus	Maxi bus	Medium bus	Articulated bus	Double-decker	Single Low Entry	Microbus
Fleets	 12 metres	 13,5 metres	 7 metres	 18 metres	 13,5 metres	 12 metres	 4 metres
Fuel types	Diesel & CNG	Diesel	Diesel	CNG	Diesel	Diesel	Gasoline & Diesel
Capacity	28 - 41 seats 26 - 35 hand grips	43 seats 42 hand grips	17 - 20 seats 13 - 20 hand grips	38 seats 72 - 104 hand grips	45 - 80 seats	30 - 41 seats 26 - 35 hand grips	11 seats
Number of Fleets (November 2022)	1001	293	106	257	28	319	2283

Service	BRT, Direct Service, Border Routes, Royaltrans	BRT, Direct Service, Border Routes	Direct Service and Affordable Housing	BRT, Border Routes	Tourism	Direct Services, Border Routes	Mikrotrans
Operation Time	Regular Service 05:00-22:00 Night Service: 22:00-05:00	Regular Service 05:00-22:00	Regular Service 05:00-22:00	Regular Service 05:00-22:00	Monday-Friday: 10:00-17:00 Saturday: 10:00-22:00 Sunday: 09:00-19:00	Regular Service 05:00-22:00	Regular Service 05:00-22:00
Operation	- Operate depots - 20% - 50% of fleets will be split during off-peak hours	- Operate depots - 20% - 50% of fleets will be split during off-peak hours	- Operate depots - 20% - 50% of fleets will be split during off-peak hours	- Operate depots - 20% - 50% of fleets will be split during off-peak hours	- Operate Depots - Shorter daily distance	- Operate depots - 20% - 50% of fleets will be split during off-peak hours	- No depots - No split during off-peak hours

However, Transjakarta has not had a plan yet to electrify double decker, and Royaltrans buses. Maxi buses will be converted to single bus.

Type of Services

Depending on demand, road features, the type and width of the road, and safety considerations, taking the bus GVW and turning radius into account, each type of services may have a variety of fleet types. The following is a list of Transjakarta's eight service categories:

1. BRT (Bus Rapid Transit)
   This service runs on dedicated BRT lanes. The service now has 50 routes spread across 13 BRT lanes totalling 251.2 kilometers. The routes do not in-and-out the BRT system[3]. There are two types of BRT routes:
   a. BRT routes operating only on one corridor.
      As there are only 13 main BRT lanes, the BRT running only on one corridor consists of 13 routes. The example is Corridor 1 that runs from Blok M to Kota, Corridor 2 that operates between Pulo Gadung and Harmoni[4], and Corridor 9 spanning from Pluit to Pinang Ranti. The routes typically coded only as one number, without an alphabet.

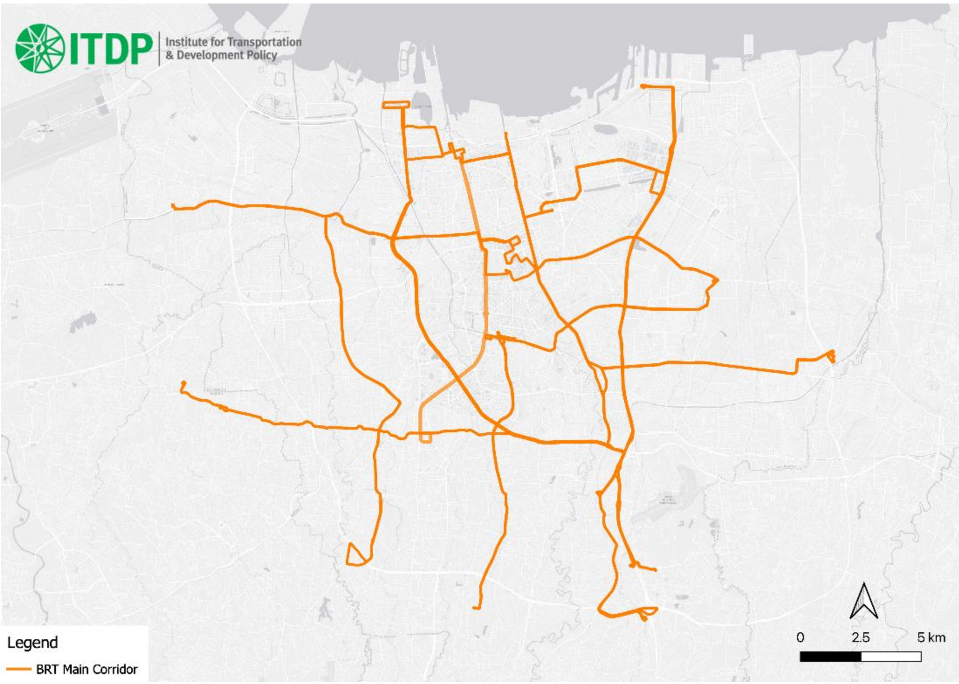


Figure 5. Transjakarta BRT Main Corridors

[3] BRT system mentioned in this report refers to the system of boarding and alighting passengers. BRT routes are fully operating in the BRT system since they only board and alight the passengers inside the BRT stations. The passengers need to tap-in and tap-out at the BRT stations once they want to enter or exit the BRT system.
[4] Corridor 2 terminus has been modified from Harmoni to Monas since March 2023 due to MRT construction.

b. BRT routes operating on multiple corridors.
The rest 37 BRT routes operating not only on a single route. The example is Route 6B (Ragunan – Monas via Semanggi)[5], that runs in segments on Corridor 1, Corridor 6, and Corridor 9.

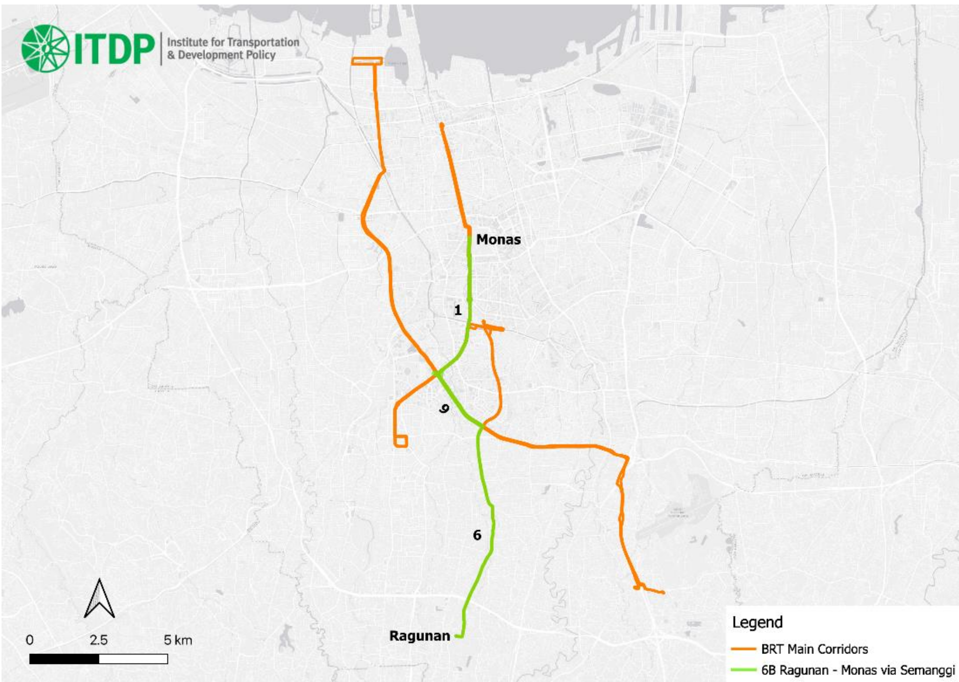


Figure 6. BRT routes operating on multiple corridors: Route 6B

BRT corridors differ from BRT routes as they can accommodate multiple routes, including direct services that run both within and outside the corridor. For example, Corridor 1 (Blok M – Kota) serves 29 routes, consisting of 15 BRT routes and 14 direct services.

[5] Route 6B terminus has been modified to from Monas to M.H. Thamrin since March 2023 due to MRT construction.

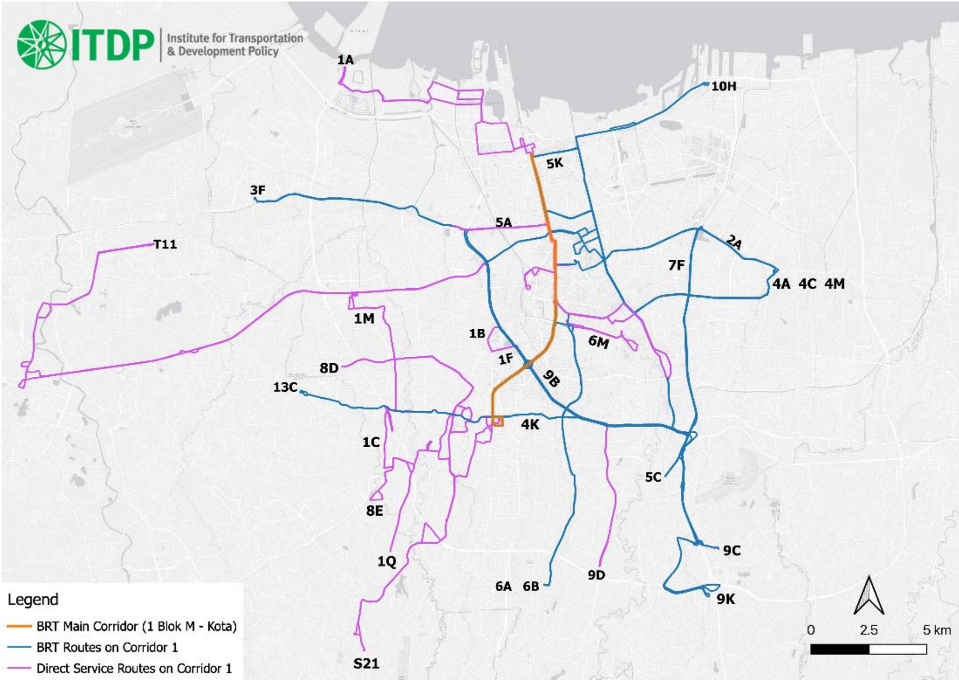


Figure 7. BRT & direct service routes running on Corridor 1

The BRT routes, to date, typically use three types of fleets: articulated bus, maxi bus, and single bus. As mentioned before, the deployment of types of fleets depends on several factors, such as road features and demand. Out of 13 BRT routes operating only on one corridor, 10 BRT routes use articulated bus due to its adequate turning radius or the needs of huge capacity to carry a significant number of passengers.

To date, all BRT routes still use conventional (non-electric bus) fleets that its energy comes from diesel or CNG. However, a pre-trial has been conducted between June and September 2022 on BRT Route 6B, using a 12-metre high-deck bus from Mobil Anak Bangsa Indonesia.

2. Integration Routes
   There are 52 Transjakarta routes categorised as integration routes. The integration routes, sometimes referred as non-BRT routes, could be divided into two types, based on its operational in the BRT system:
   a. Integration routes fully operated outside the BRT system.
      The integration routes fully operated outside the BRT system typically use single-bus (mostly low-floor) or medium bus. There are three routes on this category already deploy electric bus using low-floor single-bus. One example of integration routes fully operated outside the BRT system is 1N, running from Tanah Abang to Bundaran Senayan.

   b. Direct Service
      This type of integration routes typically uses high-deck bus, either 12-m single or 7-m medium, because the routes provide access to and from the BRT system as the

bus at some points board and alight the passengers at BRT stations. One example of direct service routes is Route 1A, operating from Balai Kota to Pantai Indah Kapuk. The routes enter the BRT system on Corridor 1, 9, and Corridor 12.

3. Mikrotrans
   Mikrotrans uses 4-m fleets, running on 80 routes fully outside the BRT system. The routes typically connect residential areas to important transit nodes, such as stations and terminals.

4. Affordable Housing Routes
   The service connects residents live on affordable housing and its surrounding to the BRT system.

5. Royaltrans
   Royaltrans, Transjakarta's premium shuttle service, running on 8 routes and mainly connect the residents of the city's outskirts. It uses 8.5m, all-seating buses. It is not subsidised. All the fleets operating under this service are owned by Transjakarta.

6. Border Routes
   The Transjakarta service known as the Border Routes (Transjabodetabek) operates between cities in the Greater Jakarta Area (known as Jabodetabek) and is integrated with the BRT service. There are currently eight routes operating within this service.

7. Tourism Routes
   The Tourism Routes use double-decker bus and do not cost any rupiah to passengers. There are two routes under this service.

8. Transcare
   Transcare uses microbus fleets that are dedicated to serving individuals with disabilities. This service is comprised of 26 buses that operate without fixed routes, and all of the vehicles utilised for this service are owned by Transjakarta.

The Dynamics of Transjakarta Operations

The operations of Transjakarta having dynamic on several operational aspects that needs to be understood in order to operate the electric bus and understand the consequences to the cost related to it, such as follows:

1. The number of buses on each route are dynamic, depending on various aspects, such as demand, aggregate number of buses, and change of the route tracks. Figure 8 illustrates the change on number of buses for each type of fleets between April and July 2022, in Corridor 1. AB and SB refer to articulated and single bus respectively.

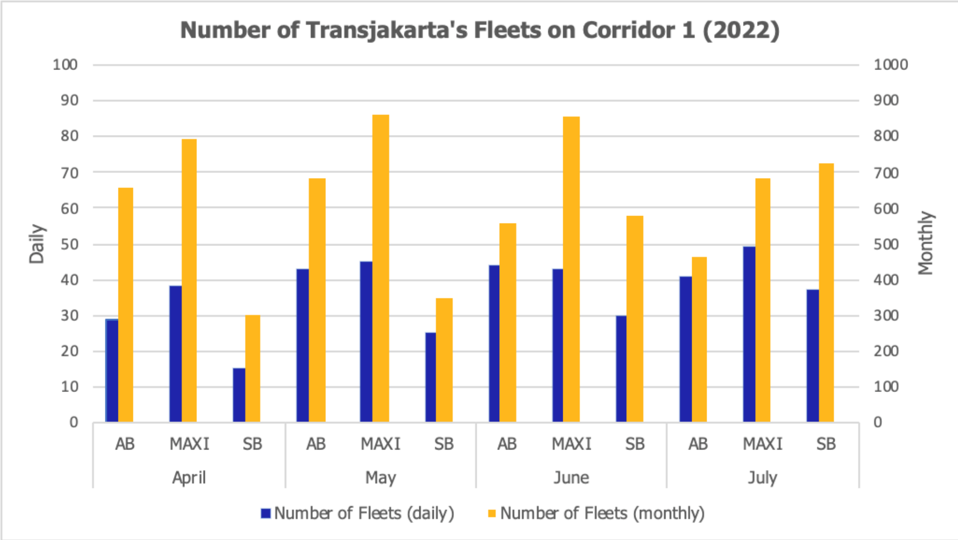


Figure 8. Change in Daily and Monthly Number of Transjakarta Fleets in Corridor 1 between April and July 2022.

2. The bus is not fixed to be operated on a route. A survey at Kampung Rambutan found a bus that initially served route 7D but later switched to 7E. This is because of BKO (*Bantuan Kendaraan Operasional,* Operational Corridor Assistance), where buses from other routes can be used to support routes that require help to maintain operational performance.
3. One routes could be operated by several operators. For example, Corridor 1 is operated by Mayasari Bakti, PPD, and Steady Safe. A few fleets owned by Transjakarta (Swakelola) is also assigned to the routes.
4. Low-floor single-bus; high-deck single bus; and medium-bus are somehow changeable, especially on non-BRT routes that are fully operate outside the BRT system. For example, route 2Q used to utilise medium bus, but recently changed to low-floor single bus.
5. Immediately preceding the outbreak of COVID, Transjakarta was operating a total of 248 routes. However, following the implementation of mobility restrictions in Jakarta in mid-March 2020, only a limited number of routes were operational. As these restrictions gradually eased, Transjakarta commenced the gradual reopening of previously closed routes while also opening new routes and increasing capacity on certain routes. Presently, Transjakarta is operating 219 routes.
6. Transjakarta routes sometimes being diverted from its original tracks due to incidents or events at a segment of the route. It makes the routes could not board and alight passengers at some bus stops or BRT stations. The example is Corridor 1 which was diverted between Sarinah[6] and Harmoni BRT station. The diverted route did not serve Monas and Bank Indonesia BRT station. Diverting the route makes the route longer 2.6 km, which results in a 19.2% longer distance in a single trip.

[6] Since March 2023, the BRT station's name has been changed to M. H. Thamrin.

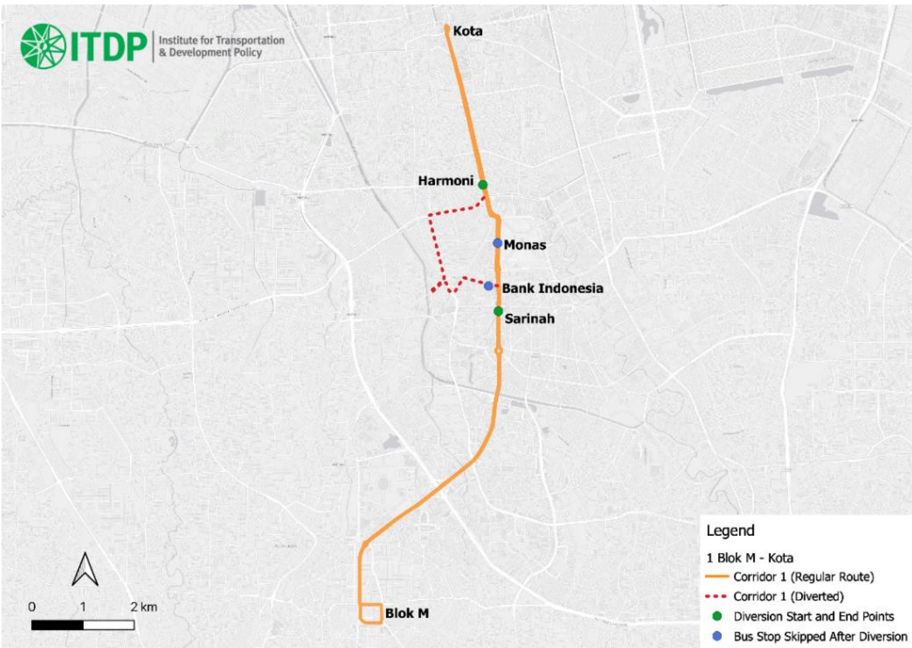


Figure 9. Diverted routes, case: Corridor 1

7. Transjakarta implements an axis routes system to optimize operations in high-demand segments, where fleets do not run from original terminus to another. For instance, Corridor 1 runs in a shorter route with the axis route system, resulting in 2.15 km (15.9%) shorter routes, hence impacting the charging scheduling and cycle time. Corridor 12 also has an axis route which operates from Penjaringan to Sunter Kelapa Gading, makes the route 36.9% shorter.

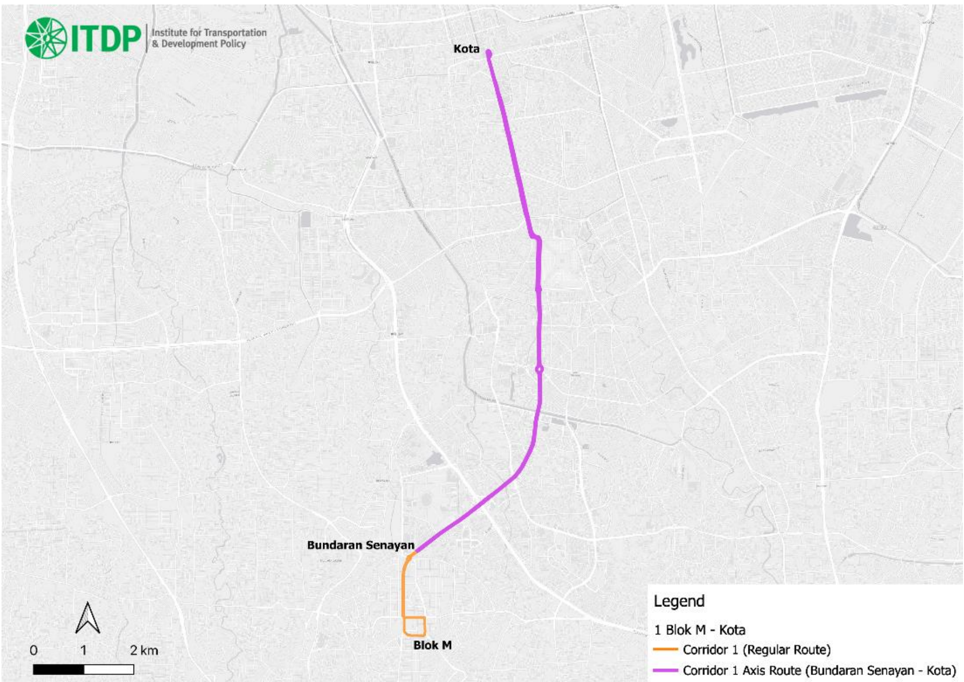


Figure 10. Axis routes, case: Corridor 1

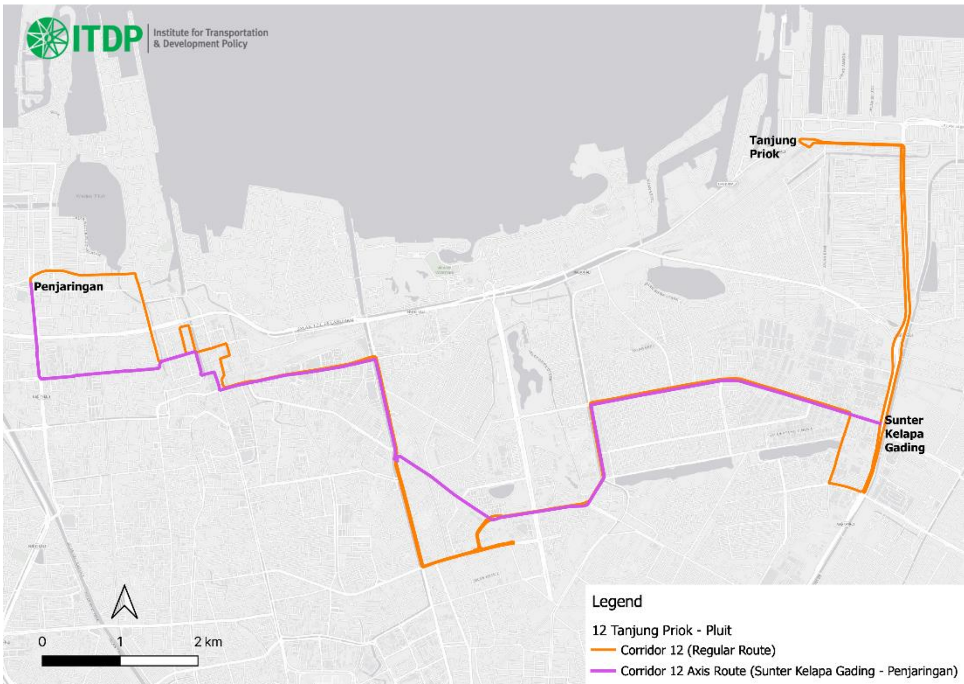


Figure 11. Axis routes, case: Corridor 12

Layover Points

Charging for electric buses may be carried out at depots, terminals, charging stations, or en-route charging stations at bus stops. Layover points, typically located at the terminus, is an area where the fleets are stagging and waiting for the next roundtrip. Layover area could potentially be utilised for electric bus charging. Based on the survey and desktop analysis, Transjakarta had 112 layover points. To establish charging infrastructure, it is necessary to create archetypes for terminal or layover points on existing routes, determine land ownership, and assume the availability of the terminal or layover points. Several terminus and layover archetypes have been identified under the Transjakarta services, such as:

1. Depots owned by Transjakarta
2. Depots owned by private operators
3. Terminals type A, owned by The Government of Jakarta
4. Terminals type B, owned by The Government of Jakarta
5. BRT stations
6. Non-terminal off-street layovers
7. On-street layovers

It is also important to identify which types of services being served in the layover area (BRT, non-BRT, microbus, or the combination of them) hence it will impact the complexity and the circulation of the fleet in case charging activities could be happen there.

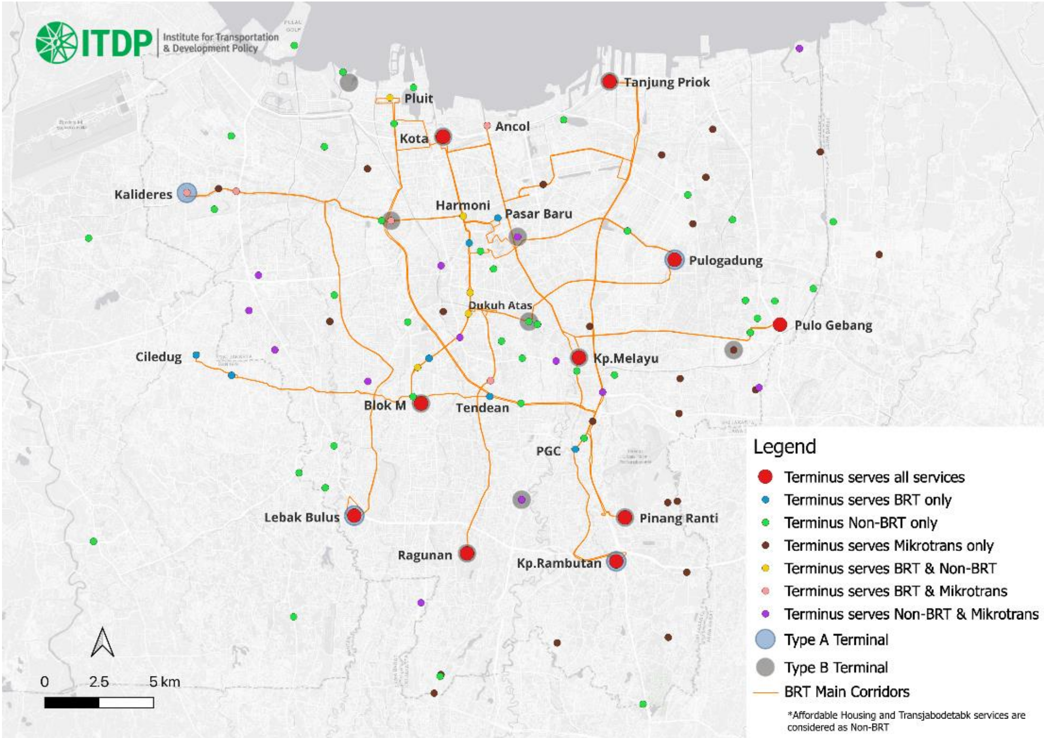


Figure 12. 112 Transjakarta layover points, divided into several archetypes

Dwelling time also become one factor that affects the possible charging availability at the layover area. Based on a survey in 10 terminals across Jakarta in November 2022, the average dwelling time for each Transjakarta services are as follows:

Table 8. Average Dwelling Time for Each Transjakarta Type of Service

Types of services	Average dwelling time
BRT	11 minutes 28 seconds
Non-BRT	25 minutes 31 seconds
Mikrotrans	21 minutes 13 seconds

Dead Kilometres

The term "dead kilometres" pertains to the distance covered by a bus during its travel from the depot to the initial stop of the operational trip, and from the last stop back to the depot. It is imperative to minimize dead kilometers by assigning buses to appropriate depots in order to enhance operational efficiency. Transjakarta stipulated a maximum of 20 kilometres for dead kilometres that would be remunerated to operators via a gross-cost (cost/km) contract. However, most of the cases, the true number of dead kilometres surpasses the maximum limit stipulated in the contract. Presently, three electric bus routes (1N, 1P, and 6D) have an average dead kilometre distance of 45.23 km, based on the analysis from Google Maps.

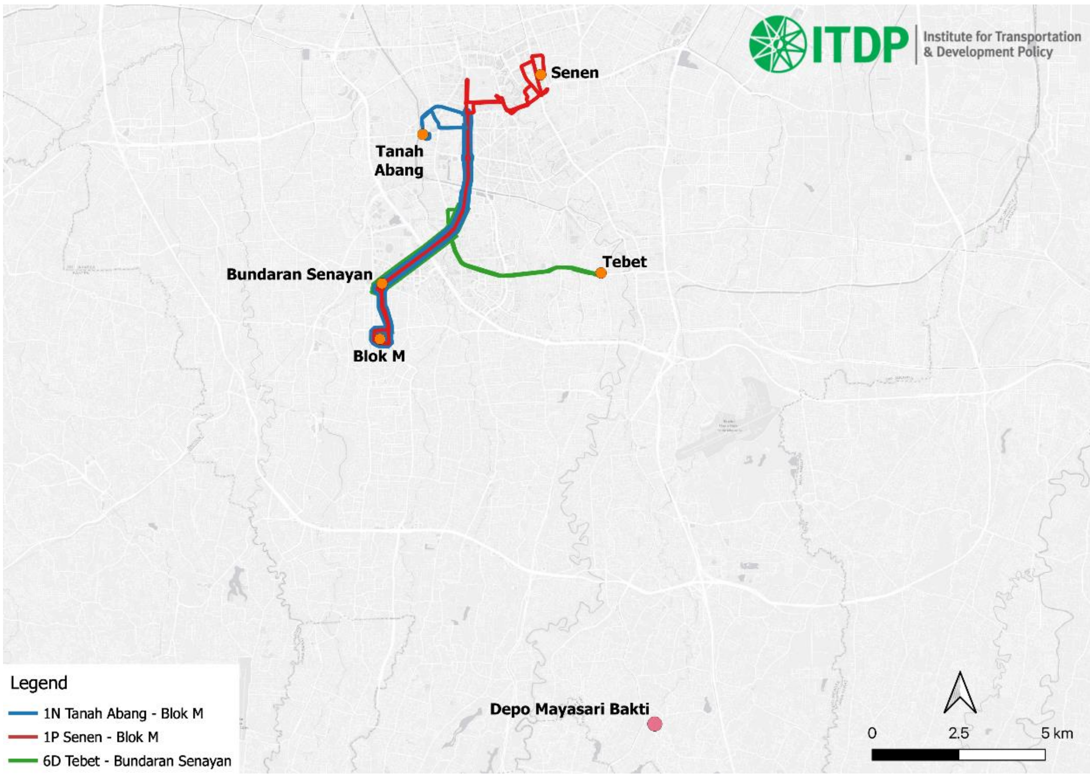


Figure 13. Transjakarta electric bus routes map.

4. Routes Ranking and Selection

4.1. Objectives of Routes Ranking for Electric Bus

In the case of conventional diesel buses, route planning typically takes into account only the starting and ending points of a route and the level of demand. However, when planning routes for electric buses, additional considerations arise due to factors such as charging infrastructure, battery performance, and charging strategy. It is essential to ensure that the buses have enough charge to complete their daily kilometres requirement and return to the depot at the end of the day. Depending on the battery range and energy demand on a route, top-up or opportunity charging may be required. Therefore, selecting the appropriate route is crucial when deploying electric buses.

Failure to plan routes properly can result in various problems, including range anxiety and higher replacement ratios, as the charging and range limitations of battery electric buses must be taken into account. Although several factors such as road conditions, traffic congestion, passenger demand, daily kilometres, energy demand, battery size and range, and charging strategy are crucial in determining the route, identifying key parameters that are critical for electric bus deployment is necessary.

Considering the first phase implementation from 2023-2025 developed in the Task 3.2 and 3.3, the route ranking will be developed for BRT routes (single and articulated bus), non-BRT medium bus, and microbus.

4.2. Parameters for Route Ranking

In this study, the crucial parameters for ranking routes have been identified and are discussed below. These parameters have been selected to ensure mutual exclusivity. For instance, daily kilometres are inherently incorporated in the calculation of total cost of ownership (TCO). As the daily kilometres on a route increase, the TCO decreases due to higher utilisation, and in such cases, TCO can be utilised as the ranking parameter. These parameters are then scored based on their respective values, and a weighted average ranking is used to derive an overall score and ranking for each route.

a. **TCO/km**
   TCO is the key information that bus operators would need to know, since they will procure the electric buses. The total cost of ownership (TCO) is a tool used to compare the costs of operating different technologies of vehicles – it does not only look at the upfront capital costs but also considers the operational cost over the lifetime of the vehicle. When transit authorities or the private sector are preparing their business models and considering the technologies, cost is one of the key factors. This parameter is therefore given the highest weightage of 45%.

b. Number of buses

Routes with higher number of buses can be prioritised for electrification. Higher number of buses per route also correlates to higher ridership and demand on the routes and will minimise the number of routes in the selection. Electric buses are usually gradually introduced, and the diesel buses can be used as backup in case of downtime or breakdown issues. Since each route especially the BRT routes have a mix of single buses, maxi buses and articulated buses operating, the total number of buses is estimated as an equivalent number of buses in terms of the single 12-m buses. The number of buses is given an overall weightage of 20% in the overall score.

c. Fleets visibility and usability

Passenger ridership or the number of passengers per bus per day is an indicator of route utilization, as higher ridership suggests greater usage of the route. In situations where passenger ridership data is unavailable or inaccurate, other parameters such as fleet visibility and usability can be considered for route selection.

Routes that operate within the central business district (CBD) area generally have higher passenger ridership and increased visibility for electric buses. Rider satisfaction and visibility are essential considerations in the deployment of electric buses. To rank the routes based on their visibility factors, the Jakarta region has been segmented into five zones (1-5) based on their proximity to the city centre.

The CBD area is located in the central zone (zone 1), as determined by a planned traffic restriction policy to reduce traffic congestion and limit private vehicle use within a designated zone covering the CBD region. Moreover, routes running in CBD area would potentially creating a good demonstration of the benefit of the electric bus to Jakarta citizens. Hence, zone 1 is deemed ideal for electric bus deployment and given the highest score. Zones 2, 3, 4, and 5 are defined as 5, 10, 15, and 20 km outside the traffic restriction area, respectively, and are scored accordingly. The visibility factor is assigned the next highest weightage, accounting for 30% of the overall score. The visibility and usability map is presented in Figure 14 below.

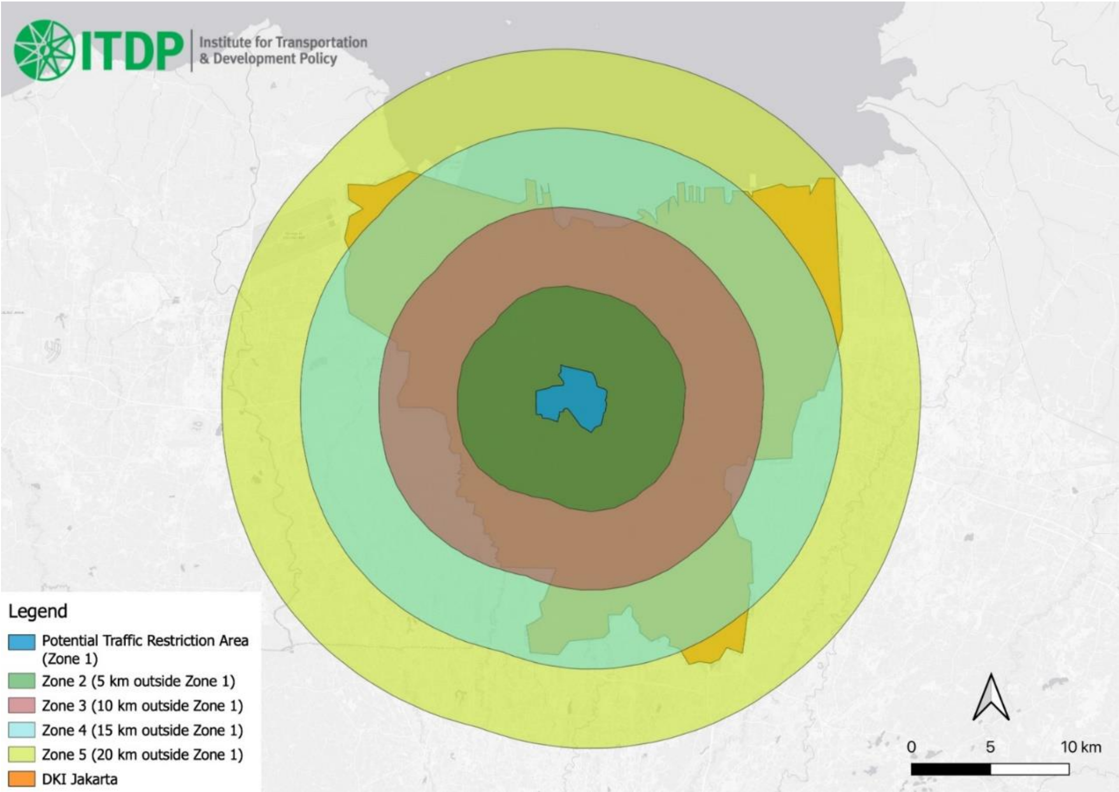


Figure 14. Route Visibility and Usability Map

4.3. Routes Ranking Result

The following tables show the overall ranking for each category of routes.

Table 9. Route Ranking for BRT Routes

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
1	170	262	21786	opportunity charging	0.11	1.00	1.00	0.60	1
9	151	239	23489	opportunity charging	0.04	0.89	0.80	0.48	2
3	100	267	21545	opportunity charging	0.12	0.59	0.80	0.44	3
13C	27	287	19839	opportunity charging	0.19	0.16	1.00	0.42	4

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
8	91	240	23198	opportunity charging	0.05	0.54	0.80	0.40	5
6A	23	318	18091	opportunity charging	0.26	0.14	0.80	0.39	6
5	59	274	21311	opportunity charging	0.13	0.35	0.80	0.38	7
6B	24	301	18995	opportunity charging	0.22	0.14	0.80	0.38	8
6	45	274	20717	opportunity charging	0.15	0.26	0.80	0.37	9
5C	33	281	19903	opportunity charging	0.19	0.19	0.80	0.37	10
2	56	257	22034	opportunity charging	0.10	0.33	0.80	0.37	11
13D	33	276	20575	opportunity charging	0.16	0.20	0.80	0.36	12
4	52	255	22203	opportunity charging	0.09	0.30	0.80	0.36	13
4D	13	298	19168	opportunity charging	0.22	0.08	0.80	0.36	14
11	44	283	20099	opportunity charging	0.18	0.26	0.60	0.32	15
9A	37	243	23294	opportunity charging	0.05	0.22	0.80	0.32	16

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
10	84	242	23996	opportunity charging	0.02	0.50	0.60	0.31	17
7	51	262	21545	opportunity charging	0.12	0.30	0.60	0.31	18
9C	26	247	22916	opportunity charging	0.06	0.15	0.80	0.31	19
3F	22	244	23198	opportunity charging	0.05	0.13	0.80	0.29	20
8A	8	253	22376	opportunity charging	0.08	0.05	0.80	0.29	21
4C	17	238	23790	opportunity charging	0.03	0.10	0.80	0.28	22
7F	17	265	21388	opportunity charging	0.12	0.10	0.60	0.26	23
12	32	245	23103	opportunity charging	0.05	0.19	0.60	0.25	24
5D	14	260	21786	opportunity charging	0.11	0.08	0.60	0.25	25
2A	9	258	21950	opportunity charging	0.10	0.05	0.60	0.24	26
10D	15	252	22464	opportunity charging	0.08	0.09	0.60	0.24	27
13A	3	266	21311	opportunity charging	0.13	0.02	0.00	0.06	28

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
2C	9	232	24422	opportunity charging	0.00	0.05	0.00	0.01	29

Table 10. Route Ranking for Non-BRT Routes

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
9H	12	238	11396	opportunity	0.626	0.71	0.80	0.70	1
1M	12	210	12396	opportunity	0.594	0.71	0.80	0.68	2
8K	10	243.5	11242	opportunity	0.631	0.59	0.80	0.67	3
6C	7	207	12518	opportunity	0.590	0.41	1.00	0.67	4
1E	10	230	11657	opportunity	0.618	0.59	0.80	0.67	5
5N	9	232	11590	opportunity	0.620	0.53	0.80	0.65	6
6N	10	192	13193	opportunity	0.567	0.59	0.80	0.64	7
1C	8	218	11242	opportunity	0.631	0.47	0.80	0.64	8
8D	8	218	12084	opportunity	0.604	0.47	0.80	0.63	9
3E	17	193	13102	opportunity	0.570	1.00	0.40	0.63	10
6Q	3	237	11428	opportunity	0.625	0.18	1.00	0.63	11
8E	7	221	11973	opportunity	0.607	0.41	0.80	0.62	12
1Q	7	204	12646	opportunity	0.585	0.41	0.80	0.61	13

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
11D	14	200.5	12821	opportunity	0.580	0.82	0.40	0.59	14
7P	9	208	12478	opportunity	0.591	0.53	0.60	0.58	15
11Q	7	213	11396	opportunity	0.626	0.41	0.60	0.56	16
5B	2	199	12866	opportunity	0.578	0.12	0.80	0.53	17
12A	2	198	12869	opportunity	0.578	0.12	0.60	0.47	18
10K	2	142	16466	opportunity	0.460	0.12	0.60	0.42	19
11M	4	279	9768	opportunity	0.680	0.24	0	0.36	20
12F	2	349	8969	opportunity	0.706	0.12	0	0.35	21
10A	5	213	12234	opportunity	0.599	0.29	0	0.34	22
2F	4	215.5	12198	opportunity	0.600	0.24	0	0.33	23
11B	1	295	9905	opportunity	0.675	0.06	0	0.32	24
11C	2	239	11365	opportunity	0.627	0.12	0	0.31	25
3B	2	212	12273	opportunity	0.598	0.12	0	0.30	26
2P	2	199	12866	opportunity	0.578	0.12	0	0.29	27
2Q	2	173	14214	opportunity	0.534	0.12	0	0.27	28
3C	2	164	14737	opportunity	0.517	0.12	0	0.26	29
11K	1	181	13758	opportunity	0.549	0.06	0	0.26	30

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
10B	2	144.5	16291	opportunity	0.466	0.12	0	0.24	31
3A	2	130	17584	overnight	0.423	0.12	0	0.22	32
GR4	1	67	30493	overnight	0.000	0.06	0	0.01	33
GR5	1	66	30495	overnight	0.000	0.06	0	0.01	34

Table 11. Route Ranking for Mikrotrans Routes

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.53	43	197	4254	Overnight Charging	0.12	0.90	1.000	0.58	1
JAK.43	40	190	4383	Overnight Charging	0.09	0.83	1.000	0.55	2
JAK.56	32	196	4271	Overnight Charging	0.12	0.67	1.000	0.52	3
JAK.49	38	208	4067	Overnight Charging	0.16	0.79	0.800	0.51	4
JAK.30	30	195	4290	Overnight Charging	0.11	0.63	1.000	0.51	5
JAK.31	30	195	4290	Overnight Charging	0.11	0.63	1.000	0.51	6
JAK.46	41	195	4290	Overnight Charging	0.11	0.85	0.800	0.50	7

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.54	27	197	4254	Overnight Charging	0.12	0.56	1.000	0.49	8
JAK.16	37	190	4383	Overnight Charging	0.09	0.77	0.800	0.47	9
JAK.15	48	189	4402	Overnight Charging	0.09	1.00	0.600	0.47	10
JAK.85	31	196	4271	Overnight Charging	0.12	0.65	0.800	0.45	11
JAK.19	42	196	4271	Overnight Charging	0.12	0.88	0.600	0.45	12
JAK.84	31	193	4326	Overnight Charging	0.11	0.65	0.800	0.45	13
JAK.12	26	175	4696	Overnight Charging	0.03	0.54	1.000	0.45	14
JAK.17	22	185	4482	Overnight Charging	0.07	0.46	1.000	0.45	15
JAK.51	30	194	4308	Overnight Charging	0.11	0.63	0.800	0.45	16
JAK.112	30	194	4308	Overnight Charging	0.11	0.63	0.800	0.45	16
JAK.77	30	194	4308	Overnight Charging	0.11	0.63	0.800	0.45	16
JAK.11	27	169	4836	Overnight Charging	0.00	0.56	1.000	0.44	19

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.71	28	197	4254	Overnight Charging	0.12	0.58	0.800	0.44	20
JAK.73	39	197	4254	Overnight Charging	0.12	0.81	0.600	0.44	21
JAK.14	36	173	4742	Overnight Charging	0.02	0.75	0.800	0.44	22
JAK.07	25	171	4788	Overnight Charging	0.01	0.52	1.000	0.43	23
JAK.60	30	185	4482	Overnight Charging	0.07	0.63	0.800	0.43	24
JAK.59	24	198	4236	Overnight Charging	0.12	0.50	0.800	0.42	25
JAK.45	24	198	4236	Overnight Charging	0.12	0.50	0.800	0.42	25
JAK.74	24	196	4271	Overnight Charging	0.12	0.50	0.800	0.42	27
JAK.24	25	192	4345	Overnight Charging	0.10	0.52	0.800	0.42	28
JAK.18	13	192	4345	Overnight Charging	0.10	0.27	1.000	0.41	29
JAK.41	24	186	4462	Overnight Charging	0.08	0.50	0.800	0.40	30
JAK.02	17	207	4084	Overnight Charging	0.16	0.35	0.800	0.40	31

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.10	17	172	4765	Overnight Charging	0.01	0.35	1.000	0.40	32
JAK.42	21	192	4345	Overnight Charging	0.10	0.44	0.800	0.40	33
JAK.75	19	198	4236	Overnight Charging	0.12	0.40	0.800	0.39	34
JAK.117	33	190	4383	Overnight Charging	0.09	0.69	0.600	0.39	35
JAK.47	20	194	4308	Overnight Charging	0.11	0.42	0.800	0.39	36
JAK.26	20	194	4308	Overnight Charging	0.11	0.42	0.800	0.39	36
JAK.27	30	196	4271	Overnight Charging	0.12	0.63	0.600	0.39	38
JAK.34	20	191	4364	Overnight Charging	0.10	0.42	0.800	0.39	39
JAK.37	20	190	4383	Overnight Charging	0.09	0.42	0.800	0.39	40
JAK.50	20	190	4383	Overnight Charging	0.09	0.42	0.800	0.39	40
JAK.61	20	193	4386	Overnight Charging	0.09	0.42	0.800	0.39	42
JAK.36	30	194	4308	Overnight Charging	0.11	0.63	0.600	0.39	43

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.72	30	194	4308	Overnight Charging	0.11	0.63	0.600	0.39	43
JAK.13	15	171	4788	Overnight Charging	0.01	0.31	1.000	0.38	45
JAK.33	17	196	4271	Overnight Charging	0.12	0.35	0.800	0.38	46
JAK.04	17	195	4290	Overnight Charging	0.11	0.35	0.800	0.38	47
JAK.08	13	173	4742	Overnight Charging	0.02	0.27	1.000	0.38	48
JAK.52	28	194	4308	Overnight Charging	0.11	0.58	0.600	0.37	49
JAK.44	27	197	4254	Overnight Charging	0.12	0.56	0.600	0.37	50
JAK.21	15	196	4271	Overnight Charging	0.12	0.31	0.800	0.37	51
JAK.32	30	194	4502	Overnight Charging	0.07	0.63	0.600	0.37	52
JAK.35	16	191	4364	Overnight Charging	0.10	0.33	0.800	0.37	53
JAK.80	39	189	4402	Overnight Charging	0.09	0.81	0.400	0.36	54
JAK.39	25	194	4308	Overnight Charging	0.11	0.52	0.600	0.36	55

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.64	24	197	4254	Overnight Charging	0.12	0.50	0.600	0.36	56
JAK.09	9	173	4742	Overnight Charging	0.02	0.19	1.000	0.36	57
JAK.22	10	198	4236	Overnight Charging	0.12	0.21	0.800	0.35	58
JAK.28	21	195	4290	Overnight Charging	0.11	0.44	0.600	0.34	59
JAK.25	21	195	4290	Overnight Charging	0.11	0.44	0.600	0.34	59
JAK.29	20	194	4308	Overnight Charging	0.11	0.42	0.600	0.33	61
JAK.01	20	192	4385	Overnight Charging	0.09	0.42	0.600	0.33	62
JAK.20	15	197	4254	Overnight Charging	0.12	0.31	0.600	0.31	63
JAK.03	15	196	4271	Overnight Charging	0.12	0.31	0.600	0.31	64
JAK.38	16	192	4345	Overnight Charging	0.10	0.33	0.600	0.31	65
JAK.06	14	197	4254	Overnight Charging	0.12	0.29	0.600	0.31	66
JAK.40	25	197	4254	Overnight Charging	0.12	0.52	0.400	0.30	67

Route code	Number of buses	Daily distance including dead km	TCO	Charging strategy	TCO score	Number of buses score	Visibility score	Overall score	Rank
JAK.58	21	196	4271	Overnight Charging	0.12	0.44	0.400	0.28	68
JAK.05	19	196	4271	Overnight Charging	0.12	0.40	0.400	0.27	69
JAK.88	16	198	4236	Overnight Charging	0.12	0.33	0.000	0.14	70
JAK.10A	12	175	4696	Overnight Charging	0.03	0.25	0.000	0.08	71
JAK.10B	2	172	4765	Overnight Charging	0.01	0.04	0.000	0.02	72

For the 1st phase of implementation, routes is selected based on the total fleet to be electrified from the implementation phase. In addition to the route ranking, the following factors will be also considered for the final route selection.

a. **Charging strategy**
   Charging strategy plays an important role in route selection. Charging strategy is determined based on the battery capacity and range and the energy demand on the route for the daily kms requirement. Routes with overnight charging only are preferred over routes which require opportunity charging.

b. **Terminal availability**
   Availability of terminal space for charging station for opportunity charging is paramount to electric bus operation along any route. Opportunity charging at terminal will reduce the dead kms and while also utilizing the dwelling time at the terminal for charging. In addition to the route ranking, the route selection can also be based on the terminals prioritised for electrification. All the routes converging at a prioritised terminal can be selected to reduce the number of terminals to be developed and hence the overall cost of terminal development for electrification.

c. Grid Accessibility

Grid accessibility and augmentation to the grid infrastructure at the terminals and depots and the associated costs can also impact the terminal/route selection for electrification.

The final selection of routes for the first phase implementation is based on all of the factors discussed above. The following table shows the total number of fleets to be electrified in each year from 2023 to 2025.

Table 12. Total number of fleet to be electrified from 2023-2025

Electric buses	Start year of Implementation		
	2023	2024	2025
Articulated Bus	0	0	111
Single Bus	100	150	31
Medium Bus	100	0	50
Microbus	0	100	200

Based on the table above, and the route ranking, the routes selected for BRT, non-BRT, and microbus are as follows:

For the BRT routes with single buses and articulated buses, routes ranking from 1 to 6 have been selected. Route 19C is included in the route selection as it shares the terminal Pinang Ranti with route number 9 and route no. 13C is excluded from the selection.

Table 13. Route Selected for BRT Routes

Route Code	Route Name	Terminus 1	Terminus 2	Number of SB*	Number of AB	Start of Electrification	% Electrification
1	Blok M – Kota	Blok M	Kota	100		2023	71%
1	Blok M – Kota	Blok M	Kota	70		2024	100%
9	Pinang Ranti – Pluit	Pinang Ranti	Pluit	80		2024	65%
1	Blok M – Kota	Blok M	Kota		41	2025	100%
3	Kalideres – Pasar Baru	Kalideres	Pasar Baru	33**	24	2025	71%
9	Pinang Ranti – Pluit	Pinang Ranti	Pluit	5**	39	2025	100%
9C	Pinang Ranti – Bundaran Senayan	Pinang Ranti	Bundaran Senayan		9	2025	45%
8	Lebak Bulus – Harmoni	Lebak Bulus	Harmoni	**63***		2025	78%

**Includes number of maxi buses as an equivalent number of single buses (conversion factor 1.3).*

*** reallocated from Corridor 1 to Corridor 8 in 2025 to account for replaced articulated buses in 2024 from Corridor 1.*

For the non-BRT medium bus routes, routes ranking from 1 to 15 are chosen. The selected routes will undergo full electrification.

Table 14. Routes selected for Non-BRT Medium Bus Routes

Route Code	Route Name	Terminus 1	Terminus 2	Number of MB	Nearest Terminal	Start year of Electrification
6C	Stasiun Tebet - Karet	Stasiun Tebet	Karet	7	Kampung Melayu	2023
1E	Pondok Labu - Blok M	Pondok Labu	Blok M	10	Blok M	2023

Route Code	Route Name	Terminus 1	Terminus 2	Number of MB	Nearest Terminal	Start year of Electrification
5N	Kampung Melayu - Ragunan	Kampung Melayu	Ragunan	9	Kampung Melayu	2023
6N	Ragunan - Blok M	Ragunan	Blok M	10	Blok M	2023
1C	Pesanggarahan - Blok M	Pesanggarahan	Blok M	8	Blok M	2023
8D	Joglo - Blok M	Joglo	Blok M	8	Blok M	2023
3E	Puri Kembangan - Sentraland Cengkareng	Puri Kembangan	Sentraland Cengkareng	17	Kalideres	2023
8E	Bintaro - Blok M	Bintaro	Blok M	7	Blok M	2023
1Q	Rempoa - Blok M	Rempoa	Blok M	7	Blok M	2023
11D	Pulogebang - Pulogadung 2	Pulogebang	Pulogadung	14	Both Terminus	2023
7P	Pondok Kelapa - BKN	Pondok Kelapa	BKN	9	Kampung Melayu	2023
11Q	Kampung Melayu - Pulo Gebang	Kampung Melayu	Pulo Gebang	7	Both Terminus	2025
9H	Cipedak - Blok M	Cipedak	Blok M	15	Blok M	2025
8K	Batusari - Tanah Abang	Batusari	Tanah Abang	13	Grogol	2025

Route Code	Route Name	Terminus 1	Terminus 2	Number of MB	Nearest Terminal	Start year of Electrification
1M	Meruya-Blok M	Meruya	Blok M	13	Blok M	2025

For microbus routes, routes ranking from 1 to 15 are chosen. Routes with at least one terminal end are given priority. The selected routes will undergo full electrification.

Table 15. Routes Selected for Microbus Routes

Route Code	No. of Buses	Terminal	Start year of Electrification
JAK.53	43	Grogol	2024
JAK.56	30	Grogol	2024
JAK.30	30	Grogol	2024
JAK.31	30	Blok M	2025
JAK.46	41	Pasar Minggu	2025
JAK.54	27	Grogol	2025
JAK.15	48	Tanjung Priok	2025
JAK.19	42	Pinang Ranti	2025
JAK.84	31	Kampung Melayu	2025

5. Terminal Location Selection & Route Grouping

5.1. Objectives of Route Grouping and Terminal Location Selection

After ranking the BRT, non-BRT, and microbus routes, the next step is to group them together in a way that allows for efficient determination of the charging location for each route. This grouping will specifically focus on routes that require opportunity charging, as those that can be covered with overnight charging are assumed to be charged at the depots or other locations. Given that Transjakarta already has 122 layover areas across Greater Jakarta, installing charging equipment at each one may not be necessary in the initial phase of electrification. Instead, route grouping can help ensure mileage efficiency by avoiding the need for buses to travel to the farthest depot for charging. From Table 11 on the Mikrotrans route ranking result, almost all of Mikrotrans routes require overnight charging only, hence the route grouping and terminal location selection analysis in this section is not applied for Mikrotrans[7].

A terminal is the preferred type of terminus for establishing charging infrastructure due to the availability of land and the potential to establish multiple charging facilities in a single location. Grouping routes by terminal while also taking into account dead kilometres is expected to increase operational efficiency. The selection of terminal charging locations is aimed at achieving the lowest possible dead kilometres.

5.2. Previous Studies' Methodology on Developing Route Grouping

Several studies for Transjakarta electrification have been conducted to determine the route grouping of Transjakarta routes for electrification purposes. The route grouping method developed in the previous study could be used as benchmarks for developing the route grouping in this study.

5.2.1. UNEP-CTCN Project: The Electrification of Transjakarta Large and Medium Buses

In order to streamline the electrification process, the Transjakarta routes that can potentially be electrified simultaneously were analysed using spatial analysis techniques. Routes that share similar charging systems and have commonalities such as stops, terminals, staging facilities, and depots were grouped together. Additionally, routes that do not have spatial overlaps with other groups were grouped based on network improvement considerations.

For non-BRT routes, the same approach was used to identify groups. Some non-BRT routes were also included in the BRT route groups if they formed a network. However, if the non-BRT network

[7] However, it is also possible to charge the Mikrotrans at the terminals that are being selected within the scope of this analysis if spaces are available.

was scattered, a separate group was created for these routes and the routes were ranked based on factors such as demand, daily distance and replacement ratio.

By conducting this route grouping exercise, the charging location for each route can be determined efficiently, while also ensuring optimal mileage efficiency. This process allows for the installation of charging equipment on selected layover areas, rather than on every layover area, thereby reducing infrastructure costs.

Based on the exercise, 12 groups of routes have been developed for 1,724 large and medium Transjakarta electric bus fleets. The study recommends implementing Group 2: Staging Facilities at Pejaten Area to be implemented for the pilot phase. Based on the analysis, the staging facility could serve around 81 electric buses. All 11 groups were spread to be electrified in the next 4 phases until 2030.

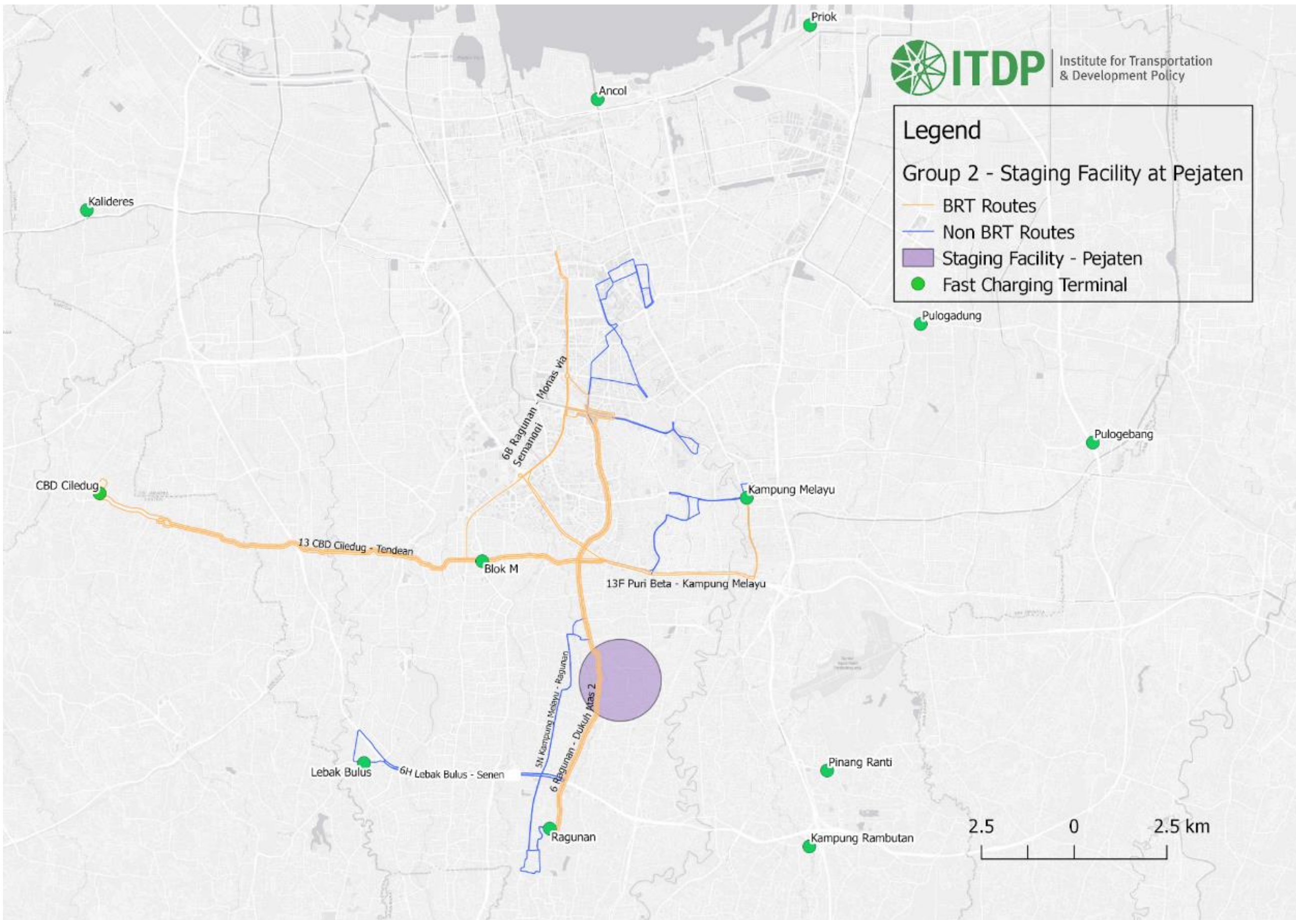


Figure 15. Group 2: Staging Facilities at Pejaten Area, developed under the UNEP-CTCN Study for The Electrification of Large and Medium Transjakarta Buses

5.2.2. UK PACT EUM 124 Phase-I Study: The Large-Scale Electrification of Transjakarta

In the context of the UK PACT EUM 124 Phase-I study, a comprehensive charging location grouping scheme has been developed for the Transjakarta microbus fleets. The grouping strategy entails categorizing layover locations based on their location type, such as terminals, on-street short and on-street long, or based on route type, such as two layovers versus looping routes, and layover areas that serve a single route versus multiple routes.

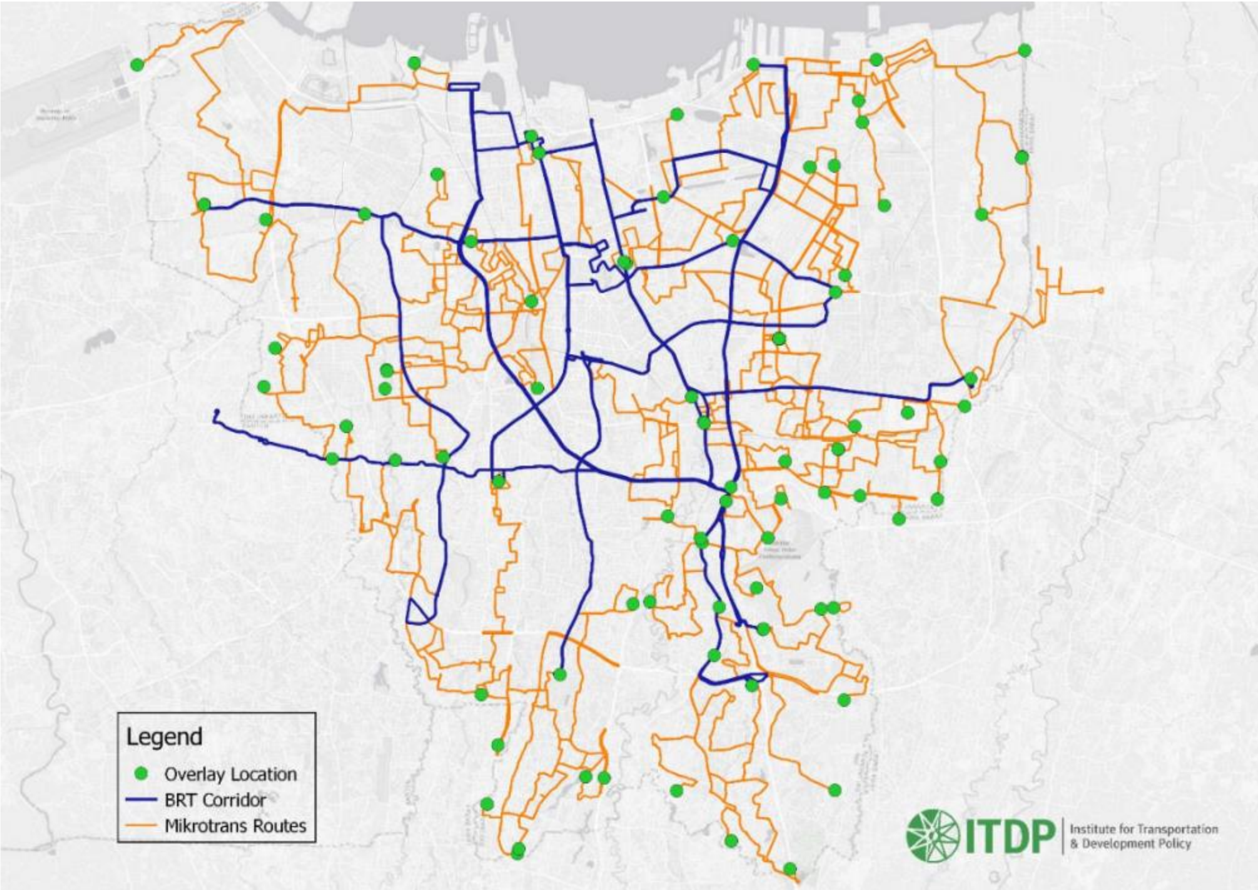


Figure 16 Microbus layover areas. The route grouping is developed based on the archetypes of the layover areas

This strategy aids in assessing the total charging load and load profile, as well as solar PV production from the microbuses. Each group will be represented by a layover location, which will serve as the charging location, and the information collected from each representative location will be used to estimate the total charging demand across all the layover locations within the group. 7 location groups located on 6 coordinates are selected to represent each group.

5.3. Route Grouping and Terminal Location Selection Methodology

To group the routes and assign them to terminal location, the terminus of BRT and non-BRT routes which will be electrified in 2023, 2024, and 2025 are identified. The list of routes that will be electrified for BRT and non-BRT routes are as follows:

Table 16. BRT Routes Selected for the Electrification in 2023, 2024, 2025, and its Terminus Characteristics

Route Code	Terminus 1	Type of Terminus 1	Terminus 2	Type of Terminus 2	Start of Electrification
1	Blok M	Terminal	Kota	BRT Stations	2023
9	Pinang Ranti	Terminal	Pluit	BRT Stations	2024
3	Kalideres	Terminal	Pasar Baru	BRT Stations	2025
9C	Pinang Ranti	Terminal	Bundaran Senayan	BRT Stations	2025
8	Lebak Bulus	BRT Stations	Harmoni	BRT Stations	2025

Table 17. Non-BRT Routes Selected for the Electrification in 2023, 2024, 2025, and its Terminus Characteristics

Route Code	Terminus 1	Type of Terminus 1	Terminus 2	Type of Terminus 2	Start of Electrification
9H	Cipedak	Looping*	Blok M	Terminal	2023
8K	Batusari	On Street	Tanah Abang	On Street (Long)	2023
6C	Stasiun Tebet	Looping	Karet	Looping	2023
1E	Pondok Labu	On Street	Blok M	Terminal	2023
5N	Kampung Melayu	Terminal	Ragunan	Terminal	2023
6N	Ragunan	Terminal	Blok M	Terminal	2023
1C	Pesanggrahan	Looping	Blok M	Terminal	2023
8D	Joglo	On Street	Blok M	Terminal	2023
3E	Puri Kembangan	Looping	Sentraland Cengkareng	On Street	2025
6Q	Dukuh Atas	BRT Station	Kota Kasablanka	Looping	2025
8E	Bintaro	Looping	Blok M	Terminal	2023
1Q	Rempoa	Looping	Blok M	Terminal	2023
11D	Pulogebang	Terminal	Pulogadung 2	Terminal	2025
7P	Pondok Kelapa	On Street	BKN	BRT Station	2025
11Q	Kampung Melayu	Terminal	Pulogebang	Terminal	2025

**A “looping” terminus refers to a route's endpoint where the route does not overlap or stay for a prolonged period of time.*

Based on the table above, several non-BRT routes do not have terminal as its terminus. Hence, a spatial analysis to determine the nearest terminal from each terminus has been conducted, as demonstrated on Table 18 below:

Table 18. Analysis of The Nearest Terminals for Non-BRT Routes

Route Code	Terminus 1	Terminus 2	Nearest Terminal	Distance (km)	From
8K	Batusari	Tanah Abang	Grogol	7.9	Batusari
6C	Stasiun Tebet	Karet	Kampung Melayu	1.1	Stasiun Tebet
3E	Puri Kembangan	Sentraland Cengkareng	Kalideres	6.7	Puri Kembangan
11Q	Dukuh Atas	Kota Kasablanka	Kampung Melayu	2.5	Kota Kasablanka
7P	Pondok Kelapa	BKN	Kampung Melayu	4.3	BKN

The BRT and non-BRT terminus analysis has led to the selection of seven terminals to serve as charging locations, namely Blok M, Pinang Ranti, Kalideres, Grogol, Kampung Melayu, Pulo Gebang, and Lebak Bulus[8]. Table 19 outlines the routes, estimated fleet quantities, and type of chargers that will be implemented at each of the selected terminals.

Table 19. Terminals Selected for Charging Locations

Terminal	Type of Terminus	BRT Routes	Non-BRT Routes	No. of Single Buses*	No. of Articulated Buses	No. of Medium Buses	Year needs to be Established
Blok M	Terminal	1	1C, 1E, 1Q, 6N, 8D, 8E, 9H	100	41	62	2023
Pinang Ranti	Terminal	9, 9C	-		48	-	2024
Kalideres	Terminal	3	3E		24	17	2023
Lebak Bulus	BRT Stations	8	-				2025
Grogol	Terminal	-	8K	-	-	10	2025
Kampung Melayu	Terminal	-	6C, 6Q, 7P, 5N	-	-	28	2023
Pulo Gebang	Terminal	-	11D, 11Q	-	-	21	2023

**number of buses reflected in Table 19 above is for 2025.*

[8] Lebak Bulus was previously a terminal but no longer serves as one, now only serving as a BRT station for BRT routes. However, taking into consideration the ranking of routes, it is imperative to include this route in order to meet the 20% target for electrification by 2025.

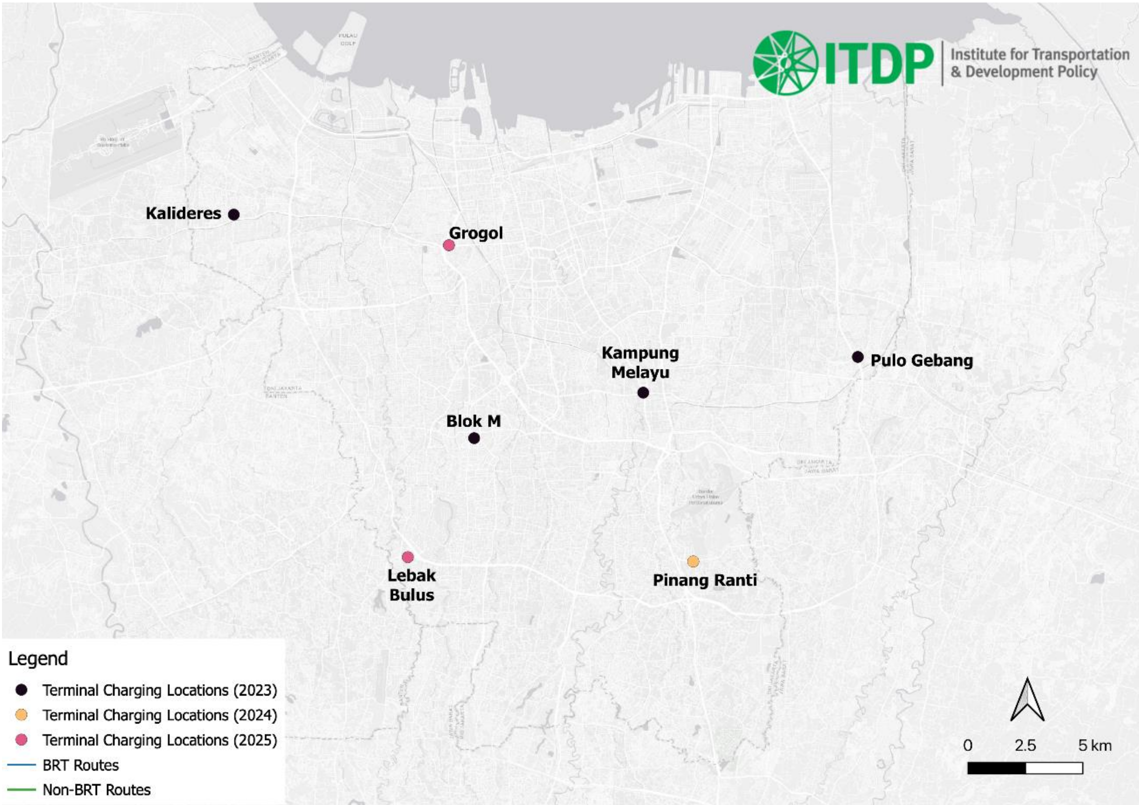


Figure 17. Terminal charging locations map

6. Detailed Charging Strategy & Charging Infrastructure Planning

Implementing zero emission buses is a multi-level complex project. The key challenge and constraints are:

- Space constraints
- Time, cost, and ease of implementation
- Coordination of stakeholders and contractors
- Availability of adequate power
- Maintainability and reliability of equipment
- Interoperability amongst operators and vehicle types

To lead the implementation, there needs to be a central point of control and coordination for infrastructure deployment, especially in large networks which have multiple operators who operate different fleets. These vehicles could be AC or DC charging and have plug-in or pantograph chargers of which the pantograph could be bus or infrastructure mounted.

For time, cost, risk and ease of implementation, most operators are leading the implementation and are empowered to deploy their preferred system. This is predominately depot-based charging as the primary mode of charging and plug-in CCS2 interface. There are increasing examples in some parts of Europe where operators and authorities are coordinating the deployment and moving towards a combination of depot and opportunity charging. Some of these operators combine both CCS2 and overhead pantograph charging at the depot while others opt for just the single overhead charging interface. The decision for charging interface is an important decision as affects the vehicle specification and potential interoperability across the network.

6.1. Benchmark on Public Depots or Terminals for Charging Infrastructure Locations

6.1.1. India

In India, most of the bus operators are the bus OEMs. The transport corporations provide the space at the depots for setting up the charging infrastructure. Usually, an OPEX model is preferred for the charging infrastructure setup wherein the charging network provider invests and operates the charging hubs on behalf of the bus operators. This helps in reducing the upfront cost of charging equipment and installation on the bus operator.

Typically, overnight charging only is preferred over overnight charging and opportunity charging. Being a price sensitive market, plug-in charging for both overnight and opportunity charging is used. Typical overnight charging powers are in the range of 80-100 kW with a charger to bus ratio of about 1:3 and opportunity/fast charging powers are in the range of 150-240 kW with a charger to bus ratio of about 1:10. Fast chargers are deployed at depots/ terminals. There are no enroute opportunity chargers.

Figure 18. Charging station at an electric bus depot in Pune, India

6.1.2. China

In China, there is no chargers installed at curb side bus stop, all the plug-in chargers are installed at depot or terminals. The bus operators mainly set up charging infrastructures at existing depots and terminals. Most of the space used for depots and terminals are owned by the government, and a few owned by private sectors. Bus operators can use the government land for free, but need to pay rental fee if they use private land. And if the bus operators are private sector, then they need to pay additional administrative fee for using government land.

Moreover, there are two charging infrastructure provision models:

1. The bus operators purchase the charging infrastructure, build, operate the chargers. Normally the bus operator will set up special department in charge of installation and operation of charging infrastructure. Some operators even share the chargers to passenger vehicle when the chargers are available for use.
2. The bus operators buy the charging service from a third party. The chargers are purchased and installed at the existing depots and terminals by a third party, and bus operators pay electricity tariff and service fee to the third party.

The following area requirements need to be followed for a typical depot design[9]:

- Area needed: 150m^2/e-bus for depot.
- Min space for parking and charging[10]: 115m^2/bus
- Min space for maintenance: 6m^2/bus
- Min space for repairing: 3.5m^2/bus

[9] Planning Land Use and Construction Standards for Bus Terminal Stations from Shanghai
[10] Min. space for parking and charging has considered space for entrance/exit, parking space, circulation, washing, charging area. This applies for 12-m single bus.

- Min space for offices: $8m^2$/bus

Figure 19. China's biggest electric bus charging station in Hangzhou[11].

6.1.3. Europe

Across Europe, there is a range of depot ownership models. In many cases, the authority owns the depots and leases or provides them to private operators through tendered contracts. However, some urban networks are still operated by local authorities as in-house public operators. On the other hand, in the UK, all networks outside of London are open commercial markets, with private operators owning the depots. To exert more control over the operations, several UK metropolitan cities are shifting towards regulating the networks through service contracting models. This includes taking ownership of depots and vehicles to reduce barriers to entry and, ultimately, facilitate greater interoperability of fleets as they transition towards zero-emission vehicles.

In almost all networks utilising electric vehicles with roadside charging infrastructure, the authority provides support or supplies the infrastructure, especially where multiple operators offer services in a network. For example, Amsterdam and Oslo. In some cases, operators are implementing roadside infrastructure as part of wider system trials in partnership with other operators, such as Harrogate and London in the UK. In such instances, the operator is responsible

[11] Wu Yuehua. China's biggest electric bus charging station debuts in HZ. https://en.hangzhou.com.cn/Business/content/2021-03/31/content_7938319.html. Accessed March 2023.

for developing the solution, including securing funding, which can be from green funds such as the ZEBRA funds in the UK.

The main benefits of depot-based charging are cost of charging equipment, power management with slower charging (40-50 kW charging) and the level of control for the works, i.e., fewer external stakeholders to obtain the necessary permits and permissions for construction and installation of high voltage roadside chargers.

Where operators choose pantograph interface as the preferred approach, they sometimes choose to utilise just one interface (pantograph) method rather than have to procure two different charging equipment interface systems and also, remove the human factor process of plugging in a vehicle. However, despite the challenges associated with implementing high voltage roadside charging, it is becoming more of a necessity to be able to charge vehicles during the day to try and achieve operational parity with ICE equivalent vehicles. The layouts and locations vary between examples with some on remote layover (staging) areas while others have them at the head of the stop when using a 'rank' type system.

Figure 20. Above left, Amsterdam remote charging and above right, Jönköping 'rank' style on stand charging

The Netherlands is a leading example of using opportunity charging on high demand services which operate long operational days, which in some cases are 24 hours. This allows vehicles to operate continuous duty cycles allowing a closer replacement ratio to ICE fleets while also providing the option for less onboard energy storage (smaller batteries) and thus reduce the vehicle gross vehicle mass and the cost of the vehicles, whilst also being able to achieve higher utilisation of roadside charging equipment. Higher utilisation of equipment contributes to the TCO through distributing the equipment CAPEX and can help achieve price parity on a route level annual equivalent cost calculation against ICE fleets.

Whilst these benefits are achievable in theory, the detailed scheduling and coordination of vehicle charging cycles with currently limited quantity of charging stations means that the battery reduction benefit is not yet fully realised.

In established cities where land availability is restricted, having sufficient area for layover between duties to charge is a key challenge. Existing stations, terminals and interchanges require modification to install high voltage equipment (HV transformers and associated equipment, not just the charging interface) while also remaining operational efficient so not to impact the quality of service to the passenger. In Amsterdam, some land has been provided for the bus operations around the airport by the local authority to allow upgrades to the bus interchanges and development of a new purpose-built electric bus depot, specifically for airport bus services including BRT as there is no additional land available in the city centre. Without this, the electric buses would need large > 400 kWh battery capacity to deliver long duties buses although would not be able to deliver comparable levels of services to ICE equivalent fleets without significant additional buses to cover for charging times and making the equivalent annual cost higher and cost parity more difficult to achieve.

6.1.4. Latin America

Latin America has the highest number of high frequency BRT systems. These are the most comparable to Transjakarta in terms of infrastructure design, service specification and passenger utilisation. These are typically operated by contracted operators with some having multiple operators. In this multi-operator environment, the Authority builds and manages the infrastructure.

These have been in operations for between 10 - 20 years and fleet replacement and expansion has been driven by demand with fleet specifications based on proven reliable propulsion systems of available vehicle types. There has been little development with the environmental enhancements normally through the latest engine and exhaust emission technology of transitioning to low carbon fuels e.g., Compressed Natural gas (CNG).

The design features of the infrastructure and high frequency of services means that the stations must remain operational while any upgrades are implemented so not to disrupt services. This makes planning and delivery of any significant maintenance a challenge. The electrification of these terminals and staging areas would be very complex.

Due to the high frequency of services, many of the terminals have a depot located adjacent the terminal at one end or close by. Additionally, they have remote staging areas for vehicle parking between duties. The ownership of the depots lies with the authority, as stipulated in the contract, and in instances where new depots are needed, they are constructed by the operator but subsequently transferred to the authority at the end of the tender. These could be potentially suitable for installation of charging equipment.

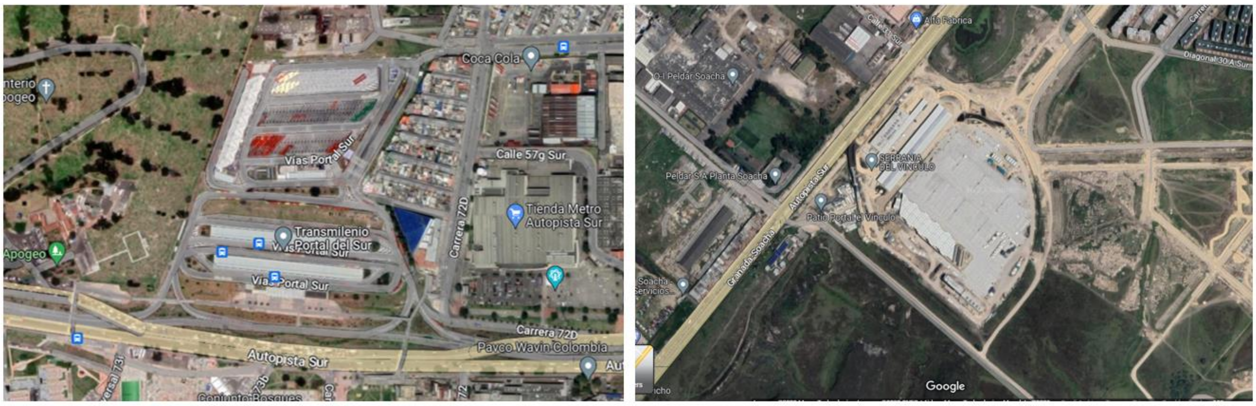


Figure 21. Existing and construction of new terminal on TransMilenio terminals in Bogota, Colombia

These cities have initiated the transition to zero emission vehicles with battery electric buses commencing with the feeder services have been the first to transition. These utilise depot based plug-in charging interface due to the complexities of delivering the required works while maintaining high service levels. Some of the areas of the BRT systems within the Latin America cities also have challenges with its power network and ability of the Distribution Network Owner (DNO) being able to provide sufficient power for high power roadside charging infrastructure. The design principle of having a depot or large staging area adjacent the terminal will allow the transition to battery electric buses without disrupting the terminal operations. Bogota has commenced the construction of a new depot and terminal which can have the capacity to transition easier.

Another example which has initiated the transition but taken a different approach is Mexico City. They have recently deployed its first electric BRT buses which are high-floor specification to evaluate electric bus technology performance. Due to the time to implement, these were selected to utilise depot based fast charge plug-in charging interface with large onboard energy storage (batteries) which will be able to provide long operating periods although less than their diesel equivalent.

6.2. Charging Technology Selected on Terminals

As detailed in the reports for Task 3.2 and Task 3.3, the selection of charging technology for each fleet type in the Transjakarta e-bus system is dependent on the feasibility and readiness of available technology. The use of LFP battery e-bus models is recommended for the initial phase due to their prevalence in the Asian market.

For 12-meter single buses, double gun plug-in chargers with a power of 200 kW are recommended for both depot overnight charging and terminal opportunity charging. A single bus can be charged at 200 kW with one gun, or two buses can be charged at 100 kW with two guns. For charging scheduling analysis, all 12-meter single buses are assumed to use opportunity charging with 200 kW power. An estimation of the ratio between the terminal charger and bus is made for opportunity charging, taking into account the power of the charger and the need for opportunity charging, with a proposed ratio of 1:10. 7-meter medium buses will have a 100-kW plug-in charger for both depot overnight charging and terminal opportunity charging. For terminal charging, the charger to bus ratio is estimated around 1:3 based on the opportunity charging requirement and the charger power.

Articulated buses with a battery size of 450 kWh will have fast charging capabilities with charger power of up to 400 kW and a charging duration of approximately 1.5 hours from 10% to 80% state of charge (SoC). Pantographs will be used to establish charging infrastructure and optimize space while providing seamless circulation of buses. Similar to 12-m single buses, charger per bus for articulated bus is set at 1:10.

However, for the first phase of electrification covering the years 2023-2025, ultra-fast charging located at bus stops is not the preferred option, unless additional charging activities are required and can be covered with ultra-fast charging, as indicated by charging scheduling results that will be analysed further.

Table 20 below provides a summary of the charger power and charger types allocated for each fleet type for terminal opportunity charging.

Table 20. Summary of Charger Power and Charger Types for Terminal Opportunity Charging

Type of fleets	Type of charger	Charger power	Initial Assumption for charger per bus ratio
12-m single buses	Double gun plug-in	200 kW	1:10
7-m medium bus	Plug-in	100 kW	1:3
18-m articulated bus	Pantograph	400 kW	1:10

6.3. Charging Scheduling & Number of Charging Facilities Needed

In order to estimate the optimum number of chargers needed for opportunity charging at the final selection of terminal each year, detailed charging scheduling is developed.

To do this, the total energy demand on the route is determined and the top up energy required to complete the daily kms is calculated. It is assumed that the buses will be charged during off peak hours in three batches of 40%, 40% and 20% of the total number of buses so that at any given time at least 60% of the buses are operational. For the single buses and articulated buses, the fast-charging power is 200 kW and 400 kW respectively with a charger efficiency of 90%. The charging window is chosen such that the total top up charge can be added in a single charging session. For medium buses, the charger power is 100 kW. Due to the smaller battery size and range, it is seen that buses need two sessions of charging.

The charging scheduling calculates the optimal time for these charging sessions and the total number of chargers taking into consideration the dwelling time at the terminals, the cycle time, head way, peak and off-peak hours, total number of buses, round trip time and round distance & energy. For routes that do not end directly at a terminal, the to and from travel distance to the terminal has also been incorporated into the analysis.

The following table summarizes the number of chargers need for each type of charger in each terminal.

Table 21. The numbers of chargers need for each type of chargers in each terminal

Terminal	2023		2024		2025			Total
	MB	*SB*	*MB*	*SB*	*MB*	*SB*	*AB*	
	100 kW	200 kW	100 kW	200 kW	100 kW	200 kW	400 kW	
Blok M	12	6	-	5	6	-	2	**31**
Grogol	-	-	-	-	4	-	-	**4**
Kalideres	6	-	-	-	-	3	2	**11**
Kampung Melayu	11	-	-	-	3	-	-	**14**
Pulogebang	5	-	-	-	-	-	-	**5**
Pinang Ranti	-	-	-	2	-	-	3	**5**
Lebak Bulus	-	-	-	-	-	2	-	**2**

6.4. Terminal Charging Conceptual Design: Blok M and Kalideres

In order to determine the optimal locations for charging bays at terminals and to ensure smooth circulation, a conceptual design will be developed. The design will identify potential locations for charging bays and detail the circulation for buses entering terminals with or without the need for charging. It's important to note that the conceptual design for terminals and depots will differ as terminals are used for boarding, alighting, staging, and charging, while maintenance and fleet washing are conducted at depots.

Blok M and Kalideres terminals have been selected for the design process, taking into account the need to accommodate charging for BRT single buses, BRT articulated buses, and non-BRT medium buses between 2023 and 2025. The number of chargers deployed in Blok M and Kalideres were taken from charger per bus ratio assumed in Task 3.2. and Task 3.3., resulting in 17 unit 200-kW plug-in chargers, 7 unit 100-kW plug-in chargers, and 5 unit 400-kW pantograph chargers in Blok-M and 3 unit 200-kW plug-in chargers, 6 unit 100-kW plug-in chargers, and 2 unit 400-kW pantograph chargers in Kalideres.

As Blok M and Kalideres serves as public terminals where passengers board and alight at the terminals, the development of charging infrastructure at terminals follows several principles, such as:

1. Minimising the changes that will impact the passengers
2. Having adequate spaces for manoeuvring and for safety measures
3. Avoiding radical layout change on the terminals
4. Minimising dead kilometres

6.4.1. Terminal Charging Conceptual Design at Blok M

Blok M is a type B terminal owned by the Government of Jakarta. Blok M becomes one of the busiest intracity terminals which serves 17 Transjakarta routes. Other than that, the terminal also serves an interprovincial (Greater Jakarta) route and an airport bus route. At the current condition, the terminal is divided into 6 platforms located parallelly, which is illustrated as follows:

Figure 22 Blok M Existing Condition

As the fleets approach the terminals, they queue up on the western side of the terminals according to their assigned platforms. Upon reaching the platform, the fleets alight their passengers and wait for instructions from Transjakarta's field officer to resume operations as per the designated operational plan. If approved, the fleet advances to the same platform to pick up passengers. Once the entire platform is served, the fleet exits the terminal from the eastern side.

A survey conducted during morning peak hours on weekdays at the Blok M terminal revealed that there were only a few buses queueing at platforms 4, 5, and 6, especially platforms 5 and 6. This suggests that these areas on the aforementioned platforms could be utilized for charging activities at the terminal.

Two conceptual design plans have been proposed for charging facilities at the Blok M terminal. The main difference between the two options is that in the first alternative, the single buses will be parked in reserve, as it uses a plug-in charger located at the back of the buses, while the second option allows for smoother entry of buses into the charging bays since it does not require reserved parking. This is achieved by using an overhead gantry for plug-in chargers, similar to what has been implemented in Bogota, Columbia.

Figure 23. Overhead gantry plug-in chargers for Transmilenio, Bogota - Columbia

A proposal to alter the boarding-alighting arrangements has been put forth, involving a slight change to the current arrangement. Platforms 1-3 will continue to be used for alighting activities, while platform 3 will now also be used for boarding intercity and airport buses. For boarding activities, the intercity bus, airport bus, Mikrotrans, and Royaltrans will have to enter platform 3 before proceeding to their respective platforms. To create an overtaking lane for single bus charging, platform 5 will be removed, resulting in the interprovincial route and airport bus route.

The proposed design layout and traffic circulation for charging activities at Blok M for alternative 1 and alternative 2 are depicted in Figure 24 and Figure 25, respectively.

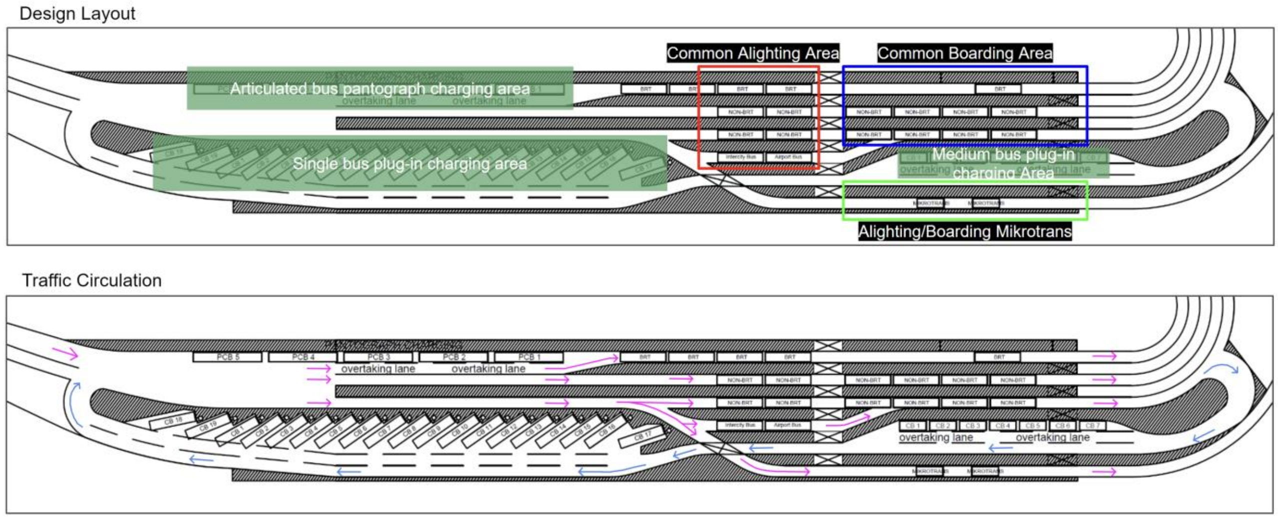


Figure 24. Proposed design layout and traffic circulation for e-bus charging at Blok M, alternative 1

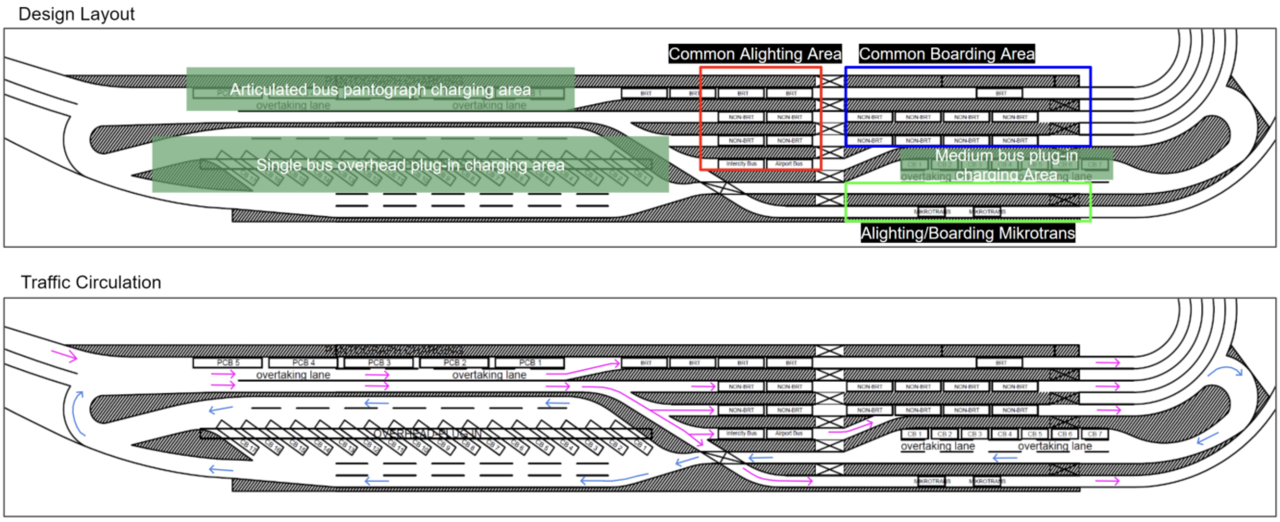


Figure 25. Proposed design layout and traffic circulation for e-bus charging at Blok M, alternative 2

6.4.2. Terminal Charging Conceptual Design at Kalideres

Kalideres is a type A terminal managed by the Jakarta Government, which serves interprovincial routes outside the metropolitan Jakarta and is an entry point for people from other provinces and islands. The terminal serves seven Transjakarta routes and is divided into several areas, including boarding and alighting at BRT stations for BRT and affordable housing routes, staging areas for large and medium buses, boarding and alighting areas for Mikrotrans routes, interprovincial bus routes area, and a park-and-ride area, as shown in Figure 26.

Figure 26. Kalideres Existing Condition

A change on the current layout and traffic circulation in Kalideres is proposed to accommodate the charging activities, which is illustrated in Figure 27 and Figure 28 below.

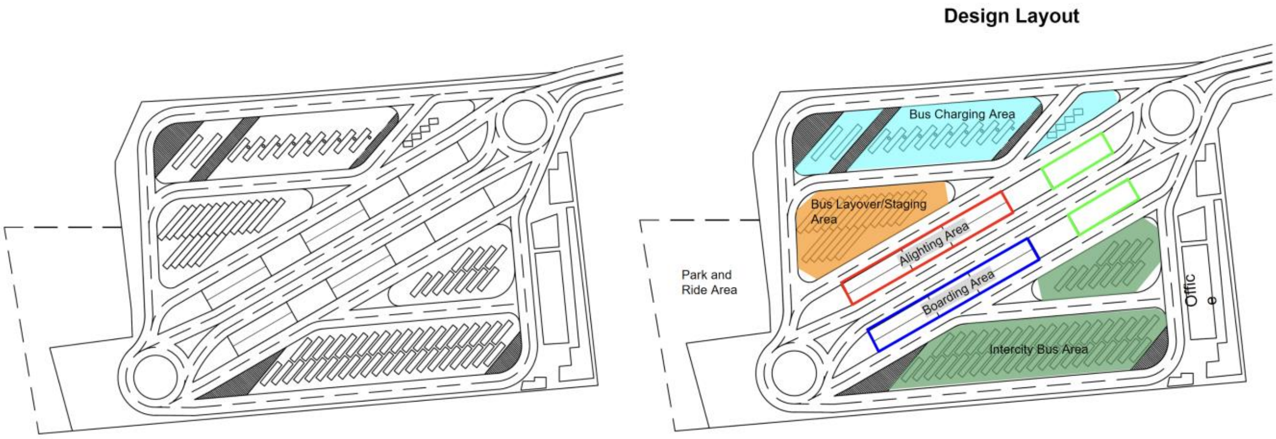


Figure 27. Proposed design layout for e-bus charging at Kalideres

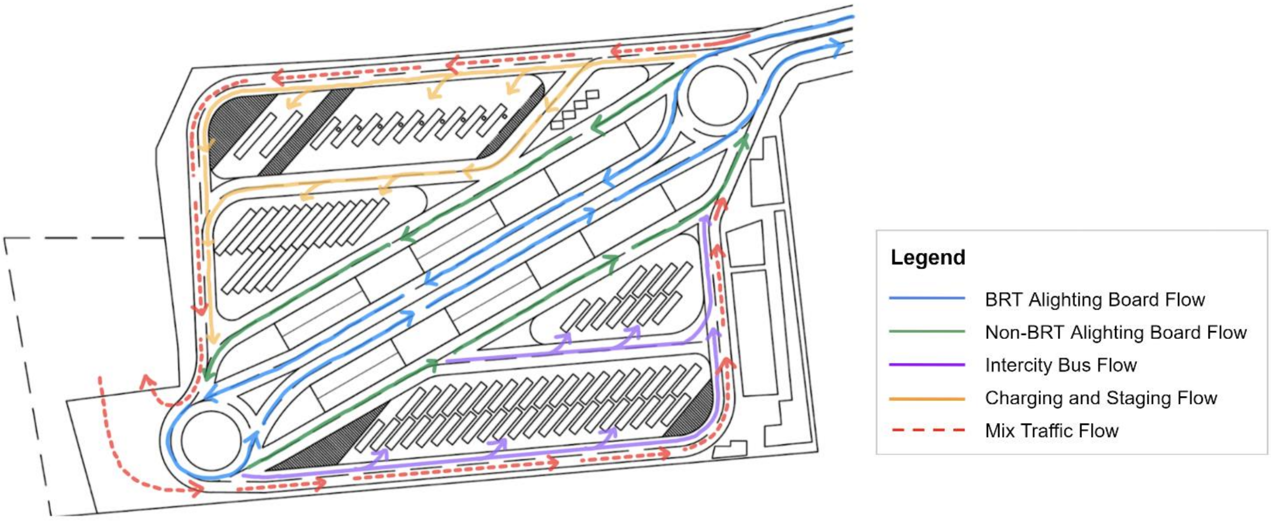


Figure 28. Proposed traffic circulation for e-bus charging at Kalideres

7. Partial Electrification Impacts Principles

The implementation pathway by 2030 is going to be complex with many strategic decisions required. The decision to implement either fully or partially on a route-by-route basis have advantages and disadvantages.

It is common to operate both conventional fuel and new technology vehicles during the fleet transition. This can be driven by key factors including:

- **Strategic objectives** can drive the decision for implementation zero emission vehicles. This could be the partial route transition for penetration across the network or full implementation on a route-by-route basis based on route characteristics or potential area of importance served.
- Under a **contracting model**, operators are obligated to meet the requirements stipulated in the contract. However, the costs for trips/duties will differ between conventional fuel and zero-emission (battery electric) vehicles due to their distinct CAPEX and OPEX characteristics. Therefore, compliance monitoring is necessary to ensure that the correct payment rates are applied.
- **Performance risk** is a key concern for operators, whether in a regulated (contracted) market where penalties might apply for failing to achieve the minimum service level or in a commercial environment where revenue risk is with the operator. The maturity or suitability of the product might not be proven for its intended deployment and thus the risk is reduced through partial implementation.
- **Financial viability** can influence decision-making, with the Total Cost of Ownership (TCO) being a relevant metric on a per-vehicle basis, but total route TCO being more appropriate due to potential differences in replacement ratio. Evaluating the return on investment should also include the route cost recovery ratio, as low utilisation may lead to insufficient revenue and require higher subsidies to offset initial procurement costs.
- **Operational planning** for conventional and battery electric vehicles have different planning requirements and possible constraints depending on duty requirements, battery size and charging strategy deployed as conventional fuel vehicles have the ability to operate longer duties whereas battery electric vehicles might require charging to be planned into the duty plan. In the event of a technical failure, operational resilience[12] through covering the duty with the next available bus might not be feasible.
- **Staff planning and training** is essential to ensure the staff know how to safely and efficiently operate the vehicles. The right staff would be needed to operate both vehicle types which is time consuming and costly which at a time when the global bus industry is facing staff shortages.

[12] Operational resilience refers to the ability of a transport system to respond and adapt to unexpected events while maintaining service regularity. In case of a bus breakdown, it is common practice to "step up" or "backplate"" the following vehicle to fill in for the failed vehicle. However, this may not be suitable when replacing a diesel vehicle with an electric one, as it could have a shorter range and different operational requirements.

- **Power management/availability** can limit the implementation of full route transitions. The available power requirements at the depot or en-route might not support full implementation and so vehicles are slowly introduced.
- **Depot space availability** is a constraint when high intensity services require a high fleet replacement ratio, which limits space. Charging equipment and line equipment compound the issue. As a result, the number of vehicles per depot or operator may be limited or distributed across different operators/depots.
- **Vehicle availability/procurement lead time** can prevent the full implementation whether due to technology maturity or even the longer delivery time for new vehicles from the manufacturers and so the transition is often phased.
- **Maintainability** is sometimes an issue as the engineers will require training and more spare parts and possible different complex maintenance strategies.

The prevailing contracting model or the prospective contracting approach may influence the decision-making process, as various factors such as CAPEX, OPEX, and cost per kilometers vary between conventional and battery electric vehicles. When implementing new contracting models, it is more likely for routes to transition entirely, rather than partially, owing to the different costs per kilometers. Typically, operators must submit proposals for both conventional and battery electric vehicles, which are then evaluated for price analysis and value for money. The contracting authority usually defines the routes at the tender stage (e.g., London/Sydney) or through service planning reviews, negotiation, and contract change mechanisms (e.g., Manchester).

Factors to Consider to Choose Partial or Full Implementation

There is no one size fits all or 'correct' implementation strategy. Many different factors can influence the decision to whether full or partial route implementation is preferred.

Table 22. Factors to consider to choose partial or full implementation

Factors	Partial implementation	Full implementation
Strategic objectives	More diverse implementation across the network.	Specific routes transitioned based on cost recovery or areas of significance (places of interest or low emission zones).
Contracting model	More difficult due to different rates for conventional and ZEB vehicles.	Single rate for payments as one vehicle/technology type with less administrative effort required.
Performance risk	Lower risk to operations.	Potentially higher risk.
Financial viability	Lower TCO and high probability of route recovery ratio.	Potentially higher route costs if replacement ratio (TVR) higher increases the annual equivalent cost to ICE fleet.
Operational Planning	Can be more complex if mid-shift charging is required or shorter shifts used compared to ICE.	Single vehicle/technology type easier to plan.
Staff planning	Staff need to be trained on both technology types.	Easier to plan and train select drivers or route groups of drivers.

Factors	Partial implementation	Full implementation
Power Management	Peak load at depot can be lower as routes will have different profiles and run back times.	Potential higher power requirements and peak load management can be more challenging.
Depot space	Few vehicles might require less charging equipment providing more parking spaces if fewer charging points required.	Economies of scale can be feasible with more vehicles per charging equipment.
Vehicle availability	Fewer vehicles required as charging strategy has less impact.	Potential logistical challenges to make the transition or maintain up time, especially with slower charging rates.
Maintainability*	More vehicle types requiring more training for engineers, different maintenance plans and more inventory.	Potentially simpler maintenance when single vehicle type is deployed.

**Standardizing maintenance plans and inventory remains a challenge until the mass introduction of electric vehicles to replace conventional fuel vehicles and achieve maintainability.*

Impact

There are opportunities and challenges in the transition strategy. Partial deployment per route could allow more routes to receive newer and cleaner emission vehicles for mass roll out and also form part of further proof of concept. It is also a good opportunity to limit the risk of interruption or deployment if sufficient depot or network infrastructure is not available to support the full transition per route, especially for high frequency BRT routes. However, there are some challenges regarding contract management and payment mechanisms as the cost/km for a diesel and electric vehicle will be different and the operator will need to be monitored to ensure they are paid correctly for the services performed.

In addition, the impact on charging equipment and power management might be adversely affected (more equipment or power required) with potentially less vehicles able to be deployed on a route/across the network or positively depending on the geographic dispersion/consolidation of the depots and/or routes to introduce electric vehicles to the network.

- Depot based charging equipment requirements is influenced by the number of vehicles assigned to each depot and the power consumption requirements. As a minimum, each depot, whether fully or partially transitioned will require sufficient grid access with transformers, high-low voltage switchgear and charging dispenser/interface - whether plug in or overhead type. The design of the interface is important to the efficiency of the depot design, charging and daily operations. Partial electrification/transition is only advantageous if economies of scale are achievable at the depots for space and cost efficiency, although might be necessary due to available power which can constrain the total volume of vehicles or the available charging time for slow charging.
- Terminal/route charging equipment requirements are dependent on the operational plan and service specifications, i.e., how many vehicles in service will utilise the equipment per

hour, the charging power requirements (slow, fast or ultra-fast charging) and ultimately, how much power is required to maintain the vehicle batteries state of charge. If more or less vehicles are deployed on routes, there is the opportunity to share roadside infrastructure (where applicable) like at the depot to achieve economies of scale and effective power management.

If the above are not possible, more equipment will be required which increases the TCO and potential Return of Investment (RoI) although in some cases, it might be necessary, for depot power grid peak load management (PLM).

However, the ability to convert routes partially could be more efficient in terms of project delivery time as less power might be required, smaller installations of equipment and simpler charging strategies and therefore, the ability to successfully implement zero emission vehicles could be quicker than the full conversion of some routes.

Contracting model

The current contracting model is more aligned to a resourcing model whereby an operator is contracted to provide a set of vehicles and deploy them on assigned routes. The operator is compensated for the services performed with penalties applied for failing to achieve the defined service levels.

Going forward, the strategic objectives and approach for tendering and contract management need to be defined, especially when considering whether to fully or partially transition the route to electric vehicles. There are different approaches which are commonly used across regulated (contracted) bus networks although they all share a common theme, only one operator operates the routes for service performance management and risk management.

The different contracting approaches are:

- Routes are tendered individually (London) to a single operator and the vehicle technology type defined (ICE, BEB, or others). The service specification is defined along with the vehicle type and the contractual rate is agreed based on these.
- Routes are bundled into regions (Manchester, Singapore, Sydney) and the electrification/transition is clearly defined. In this approach, the base network is defined with conventional fuel vehicles but plans are developed for the full or partial transition of the routes and the operator commits to delivering the services using zero emission vehicles. Some exemptions are permitted for technology risk but the operator may incur penalties in some instances for using conventional fuel vehicles.

Routes that employ a combination of different technologies and multiple operators can present challenges in terms of contracting and contract management. This can be attributed to varying rates, as well as the need to monitor the services provided to ensure that the assigned trips are being serviced using the appropriate technology, among other factors.

There are four potential scenarios:

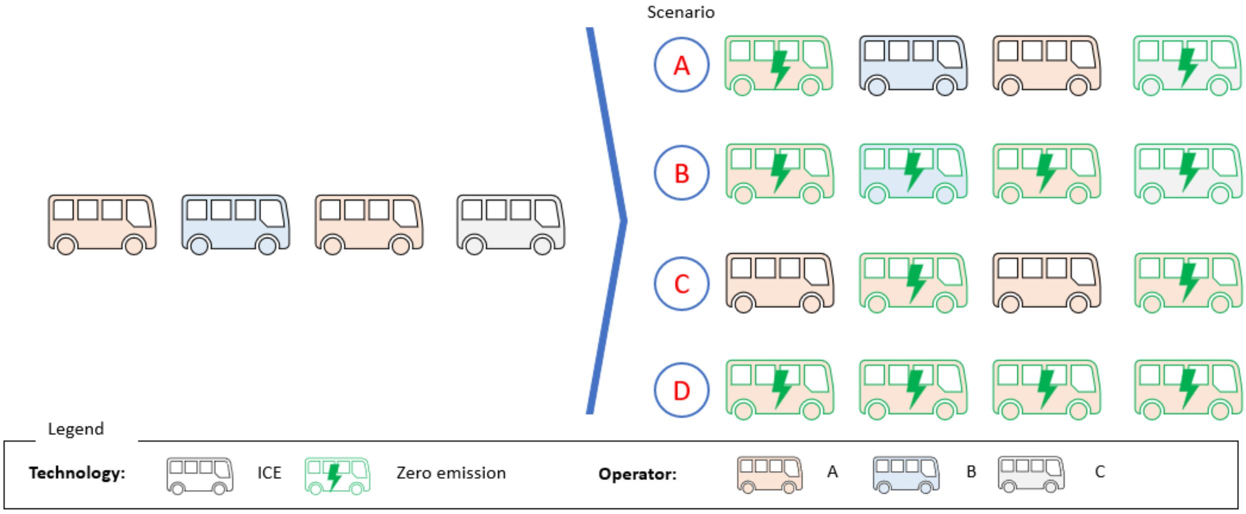


Figure 29. Four contracting scenario for electric buses in a route-basis

Table 23. Advantages and challenges of each scenario.

Scenario		Advantages	Challenges
A	Multiple operators, partial transition	Risk shared between operators Implementation time potentially shorter	More depot equipment required Varying contract rates More complex contract management
B	Multiple operators, full transition	Contract payment less complex Risk shared across operators	More depot equipment required
C	Single operator, partial transition	Less equipment, economies of scale at single depot Simple contract management	Varying contract payments Potentially more roadside infrastructure
D	Single operator, full transition	Less equipment, economies of scale at single depot Simple contract management	Higher risk for implementation Potential longer lead time for upgrades

In order to achieve a route-based approach, the existing depots could be used by the operators to deploy the electric vehicles. The equipment installation and power management would be less per depot making installation potentially quicker. This would require all necessary agreements to be concluded with the operator for the installation and then the potential end of contract arrangements in place if the operator was not successful in retaining all or any operating contracts.

For region-based tendering, it might be necessary to design and build a new depot purpose built for electric vehicles to be able to retain sufficient long-term control over assets and implement with no impact on current day-to-day operations. Whilst this approach is more costly, it provides more control to the contracting authority as they own and retain all assets giving them more control over operator performance and removing barriers to entry for potential new market entrants.

To provide more incentive for operators to invest in the transition to zero emission fleets, it might be necessary to modify the contract duration. This will provide additional time for the operator to recover the investment costs of the fleet and charging equipment and by increasing the fleet lifecycle and therefore depreciation schedule, it could be possible to reduce the overall annual costs. This approach has been adopted in Mexico as it commences the transition of the first of its BRT network.

8. Conclusions and Next Steps

8.1. Conclusion

The first phase of Transjakarta electrification (after pilot) will be conducted between 2023 – 2025, considering several aspects, such as year-on-year implementation plan of the number of buses, technology readiness, and market cap for a single investment. The detailed technical plan is summarised on following points:

1. The electrification in 2023 – 2025 will be conducted for single bus BRT, articulated bus BRT, medium bus non-BRT, and microbus. For the analysis purpose, the 12-m single bus BRT will use 324 kWh LFP battery and be charged using double gun plug-in 2 x 100 kW charger for opportunity charging at terminal. 18-m articulated bus will use 450 kWh battery, charged using pantograph 400 kW charger for terminal opportunity charging. 7-m medium bus will use 135 kWh battery, charged at terminal for opportunity charging using 100 kW plug-in charger. Microbus will use 42 kWh LFP battery and 22 kW chargers.
2. Based on route ranking, the selected BRT, non-BRT, and Mikrotrans routes are as follows:
    a. 5 BRT routes is selected for electrification in 2023 - 2025: Corridor 1, Corridor 3, Corridor 8, Corridor 9, and Route 9C. Only 71% of fleets in corridor 1 will carry out electrification in 2024, followed by other routes to be electrified in 2024 and 2025.
    b. 15 non-BRT routes using medium bus is selected for the electrification in 2023 – 2025: 6C, 1E, 5N, 6N, 1C, 8D, 3E, 8E, 1Q, 11D, 7P, 11Q, 9H, 8K, and 1M. Based on the order, route 6C – 7P will be electrified in 2023.
    c. 9 Mikrotrans routes are selected: JAK.53, JAK.56, JAK.30, JAK.31, JAK.46, JAK.54, JAK.15, JAK.19, and JAK.84, and will undergo electrification starting in 2024.
3. 7 terminals are selected over 122 Transjakarta layover area for charging activities between 2023 – 2025: Blok M, Kampung Melayu, Pulo Gebang, Kalideres, Pinang Ranti, Lebak Bulus, and Grogol. The number of charging equipment allotted to each terminal are as follows:

Table 24. Number of chargers needed on each terminal

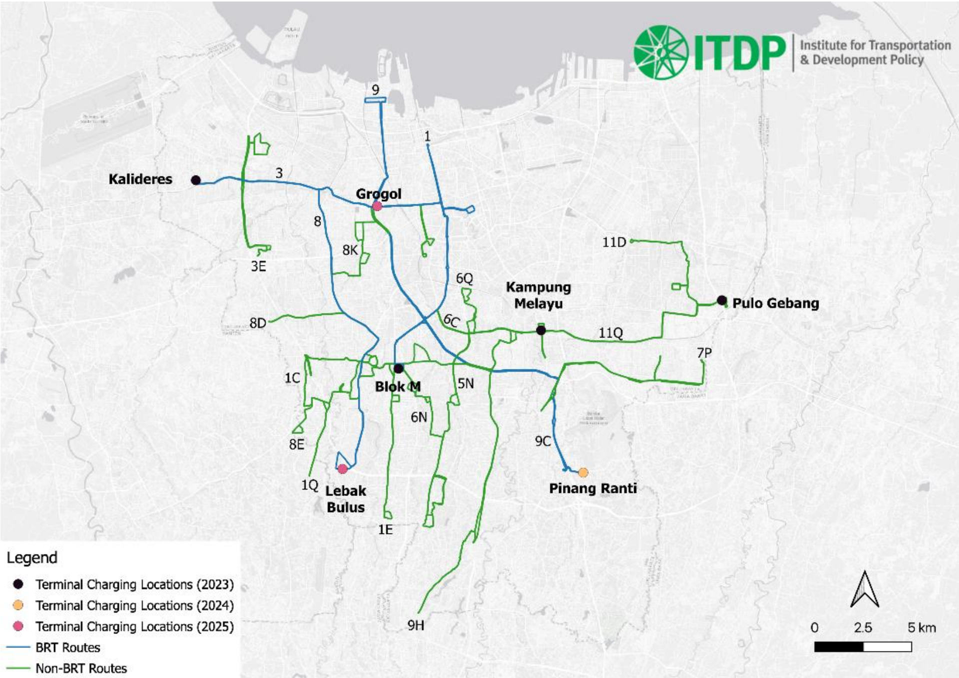
Terminal	2023		2024		2025			Total
	MB	*SB*	*MB*	*SB*	*MB*	*SB*	*AB*	
	100 kW	200 kW	100 kW	200 kW	100 kW	200 kW	400 kW	
Blok M	12	6	-	5	6	-	2	**31**
Grogol	-	-	-	-	4	-	-	**4**
Kalideres	6	-	-	-	-	3	2	**11**
Kampung Melayu	11	-	-	-	3	-	-	**14**
Pulogebang	5	-	-	-	-	-	-	**5**
Pinang Ranti	-	-	-	2	-	-	3	**5**
Lebak Bulus	-	-	-	-	-	2	-	**2**

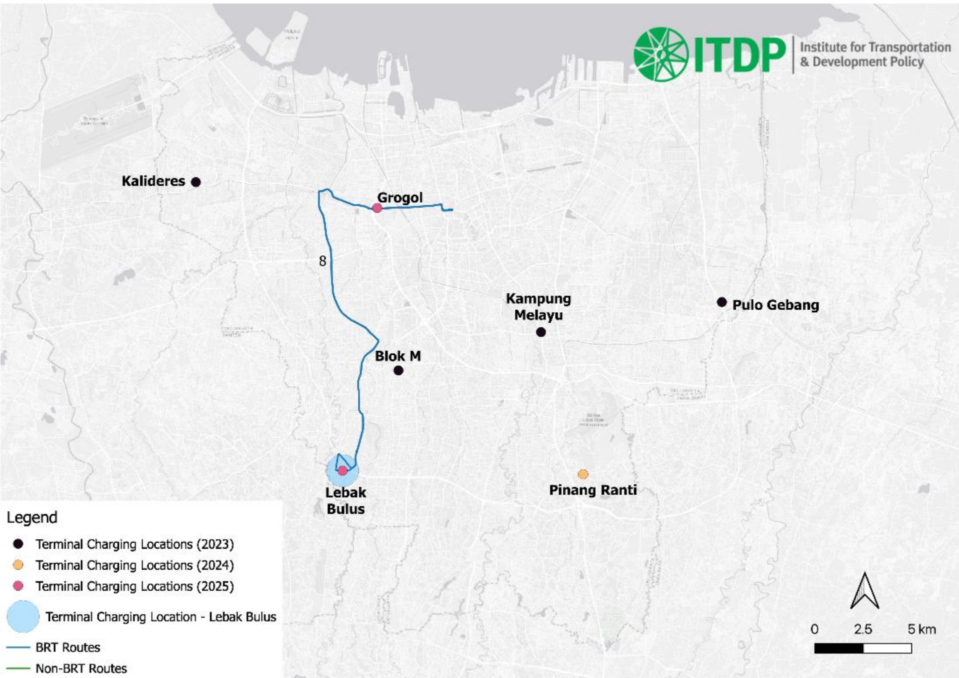
8.2. Next Steps

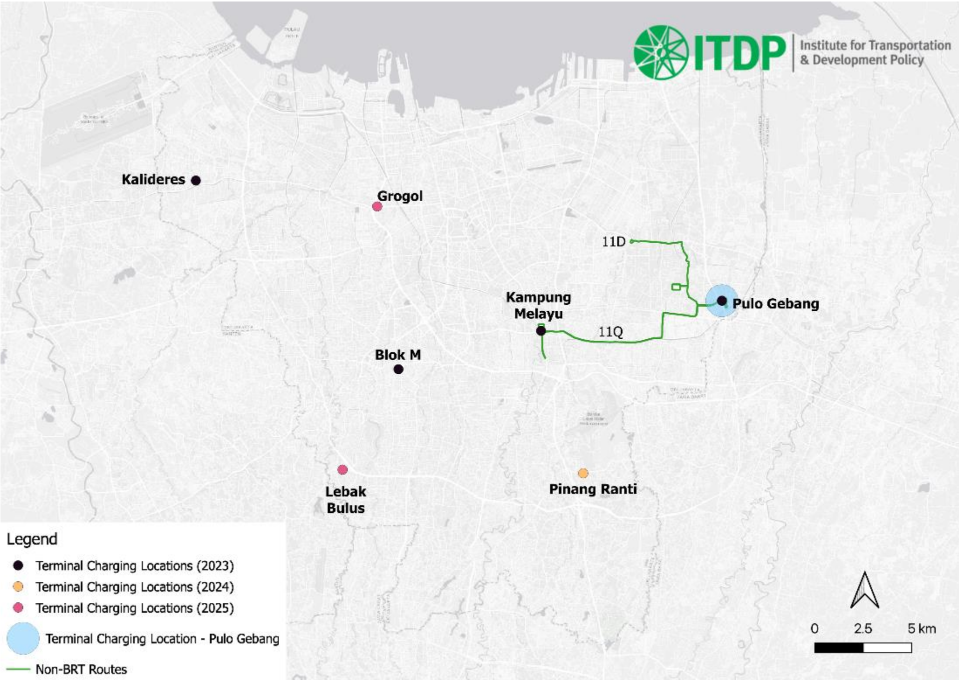
As discussed in the previous chapters that the purpose of this report is to provide a detailed technical implementation plan for the first phase (2023 – 2025) of Transjakarta electrification, this report is not intended to be used as a feasibility study to procure the assets. The implementation plan presented here is to depict the conceptual requirements for electrification hence a more comprehensive feasibility study on route level should be conducted to **give confidence on the transaction stage**. Furthermore, below are a brief way forwards that can be taken further by Transjakarta using this implementation plan as a leverage:

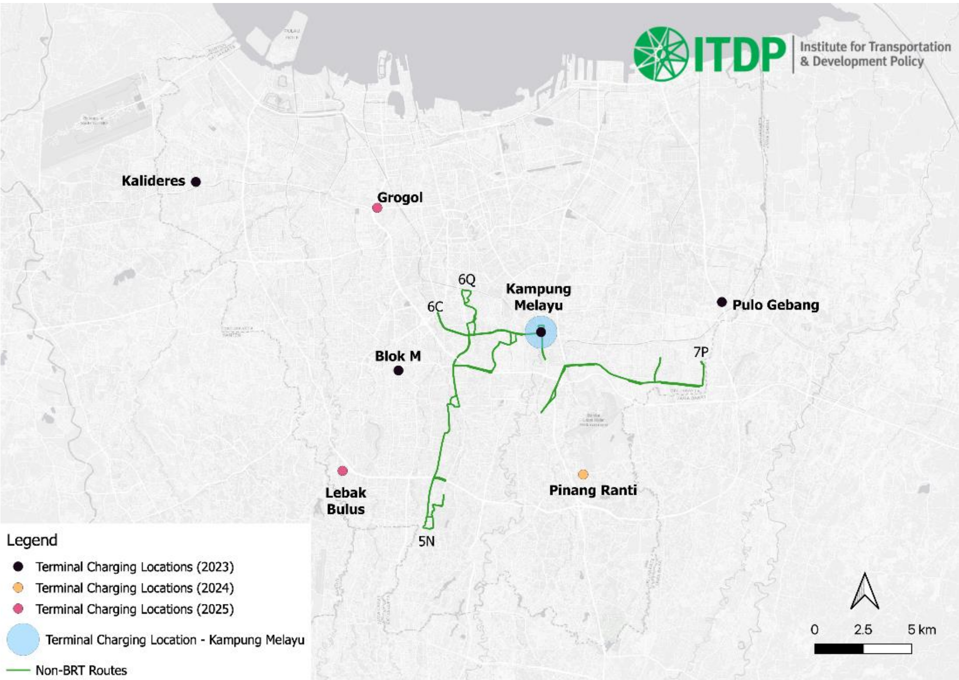
1. Agree on technical aspects with financing institutions and conduct a detailed feasibility study for the first electrification procurement using one of the alternative financing mechanisms that are presented in Report 4.6.
2. In order to support the adoption rate of electric buses, charging infrastructure network provision is definitely required. Hence, efforts on accelerating such provision should be done from the early stage by obtaining government commitment to provide the charging infrastructure in bus terminals. This can be done by leveraging the conceptual design in Blok M and Kalideres terminal as an example to develop detailed engineering design for 7 terminals.
3. It is suggested that a further discussion with utility company (PLN) should be done regarding grid impact in order to minimise any potential risks such as down time at the select sub stations due to lower capacity.

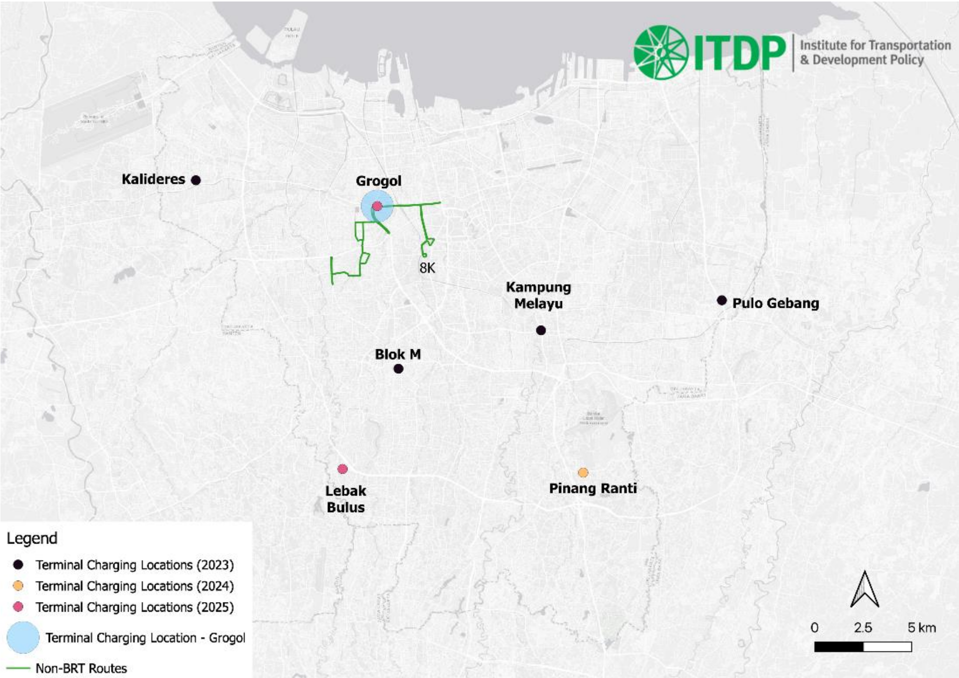
Annex 1. Route Grouping Map

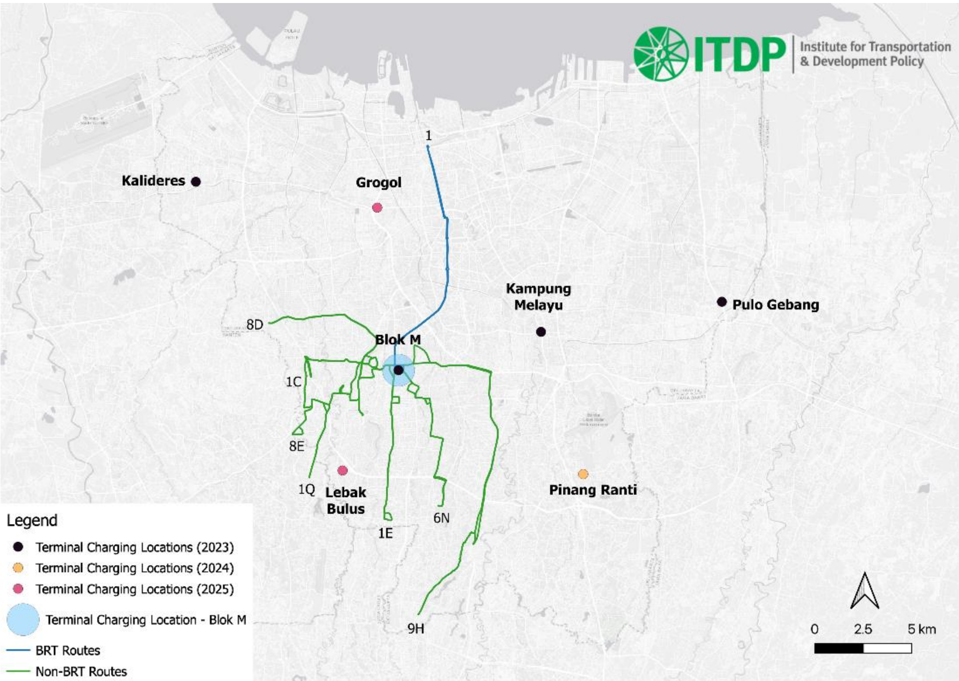


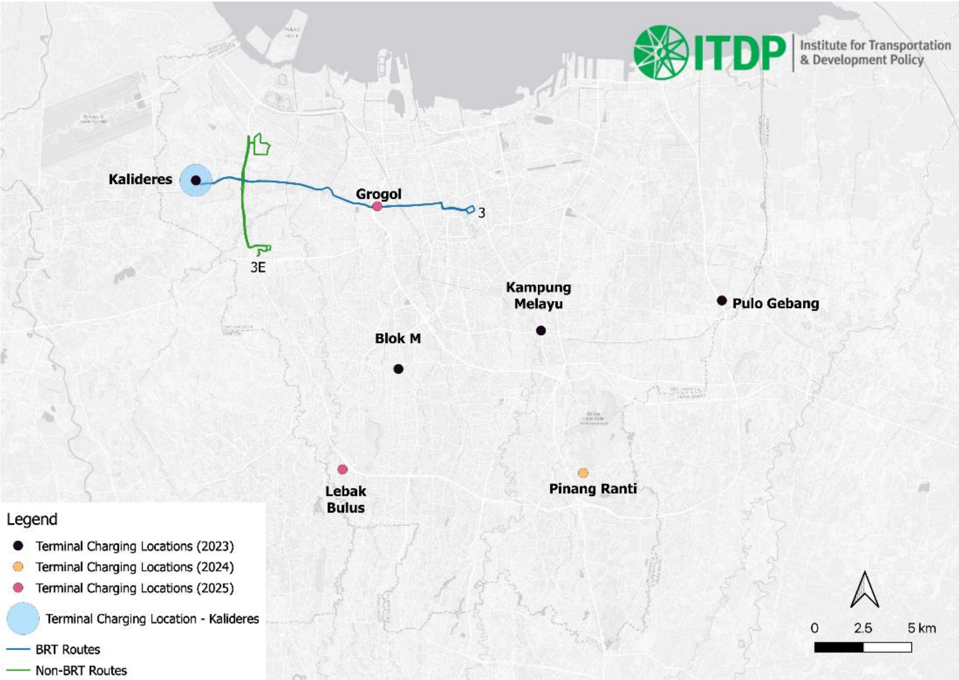


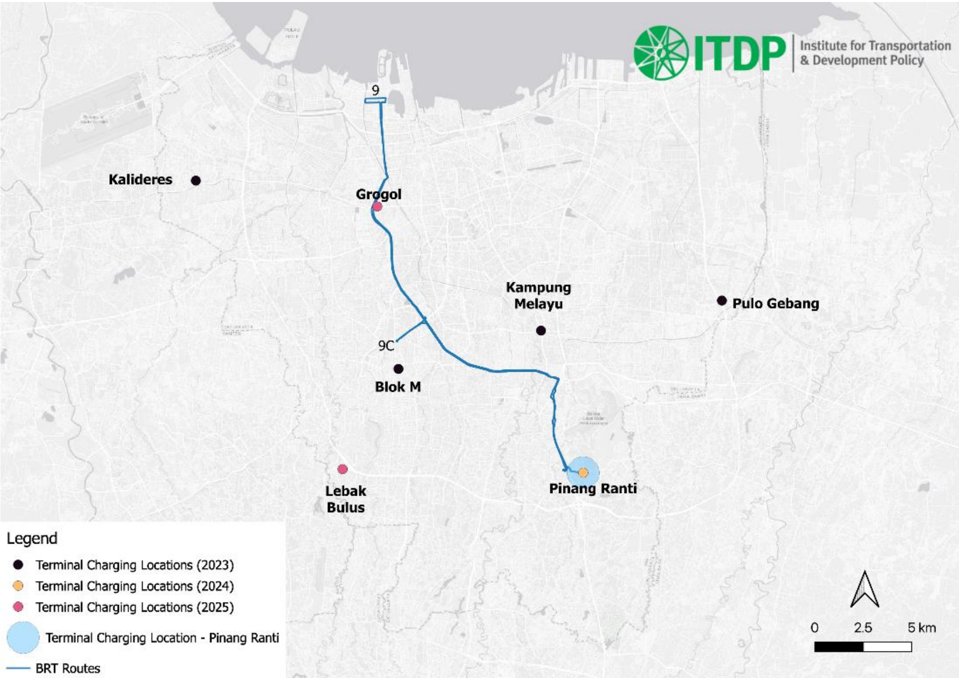

ITDP Institute for Transportation & Development Policy
Kalideres
Grogol
11D
Kampung Melayu
Pulo Gebang
11Q
Blok M
Lebak Bulus
Pinang Ranti
Legend
Terminal Charging Locations (2023)
Terminal Charging Locations (2024)
Terminal Charging Locations (2025)
Terminal Charging Location - Pulo Gebang
Non-BRT Routes
0 2.5 5 km


ITDP Institute for Transportation & Development Policy
Kalideres
Grogol
6Q
6C
Kampung Melayu
Pulo Gebang
Blok M
7P
Lebak Bulus
Pinang Ranti
5N
Legend
Terminal Charging Locations (2023)
Terminal Charging Locations (2024)
Terminal Charging Locations (2025)
Terminal Charging Location - Kampung Melayu
Non-BRT Routes
0 2.5 5 km


ITDP Institute for Transportation & Development Policy
Kalideres
Grogol
8K
Kampung Melayu
Pulo Gebang
Blok M
Lebak Bulus
Pinang Ranti
Legend
Terminal Charging Locations (2023)
Terminal Charging Locations (2024)
Terminal Charging Locations (2025)
Terminal Charging Location - Grogol
Non-BRT Routes
0 2.5 5 km


ITDP Institute for Transportation & Development Policy
1
Kalideres
Grogol
Kampung Melayu
Pulo Gebang
8D
Blok M
1C
8E
1Q
Lebak Bulus
1E
6N
Pinang Ranti
9H
Legend
Terminal Charging Locations (2023)
Terminal Charging Locations (2024)
Terminal Charging Locations (2025)
Terminal Charging Location - Blok M
BRT Routes
Non-BRT Routes
0 2.5 5 km


ITDP Institute for Transportation & Development Policy
Kalideres
Grogol
3
3E
Kampung Melayu
Pulo Gebang
Blok M
Lebak Bulus
Pinang Ranti
Legend
Terminal Charging Locations (2023)
Terminal Charging Locations (2024)
Terminal Charging Locations (2025)
Terminal Charging Location - Kalideres
BRT Routes
Non-BRT Routes
0 2.5 5 km


ITDP Institute for Transportation & Development Policy
9
Kalideres
Grogol
Kampung Melayu
Pulo Gebang
9C
Blok M
Lebak Bulus
Pinang Ranti
Legend
Terminal Charging Locations (2023)
Terminal Charging Locations (2024)
Terminal Charging Locations (2025)
Terminal Charging Location - Pinang Ranti
BRT Routes
0 2.5 5 km

Annex 2. Detailed Analysis of Type of Charging Infrastructure

The are two types of charging interface; manual plug in and automated and these come in a range of power outputs of slow, fast and ultra-fast with solutions available for depot based and roadside based equipment.

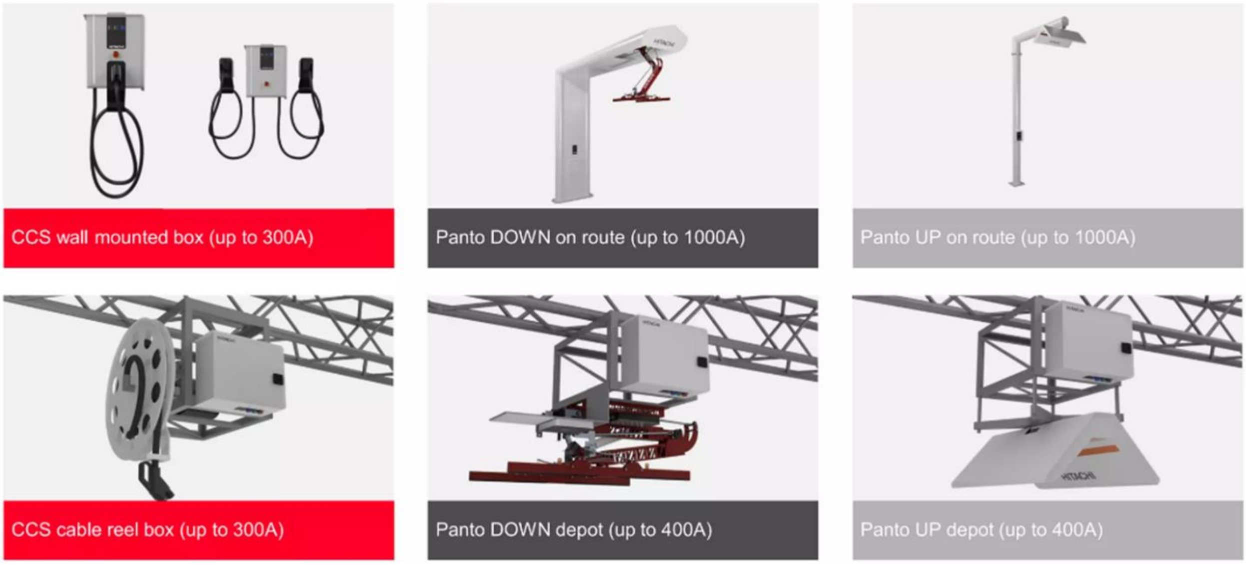
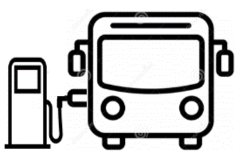
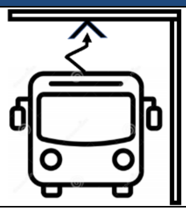
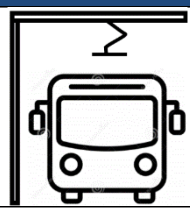


Figure 30. Types of Charging Infrastructure

The charging equipment interface and power requirements require monitoring and management to ensure Peak [power] Load Management (PLM) during charging of the fleet but also, battery condition management. Therefore, it is more optimum to slow charge vehicles at night to condition the batteries but this needs to be completed within adequate time to ensure sufficient vehicle uptime and availability.

Table 25. Charging Technology Selection Matrix

	Plug-in	Pantograph (infrastructure)	Pantograph (bus mounted)
			
Connection	Manual connection	Automated through digital connection (Wi-Fi or Bluetooth) or activated by driver switch	
Vehicle interface	Multiple vehicles simultaneous	Single vehicle at time	
Power (kW)	40-300	150-600	150-600
Cost of charging interface	Low	Medium	High
Ease of implementation	Wall mounted or free standing	Mounted onto overhead Gantry or to building structure	

Complexity of equipment	No moving parts	Less susceptible to roadside damage/bus wash	More susceptible to damage in service or bus wash

The type of charging, whether fast or slow, plug-in or pantograph requires coordination between the various stakeholders to ensure optimum solution but also one that is scalable in interoperable.

Depot based systems need to be space efficient to enable the equipment to be installed without losing too much depot space. As the fleet transitions to electric, more space is required for the equipment system, and thus more efficient options are required.

The type of equipment and charging strategy is an important depot design criterion. Depots are generally compact, and the installation of charging equipment requires considerable space for the transformers, high-low switch panels and the charging interface points etc.

Plug-in charging allows for multiple vehicles to be potentially charged simultaneously although at a slower rate, whereas pantograph interface is a 1:1 charging solution of vehicle to equipment although at a faster rate. Due to the faster rate but restriction of 1:1, either more charging points are required, or the vehicles need to be manoeuvred to move the vehicles between charging equipment and parking areas. Due to the depot space constraints and safety at night, its undesirable to be constantly moving vehicles. Due to this, when both charging interface options are used for fleet charging, depots are often installed with a combination of charging equipment types.

For terminal charging, there is more of a preference in Europe for overhead pantograph charging due to space constraints so the vehicles are charged quicker to enable more efficient turn around. These vary between 350 – 600 kW charging and between infrastructure and bus mounted interface.

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