ABOUT THE C40 CITIES FINANCE FACILITY

The C40 Cities Finance Facility (CFF) is a collaboration of the C40 Cities Climate Leadership Group and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The CFF supports cities in developing and emerging economies to develop finance-ready projects to reduce emissions to limit global temperature rise to 1.5°C and strengthen resilience against the impacts of a warming climate. The CFF is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), the Children’s Investment Fund Foundation (CIFF), the Government of the United Kingdom and the United States Agency for International Development (USAID).

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EXECUTIVE SUMMARY

Introduction
The Provincial Government of DKI Jakarta has prepared a project entitled “Zero Emission Buses in Jakarta”. The project is being implemented with TJ (TJ) over an 11-month period beginning February 2020, with the support of the C40 Cities Finance Facility (CFF).

Technical Aspects
It is very clear that with the battery degradation there is an impact on the operations of the electric buses. Operational plans must be revised and updated on a regular basis. In addition, the data that is collected through BMS from the battery pack should be checked on a regular basis for the reduction in the battery capacity. This will then enable the transit agency to clearly understand how to plan the operations.

One of the first options to be explored is if the bus can be charged in addition to the first episode of charging. It becomes important to relook at the operational plan and design the operational plan in such a way that the bus is able to charge at the terminal through opportunity charging or deploy additional buses along the route to match the operational needs. As deployment of electric buses happens at scale, buses that are not suitable for longer routes can be deployed on routes which have lesser daily kilometers as feeder service and are able to match to the battery capacity. Finally, it may be necessary for the battery to be replaced before the end of its warranty period.

The area around JIS is being envisioned as Low Emission Zone. Therefore, it is very likely to promoted for corridors around JIS for electric buses. Because of this TJ is interested in deploying electric buses around JIS as this will bring high visibility to electric buses and acceptance among citizens.

JIS has the potential to serve more than 40 electric buses and could serve as a potential charging facility during daytime for opportunity charging for several BRT corridors. The section looks at evaluating the feasibility of JIS as a charging facility location. Charging stations in JIS will be developed by Jakarta Propertindo (Jakpro), the government-owned company. TJ has cooperation with Jakpro, which is willing to provide staging facility at JIS.

Based on the electric buses model available in the market that have been tested by TJ a battery capacity of 250 kWh was assumed. The energy losses are estimated to be about 35% which results in an efficiency of approximately 1.4 kWh per kilometer which takes into consideration the 20% minimum depth of discharge that has to be maintained, as well as the air conditioning and passenger loading. Taking these factors into consideration the total distance that a bus can travel on single charge of battery is calculated to be approximately 180 kilometers. Assuming that the daily utilization of BRT routes is approximately about 230 kilometers (this can vary for each route based on TJ’s decision, the calculations being done in this study is for maximum possible kms including dead kms), this results in additional 50 kilometers that will be need and to be charged during the daytime. This translates roughly to about 70 kWh of energy requirement that will need to be charged and stored in the battery. The time
taken to charge the battery with a 180 kW charger to store additional 70 kWh of energy would take approximately about 24 minutes at the JIS facility.

It is assumed that only one episode of charging is preferred during the mid-day hours. It will not be possible to have two charging episodes, because these are BRT routes with a very high frequency of service. Some of the routes have frequency of bus every two minutes. Due to this, only one charging episode is possible for most of the BRT corridors to meet the desired level of service.

BRT Corridors 1, 2, 4, 5 and 10 have been evaluated if JIS facility. JIS will be feasible as an appropriate location for charging during daytime.

Only those routes that have the total time taken for charging less than the cycle time can be selected for charging at JIS facility. It is evident, that route 4, which has the total time taken for charging greater than the cycle time, cannot be charged at JIS facility. All other routes are feasible for charging at JIS facility.

The number of charges is estimated by taking into consideration the number of buses to be charged, the time taken for charging, and the number of hours available for charging. It is considered that approximately about 5 hours are available during the midday for charging the buses.

Furthermore, the arrival rate and departure rates of buses must be taken into consider while designing the charging plan. While buses are getting charged at the terminal, other buses will need to wait in the parking bay at the JIS facility. The last set of buses that arrive for charging at the JIS facility should have completed their charging before the peak hour starts.

**Financing of E-Buses – New business models**

E-bus as technology as well as the procurement and operations are new to Jakarta (Indonesia for that matter) and TJ is taking a lead role in introducing them into mass transit operations in the country. The current BTS model which is working fine for diesel bus-based city operations, will not work for the E-bus procurement due to a much larger investment needed as well as operational challenges including charging, inexperience of operators and financers in operating and financing E-buses respectively. As new operating and maintenance practices are needed inculcated, there is a need for involvement of the OEM for the term of the concessions during initial deployment. The total investment in E-buses and charging infrastructure between 2021 and 2030 is estimated at USD 2.78 billion, i.e. an average of USD 325 million p.a. and a maximum of USD 475 million in the year 2023.

Internationally, business models involving separation of asset ownership and operations have worked well. The same is recommended for TJ. There is a role for state owned entities such as PT SMI to formulate and implement new business models as an example for other players to adopt and adapt not only for Jakarta but for other Indonesian cities as well. Since TJ is restricted to deploy the current set of operators due to the quota system, providing the operators with E-buses on lease appears to be the most suitable model rather than project financing models. However, the charging infrastructure could be implemented in a PPP framework with an availability cum usage-based payment structure.

From the above, it is clear that the requirement for financing-bus and infrastructure is huge and the Operator’s financing capacity is inadequate. To ensure TJ’s complete
transitioning to E-buses by 2030, the separation of ownership and operations is a must and therefore new business models and procurement processes are needed which will ensure proper risk assessment and mitigation through allocation of regulatory, control, operations and maintenance as well as financing responsibilities with parties that have these capabilities and are able to do it in the most efficient manner. Further, the business model should allow economy of scale through volumes and multi-year programs in procurement, financing, and maintenance functions.

In view of the foregoing, it is recommended that TJ explores new business and financing models, which could be piloted during the 2022 pilot BRT roll out of E-buses after discussing the same with the Government of DKI Jakarta and other stakeholders such as the operators, OEMs and financing entities such as PT SMI. In this regard, initial interaction with PT SMI was encouraging. It is recommended that TJ evolves a new business model along the lines recommended in this report which will be bankable and should enable operators to either avoid any financing needs or help them secure maximum amount from the banks.

It is further recommended that, TJ should obtain the confirmation from the Government of DKI, Jakarta regarding:

- Definitive year-wise roll-out plan of e-buses
- Policy and plan for phasing out of diesel buses
- Budgetary support required for setting up charging infrastructure and E-bus roll out in initial phases

Policy and regulatory support to enable the proposed changes in the procurement process.

**Legal Aspects**

The legal aspect in this report only focuses on the impact due to introduction of new leasing models for financing large volume of E-buses as TJ scales up the electrification of its entire fleet. Pursuant to the analysis from the Finance Expert, it is concluded that a new financing model is need for TJ’s Operator financing, for the following reasons:

a) Present financing pattern of bus Operators is insufficient to meet E-bus financing needs;
b) Operators do not have the capacity to meet the equity requirements; and
c) Lenders may be reluctant to invest heavily on a new technology.

One of the options for the financing is a new Leasing Model. In the new Leasing Model, the proposed scheme is to separate ownerships from operation. The Lessor can lease the E-buses to any Operator and can step-in or re-lease the E-buses to another Bus Operator, in the event the current Operator breaches or fails to make payment. Basically, it ensures the continuing operation of the buses, regardless the financial capacity of the Operator. The Rp/Km Formulation needs to be revisited to accommodate the new Leasing Model as mentioned above and be included in the procurement process in future.
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<tr>
<td>AC</td>
<td>Air Conditioning</td>
</tr>
<tr>
<td>BAU</td>
<td>Business as Usual</td>
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<tr>
<td>BEB</td>
<td>Battery Electric Bus</td>
</tr>
<tr>
<td>BMS</td>
<td>Battery Management Service</td>
</tr>
<tr>
<td>BTS</td>
<td>Buy the Service Model</td>
</tr>
<tr>
<td>BPPBJ</td>
<td>Badan Pelayanan Pengadaan Barang/Jasa</td>
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<tr>
<td>BRT</td>
<td>Bus Rapid Transit</td>
</tr>
<tr>
<td>CapEx</td>
<td>Capital Expenditure</td>
</tr>
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<td>C40</td>
<td>C40 Cities Climate Leadership Group</td>
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<td>CFF</td>
<td>C40 Cities Finance Facility</td>
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<td>C40 KAPM</td>
<td>C40 Knowledge and Partnership Manager</td>
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<tr>
<td>CO2</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DO</td>
<td>Driver Order</td>
</tr>
<tr>
<td>DoD</td>
<td>Depth of Discharge</td>
</tr>
<tr>
<td>DKI Jakarta</td>
<td>Daerah Khusus Ibukota or Special Capital Region of Jakarta</td>
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<tr>
<td>E-bus</td>
<td>Electric bus</td>
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<tr>
<td>E-mobility</td>
<td>Electric mobility</td>
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<tr>
<td>EV</td>
<td>Electric Vehicles</td>
</tr>
<tr>
<td>FUSE</td>
<td>Discussion Forum for Electric Vehicles and Buses, Indonesia</td>
</tr>
<tr>
<td>GCF</td>
<td>Green Climate Fund</td>
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<tr>
<td>GEFF</td>
<td>Green Economy Financing Facility</td>
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<tr>
<td>GGGI</td>
<td>Global Green Growth Institute</td>
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<tr>
<td>GGF</td>
<td>Green for Growth Fund</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>GIZ</td>
<td>German Development Agency</td>
</tr>
<tr>
<td>ICE</td>
<td>Internal Combustion Engine</td>
</tr>
<tr>
<td>IDR</td>
<td>Indonesian Rupiah</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IPCC</td>
<td>Inter-Governmental Panel on Climate Change</td>
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<tr>
<td>JIS</td>
<td>Jakarta International Stadium</td>
</tr>
<tr>
<td>KWH</td>
<td>Kilowatt Hour</td>
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<tr>
<td>LFP</td>
<td>Lithium Iron Phosphate</td>
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<tr>
<td>LKPP</td>
<td>The Government Goods/Services Procurement Policy Agency</td>
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<tr>
<td>LIB</td>
<td>Lithium-ion Battery</td>
</tr>
<tr>
<td>MAB</td>
<td>Mobil Anak Bangsa (Indonesian e-bus manufacturer)</td>
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<tr>
<td>MEMR</td>
<td>Ministry of Energy and Mineral Resources, Indonesia</td>
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<tr>
<td>MYS</td>
<td>PT Mayasari Bakti bus company</td>
</tr>
<tr>
<td>NAMA</td>
<td>Nationally Appropriate Mitigation Action</td>
</tr>
<tr>
<td>NMC</td>
<td>Lithium-manganese-cobalt-oxide</td>
</tr>
<tr>
<td>NOx</td>
<td>Nitrous Oxide pollutants</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>OpEx</td>
<td>Operational Expenditure</td>
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<tr>
<td>PIU</td>
<td>Project Implementation Unit</td>
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<tr>
<td>PLN</td>
<td>Perusahaan Listrik Negara (Indonesia’s state-owned electricity company)</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>---------</td>
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</tr>
<tr>
<td>PM</td>
<td>Particulate Matter</td>
</tr>
<tr>
<td>PM2.5</td>
<td>Particulate Matter less than 2.5 micrometers in width</td>
</tr>
<tr>
<td>PPF</td>
<td>Project Preparation Facility</td>
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<tr>
<td>PPP</td>
<td>Public-Private Partnership</td>
</tr>
<tr>
<td>Presidential decree</td>
<td>The Presidential Decree on Acceleration of Battery-Based Electric Vehicles</td>
</tr>
<tr>
<td>SGO</td>
<td>Gross Fleet</td>
</tr>
<tr>
<td>SOC</td>
<td>State of Charge</td>
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<tr>
<td>SP</td>
<td>Service Provider</td>
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<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
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<tr>
<td>TJ</td>
<td>TJ</td>
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<td>ToR</td>
<td>Terms of Reference</td>
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1. INTRODUCTION

1.1. BACKGROUND

The CFF has been supporting Jakarta since December 2019 in its transition to electric buses (E-buses) – a first step towards a system change to sustainable public transport and lower emissions in the capital and beyond. The 100 E-Bus Trial is seen as a pilot phase prior to the full deployment of E-bus fleet in Jakarta. TransJakarta (TJ) is operating its fleet both on the owner-operator model as well as the Gross Cost Contracting model, also known as the "Buy The Service (BTS)" model.

The CFF supported the city in the timeframe December 2019 to March 2021 in preparing a finance ready 100 E-Bus Trial project on its award-winning bus transit system. The planning phase has been completed with the support from the CFF. Based on the CFF support, TJ identified BRT and Non-BRT routes for implementation.

1.2. PROJECT SCOPE

The provision of 100 E-Buses is following a procurement process within DKI, managed by BPPBJ (through their own SOP’s under LKPP guidelines). DKI’s Transportation Agency (Dinas Perhubungan) and TJ provide necessary technical support for the procurement process. The CFF recommendations have been used for first steps in the procurement planning. In the timeframe April to December 2021, the CFF is providing further support for completion of the procurement of the 100 E-Buses for the trial.

E-bus as technology as well as the procurement and operations are new to Jakarta and are being introduced for commercial route operation. BTS model is in operation for diesel bus-based city operations. The objective of the assignment is to:

- Provide hands-on support for the development of a proper tendering and procurement according to the Local Government procurement regulation.
- Ensure that tender requirements meet legal, technical and financial requirements to serve the purpose of the procurement.
- Facilitate broader participation by suitable local and international parties.

1.3. DATA COLLECTION

The data collection focuses on the following aspects:

- Final routes selected for the implementation of E-buses obtained from TJ;
- Details about Jakarta International Stadium from TJ;
- Review of contract document obtained from TJ;
- Review of existing studies on financing structures carried out for implementation and procurement of E-buses globally.

1.4. PURPOSE OF THIS REPORT

The purpose of the Report is as follows:

i. Gather relevant information from all available sources; and
ii. On the basis of the study findings, prepare the technical, financial and legal aspects of the project to a degree that allows the city for the development of a proper tendering and procurement according to the Local Government procurement regulation for the deployment of BRT buses.

1.5. STRUCTURE OF THE REPORT

This report introduces the transition plan of TJ in Chapter 2 and impact of battery degradation on the operations of buses and the recommendations for reworking the operational plan in Chapter 3. This is followed by evaluation of JIS as a charging facility option for opportunity charging for various BRT corridors taking into consideration the option of only one fast charging episode, in Chapter 4. Chapter 5 focuses on financing of e-buses by taking into consideration various options such as fully separating the ownership and operation of the buses, creating an independent bankruptcy-remote trust funds, establishing a centralized fare collection system, structuring payment models to shield external parties like operators and fleet providers from demand risk, involving a third-party fleet provider to finance and own the buses and their batteries, creating swap lines and use inflation-indexed contracts for fleet providers. Chapter 6 focuses on the legal aspects due to new leasing model. Finally, Chapter 7 includes the recommendations for technical, financial and legal requirements for deploying e-buses on the BRT corridors.
2. E-BUS TRANSITION PLAN OF TJ

TJ currently operates about 4,000 large buses including about 1,800 mikrobuses and it proposes to induct more buses to its network such that it is expected to have a fleet of more than 10,000 buses by 2030. TJ has prepared a plan to complete transition of the diesel fleet to E-bus by 2030 (50% by 2025) as shown in Table 1.

Table 1 Electrification Plan for TJ (2030)

<table>
<thead>
<tr>
<th></th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Single Bus-HE</td>
<td>--</td>
<td>140</td>
<td>315</td>
<td>95</td>
<td>165</td>
<td>89</td>
<td>89</td>
<td>144</td>
<td>208</td>
<td>153</td>
<td>1398</td>
</tr>
<tr>
<td>Single Bus-LE</td>
<td>100</td>
<td>205</td>
<td>715</td>
<td>625</td>
<td>447</td>
<td>99</td>
<td>70</td>
<td>98</td>
<td>135</td>
<td>69</td>
<td>2563</td>
</tr>
<tr>
<td>Medium Bus</td>
<td>--</td>
<td>--</td>
<td>57</td>
<td>65</td>
<td>327</td>
<td>270</td>
<td>220</td>
<td>298</td>
<td>511</td>
<td>239</td>
<td>1987</td>
</tr>
<tr>
<td>Articulated Bus</td>
<td>--</td>
<td>--</td>
<td>121</td>
<td>141</td>
<td>154</td>
<td>45</td>
<td>66</td>
<td>126</td>
<td>140</td>
<td>157</td>
<td>950</td>
</tr>
<tr>
<td>Small Bus</td>
<td>--</td>
<td>--</td>
<td>557</td>
<td>564</td>
<td>410</td>
<td>305</td>
<td>262</td>
<td>361</td>
<td>566</td>
<td>284</td>
<td>3309</td>
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<tr>
<td>Total</td>
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<td>345</td>
<td>1765</td>
<td>1490</td>
<td>1503</td>
<td>808</td>
<td>707</td>
<td>1027</td>
<td>1560</td>
<td>902</td>
<td>10207</td>
</tr>
</tbody>
</table>
| Cumulative       | 100  | 445  | 2210 | 3700 | 5203 | 6011 | 6718 | 7745 | 9305 | 10207|--

HE: High Entry    LE: Low Entry

2.1. IMPACT OF ELECTRIFICATION OF TJ FLEET ON GHG EMISSIONS

Electric buses dominate Transjakarta's fleet starting 2025

Expressed in vehicle units

Figure 1 E-Buses to start dominating TJ Fleet from 2025
As can be seen from Figure 1, TJ's fleet will be dominated by E-buses starting 2025. The effects of this in term of reduction in GHG emissions is shown in Figure 2. It is estimated that by 2025, TJ would have avoided 177 kTCO$_2$e due to electrification.

![Figure 2 Estimated GHG reduction because of e-bus deployment](source: ICCT)
3. BATTERY DEGRADATION

3.1. INTRODUCTION

Battery in electric buses degrade with time and use. Degradation is the process of performance deterioration with time and operation. Battery degradation effects in the loss of capacity and power ability. Major drivers for battery degradation include:

- Cell chemistry and design - Chemical changes and degradation mechanisms
- BMS and battery pack design - Thermal management and cell balancing
- Operating conditions - Climatic condition and road profile
- Operating mode - Charging, parking, and driving

In electric buses, the standby time account for a significant proportion of the entire battery life. This means calendar aging cannot be ignored during assessment of battery degradation and lifetime. In some cases, more than 75% of capacity fade is caused by calendar aging during the electric bus operation.

![Figure 3 Capacity fade vs driving range](image)

The cell degradation occurs due to chemical and physical changes (Degradation mechanism) accelerated by stress factors resulting in active loss of active materials. This results in both capacity and power fade.
The battery pack degradation combines effect at cell level and operation at pack level. Degradation of simultaneously operating connected cells in pack is due to thermal management of cells and cell-balancing as there is difference in parameters of individual cells. The arrangement of cell in pack and type of connection whether in series or parallel also impact the degradation.

![Graphical representation of arrangement of cell pack](image)

**Figure 4** Graphical representation of arrangement of cell pack

### 3.2. CYCLING AGING VS CALENDAR AGING

Although the calendar aging process is slow, and it may take several years (even tens of years) for a battery to end its service life by calendar aging only, but elevated temperature and/or high SOC can accelerate calendar aging. Following are two mechanisms that shorten battery life and deteriorate performance of Lithium batteries in EVs.

Cycling Aging occurs while charging and driving condition. Typical characteristics include:

- Depends on the number of charging/discharging cycles, and cycling condition (c-rate, temperature, DoD)
- Attributed to the formation of SEI (Solid Electrolyte Interphase) layer, Structural Changes in the electrodes, and loss of lithium during battery charging/discharging
- Cyclic aging increases at lower temperature, due to lithium plating

Calendar Aging occurs while standby or storage condition. Typical Characteristics include:

- Depends on the State of Charge (SoC), aging time, and expose of the battery to high temperatures
- Attributed to battery self-discharge and side reactions that occur during the energy storage period
- Calendar aging accelerates at high SoC and high temperature

LFP and batteries are the common batteries that are exclusively used for electric buses. The table below demonstrates how different parameters like state of charge,
temperature, depth of discharge, the electrode materials, and the C rate impact the calendar aging and cycling aging of these batteries. For instance, in calendar aging the lower the state of charge it is very less likely to degrade.

Similarly for cyclic aging the impact of c-rate is very well understood. Higher the c-rate, faster is the degradation of batteries. In addition, if the depth of discharge is very wide then the batteries are likely to degrade faster.
### Table 2: Calendar aging and cycling aging tests

<table>
<thead>
<tr>
<th>Test method</th>
<th>Parameter</th>
<th>Positive electrode</th>
<th>Negative electrode</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calendar aging tests</td>
<td>SOC</td>
<td>NMC</td>
<td>Graphite</td>
<td>The lower the SOC, the less likely it is to degrade. Takes 220 days to degrade to 90% of capacity at 50% of SOC.</td>
</tr>
<tr>
<td></td>
<td>LFP</td>
<td>Graphite</td>
<td></td>
<td>Similarly, lower SOC leads to slower degradation than NMC (&gt;600 days under equivalent conditions).</td>
</tr>
<tr>
<td>Temperature</td>
<td>LFP</td>
<td>Graphite</td>
<td></td>
<td>The higher the temperature (20°C to 60°C), the faster the degradation is. Film formation on the surface of the negative electrode is presumed to be a factor.</td>
</tr>
<tr>
<td>Cycling aging tests</td>
<td>SOC</td>
<td>NMC</td>
<td>Graphite</td>
<td>Tends to degrade easily in SOC regions that are high or low. Presumed to be electrode erosion at the sudden point of change where dV/dQ passes through.</td>
</tr>
<tr>
<td></td>
<td>LFP</td>
<td>Graphite</td>
<td></td>
<td>Smaller dependence on SOC for degradation and less degradation than NMC.</td>
</tr>
<tr>
<td></td>
<td>DOD</td>
<td>NMC</td>
<td>Graphite</td>
<td>The wider the DOD, the easier it degrades, with the capacity lowering to 80% after 500 cycles. Presumed to be erosion at the sudden point of change for dV/dQ.</td>
</tr>
<tr>
<td></td>
<td>LFP</td>
<td>Graphite</td>
<td></td>
<td>Degradation is slower than that of NMC, and it takes about 3,000 cycles to reach 80% of capacity.</td>
</tr>
<tr>
<td>Electrode materials</td>
<td>—</td>
<td>—</td>
<td></td>
<td>Positive NMC and negative LTO has the slowest rate of degradation; it takes about 3,000 cycles to reach 90% of capacity.</td>
</tr>
<tr>
<td>Temperature</td>
<td>NMC</td>
<td>Graphite</td>
<td></td>
<td>34°C→46°C leads to capacity degrading to 80% in 1,200→500 cycles. Presumably an effect of preservation.</td>
</tr>
<tr>
<td></td>
<td>LFP</td>
<td>Graphite</td>
<td></td>
<td>35°C→45°C leads to capacity degrading to 90% in &gt;3,000 → &lt;2,000 cycles. Presumably an effect of calendar aging.</td>
</tr>
<tr>
<td>C-rate</td>
<td>NMC</td>
<td>Graphite</td>
<td></td>
<td>A C-rate of 6.5 degrades faster than one of 2 or less. 80% of capacity reached in 1,000 or less cycles.</td>
</tr>
<tr>
<td></td>
<td>LFP</td>
<td>Graphite</td>
<td></td>
<td>If the c-rate is 8, takes 1,700 cycles or less to reach 80% of capacity. 2,000 cycles or more for &lt;4C.</td>
</tr>
</tbody>
</table>
3.3. LI-ION BATTERY DEGRADATION CONDITIONS

Lithium-ion batteries can degrade because of several conditions some of the prominent conditions include batteries operating in extreme low temperatures or very high temperatures. It is also possible due to high discharging current or high charging current and furthermore due to high state or very low state of charge and overcharge. All these degradations result in reducing the battery capacity and thus impact the operations of electric buses.

![Lithium-ion battery degradation conditions](image)

Once the battery losses 20% of its initial capacity and has more than 5% of self-discharge rate over 24 hrs, the battery completes its life in an automotive application. In addition to time and usage conditions, battery life also depends upon the type of chemistry of the battery. LFP and NMC are the most widely used LIBs variants in the buses. A higher c-rate adversely affects the battery life of NMC (<1C rate is better) compared to LFP battery (<4C is better). Globally, LFP, NMC, and LTO-LFP variants are used in the electric bus application.

As shown in Figure, the annual battery capacity loss for LMO batteries decreases from 6.34% in year 1 to 2.12% in year 10, and this is mainly due to drop in calendar loss from 5.48% in year 1 to 1.31% in year 10. The cycling loss decreases only slightly from 0.86% in the 1st year to 0.81% in the 10th year.
Figure 6 Annual battery capacity loss in the US

Figure below depicts the electric vehicle battery degradation and capacity loss in different states of the USA under actual operating conditions. The temperature-induced calendar loss is dominating the battery degradation, particularly in 1st year. As shown in the Figure, the 10-year battery calendar loss varies from 18.02% in Alaska (Low temp. region) to 39% in Hawaii (High temp. region), where the national average value is 27%, suggesting a positive correlation between the calendar aging and ambient temperature. Note that the share of calendar aging decreases over time.

Figure 7 Electric vehicle battery degradation and capacity loss in different states of the USA under operating conditions
3.4. LFP BATTERY LIFE IN EV APPLICATION

Most of the electric buses that will be deployed by TJ in Jakarta would be of LFP chemistry. Generally, LFP battery can offer ~2500 cycles (i.e. ~7-8yrs in EV application with daily 1 charge/discharge cycle). The life of the LFP battery can be further extended if stress conditions are well managed to minimize calendar and cyclic aging. First year degradation rate is expected to be higher due to high calendar aging.

Recommendations for extending EV Battery life or Optimum Condition for longer Battery Life include:

- To balance between calendar and cyclic aging, maintaining battery temperature at 25 degree Celsius and SoC 20-30% (during storage condition) is essential
- During storage periods, it is important to keep low temperature and low SoC to reduce calendar aging
- While cycling the battery, maintaining higher temperature to minimize cyclic aging due to lithium plating is essential
- While charging for longer time at low temperature, keeping lower c-rate would reduce cyclic aging

3.5. OPERATION PLANNING FOR E-BUSES DUE TO BATTERY DEGRADATION

Battery degradation will require operational planning of the routes to be adjusted this is because as the battery capacity reduces the available energy for the bus to complete the daily kilometers gets reduced. One of the first things is to check if the battery range is more than the daily distance if that's not the case then it is important to determine the additional energy required. The second step involves checking if the available time at terminal for charging is sufficient with just one episode of charging, then the buses can automatically be charged but in case additional charging is required due to the degradation in the battery capacity then following options need to be explored.

One of the first options to be explored is the bus can be charged in addition to the first episode of charging. If that option does not work, then it becomes important to relook at the operational plan and design the operational plan in such a way that the bus is able to charge at the terminal through opportunity charging. The other option to explore is maybe these buses should be deployed on routes which have lesser daily kilometers and are able to match to the battery capacity. One more option is to deploy additional buses along the corridor. Finally, it may be necessary for the battery to be replaced before the end of its warranty period.

It is very clear that with the battery degradation there is an impact on the operations of the electric buses. Operational plans must be revised and updated on a regular basis. In addition, the data that is collected through BMS from the battery pack should be checked on a regular basis for the reduction in the battery capacity this will then enable the agency to clearly understand how to plan the operations. The flow chart below gives the operational planning process for a transit agency due to the impact of battery degradation.
Figure 8 Flow chart with operational planning process for a transit agency due to the impact of battery degradation
4. EVALUATION OF CHARGING FACILITY AT JIS

4.1. INTRODUCTION

Jakarta International Stadium (JIS) is a retractable roof football stadium under construction at Tanjung Priok, Jakarta, Indonesia. Once completed, it will be the largest stadium in Indonesia that can host up to 82,000 people. The stadium complex is built on 22 hectares of land.

The area around JIS is being envisioned as Low Emission Zone. Therefore, it is very likely to promoted for corridors around JIS for electric buses. Because of this TJ is interested in deploying electric buses around JIS as this will bring high visibility to electric buses and acceptance among citizens.

JIS has the potential to serve more than 40 electric buses and could serve as a potential charging facility during daytime for opportunity charging for several BRT corridors. The section looks at evaluating the feasibility of JIS as a charging facility location. Charging stations in JIS will be developed by Jakarta Propertindo (Jakpro), the government-owned company. TJ has cooperation with Jakpro, which is willing to provide staging facility at JIS.

Bus operators often complement overnight charging of the e-bus fleet with charging during operating hours. Overnight charging remains the mainstay of the e-bus fleet, and when the daily schedule on a route has a break of about an hour, operators may take this “opportunity” for rapid charging of the e-bus at a depot or route terminal. Generally, the purpose of such charging is to add range and not necessarily to do a full charge. The bus operator does rapid charging at intermediate halting points. This is possible by two means: one, when the halting time at a stop is sufficient to add required travel range by charging using fast DC plug-in chargers, and two, the operator employs an ultra-fast pantograph charging system capable of adding the necessary range within a few minutes of halting time. In the latter case, the bus must be suitable for pantograph-based charging.
4.2. EVALUATION OF BRT CORRIDORS

BRT Corridors 1, 2, 4, 5 and 10 have been evaluated if JIS facility will be feasible as an appropriate location for charging during daytime. The nearest terminal point for each of the corridors was selected and travel times were calculated from google maps. Table below summarizes the total travel time between the terminal and JIS and back to the terminal. Corridor 10 has the least travel time which is about 20 minutes while corridor 2 and 4 have the highest travel times of about 52 minutes.

**Table 3 Travel times to JIS for various BRT Corridors from closest BRT terminal**

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Terminal Point</th>
<th>Distance to JIS (Kms)</th>
<th>Distance from JIS (kms)</th>
<th>Off-Peak Travel time (Roundtrip) - Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>Kota</td>
<td>6.9</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>Pulo Gadung 1</td>
<td>16.8</td>
<td>13</td>
<td>52</td>
</tr>
<tr>
<td>Corridor 4</td>
<td>Pulo Gadung 2</td>
<td>16.9</td>
<td>13</td>
<td>52</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>Ancol</td>
<td>5.6</td>
<td>5.9</td>
<td>24</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>Tajunk Priok</td>
<td>3.8</td>
<td>2.3</td>
<td>20</td>
</tr>
</tbody>
</table>

The following maps depicts the travel times for each corridor that was obtained from google map during a typical mid-day hours.

Corridor 1

Figure 10 Travel time to JIS facility from nearest terminal of Corridor 1
Corridor 2

Figure 11 Travel time to JIS facility from nearest terminal of Corridor 2

Corridor 4

Figure 12 Travel time to JIS facility from nearest terminal of Corridor 4
4.3. ROUTE CHARACTERISTICS

The table below shows the various route characteristics including the frequency of services, the total time taken for the roundtrip known as the cycle time that includes the wait time at the terminal. Using this, the total number of buses are calculated that are required for operating during the peak hours.
Table 4: BRT Route Characteristics and bus requirement during peak hours

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Length (km)</th>
<th>headway (mins)</th>
<th>Speed (kmph)</th>
<th>time taken (mins)</th>
<th>Total wait time (mins)</th>
<th>cycle time (mins)</th>
<th>no. of buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>12.9</td>
<td>1.5</td>
<td>22</td>
<td>35</td>
<td>20</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>24.4</td>
<td>5</td>
<td>22</td>
<td>67</td>
<td>20</td>
<td>153</td>
<td>31</td>
</tr>
<tr>
<td>Corridor 4</td>
<td>11.85</td>
<td>5</td>
<td>22</td>
<td>32</td>
<td>20</td>
<td>85</td>
<td>17</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>13.5</td>
<td>3</td>
<td>22</td>
<td>37</td>
<td>20</td>
<td>94</td>
<td>31</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>19.4</td>
<td>3</td>
<td>22</td>
<td>53</td>
<td>20</td>
<td>126</td>
<td>42</td>
</tr>
</tbody>
</table>

The total number of buses required to operate during the midday are also calculated based upon the headway of the service which is different from the peak cover. As clearly seen from the table below, the number of buses are reduced. This is the minimum number of buses that are needed to operate and maintain the level of service during the midday peak.

Table 5: BRT Route Characteristics and bus requirement during off-peak hours

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Length (km)</th>
<th>headway (mins)</th>
<th>Speed (kmph)</th>
<th>time taken (mins)</th>
<th>Total wait time (mins)</th>
<th>cycle time (mins)</th>
<th>no. of buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>12.9</td>
<td>5</td>
<td>22</td>
<td>35</td>
<td>20</td>
<td>90</td>
<td>18</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>24.4</td>
<td>10</td>
<td>22</td>
<td>67</td>
<td>20</td>
<td>153</td>
<td>15</td>
</tr>
<tr>
<td>Corridor 4</td>
<td>11.85</td>
<td>10</td>
<td>22</td>
<td>32</td>
<td>20</td>
<td>85</td>
<td>8</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>13.5</td>
<td>10</td>
<td>22</td>
<td>37</td>
<td>20</td>
<td>94</td>
<td>9</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>19.4</td>
<td>10</td>
<td>22</td>
<td>53</td>
<td>20</td>
<td>126</td>
<td>13</td>
</tr>
</tbody>
</table>

Typically, the midday peak is approximately between 10:00 AM to 3:00 PM. During this time the buses should be charged so that they can operate for the rest of the day and complete the daily kilometers. It is very clear from both the tables above that the buses that are not operating during the midday can be easily charged at the JIS facility. However, buses that are operating during the midday peak also should be charged. Further analysis needs to be carried out to understand if buses that have already been
charged can be introduced into the BRT corridor for providing the services while buses that are operating during the midday peak can be withdrawn from the system and go to JIS facility for charging. This will ensure that all the buses have been charged at least once during the midday and are able to provide the required level of service.

4.4. ENERGY REQUIREMENT

Based on the electric buses model available in the market that have been tested by TJ a battery capacity of 250 kWh was assumed that will be used by buses. The energy losses are estimated to be about 35%, which results in an efficiency of approximately 1.4 kWh per kilometer, taking into consideration the 20% minimum depth of discharge that has to be maintained as well as the air conditioning and passenger loading. Taking these factors into consideration the total distance available per bus is calculated to be approximately 180 kilometers. Assuming that the daily utilization of BRT routes is approximately about 230 kilometers, this results in additional 50 kilometers that will be need and charged during the daytime. This translates roughly to about 70 kWh of energy requirement that will need to be charged and stored in the battery. The time taken to charge the battery with a 180 kW charger to store additional 70 kWh of energy would take approximately about 24 minutes at the JIS facility.

It is assumed that only one episode of charging is preferred during the mid-day hours. It will not be possible to have two charging episodes, because these are BRT routes with a very high frequency of service. Some of the routes have frequency of bus every two minutes. Due to this only one charging episode is possible for most of the BRT corridors to meet the desired level of service.

4.5. DISTANCE TRAVELLED AFTER EVERY TRIP

The table below summarizes the total distance travelled after each one-way trip. This helps to understand how many trips a bus can complete with given energy. As discussed in the previous section, the maximum distance available without any charging is about 180 kilometers. The highlighted cells show the maximum possible trips that a bus can complete. For instance, in corridor 1 the bus can travel up to six trips without any charging. However, corridor 2 can only complete three trips. Similarly, corridors 4 and 5 can complete up to six trips while corridor 10 can complete only four trips.

<table>
<thead>
<tr>
<th>Corridor</th>
<th>After 1.5 Trips</th>
<th>After 2 Trips</th>
<th>After 2.5 Trips</th>
<th>After 3 Trips</th>
<th>After 3.5 Trips</th>
<th>After 4 Trips</th>
<th>After 4.5 Trips</th>
<th>After 5 Trips</th>
<th>After 5.5 Trips</th>
<th>After 6 Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>52.5</td>
<td>65.4</td>
<td>78.3</td>
<td>91.2</td>
<td>104.1</td>
<td>117</td>
<td>129.9</td>
<td>142.8</td>
<td>155.7</td>
<td>168.6</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>106.8</td>
<td>131.2</td>
<td>155.6</td>
<td>180</td>
<td>204.4</td>
<td>228.8</td>
<td>253.2</td>
<td>277.6</td>
<td>302</td>
<td>326.4</td>
</tr>
</tbody>
</table>
4.6. TOTAL DISTANCE TO BE COVERED TO COMPLETE DAILY UTILIZATION

The table below summarizes the total distance that needs to be covered after each trip to complete the daily utilization kilometer of 230 Kms. For example, in corridor 1, after 1.5 trips the bus still needs to complete about 178 kilometers and after six trips it is about 61 kilometers. This will help in understanding the kWh energy required and remaining in the battery after each trip.

Table 7: Distance to be completed (in kms) for completing daily utilization

<table>
<thead>
<tr>
<th>Corridor</th>
<th>After 1.5 Trips</th>
<th>After 2 Trips</th>
<th>After 2.5 Trips</th>
<th>After 3 Trips</th>
<th>After 3.5 Trips</th>
<th>After 4 Trips</th>
<th>After 4.5 Trips</th>
<th>After 5 Trips</th>
<th>After 5.5 Trips</th>
<th>After 6 Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>178</td>
<td>165</td>
<td>152</td>
<td>139</td>
<td>126</td>
<td>113</td>
<td>100</td>
<td>87</td>
<td>74</td>
<td>61</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>123</td>
<td>99</td>
<td>74</td>
<td>50</td>
<td>26</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corridor 4</td>
<td>161</td>
<td>149</td>
<td>137</td>
<td>125</td>
<td>113</td>
<td>101</td>
<td>90</td>
<td>78</td>
<td>66</td>
<td>54</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>178</td>
<td>165</td>
<td>151</td>
<td>138</td>
<td>124</td>
<td>111</td>
<td>97</td>
<td>84</td>
<td>70</td>
<td>57</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>164</td>
<td>145</td>
<td>125</td>
<td>106</td>
<td>87</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*one trip indicates a full round trip between terminals points of a route

4.7. ENERGY REQUIREMENT AFTER EVERY TRIP (KWH)

Accordingly, the energy requirement has been calculated after every trip. The highlighted cells indicate the battery storage that is available for charging additional 70 kWh that is required for completing the daily kms of 230 kms. Thus, the threshold value is 180 kWh below which a battery can be charged through one charging episode.
Table 8: Energy requirements (kWh) after every trip

<table>
<thead>
<tr>
<th>Corridor</th>
<th>After 1.5 Trips</th>
<th>After 2 Trips</th>
<th>After 2.5 Trips</th>
<th>After 3 Trips</th>
<th>After 3.5 Trips</th>
<th>After 4 Trips</th>
<th>After 4.5 Trips</th>
<th>After 5 Trips</th>
<th>After 5.5 Trips</th>
<th>After 6 Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>249</td>
<td>230</td>
<td>212</td>
<td>194</td>
<td>176</td>
<td>158</td>
<td>140</td>
<td>122</td>
<td>104</td>
<td>86</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>172</td>
<td>138</td>
<td>104</td>
<td>70</td>
<td>159</td>
<td>142</td>
<td>125</td>
<td>109</td>
<td>92</td>
<td>76</td>
</tr>
<tr>
<td>Corridor 4</td>
<td>225</td>
<td>208</td>
<td>192</td>
<td>175</td>
<td>174</td>
<td>155</td>
<td>136</td>
<td>117</td>
<td>98</td>
<td>80</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>250</td>
<td>231</td>
<td>212</td>
<td>193</td>
<td>174</td>
<td>155</td>
<td>136</td>
<td>117</td>
<td>98</td>
<td>80</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>230</td>
<td>203</td>
<td>176</td>
<td>148</td>
<td>121</td>
<td>94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*one trip indicates a full round trip between terminals points of a route

4.8. TIME TAKEN FOR COMPLETING THE TRIPS

The table below gives a rough estimate of the actual time after completion of every trip. It is assumed that the trips begin at 5:00 AM in the morning. Accordingly, the cycle time has been used to estimate the completion time. As seen from the table below the highlighted cells indicate when the buses are ready to be charged for the additional requirement of 70 kWh of energy to complete the daily kilometers of 230 kilometers. For corridor 1 the buses are ready to be charged around 10:16 AM, for corridor 2 it is about 8:49 AM, for corridor 4 it is 9:13 AM, for corridor 5 it is 10:27 AM and for corridor 10 it is about 10:14 AM.

Table 9: Actual time (24 hour time) for completing after every trip

<table>
<thead>
<tr>
<th>Corridor</th>
<th>After 1.5 Trips</th>
<th>After 2 Trips</th>
<th>After 2.5 Trips</th>
<th>After 3 Trips</th>
<th>After 3.5 Trips</th>
<th>After 4 Trips</th>
<th>After 4.5 Trips</th>
<th>After 5 Trips</th>
<th>After 5.5 Trips</th>
<th>After 6 Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>7:15</td>
<td>8:00</td>
<td>8:45</td>
<td>9:31</td>
<td>10:16</td>
<td>11:01</td>
<td>11:46</td>
<td>12:31</td>
<td>13:17</td>
<td>14:02</td>
</tr>
</tbody>
</table>
**4.9. TOTAL TIME TAKEN FOR CHARGING**

The total time taken for charging includes the time taken to travel to the JIS facility, the time for charging at the terminal and any additional time required for parking. The total time taken for each of the routes is shown in table below. Only those routes that have the total time taken for charging less than the cycle time can be selected for charging at JIS facility. It is evident that route 4, which has the total time taken for charging greater than the cycle time, cannot be charged at JIS facility. All other routes are feasible for charging at JIS facility.

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Roundtrip time to and from terminal (minutes)</th>
<th>Time for charging (minutes)</th>
<th>Additional time for parking, unexpected congestion (minutes)</th>
<th>Total time required (minutes)</th>
<th>Cycle time of the route (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>26</td>
<td>24</td>
<td>10</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>52</td>
<td>24</td>
<td>10</td>
<td>86</td>
<td>153</td>
</tr>
<tr>
<td>Corridor 4</td>
<td>52</td>
<td>24</td>
<td>10</td>
<td><strong>86</strong></td>
<td><strong>85</strong></td>
</tr>
<tr>
<td>Corridor 5</td>
<td>24</td>
<td>24</td>
<td>10</td>
<td>58</td>
<td>94</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>20</td>
<td>24</td>
<td>10</td>
<td>54</td>
<td>126</td>
</tr>
</tbody>
</table>

*one trip indicates a full round trip between terminals points of a route

**4.10. FINDINGS**

From the analysis it is evident that JIS facility is not suitable for corridor 4 for charging. Hence, the number of charges is estimated for the other four corridors only. The number of charges is estimated by taking into consideration the number of buses to be charged, the time taken for charging and the number of hours available for charging. It is considered that approximately about 5 hours are available during the midday for charging the buses.
Formular for estimating the number of chargers =

\[ \text{Number of buses to be charged} \times \text{Time taken for charging (in hours)} \]
\[ \text{Hours available for charging} \]

Furthermore, the arrival rates and departure rates of buses has to be taken into consideration while designing the charging plan. While buses are getting charged at the terminal, other buses will need to wait in the parking bay at the JIS facility.

The last set of buses that arrive for charging at the JIS facility should have completed their charging before the peak hour starts. Based on the above formula and the conditions above, the number of chargers has been estimated for each corridor as shown in the table below.

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Total number of chargers required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>13</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>9</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>7</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>8</td>
</tr>
</tbody>
</table>
5. NEW BUSINESS MODEL FOR FINANCING OF E-BUSES

5.1. E-BUS FINANCING REQUIREMENTS

The cost of each large (12 m) E-bus is estimated at USD 350,000 currently with an additional 15% to be invested in the charging infrastructure and maintenance facilities. Accordingly, to implement the above transition plan, the total investment requirement is estimated to be USD 2,78 billion as shown in Figure 15 with an average of USD 325 million per year and a maximum requirement of USD 475 million in 2023.

Due to lack of available data on operation of E-buses, higher capital expenditure, uncertainty on residual value of the assets, the traditional financiers of public transport buses in various countries are found to be reluctant to fund the E-buses. They impose stricter conditions such as higher equity contribution, loan tenures restricted to about 80% the length of the concessions etc. This results in practically non-fruition of the loans as the operators are not in a position to bring in the additional equity requirements e.g. A diesel bus costing USD 150,000 can be financed with an 80:20 debt equity ratio implying a contribution of USD 30,000 per bus from the operators. On the other hand, an E-bus costing USD 350,000 with a 60:40 debt equity structure, will require the operator to invest up-front USD 140,000 per E-bus, equivalent to almost 5 times the equity required for a diesel bus. At the same time, the debt requirement is also USD 210,000 per E-bus higher by USD 90,000 per bus as compared to a diesel bus. Therefore, it is highly unlikely that TJ’s Operators under the current BTS model will be arrange the financing needed beyond the initial 100 E-Bus Trial.
From the above, it can be safely concluded that the present financing pattern is insufficient to meet E-bus financing needs since the lenders may be reluctant to invest heavily on a new technology due to structure of the BTS contract where the operator takes the complete risk. Further, the operators would not have the capacity to meet the equity requirements even if the debt financing could be arranged. Hence, new financing model is the need of the hour.

5.2. INTERNATIONAL BEST PRACTICES

The challenge for financing of E-buses is not new for TJ and every city in the world has faced similar dilemma when attempting to transition to E-buses. A few examples of successful financing of E-buses are presented in the following paragraphs from different cities/countries.

5.2.1. Dual Concession Model, Bogota

Bogota has a very sophisticated bus transit system, which transports more than four million people per day. Currently, bus operators are not obliged to invest in electric buses. In order to overcome the main challenge of motivating the operators to invest in more sustainable (but expensive) technology and avoid the increase of tariffs to the end-users, Transmilenio has launched a new concession scheme that separates the acquisition and supply of the electric buses (first concession) from their operation and maintenance (second concession). The terms of the first and second concessions are 15 years and 10 years respectively. This mechanism reduces the financial risk to the investor and the technological risk to the operator. Enel-Codensa, the utility company, is responsible for design, construction and provisioning of the charging system. Under this scheme, Celsia, an Argos Group energy company, has purchased 470 electric buses from BYD, China and leased them to Transmilenio for 15 years.
5.2.2. Pay As You Save® (PAYS®1) Model

PAYS model helps in overcoming barriers to investment without imposing additional liabilities on customers (unlike loans or leases). The PAYS model for Clean Transport, endorsed by the Global Innovation Lab for Climate Finance works is graphically represented in Fehler! Verweisquelle konnte nicht gefunden werden.

The mechanics of the PAYS model are as follows:

- A utility invests in batteries and charging infrastructure for e-buses thereby reducing the upfront cost of the e-bus. The utility leverages its access to capital to expand its revenue base.

- The utility then provides charging service to the bus operator. The PAYS tariff allows the utility to recover its costs within the warranty period through a fixed charge on the bus service provider’s regular monthly electric bill. The tariff is calibrated to ensure the estimated operating cost of an electric bus is less than that of a comparable diesel bus. This approach enables bus service providers to pay for the costs of the batteries and charging stations over time rather than all upfront.

- Without the cost of the battery and charging infrastructure, the cost of the e-bus is almost same as the diesel bus while the charging fee is less than cost of diesel saved. Thus, the bus operator saves from day one without incurring additional balance sheet liabilities.

- Once the utility’s costs are fully recovered, the bus service provider owns the battery and charger assets. In some cases, the battery and charger cannot be fully capitalized within these constraints, so the remaining amount needed to bring the upfront costs of electric and diesel buses to parity is met with grant support; or concessional capital is used to reduce financing costs.

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1 Pay As You Save® and PAYS® are registered trademarks in the U.S. held by Energy Efficiency Institute, Inc.
In many cities, an electric bus purchased with PAYS is cheaper than diesel over its life, leverages much greater private investment per grant dollar, and dramatically reduces fleet greenhouse gas and urban pollutant emissions. In Chile and Shenzhen, the implementation is broadly in line with the PAYS model but with some additional innovations and is briefly described in the following sections.

5.2.3. Procurement e-buses in Santiago, Chile

In 2017, two energy utility companies Enel X and Engie implemented a bus financing structure very similar to the PAYS model but went beyond merely financing the battery and charging infrastructure. The utilities also financed the buses. However, in return, they got payment guarantees from the city transit authority, DMTT. The financial administrator, AFT which manages the project cashflows (receives the fare revenue and pays operator's fees) is instructed to make the payment of lease charges directly to the utility company deducting the amounts from the operator fees. Consequently, the investment for 100 buses leveraged more than 70 dollars of investment capital for each grant dollar, while reducing overall grant requirements by 97%, generating US$ 25 million in electricity sales revenues, and eliminating 62,000 tons of CO2 emissions.

Table 12 The Enel-Engie Financing Model

<table>
<thead>
<tr>
<th>Entity</th>
<th>Deal 1</th>
<th>Deal 2</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Company</td>
<td>Enel X</td>
<td>Engie</td>
<td>Buys buses and charging infrastructure from OEM, leases buses to operator, charges the buses and supplies renewable energy</td>
</tr>
<tr>
<td>Bus operator(s)</td>
<td>Metbus</td>
<td>Buses Vule, STP</td>
<td>Operate Gross Cost Contract, pay lease rent, energy charges</td>
</tr>
<tr>
<td>OEM</td>
<td>BYD</td>
<td>Yutong</td>
<td>E-bus manufacturer, warranty, O&amp;M</td>
</tr>
<tr>
<td>City Authority</td>
<td>DTPM³</td>
<td>DTPM</td>
<td>Guarantees Payment to Leasing Company</td>
</tr>
<tr>
<td>Financial Administrator</td>
<td>AFT⁴</td>
<td>AFT</td>
<td>Deducts lease fee from operator’s fee and remits directly to Enel X</td>
</tr>
<tr>
<td>Lease Duration</td>
<td>10 years</td>
<td>10 years</td>
<td></td>
</tr>
<tr>
<td>Number of buses</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The graphical representation of the Enel-Engie model is shown in Figure 18.

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² Pay As You Save for Clean Transport - The Global Innovation Lab for Climate Finance (climatefinancelab.org)
³ Directorio de Transporte Publico Metropolitano
⁴ Administrador Financiero de Transantiago
5.2.4. Implementation of PAYS model in Shenzhen

Shenzhen Bus Group Co. Ltd. (SZBG) is the largest e-bus operating company in the world. It has a fleet of over 6,000 e-buses (10.5 m long) and operates a fully electric fleet (excluding a few diesel buses for emergency use). The “Shenzhen model” is characterized by financial leasing, separation of vehicles and battery, and integration of charging and maintaining.

In 2010, SZBG entered into a strategic partnership with Shenzhen Lineng (a wholly owned subsidiary of Potevio, an SOE) for accelerating the deployment of e-buses in the city by virtue of which Shenzhen Lineng obtained the right to construct and franchise the new energy charging facilities in Shenzhen. The financing of the various components of the e-bus system was as under:

1. Separation of vehicles and battery: The vehicle and battery are separately purchased. The battery was purchased by Shenzhen Lineng who received financial subsidies from both the central government and the Shenzhen municipality.

2. Financial leasing: The bus (without the battery) was purchased by the leasing company and leased to the bus company for 8 years. Shenzhen Lineng provided guarantee to the financial leasing company on behalf of the bus operating company.

3. Integration of charging and maintenance: Shenzhen Lineng is also responsible for the investment, construction, operation of the charging facilities, and the charging cost, the maintenance costs of batteries and charging facilities. The bus company pays charging fees to the charging facility operator.
After deducting the national and provincial subsidies and the cost of the battery, the cost of the e-bus (US$ 320,000) was reduced to US$ 104,000, similar to the cost of the diesel buses.

Since 2015, SZBG uses a slightly different financing structure as shown in Figure 20. SZBG does not own or operate the charging infrastructure but pays charging service fee to the charging service provider who constructs the charging infrastructure. The Shenzhen municipal government under the “Shenzhen Blue Plan” provided subsidies for charging station construction (DC fast charging: 93 USD /kW; AC charging: > 40 kW - 46 USD/kW; < 40 kW - 30 USD/kW).

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5 @ 6.46 RMB/USD
5.2.5. Project Financing

Given the dependence of the e-bus deployment on the charging strategy, charging infrastructure, and operating characteristics of a particular application there is high asset specificity\(^6\) in e-bus operating contracts. The fact that the e-bus technology is still evolving and prices are coming down consistently, the residual value in alternate deployment is highly uncertain. In other words, in case the operating contract were to be terminated prematurely by whatever reason, the investors are unlikely to realise full value of the assets in case the e-buses are deployed a few years down the line in any other application. The loss of value arises from reduction in cost of new E-buses, cost of recreating/relocating the charging infrastructure and repurposing costs including replacement of batteries, rebranding, idling costs during the transition etc. Further, the transit authorities generally require supply of new buses for new contracts, leaving the bus owner to look for plying the buses in school or corporate fleets as the only options.

In view of the above, the bankers are likely to apply the project financing approach to fund the e-bus projects. Where, if they do not find the concessions bankable, they may require additional collaterals, credit support or guarantees.

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\(^6\) the degree to which a thing of value, or even a person of value, can be readily adapted for other purposes. A thing with high specificity is useful only for certain tasks or in certain circumstances.
5.2.6. Lessons Learned from International Examples

From the above examples, the key lessons learned which could be relevant for TJ’s E-bus implementation plan are as follows:

- Fully separate the ownership and operation of the buses
- Consider creating independent, bankruptcy-remote trust funds
- Establish a centralized fare collection system
- Structure payment models to shield external parties like operators and fleet providers from demand risk
- Involve a third-party fleet provider to finance and own the buses and their batteries
- Create swap lines and use inflation-indexed contracts for fleet providers

5.3. NEW BUSINESS MODELS AND PROCUREMENT PROCESSES FOR E-BUSES

From the international best practices, it is seen that the utilities with good financial credentials have come forward to finance the E-buses in the form of a wet/operating lease. It also helped them secure future electricity supply the E-buses. In case of TJ, this is not seen feasible with the reluctance of PLN to get involved in the E-bus financing; especially considering their monopoly position in electricity supply and financial constraints in making investments. Another possibility is of project finance structure; but considering that the project revenue from fare and non-fare sources do not even cover a quarter of the investment and operating expenses requiring reliance on PSO subsidy from DKI Jakarta. Hence the PPP form is also considered unsuitable.

Accordingly, leasing by non-utility companies is considered to be the only suitable structure for rapid rolling out of the E-buses. This would require a structural change in procurement processes as well as a guaranteed lease payment structure from TJ to the lessors who would not want to bet on the fragile financial condition of the operators.

The business/procurement model is shown in Figure 22 and explained as follows:

1. TJ conducts procurement process for leasing of E-buses of requisite specifications for a period of 12-15 years (longer the better) and determines the lease cost per bus, including maintenance, but excluding investment in charging infrastructure. The leasing agreement shall have an agreed roll-out plan, so that the lessor can negotiate bulk procurement contracts and achieve pricing efficiency. The contracts shall have a fixed payment per month for making the buses available and a variable component for the maintenance of the buses depending on kilometres operated.

2. Similarly, TJ conducts procurement process for making available charging infrastructure services at suitable locations with a provision for scaling up as the number of E-buses increase. These contacts shall also have 2 payment components: (i) Availability Payments paid/guaranteed by TJ (ii) energy charge for units of electricity actually used for charging the buses. This will reduce the risk of non-usage on the part of the service provider who can then be able to
raise the financing necessary for installation of the charging infrastructure and meet fixed costs like rents, repairs and maintenance etc.

3. TJ selects the operators on the basis of least operating cost for the E-buses through tendering process. The operator will receive the buses from the lessor/TJ and charging services from the concerned service provider as explained above.

Two options are available to implement the lease structure as shown in Figure 23. In Option 1, the lease contract can be between TJ and the Lessor similar to the Bogota example discussed above or the lease contract can be between the operator and the Lessor as in the Enel-Engie example from Santiago, Chile.
The pros and cons of the above options are shown in Table 13:

**Table 13 Pros and Cons of the Leasing Options**

<table>
<thead>
<tr>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Assured payment for Lessor</td>
<td>✓ TJ only have to pay the Operator</td>
</tr>
<tr>
<td>✓ Simple structure. In case of Operator default/insolvency, operators can be replaced without any implication on the lessor.</td>
<td>✓ Operator responsible for maintenance costs</td>
</tr>
<tr>
<td>× Responsibility to ensure usage on TJ</td>
<td>× Responsibility to ensure usage on TJ</td>
</tr>
<tr>
<td>× Operator not responsible for wear &amp; tear</td>
<td>× More Complex structure. Lessor remains exposed to Operator defaults/insolvency</td>
</tr>
</tbody>
</table>

5.4. STRUCTURE OF THE LEASING COMPANY

As per the business model suggested in the previous sub-section, the onus for financing the E-Bkses and charging infrastructure shifts to the leasing company and the charging company. Here we discuss the former as the financing requirement for the latter is much smaller and similar principles can be adopted for financing the charging infrastructure as well.

5.4.1. OEM sponsored Leasing Company

During the initial phase of E-bus deployment, it is seen that the manufacturers are quite keen to procure the E-bus orders and they are even willing to finance and operate the buses. E.g., In India, Olectra Greentech Ltd., a technical partner of BYD, has set up a 100% subsidiary, Evey Trans to procure and manage the E-bus operating contracts. Considering the legal and policy hurdles associated with displacing the existing operators of TJ, it is suggested that the OEMs only finance and maintain the buses whereas the operations continue to remain with the present set of Operators. As shown in Figure 24, respective OEMs selected to provide the E-buses on lease could directly or through a subsidiary provide the E-buses to either TJ or the Operator(s) depending on the option chosen through one or more contracts. The entity holding the assets will be able to raise substantial amount of debt from the banks and financing institutions with the E-buses as collateral further strengthened by the OEMs technical capability to repair and maintain the assets and their financial credibility. The technical risks are borne and mitigated by the most competent party.
5.4.2. INDEPENDENT Leasing Company

The model is quite similar to the OEM sponsored Leasing company except that the leasing company is free to procure the E-buses from any OEM that suits the requirements and offers a competitive pricing. The advantage of this model is that the leasing company is in a position to negotiate/bargain/structure a more efficient procurement transaction and may even have better financing terms than the OEMs in some cases. Over a period of time, it is expected that the OEM would withdraw from the E-bus financing as their products get mainstreamed and independent leasing company take over the financing/maintenance responsibility.
5.4.3. GOVERNMENT BACKED Leasing Company

Currently, there are no E-bus manufacturers in Indonesia and those setting up assembling facilities/Joint Ventures, may be focused on manufacturing and marketing of E-buses rather than financing and maintaining them. In such a situation, it will be the responsibility of Government Institutions to pilot the new financing models and finetune and perfect them for large scale adoption by other leasing/financing entities. If the initiative is taken by the Government of Indonesia or their owned entities like PT SMI, this could be a national entity which could enable the provinces to procure and deploy the E-buses benefitting from the large volumes. On the other hand, if the initiative is taken by regional governments like DKI, Jakarta, then a BUMD may be set up in partnership with other entities which can bring in financing and technical expertise. This implementation structure is shown in Figure 26.
5.5. A CASE FOR LOW CARBON MOBILITY FUND FOR INDONESIA

Low carbon mobility has become a priority of the Government of Indonesia. Some of larger cities like Jakarta are able to take small steps towards initiating E-mobility while other cities lack the knowhow as well as the financial capability to progress towards electrification of their fleets. In this regard, a central institution for facilitating and co-financing E-mobility projects can be helpful. A similar example is seen in the form of the Green Growth Equity Fund (GGEF) established by the Government of India’s National Investment and Infrastructure Fund (NIIF) along with the Government of UK’s Foreign, Commonwealth & Development Office (FCDO) for investing in sustainability projects. The GGEF is in the process of raising USD 940 million. Apart securing about USD 150 million each from anchor investors, NIIF and FCDO, the GGEF has also received commitments from BP Plc (USD 70 million), Green Climate Fund (USD 137 million) etc. It has created several platforms for investing in sustainability projects including renewable energy, E-Mobility and waste management. The GGEF is managed by private equity asset manager Eversource Capital.

In a similar way, a Low Carbon Mobility can be proposed with anchor investment from Government of Indonesia and one or more of the multilateral institutions with debt/equity/guarantee support from other national and domestic institutions. The Fund could develop technical knowhow in the field of E-mobility and support various cities in conducting feasibility studies, pilot projects as well as implementing their E-bus rollouts programmes as shown in Figure 27.

![Figure 26 BUMD Leasing Company Structure](image-url)
5.6. RISK ASSESSMENT AND MITIGATION FRAMEWORK

No discussion on any business model can be completed without a robust risk identification and mitigation framework. The various risks associated with the E-bus leasing business model and their possible mitigation strategy is presented in Table 14.

Table 14 Risk Mitigation Risk

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk Bearing Party</th>
<th>Mitigation Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Risk (E-Bus/ Battery/ Charging)</td>
<td>OEM</td>
<td>Operating lease structure or long-term maintenance contract and warranties</td>
</tr>
<tr>
<td>Operating Risk</td>
<td>Operator</td>
<td>Operator is paid based on the value of services provided and penalized in case of deficiencies.</td>
</tr>
<tr>
<td>E-Bus Usage Risk</td>
<td>TJ</td>
<td>TJ as the network and operations planning entity, has the responsibility to ensure that the Assets are used optimally and the E-Bbs kilometres are maximized and only residual kilometres are produced using diesel bus.</td>
</tr>
<tr>
<td>Financing/Interest rate Risk</td>
<td>Lessor</td>
<td>The Lessor has adequate solvency and high credit rating to achieve requisite finance at lower cost than operators. A payment guarantee mechanism to protect the lessor against operator defaults or delay in receipt of subsidy from the Government.</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>Operator/OEM/TJ</td>
<td>Excess energy consumption could be due to traffic/operating conditions (TJ), operating skills (Driver/Operator) or the E-Bus performance (OEM) and needs to be borne by respective parties. This needs to be addressed suitably in the lease/operating contracts.</td>
</tr>
<tr>
<td>Risk</td>
<td>Risk Bearing Party</td>
<td>Mitigation Structure</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>--------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Non-availability of electricity</td>
<td>PLN</td>
<td>As the monopoly supplier, PLN is responsible for ensuring availability of grid power reliably. Redundancy of grid connections to be ensured to further safeguard against unscheduled maintenance/outage issues.</td>
</tr>
<tr>
<td>Non-availability of Charging</td>
<td>Charging service</td>
<td>The contract shall be on take or pay basis and penalties on the service provider in case of non-availability of charging infrastructure. Multiple charging locations with some amount of reserve capacity will reduce the risk further.</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>provider</td>
<td></td>
</tr>
<tr>
<td>Payment Risk</td>
<td>TJ/Operator</td>
<td>The payment risk to the lessor and charging services provider can be mitigated through a cascading waterfall mechanism in which the monthly Operating fee are first released charging service provider, then to the lessor and any remaining amount goes to the Operator. However, since the fare revenues contribute barely 20% of TJ’s expenses, the timely payment of the PSO obligation from DKI Jakarta directly to the Escrow Account is needed. The DKI Jakarta needs to enact necessary legislations for determining the basis of PSO subsidy each year and disbursing the same to TJ/Escrow account on a timely manner. A political risk guarantee/insurance or a line of credit to TJ from the multilateral institutions to cover the risk of delayed/non-payment of PSO subsidy can also be considered.</td>
</tr>
<tr>
<td>Demand Risk</td>
<td>TJ</td>
<td>The risk of ridership is same as in the case of diesel buses. This needs to be borne by TJ/DKI Jakarta.</td>
</tr>
</tbody>
</table>
6. LEGAL ASPECTS

6.1. REGULATORY FRAMEWORK FOR NEW E-BUS FINANCING SCHEME

New Financing Scheme for E-Bus Operator Contract

The current formulation of Rp/Km only accommodates the bus financing. This is called the investment component within the Rp/Km Formulation. This component includes the price of the buses, bank interest and legal fees. Thus in practice, the bus Operators will apply for bus financing or leasing from Banks or leasing companies.

Pursuant to the analysis from the Finance Expert, it is concluded that a new financing model needs to be introduced for TJ’s Operator financing, for the following reasons:

d) Present financing pattern of the bus Operators is insufficient to meet E-bus financing needs;

e) Operators do not have the capacity to meet the equity requirements; and

f) Lenders may be reluctant to invest heavily on a new technology;

One of the options for the financing is the Leasing Model as follows:

![Leasing Model Diagram]

**Advantages:**
1. Higher amount of financing
2. Charging infrastructure can be set up as per requirements of TJ
3. Reduces investment requirement for operators and minimises chances of operator default
4. Amount and cost of financing dependent on credentials of TJ/DIKI

*Figure 28 Implementation Structure with Leasing Model*

The leasing model as per structure above will result in changes to the investment component in Rp/Km Formulation to include [Price of Buses + OEM cost + interest + margins for Lessor]. These are the comparisons of the existing model and the proposed model:

*Table 15 Comparison of Existing Model and Proposed Model*
<table>
<thead>
<tr>
<th>Bus Leasing per Existing Rp/Km Formulation</th>
<th>Leasing Model as Project Financing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus price + interest</td>
<td>Bus price + OEM cost + interest + Margin</td>
</tr>
<tr>
<td>Operator owns the E-Buses</td>
<td>Lessor owns the E-Buses</td>
</tr>
</tbody>
</table>

### 6.2. REGULATORY FRAMEWORK FOR LEASING FINANCING FOR E-BUS OPERATOR

**Regulation on the E-Buses roll out**

This is a great momentum for the Government of Jakarta to plan the E-buses roll out to be in line with Indonesia National Determined Contribution of 29% GHG emission reduction by 2030. The Government of Jakarta can develop a study to support the regulation that certain numbers of E-buses will contribute to the reduction of GHG emission and that the roll out will be conducted as direct appointment by TJ as the regional owned company.

**Regulation concerning the bus operation permit separated from bus ownerships**

- The current regulation provides that bus operation permit is attached to bus ownerships. For example, an operator, say Mayasari Bakti can only obtain bus operation permit to operate in TJ route if the buses used for such operation belong to Mayasari Bakti as the bus operator. Thus, the current bus leasing scheme directly allows the Bus Operator to own the bus and become the lessee.
- In this new Leasing Model, the proposed scheme is to separate ownerships from operation. The Lessor can lease the E-buses to any Operators and can exercise step in or re-lease the E-buses to another bus Operators, in the event the current Operator breaches or fails to make payment. Basically, it ensures the continuing operation of the buses, regardless the financial capacity of the Operators.

**Changes to Rp/Km Formulation in the E-Bus Operator Contract**

- Currently Governor Regulation No 62/2016 sets out that the Production Cost to be covered by Subsidy consists, among other, the direct cost. This direct cost includes investment cost as mentioned above which is translated into Rp/Km Formulation in the E-Bus Operator Contract. This Rp/Km Formulation needs to be revisited to accommodate the Leasing Model as mentioned above and be included since the procurement process. The Rp/Km Formulation must first be approved by Dinas Perhubungan (Office of Transportation of DKI Jakarta) so that it can be adopted in the Subsidy Agreement between Dishub and TJ.
Revisiting the 10 years maximum age of service and contract duration

- The current regulations are based on diesel buses, e.g. the buses can not be operated for more than 10 years. Such restriction should not apply to E-buses as these have much longer life and their performance do not deteriorate like the Diesel buses. Another restriction is on the duration of the contracts is limited to 10 years for E-buses). Longer duration of contracts reduces the operating fee due to better utilisation of the assets. These regulations should be thoroughly reviewed and updated for E-buses.
7. CONCLUSION

7.1. BATTERY DEGRADATION

Battery degradation will require operational planning of the routes to be adjusted this is because the battery capacity reduces the available energy for the bus to complete the daily kilometers gets reduced.

- One of the first options to be explored is the bus can be charged in addition to the first episode of charging.
- It becomes important to relook at the operational plan and design the operational plan in such a way that the bus is able to charge at the terminal through opportunity charging or deploy additional buses along the route to match the operational needs.
- As deployment of electric buses happens at scale, buses that are not suitable for longer routes can be deployed on routes which have lesser daily kilometers as feeder service and are able to match to the battery capacity.
- Finally, it may be necessary for the battery to be replaced before the end of its warranty period.

It is very clear that with the battery degradation there is an impact on the operations of the electric buses. Operational plans must be revised and updated on a regular basis. In addition, the data that is collected through BMS from the battery pack should be checked on a regular basis for the reduction in the battery capacity this will then enable the transit agency to clearly understand how to plan the operations.

Recommendations for extending EV Battery life or Optimum Condition for longer Battery Life

- To balance between calendar and cyclic aging, maintaining battery temperature at 25 degree Celsius and SoC 20-30% (during storage condition) is essential
- During storage periods, it is important to keep low temperature and low SoC to reduce calendar aging
- While cycling the battery, maintaining higher temperature to minimize cyclic aging due to lithium plating is essential
- While charging for longer time at low temperature, keeping lower c-rate would reduce cyclic aging

7.2. JIS AS STAGING FACILITY FOR CHARGING

BRT Corridors 1, 2, 4, 5 and 10 have been evaluated if JIS facility will be feasible as an appropriate location for charging during daytime.

Only those routes that have the total time taken for charging less than the cycle time can be selected for charging at JIS facility. It is evident that route 4, which has the total time taken for charging greater than the cycle time, cannot be charged at JIS facility. All other routes are feasible for charging at JIS facility.

The number of charges is estimated by taking into consideration the number of buses to be charged, the time taken for charging and the number of hours available for
charging. It is considered that approximately about 5 hours are available during the midday for charging the buses.

Furthermore, the arrival rate and departure rates of buses has to be taken into consideration while designing the charging plan. While buses are getting charged at the terminal, other buses will need to wait in the parking bay at the JIS facility.

The last set of buses that arrive for charging at the JIS facility should have completed their charging before the peak hour starts. Based on the provided formula and the conditions, the number of chargers has been estimated for each corridor as shown in the table below.

Table 16 Number of opportunity chargers required for BRT corridors

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Total number of chargers required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>13</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>9</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>7</td>
</tr>
<tr>
<td>Corridor 10</td>
<td>8</td>
</tr>
</tbody>
</table>

7.3. FINANCING REQUIREMENT

Requirement for financing bus and infrastructure is huge and is beyond the capability of the Operators. Therefore, separation of ownership of E-buses and operations is a must. Further, economy of scale can be achieved through larger volumes and therefore there is a need to centralize the E-bus procurements and have a definitive roll out plan so that the procurers have a clear and large to negotiate with the E-Bbs and charging equipment OEMs.

The contractual structure needs to be robust with risk allocated to parties that can bear and manage them most with flexibility to change the contractors in case of default without long drawn legal procedures or expensive transactions.

The commitment of the Regional Government is needed in this regard for

- Definitive roll-out plan of e-buses
- Phasing out of diesel buses
- Budgetary support
- Policy support
- Change in Procurement Process and regulation

7.4. LEGAL REQUIREMENT

The current regulations are based on diesel buses, e.g. the buses can not be operated for more than 10 years. Such restriction should not apply to E-buses as these have
much longer life and their performance do not deteriorate like the Diesel buses. Another restriction is on the duration of the contracts, which is limited to 10 years for E-buses). Longer duration of contracts reduces the operating fee due to better utilisation of the assets. These regulations should be thoroughly reviewed and updated for E-buses.

In the new Leasing Model, the proposed scheme is to separate ownerships from operation. The Lessor can lease the E-buses to any Operators and can exercise step in or re-lease the E-buses to another Bus Operators, in the event the current Operator breaches or fails to make payment. Basically, it ensures the continuing operation of the buses, regardless the financial capacity of the Operators. The Rp/Km Formulation needs to be revisited to accommodate the Leasing Model as mentioned above and be included in the procurement process.

The Rp/Km Formulation must first be approved by Dinas Perhubungan (Office of Transportation of DKI Jakarta) so that it can be adopted in the Subsidy Agreement between Dishub and TJ.
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