

REPORT

# PERFORMANCE EVALUATION FRAMEWORK

FOR ELECTRIC BUSES IN INDIA

FINAL REPORT

JULY | 2020



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## FOR ELECTRIC BUSES IN INDIA

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**About Shakti:**

Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

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**About UITP:**

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## Abbreviations

|                       |                                                                   |
|-----------------------|-------------------------------------------------------------------|
| <b>ADB</b>            | Asian Development Bank                                            |
| <b>ARAI</b>           | Automobile Research Association of India                          |
| <b>ASRTU</b>          | Association of State Road Transport Undertaking                   |
| <b>CAPEX</b>          | Capital Expenditure                                               |
| <b>CARB</b>           | California Air Resources Board                                    |
| <b>CIRT</b>           | Central Institute Road Transport                                  |
| <b>CNG</b>            | Compressed Natural Gas                                            |
| <b>CO<sub>2</sub></b> | Carbon Dioxide                                                    |
| <b>COVID-19</b>       | Coronavirus disease                                               |
| <b>CPKM</b>           | Cost per kilometre                                                |
| <b>DHI</b>            | Department of Heavy Industries                                    |
| <b>DISCOM</b>         | Electricity Distribution Company                                  |
| <b>e-bus</b>          | Electric bus                                                      |
| <b>EoI</b>            | Expression of Interest                                            |
| <b>EV</b>             | Electric Vehicle                                                  |
| <b>FAME</b>           | Faster Adoption and Manufacturing of Hybrid and Electric Vehicles |
| <b>FTA</b>            | Federal Transit Administration                                    |
| <b>GCC</b>            | Gross-Cost Contract                                               |
| <b>GHG</b>            | Greenhouse Gas                                                    |
| <b>GoI</b>            | Government of India                                               |
| <b>GPS</b>            | Global Positioning System                                         |
| <b>HP</b>             | Horsepower                                                        |
| <b>HRTC</b>           | Himachal Road Transport Corporation                               |
| <b>HSD</b>            | High-Speed Diesel                                                 |
| <b>ICAT</b>           | International Centre for Automotive Technology                    |
| <b>ICE</b>            | Internal Combustion Engine                                        |
| <b>ICCT</b>           | International Council on Clean Transportation                     |
| <b>ICTSL</b>          | Indore City Transport Service Limited                             |
| <b>IFI</b>            | International Financing Institution                               |
| <b>IIT</b>            | Indian Institute of Technology                                    |
| <b>INR</b>            | Indian Rupee                                                      |
| <b>ITS</b>            | Intelligent Transport System                                      |
| <b>kg</b>             | kilogramme                                                        |

|                    |                                                              |
|--------------------|--------------------------------------------------------------|
| <b>kL</b>          | kilolitre                                                    |
| <b>km</b>          | kilometre                                                    |
| <b>KMPL</b>        | kilometre per litre                                          |
| <b>KPI</b>         | Key Performance Indicator                                    |
| <b>KSRTC</b>       | Kerala State Road Transport Corporation                      |
| <b>kV</b>          | kilo-volt                                                    |
| <b>kWh</b>         | kilowatt-hour                                                |
| <b>LCTSL</b>       | Lucknow City Transport Service Limited                       |
| <b>LEB</b>         | Low Emission Bus                                             |
| <b>MBTA</b>        | Massachusetts Bay Transportation Authority                   |
| <b>MIS</b>         | Management Information System                                |
| <b>MoRTH</b>       | Ministry of Road Transport & Highways                        |
| <b>NMMT</b>        | Navi Mumbai Municipal Transport                              |
| <b>NREL</b>        | National Renewable Energy Laboratory                         |
| <b>O&amp;M</b>     | Operation and Maintenance                                    |
| <b>OEM</b>         | Original Equipment Manufacturer                              |
| <b>OPEX</b>        | Operational Expenditure                                      |
| <b>Ps./eff. km</b> | Paise/effective km                                           |
| <b>PTA</b>         | Public Transport Authority                                   |
| <b>R / C</b>       | Reconditioned                                                |
| <b>R&amp;D</b>     | Research and Development                                     |
| <b>SLA</b>         | Service Level Agreement                                      |
| <b>SoC</b>         | State of Charge                                              |
| <b>SPV</b>         | Special Purpose Vehicle                                      |
| <b>sq km</b>       | square kilometre                                             |
| <b>SSEF</b>        | Shakti Sustainable Energy Foundation                         |
| <b>STU/SRTU</b>    | State Transport Undertaking/State Road Transport Undertaking |
| <b>TCO</b>         | Total Cost of Ownership                                      |
| <b>TfL</b>         | Transport for London                                         |
| <b>TRL</b>         | Transport Research Laboratory                                |
| <b>TRW</b>         | Transport Research Wing                                      |
| <b>UITP</b>        | International Association of Public Transport                |
| <b>US</b>          | United States                                                |
| <b>ZEB</b>         | Zero-Emissions Bus                                           |

# 1. Introduction



## 1.1 Electric buses in India: the story so far

Electric buses (e-buses) in India have a relatively short history. The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, launched by the Government of India (GoI) in 2015 to accelerate India's transition from fossil fuel-based vehicles to zero-emission vehicles, kick-started the adoption of electric buses. The scheme provides financial incentives for electric vehicle (EV) purchase, charging infrastructure deployment, and research and development (R&D). The FAME I scheme sanctioned a total of 390 e-buses to be deployed across 11 cities. At the end of FAME-I, in April 2019, GoI announced the second phase of the scheme. The FAME II scheme is being rolled out with an outlay of Indian Rupee (INR) 10,000 crores spread over three years, i.e. Financial Year (FY) 2019-20 to FY 2021-22, to provide demand incentives for EVs. Thirty-five percent of the total FAME II scheme outlay is allocated to e-bus procurement in cities. For this, the Department of Heavy Industries (DHI) has selected 64 cities across India to receive financial incentives for the deployment of 5,595 e-buses. In addition to the FAME scheme, urban bus providers in Ahmedabad, Pune, and Bangalore and State Transport Undertakings (STUs) like Himachal Road Transport Corporation (HRTC) are also procuring e-buses through independent efforts.

More than 600 e-buses are currently operational across India through the FAME I scheme and other independent efforts. The tendering process and identification of operators and Original Equipment Manufacturers (OEMs) for a total of 2,450 buses to be subsidised under FAME-II have already been completed, while close to 1,500 buses are at various stages of procurement. Despite the Coronavirus disease (COVID-19) induced delay in procurement and financing, India is likely to have at least 3,000 e-buses operating across the country within the next year.

## 1.2 Need for e-bus performance evaluation framework

The introduction of e-buses is ushering in a new era of bus service provision in India. First, e-buses themselves are an expensive new technology that varies significantly in operations, planning, and maintenance compared to internal combustion engine (ICE) buses. Cities are yet to identify the best-fit e-bus technologies for their operating conditions. Even as more electric buses are being deployed, it is important to evaluate the performance of already deployed e-buses to **improve their operational performance and inform future procurement choices**. In addition to the technology switch, many bus agencies are also witnessing a change in business models. Many STUs, responsible for public bus operations in India, have traditionally owned and operated their buses. However, they are moving towards the Gross-Cost Contract (GCC) procurement model under FAME-II, wherein the technology risk and investment for the buses is covered by the service provider, while the contracting authority takes responsibility for service planning and delivery and the revenue risk. Performance monitoring of service providers is crucial to ensuring the transparent functioning of GCC operations.







In this context, a data-driven performance evaluation framework for e-buses can help Indian bus agencies meet the following objectives:

- **Technology evaluation to inform future procurement:** Develop a comprehensive understanding of the performance of different e-bus technologies under varying operating conditions and business models, which can be used to define decision-making criteria for future procurement and, at the same time, inform OEMs on vehicle technology improvement needs.
- **Peer to peer learning to improve deployed buses' performance:** Facilitate peer to peer learning across cities through standardised data management and sharing practices. This will help them adopt the best operational practices for the available e-bus technologies, thereby increasing the e-bus lifespan and improving battery and charging infrastructure performance.
- **Monitoring operations and contract management:** Review e-bus operator performance against the Service Level Agreements (SLAs) listed in their contracts to ensure the success of the contract and provide

timely inputs to improve the efficiency of e-bus service delivery.

DHI has already created the necessary ecosystem for such a national performance evaluation framework, mandating that all agencies receiving the FAME-II subsidy create an online platform for performance monitoring and data sharing. However, specific actions have not yet been taken to operationalise the performance monitoring platform.

This report fills in the gap in the available literature to provide guidance to contracting authorities and service providers deploying e-buses on how to evaluate their performance across different vehicle and charging technologies, business models, and operating conditions.

### 1.3 Project background

International Association of Public Transport (UITP), with support from Shakti Sustainable Energy Foundation (SSEF), has undertaken a project on “Creating enabling mechanisms to scale-up adoption of electric buses in Indian cities”. The project focused on providing knowledge support on financial incentives and alternative approaches for e-bus procurement.



As some cities have deployed e-buses under FAME-I, and many others are gearing up for e-bus rollout under FAME-II, it is an opportune time to inform them about best practices in bus performance evaluation, in order to enable them to effectively carry out e-bus performance evaluation. In this context, UITP has undertaken the current exercise, with the following objectives:

- To develop a national framework for e-bus performance monitoring and evaluation mechanisms
- To support STUs and other agencies deploying e-buses in their performance monitoring and evaluation practices

Accordingly, this report has been prepared as part of Objective I, covering the following:

- The importance of performance evaluation for successful e-bus rollout and scale-up in India
- Learnings from current bus performance evaluation practices worldwide and in India
- Recommendations on e-bus performance evaluation in India

## 1.4 Report outline

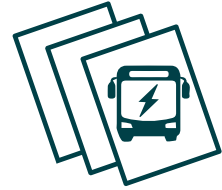
This report focuses on the National Framework for Electric Bus Performance Evaluation, discussing the ecosystem required, the framework's potential applications, and the indicators to be evaluated. The rest of the report is organised as follows:

Chapter 2- Applications and beneficiaries of performance evaluation: Provides an overview of performance evaluation and its applications for e-buses, followed by the benefits that can be accrued by various stakeholders.

Chapter 3- Current performance evaluation practices: Discusses various global practices in e-bus performance evaluation and compares them to Indian practices for e-buses and ICE buses.

Chapter 4- Performance evaluation framework for e-buses: Details the specific Key Performance Indicators proposed for e-buses, the methods, sources, and periodicity of data collection needed to develop these KPIs, and the stakeholders best suited to carry out the data collection.

## 2. Applications and benefits of e-bus performance evaluation



### 2.1 Applications

Performance evaluation refers to specific monitoring and analysis processes to determine how well policies, programmes, and projects perform with regard to their intended goals and objectives<sup>1</sup>. Globally, public transport agencies use performance evaluation and monitoring to:

- Provide information on public transport performance to the authorities and public
- Monitor service improvements, assess past interventions, attract more passengers, and improve the appeal of public transport
- Diagnose problems and the health of the public transport system, making course corrections and refining the strategy
- Provide decision-makers with accurate information to inform decisions on investments, budgeting, etc.
- Set service standards
- Facilitate internal communication and management

In terms of meeting the e-bus technology evaluation, peer to peer learning, and contract management objectives outlined in Chapter 1, performance evaluation can contribute to the following:

**1. Total Cost of Ownership:** The Total Cost of Ownership (TCO) of electric buses includes the capital expenditure (CAPEX) and operational expenditure (OPEX), including cost of financing. CAPEX covers the capital cost of e-buses and associated charging infrastructure, amortised over their lifespan (10-15 years), along with the capital cost of supporting civil and power infrastructure, amortised over their lifespan of 25-30 years. OPEX includes expenditure on staff, energy, vehicle and

battery maintenance, taxes, insurance, and other miscellaneous costs and accounts for the majority of the TCO. Performance evaluation of deployed e-buses in various operating contexts can provide accurate estimates of various components of the TCO, thereby helping cities identify the least expensive option for their operating conditions. The TCO analysis, in turn, can help in the following:

- Incentive design:** The current e-bus incentives under FAME-II and other state-level subsidies are designed as CAPEX subsidies on the vehicle cost in both outright purchase and GCC procurement models. Vehicle CAPEX is typically a minor component of the bus TCO, as staff, energy, and maintenance costs together account for the majority of the cost. An accurate estimation of each of these TCO components can facilitate evaluation of the FAME-II incentive mechanism and the design of alternative incentives for the future.
  - Procurement planning and business model selection:** The performance evaluation of deployed e-buses could help STUs identify the best business model for procurement based on the TCO analysis, i.e. outright purchase or GCC. It could also help them identify appropriate vehicle and infrastructure specifications for the specific operational requirements, based on data from ongoing operations
- 2. Service planning and delivery:** Bus agencies have experience in operating standard ICE buses, which typically operate for the entire day, with just 5-10 minutes of fuelling time. In contrast, e-buses need more time for charging, thus reducing their 'uptime'<sup>2</sup> for operations. Required charging time varies based on e-buses' battery size, energy efficiency, and, consequently, their maximum range per charge. Performance evaluation can include a

<sup>1</sup>Measuring public transport performance, Lessons for Developing Countries, SUTP Technical Document #9, GIZ

<sup>2</sup>Uptime refers to the ratio of the total operational time of a piece of equipment to the total available time.



comprehensive evaluation of e-buses' operational constraints, thereby facilitating the following:

- a. Selection of routes and depots based on performance constraints
- b. Planning for opportunity charging needs
- c. Planning for spare bus fleet needs

**3. Training and capacity building:** Operations management, driving behaviour, and maintenance are some of the key factors that impact e-bus performance. Performance evaluation can help determine the scope for improvement in these areas and aid in identifying areas for staff training and capacity building.

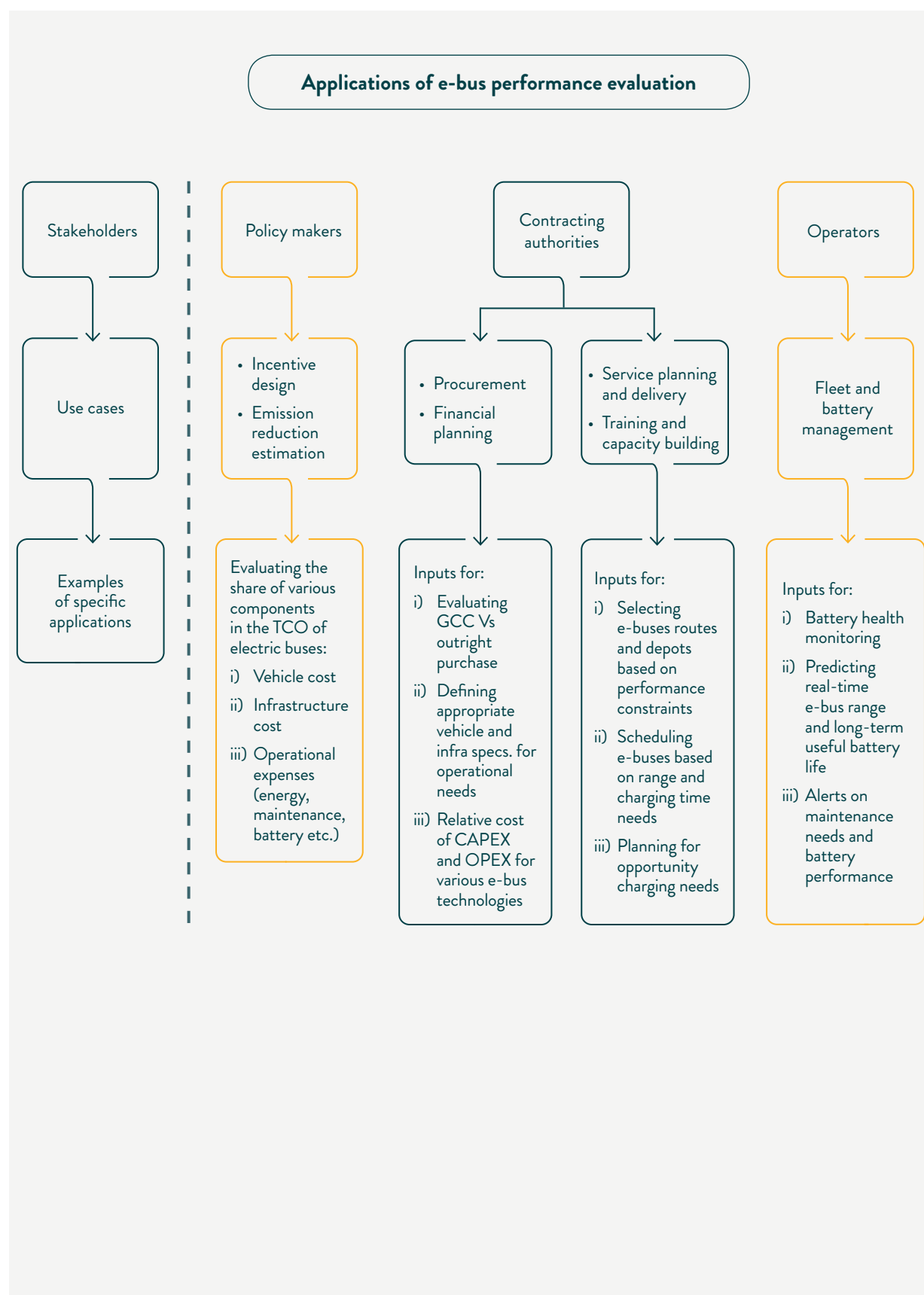
**4. Battery management:** Batteries are the most expensive asset of electric buses and are at the heart

of ensuring the sustainability of e-bus operations. Therefore, e-bus performance evaluation can assist OEMs/operators in

- a. Battery health monitoring
- b. Prediction of the real-time e-bus range and useful battery life for the contract period
- c. Provision of alerts on maintenance needs and battery performance

**5. Emission reduction estimates:** The adoption of e-buses is expected to help reduce emissions from buses. Performance evaluation will facilitate accurate estimation of the air pollution and Greenhouse Gas (GHG) impacts of e-bus deployment, thereby strengthening the case for bus electrification. This will entail continuous evaluation throughout the e-bus lifecycle.

Figure 1: summarises the key applications of performance evaluation, use cases, and stakeholders benefitted.





## 2.2 Stakeholder-wise benefits

e-bus performance evaluation requires the collaboration of all key stakeholders, in order to effectively shape their decision-making and enable improved procurement and operations in the future. The key benefits of e-bus performance evaluation accrued by various categories of stakeholders are outlined below:

### 1. Policy makers and financing institutions

Policy makers and agencies involved in e-bus funding and financing, e.g. DHI, state governments, and International Financing Institutions (IFIs), will benefit from e-bus performance evaluation through:

- o Assessing the impact of current financial and policy incentives for e-bus deployment and learnings for future investments
- o Tracking the contribution of e-buses to achieving India's commitment to global GHG emission reduction targets

### 2. Public transport authorities

STUs and Special Purpose Vehicles (SPVs) that outsource e-bus services or purchase them are categorised as public transport authorities. e-bus performance evaluation benefits these authorities in both short- and long-term decision-making by enabling the following:

- o Effectively monitoring e-bus technical and operational performance against the SLAs outlined in the contract
- o Improving service planning and maximising service delivery based on actual e-bus performance
- o Informing future procurement and financial planning decisions

### 3. Service providers

Performance evaluation helps bus service providers minimise their cost of operations, while simultaneously meeting SLAs, by:

- o Improving charging and battery management
- o Predicting maintenance requirements and associated procurement needs
- o Facilitating battery replacement planning

### 4. Manufacturers

e-bus technology is in its nascent stage and is still evolving. Hence, learning from real-world performance helps OEMs identify improvements that can be incorporated into future product development. Performance evaluation will also help manufacturers project demand based on which model works in what context.



### 3. Current e-bus performance evaluation practices



In this study, the various global examples of e-bus performance evaluation and current practices in India were reviewed to extract learnings to inform the development of an India-specific e-bus performance evaluation framework.

#### 3.1 Global practices

Globally, around 0.42 million (4.2 lakh) e-buses are operational, 99% of which are in China. It is expected that this number will increase to around 18 million by 2020 (BNEF, 2018). China, Europe, and the United States (US) are the three regions with the largest e-bus fleets. A detailed review of the performance evaluation mechanisms adopted in these regions is presented in this section. A brief overview of documents reviewed for this project is given in Table 1. While the transit agencies in certain cities in these regions such as Transport for London (TfL) and Massachusetts Bay Transportation Authority

(MBTA) may be carrying out more comprehensive performance evaluation, only the publicly available data analysed in the current project is covered in this report.

The following sub-sections present the review of the international practices described in the abovementioned documents, covering their strategic priorities, data collection methods, and performance evaluation indicators.

##### 3.1.1 Performance evaluation agencies and objectives

Globally, e-bus performance evaluation is mainly commissioned by transit authorities and government agencies, as well as independent entities in many cases. In Europe and the US, government entities such as Transport for London (TfL) and Federal Transit Administration (FTA) Research commissioned studies to provide guidance on future procurement and evaluate e-bus performance against the set

**Table 1: Documents reviewed on global practices**

| Sl. No | Region | Document Title                                                                               | Published By                                                   | Year    |
|--------|--------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------|---------|
| 1      | China  | Sustainable Transport Solutions: Low Carbon Buses in the People's Republic of China          | Asian Development Bank (ADB)                                   | 2018    |
|        |        | New Energy Bus Operation Evaluation Framework Study                                          | Shenzhen Urban Transport Planning & Design Institute Co., Ltd. | 2018    |
|        |        | Real-world performance of hybrid and electric buses                                          | Grutter Consulting AG                                          | 2015    |
| 2      | Europe | Low Emission Bus System Evaluation Methodology                                               | Transport Research Laboratory (TRL)                            | 2018-19 |
| 3      | US     | FTA Research: Zero-Emission Bus Evaluation Results: King County Metro Battery Electric Buses | National Renewable Energy Laboratory (NREL)                    | 2018    |
|        |        | Foothill Transit Battery Electric Bus Demonstration Results                                  | NREL                                                           | 2016    |

targets. In Shenzhen, China, performance evaluation was undertaken by the Asian Development Bank, in association with Shenzhen Urban Transport Planning and Design Institute. ADB also conducted an independent evaluation in partnership with Grutter, covering multiple Chinese cities with large-scale fleet operations. Most of these studies focused on a specific city. Independent evaluation studies in China were not as comprehensive as the reviews commissioned by public authorities in Europe and the US.

A summary of the strategic objectives, scale, and timelines of the performance evaluation initiatives is given in Table 2. These aspects varied across the cases reviewed according to their applications. In terms of objectives, while financial performance and cost implications were evaluated in all the studies, the evaluation in London also included user feedback and perception on e-buses. The duration of the evaluations also varied significantly amongst the cases, with London having the longest duration, as the project started in 2017 and is still under way.

The applications of performance evaluation also varied based on the strategic objective of the

authority commissioning the evaluation. The major objectives of e-bus performance evaluation globally are the following:

- To estimate the emission reductions from e-buses- The performance evaluation of e-buses in Chinese cities focused on this aspect.
- To evaluate the e-bus TCO- US cities conducted e-bus performance evaluation to estimate the TCO, in order to develop further deployment strategies.
- To identify training and capacity building needs- Chinese and US cities also conducted performance evaluation to identify training and capacity building requirements.
- To assess scope for further improvement in e-buses: All the reviewed entities conducted performance evaluation in part to identify room for further improvement. The key areas of improvement include operational planning, infrastructure procurement, and deployment strategies, real-world e-bus performance, operations, and technology.

**Table 2: Comparison of global e-bus performance evaluation approaches**

| Indicator                              | China                                                                                                                       | Europe                                                                                                                                  | US                                                                                                                                                                                             |                                               |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Coverage                               | Multiple cities                                                                                                             | London                                                                                                                                  | Foothill Transit                                                                                                                                                                               | King County                                   |
| Review undertaken by                   | <ul style="list-style-type: none"> <li>• ADB</li> <li>• Shenzhen Urban Transport Planning &amp; Design Institute</li> </ul> | TRL                                                                                                                                     | NREL                                                                                                                                                                                           | NREL                                          |
| Authority commissioning the evaluation | <ul style="list-style-type: none"> <li>• Independent agencies</li> </ul>                                                    | TfL                                                                                                                                     | FTA                                                                                                                                                                                            | California Air Resources Board (CARB) and FTA |
| Objective                              | Evaluate real-world e-bus performance in China                                                                              | Provide guidance on future Low Emission Bus (LEB) adoption                                                                              | Evaluate e-bus performance against targets                                                                                                                                                     | Demonstrate advanced technology               |
| Scale                                  | Large e-bus fleets                                                                                                          | Large e-bus fleets                                                                                                                      | Pilot evaluation                                                                                                                                                                               | Large e-bus fleets                            |
| Evaluation categories                  | <ul style="list-style-type: none"> <li>• Environmental performance</li> <li>• Financial performance</li> </ul>              | <ul style="list-style-type: none"> <li>• Buses and infrastructure</li> <li>• Public opinion</li> <li>• Financial performance</li> </ul> | <ul style="list-style-type: none"> <li>• Buses and infrastructure</li> <li>• Operations</li> <li>• Cost</li> <li>• Experience of transit authority</li> <li>• Financial performance</li> </ul> |                                               |
| Timeframe                              | 2011- 2017                                                                                                                  | 2017-present                                                                                                                            | July 2014-May 2015                                                                                                                                                                             | April 2016-March 2017                         |



### 3.1.2 Performance evaluation indicators

All the reviewed cases entailed very comprehensive data collection, including documentation of the baseline scenario through data collection on bus system characteristics and infrastructure facilities. The major categories of data collection included:

1. Bus system details
  - a. Bus specifications
  - b. Infrastructure
  - c. Operations and energy
2. Funding and financials
  - a. Investment cost
  - b. Financials
  - c. Operation and maintenance (O&M) costs
3. Other indicators
  - a. Attitude and perception
  - b. Driver satisfaction

Bus specifications and infrastructure details are captured at the beginning of the evaluation, as it is important to analyse the baseline information. Bus operations data collected included route details, daily driving range in kilometres (km), energy consumption, etc. These indicators can provide insights into e-bus reliability, battery performance,

and range in each operating scenario. In full-fledged performance evaluations carried out over a longer period, data variation across time period and temperature were also analysed. Cities in the US also conducted an in-depth analysis of breakdowns and bus availability to assess e-bus reliability. Energy consumption and driving range was collected in all reviewed cases, as this data is needed to calculate energy consumption per km.

The detailed breakup of both the initial CAPEX and OPEX were collected in all cases. US performance evaluations included collection of detailed maintenance data to compare the associated cost with that of ICE buses and determine the reasons for e-buses' higher initial maintenance cost. The work order maintenance cost was also analysed in US cities to estimate each e-bus vehicle part's related cost of operations.

Two additional parameters collected across the reviewed cases were user and driver satisfaction and the ability of the organisation to deliver high-quality bus services based on its previous experience with zero-emissions buses (ZEBs). Inclusion of these parameters indicates a comprehensive approach to evaluation of e-bus service delivery, capturing the perception of end-users and service operators. The summary of performance evaluation indicators is given in Annexure II.



### 3.1.3 Data collection methods and periodicity

The reports published by independent agencies and authorities are based on the collaborative efforts of different stakeholders. In most cases, the agency that conducted the performance evaluation collected the data from manufacturers, operators, and users. Except for Chinese cities, where the data collection was a one-time exercise, the other studies involved frequent data collection. In most cases, the data collection was based on transit agencies' current monitoring practices, and these agencies/authorities already had an extensive performance evaluation mechanism in place.

Furthermore, the data was collected from multiple sources, including telematics, utility bills, activity sheets, etc. An overview of the data collection methods and periodicity is given in Table 3.

2. The major applications for which performance evaluation was conducted include:
  - a. Emission reduction estimation
  - b. TCO estimation
  - c. Identification of training and capacity building needs
  - d. Identification of scope for further operational improvement
3. Transit agencies, bus operating companies, and manufacturers need to collaborate to ensure data availability in order to facilitate efficient data collection in the evaluation.
4. In the majority of reviewed cases, performance evaluation data was collected from standard data logs maintained by transit agencies, instead of

**Table 3: Data collection methods and periodicity in global performance evaluation**

| Description               | China                                             | Europe                                                               | US                                                                                                                                                                 |                                                                                                                           |
|---------------------------|---------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Data collection agency    | ADB, Shenzhen                                     | TRL                                                                  | NREL                                                                                                                                                               | NREL                                                                                                                      |
| Data collection frequency | • Once                                            | • Daily<br>• Monthly<br>• Once                                       | • Daily<br>• Monthly<br>• Once                                                                                                                                     | • Daily<br>• Monthly<br>• Once                                                                                            |
| Data sources              | • Manual surveys<br>• GPS<br>• Electronic reports | • Telematics data<br>• Fuel data<br>• Surveys<br>• Pilot information | • GPS<br>• Utility bills<br>• National Transit Database<br>• Maintenance work orders<br>• Battery SoC<br>• Daily service reports<br>• Daily garage activity sheets | • GPS<br>• Utility bills<br>• National Transit Database<br>• Maintenance work orders<br>• Text format data from operators |
| Stakeholders              | Passengers<br>Operators<br>Transport Authorities  | Passengers<br>Bus Operators                                          | Manufacturers<br>Operators<br>Transport Authority                                                                                                                  | • Manufacturers<br>• Operators<br>• Transport Authority                                                                   |

### 3.1.4 Key learnings from global practices

The key learnings from the review of global practices are summarised below:

1. Initiation of e-bus performance evaluation by decision-makers like transit authorities or other government agencies is a key feature of the more comprehensive evaluations.
2. The major applications for which performance evaluation was conducted include:
  - a. Emission reduction estimation
  - b. TCO estimation
  - c. Identification of training and capacity building needs
  - d. Identification of scope for further operational improvement
3. Transit agencies, bus operating companies, and manufacturers need to collaborate to ensure data availability in order to facilitate efficient data collection in the evaluation.
4. In the majority of reviewed cases, performance evaluation data was collected from standard data logs maintained by transit agencies, instead of through surveys or other evaluation-specific collection campaigns.
5. The key categories of performance evaluation indicators adopted globally are:
  - a. Bus system details
    - i. Bus specifications



- ii. Infrastructure
    - iii. Operations and energy
  - b. Funding and financials
    - i. Investment and financials
    - ii. O&M costs
  - c. Other indicators
    - i. Attitude and perception
    - ii. Driver satisfaction
6. The evaluation needs to be undertaken using the same indicators consistently over several years to establish robust performance results.

## 3.2 Current practices in India

Public bus performance evaluation in India is typically conducted using Key Performance Indicators (KPIs) established by the GoI Central Institute of Road Transport (CIRT). There is great variation in the data collection and KPI reporting practices used across India, with many states and cities not even collecting adequate data to generate the KPIs proposed by CIRT (IIT Delhi, 2016<sup>3</sup>). Furthermore, some STUs adopt different variations of CIRT indicators according to their local contexts and operating models. At the same time, there is significant scope for improvement in the CIRT KPIs themselves, when compared to International best practice examples in performance monitoring, such as those of Transport for London and Massachusetts Bay Transportation Authority (MBTA). It is in this context of inadequate performance evaluation and management of conventional buses that e-buses are being deployed in India.

This section discusses the current bus performance evaluation practices in India in two categories. First, the study examines the evaluation mechanisms and framework for conventional ICE Internal Combustion Engine (ICE) buses. Second, the performance evaluation mechanism for already deployed e-buses is reviewed.

Public bus transport services in India are either

managed by STUs or SPVs. In most cases, the performance evaluation is undertaken by the STU/SPV on a daily basis for the entire fleet and is not linked to policy making, transport planning, decision-making, etc. Some STUs use KPIs for peer comparison between depots and set targets based on them. Additionally, CIRT and the Ministry of Road Transport and Highways (MoRTH) compare the performance of multiple STUs every year to provide a pan-India perspective on public bus systems throughout the country.

### 3.2.1 Indicator categories

The published data on STUs) comprises indicators on their financial and operational performance. The financial performance indicators are grouped into:

- Capital
- Liabilities
- Assets
- Cost
- Taxes
- Interest
- Revenue

Operational performance indicators are grouped into:

- Category I: Fleet utilisation- bus count and total km covered by the STUs
- Category II: Capacity utilisation in terms of the average number of seats, passengers, etc.
- Category III: Quality of service, including regularity, reliability, and punctuality. This also includes safety indicators.
- Category IV: Manpower productivity in terms of staff strength and category
- Category V: Material performance indicators, including consumption of fuel and other materials like lubricants, engine oil, tyres, etc.

Furthermore, SRTUs also collect data categorised based on the different manufacturers, spare parts, etc. The current detailed indicator list for ICE buses is given in Annexure I.

<sup>3</sup>M Jain, M., Jain, H., Tiwari, G. & Rao, K.R. (2016) Indicators to Measure Performance Efficiency of Bus Systems. Final Report. Prepared for Shakti Sustainable Energy Foundation, New Delhi. TRIPP-PR-16-02. Transportation Research and Injury Prevention Programme, Indian Institute of Technology Delhi.

### 3.2.2 Data collection methods and periodicity

The annual reports published by CIRT are based on the data supplied by the STUs on a quarterly basis in a predefined format. The data is collected from approximately 53 reporting STUs and SPVs across the country, which includes both urban and rural services. One challenge is that most SPVs are not part of the regular data collection process. Therefore, the annual compilation by CIRT or the Transport Research Wing (TRW) only includes evaluation of data from the reporting STUs and a few SPVs.

### 3.3 Performance evaluation practices of Indian e-bus operators

STUs typically monitor their operational performance schedule-wise at a depot level. This data is compiled at the STU level for submission to CIRT. The typical operational information, i.e. Management Information System (MIS) data, is collected through manual methods or an Intelligent Transport System (ITS) in the case of advanced STUs. The O&M data at the depot level are collected on a daily basis, whereas financial performance indicators are typically collected on a monthly basis. In the case of outsourced

operations, the frequency of data collection may also depend on the frequency of payment, which is typically linked to KPIs. Performance evaluation practices of Indian e-bus operators

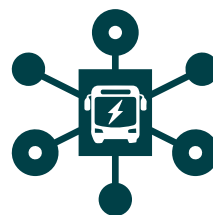
India currently has about 600 e-buses, out of which 560 can be considered public transport fleets (i.e. at least 10 buses per fleet) deployed by 11 bus agencies, as presented in Table 4. While 385 of these were procured through GCC, a total of 175 buses in Lucknow, Kolkata, Jammu and Kashmir, and Guwahati were procured through outright purchase using the FAME I subsidy. While these agencies continue to collect bus operations related KPIs such as fleet availability, vehicle utilisation, and punctuality, e-bus technology-specific KPIs such as energy consumption, charger and battery performance, etc. are not captured in great detail. Most agencies just collect the electricity consumption data across all the buses, without measuring bus, charger, and route-wise performance. Hence, Indian bus agencies need to improve their performance evaluation practices to track their own e-bus performance and compare themselves with other agencies. A standardised set of KPIs across agencies can improve operational efficiency and inform future procurement decisions.

**Table 4: Overview of current e-bus fleets in India\***

| Location          | No. of e-buses | OEM/ Supplier                                 |
|-------------------|----------------|-----------------------------------------------|
| Pune              | 144            | Olectra Goldstone-BYD                         |
| Himachal Pradesh  | 75             | Olectra Goldstone-BYD (25) and Foton-PMI (50) |
| Mumbai            | 46             | Olectra Goldstone-BYD                         |
| Hyderabad         | 40             | Olectra Goldstone-BYD                         |
| Ahmedabad         | 40             | Ashok Leyland + Sun Mobility                  |
| Navi Mumbai       | 30             | JBM Solaris                                   |
| Lucknow           | 40             | Tata Motors                                   |
| Kolkata           | 80             | Tata Motors                                   |
| Jammu and Kashmir | 40             | Tata Motors                                   |
| Guwahati          | 15             | Tata Motors                                   |
| Kerala            | 10             | Olectra Goldstone-BYD                         |
| Total e-buses     | 560            |                                               |

\* This list only includes e-bus fleets (at least 10 buses) being used for public transport. There are other niche applications and trials for such e-buses across India, such as a single e-bus operating on trial in Thane, using e-buses in tarmac operations in the Delhi, Chennai, and Hyderabad airports, and private intercity e-buses in Maharashtra, among others.

## 4. Proposed e-bus performance evaluation framework



A performance evaluation framework for e-buses in India is presented in this chapter, based on the best practices from current bus performance evaluation in India and the review of international examples. This section discusses the strategic intent of performance evaluation, proposed indicators, and the possible data collection methods and sources for these indicators. Further details on the specific stakeholders to be in charge of data collection, data sources, etc. have been detailed in Annexure III. Real-time performance monitoring is a continuous effort that involves continuous tracking of KPIs, which, in turn, requires an efficient Intelligent Transport System for buses.

As discussed in Chapter 2, many Indian states and cities have poor data management and ITS practices that prevent them from carrying out effective real-time performance monitoring. In these cases, periodic performance evaluation of the identified KPIs should be taken up in simple spreadsheet/ excel based templates as a first step, even in cities without ITS and real-time monitoring systems. Hence, this chapter explains performance evaluation assuming there is periodic, as opposed to real-time, data collection. The same indicators can easily be incorporated into real-time monitoring systems where available. Furthermore, these indicators are presented in two stages: Stage 1 comprises essential

indicators specific to electric buses that all e-bus implementing agencies are advised to collect to ensure successful operations, whereas Stage 2 incorporates the essential indicators within a broader set of indicators that cover the overall operational and financial performance of the bus system, in addition to just evaluating the e-bus specific indicators. These are termed as ‘recommended indicators’ that can make the evaluation more comprehensive. Both essential and recommended indicators can be generated by most traditional/ manual methods of data collection, as well as from advanced ITS/ MIS.

### 4.1 Proposed e-bus performance evaluation indicators

The proposed indicators for electric bus performance evaluation are categorised into:

- a. Bus system details
  - i. Bus specifications
  - ii. Infrastructure
  - iii. Operations
  - iv. Energy
  - v. Personnel
- b. Funding and financial indicators
- c. Other indicators
  - i. User attitude and perception

The list of indicators is based on the CIRT list, with new indicators added that are specific to electric buses. The indicator list and its comparison to CIRT indicators are given in Annexure III.

Table 5 presents the essential indicators that should be collected by all bus agencies implementing e-buses. These should be collected for both GCC and outright purchase based procurement, as these indicators are needed to effectively monitor e-bus performance and develop operational improvement strategies and procurement specifications for planned e-bus deployments.



Table 5: Essential e-bus performance evaluation indicators

| SI No                        | INDICATOR                             | SUB-INDICATOR                                | DESCRIPTION                                                                                      |
|------------------------------|---------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------|
| <b>BUS SYSTEM DETAILS</b>    |                                       |                                              |                                                                                                  |
| <b>I. BUS SPECIFICATIONS</b> |                                       |                                              |                                                                                                  |
| 1                            | Total number of buses                 |                                              |                                                                                                  |
| 1a                           |                                       | No. of 9m buses                              |                                                                                                  |
| 1b                           |                                       | No. of 12m buses                             |                                                                                                  |
| <b>III. Operations</b>       |                                       |                                              |                                                                                                  |
| 2                            | Average number of buses on-road       |                                              |                                                                                                  |
| 3                            | No. of operational days per month     |                                              |                                                                                                  |
| 4                            | Scheduled km per bus per day          |                                              |                                                                                                  |
| 5                            | Operated km per bus per day           |                                              | Average operated km across the routes                                                            |
| 6                            | Average odometer reading              |                                              |                                                                                                  |
| 7                            | Scheduled revenue hours per bus       |                                              |                                                                                                  |
| 8                            | Time spent at a depot per bus per day |                                              | Total time spent, including charging, cleaning, & routine maintenance                            |
| 9                            | Total cancelled km                    |                                              |                                                                                                  |
| 9a                           |                                       | due to power availability issues             |                                                                                                  |
| 9b                           |                                       | due to charging issues                       |                                                                                                  |
| 9c                           |                                       | due to battery issues                        |                                                                                                  |
| 9d                           |                                       | due to electric drive issues                 |                                                                                                  |
| 9e                           |                                       | due to other reasons                         |                                                                                                  |
| 10                           | Total number of bus breakdowns so far |                                              |                                                                                                  |
| <b>IV. Energy</b>            |                                       |                                              |                                                                                                  |
| 11                           | Bus energy efficiency (kWh/km)        |                                              | Total energy consumed (measured in Kilo-Watt Hours (kWh)) over the total distance travelled (km) |
| 12                           | Charger capacity (kWh)                |                                              |                                                                                                  |
| 13                           | No. of charging events per day        |                                              |                                                                                                  |
| 14a                          | Charging 1                            | Charging duration                            |                                                                                                  |
| 14b                          |                                       | State of Charge (SoC) at start of Charging 1 |                                                                                                  |
| 14c                          |                                       | SoC at end of Charging 1                     |                                                                                                  |
| 14d                          |                                       | Distance travelled for Charging 1 (km)       |                                                                                                  |

| SI No                            | INDICATOR                               | SUB-INDICATOR                                                                  | DESCRIPTION                                 |
|----------------------------------|-----------------------------------------|--------------------------------------------------------------------------------|---------------------------------------------|
| 15a                              | Charging 2                              | Charging duration                                                              |                                             |
| 15b                              |                                         | SoC at start of Charging 2                                                     |                                             |
| 15c                              |                                         | SoC at end of Charging 2                                                       |                                             |
| 15d                              |                                         | Distance travelled for Charging 2 (km)                                         |                                             |
| 16a                              | Charging 3                              | Charging duration                                                              |                                             |
| 16b                              |                                         | SoC at start of Charging 3                                                     |                                             |
| 16c                              |                                         | SoC at end of Charging 3                                                       |                                             |
| 16d                              |                                         | Distance travelled for Charging 3 (km)                                         |                                             |
| 17                               | Power consumed per day (kWh)            |                                                                                | Total power consumed in all charging events |
| 18                               | Energy cost (INR per kWh)               |                                                                                |                                             |
| <b>B. FUNDING AND FINANCIALS</b> |                                         |                                                                                |                                             |
| 19                               | Business model (Outright purchase/ GCC) |                                                                                |                                             |
| 20                               | If GCC                                  |                                                                                |                                             |
| 20a                              |                                         | Cost per km (CPKM) (paid to the operator if GCC)/ Payment paid to the operator |                                             |
| 20b                              |                                         | Conductor CPKM                                                                 |                                             |
| 20c                              |                                         | CPKM of traffic supervision staff + admin staff                                |                                             |
| 20d                              |                                         | Energy CPKM                                                                    |                                             |
| 21                               | If outright purchase                    |                                                                                |                                             |
| 21a                              |                                         | Cost of bus purchase                                                           |                                             |
| 21b                              |                                         | Cost of charging infrastructure (if available)                                 |                                             |
| 21c                              |                                         | Staff CPKM                                                                     |                                             |
| 21d                              |                                         | Maintenance CPKM                                                               |                                             |
| 21e                              |                                         | Energy CPKM                                                                    |                                             |
| 22                               | e-bus earnings per km (EPKM)            |                                                                                |                                             |

Table 6 presents the ‘recommended indicators’ for e-bus performance evaluation, which expand on the ‘essential indicators’ covered in Table 5. It includes a total of 57 Key KPIs identified to monitor and evaluate e-bus performance. The bus system details, manpower, infrastructure component, and bus operations include CIRT indicators that are typically

collected. The main new indicators proposed include those related to charging infrastructure specifications, energy consumption, and financing patterns for new procurement models. The detailed definition of each indicator and any associated formula is given in Annexure II.



Table 6: Recommended e-bus performance evaluation indicators

| SI No                             | INDICATOR                                           | SUB-INDICATOR    | DESCRIPTION                                              |
|-----------------------------------|-----------------------------------------------------|------------------|----------------------------------------------------------|
| C. BUS SYSTEM DETAILS             |                                                     |                  |                                                          |
| I. BUS SPECIFICATIONS             |                                                     |                  |                                                          |
| 1                                 | OEM name                                            |                  | Manufacturer name                                        |
| 2                                 | Total number of buses                               |                  |                                                          |
| 2a                                |                                                     | No. of 9m buses  |                                                          |
| 2b                                |                                                     | No. of 12m buses |                                                          |
| 3                                 | Date of bus induction                               |                  | Date of induction of each bus lot                        |
| 4                                 | Length/width/height                                 |                  | Technical specifications of the e-buses                  |
| 5                                 | Gross Vehicle Weight                                |                  |                                                          |
| 6                                 | Wheelbase                                           |                  |                                                          |
| 7                                 | Passenger capacity                                  |                  |                                                          |
| 8                                 | Rated power (Horse Power (HP))                      |                  |                                                          |
| II. INFRASTRUCTURE SPECIFICATIONS |                                                     |                  |                                                          |
| 9                                 | Charger description                                 |                  |                                                          |
| 10                                | Total no. of chargers                               |                  |                                                          |
| 11                                | Capacity of depot charging infrastructure (kW)      |                  | Capacity provided at the depot                           |
| 12                                | Capacity of enroute charging facility (if any) (kW) |                  |                                                          |
| 13                                | Power supply to the depot (kV)                      |                  |                                                          |
| 14                                | Number of e-bus depots                              |                  |                                                          |
| 15                                | No. of e-buses per depot                            |                  |                                                          |
| 16                                | Total depot land area available (sq km)             |                  | Specified as land per depot                              |
| III. Operations                   |                                                     |                  |                                                          |
| 17                                | Average number of on-road buses                     |                  |                                                          |
| 18                                | No. of operational days per month                   |                  |                                                          |
| 19                                | Scheduled km per bus per day                        |                  |                                                          |
| 20                                | Dead km per bus per day                             |                  | Average dead km across all routes                        |
| 21                                | Operated km per bus per day                         |                  | Average operated km across all routes                    |
| 22                                | Average odometer reading                            |                  |                                                          |
| 23                                | Steering hours per bus per day                      |                  | Total operational hours of the bus including break times |

| SI No             | INDICATOR                                | SUB-INDICATOR                          | DESCRIPTION                                                           |
|-------------------|------------------------------------------|----------------------------------------|-----------------------------------------------------------------------|
| 24                | Scheduled revenue hours per bus          |                                        |                                                                       |
| 25                | Time spent at a depot per bus per day    |                                        | Total time spent, including charging, cleaning, & routine maintenance |
| 26                | Total cancelled km                       |                                        |                                                                       |
| 26a               |                                          | due to staff shortage                  |                                                                       |
| 26b               |                                          | due to bus unavailability              |                                                                       |
| 26c               |                                          | due to bus breakdown during operations |                                                                       |
| 26d               |                                          | due to traffic congestion              |                                                                       |
| 26e               |                                          | due to power availability issues       |                                                                       |
| 26f               |                                          | due to charging issues                 |                                                                       |
| 26g               |                                          | due to battery issues                  |                                                                       |
| 26h               |                                          | due to electric drive issues           |                                                                       |
| 26i               |                                          | due to other reasons                   |                                                                       |
| 27                | Time interval between maintenance events |                                        |                                                                       |
| 28                | Total number of bus breakdowns           |                                        |                                                                       |
| 29                | No. of routes                            |                                        |                                                                       |
| 30                | Average route length                     |                                        |                                                                       |
| 31                | Buses per route                          |                                        |                                                                       |
| 32                | Stops per route                          |                                        |                                                                       |
| 33                | Trips per route                          |                                        |                                                                       |
| 34                | Average speed                            |                                        |                                                                       |
| 35                | Average e-bus Load Factor (LF)           |                                        |                                                                       |
| <b>IV. Energy</b> |                                          |                                        |                                                                       |
| 36                | Bus energy efficiency (kWh/km)           |                                        | Total energy consumed (kWh) over the total distance travelled         |
| 37                | No. of charging events per day           |                                        |                                                                       |
| 38a               | Charging 1                               | Charging duration                      |                                                                       |
| 38b               |                                          | SoC at start of Charging 1             |                                                                       |
| 38c               |                                          | SoC at end of Charging 1               |                                                                       |
| 38d               |                                          | Distance travelled for Charging 1 (km) |                                                                       |

| SI No                            | INDICATOR                                                           | SUB-INDICATOR                                                    | DESCRIPTION                                                   |
|----------------------------------|---------------------------------------------------------------------|------------------------------------------------------------------|---------------------------------------------------------------|
| 39a                              | Charging 2                                                          | Charging duration                                                |                                                               |
| 39b                              |                                                                     | SoC at start of Charging 2                                       |                                                               |
| 39c                              |                                                                     | SoC at end of Charging 2                                         |                                                               |
| 39d                              |                                                                     | Distance travelled for Charging 2 (km)                           |                                                               |
| 40a                              | Charging 3                                                          | Charging duration                                                |                                                               |
| 40b                              |                                                                     | SoC at start of Charging 3                                       |                                                               |
| 40c                              |                                                                     | SoC at end of Charging 3                                         |                                                               |
| 40d                              |                                                                     | Distance travelled for Charging 3 (km)                           |                                                               |
| 41                               | Power consumed per day                                              |                                                                  | Total power consumed in all charging events (kWh)             |
| 42                               | Energy cost (INR per kWh)                                           |                                                                  |                                                               |
| <b>V. Personnel</b>              |                                                                     |                                                                  |                                                               |
| 43                               | No. of drivers                                                      |                                                                  |                                                               |
| 44                               | No. of conductors                                                   |                                                                  |                                                               |
| 45                               | No. of maintenance staff                                            |                                                                  |                                                               |
| 46                               | No. of contract management staff                                    |                                                                  |                                                               |
| 47                               | Other staff                                                         |                                                                  |                                                               |
| <b>D. FUNDING AND FINANCIALS</b> |                                                                     |                                                                  |                                                               |
| 48                               | Cost of electric infrastructure (11kV/ 66kV line, transformer etc.) |                                                                  | This includes the cost of upstream electricity infrastructure |
| 49                               | Business model (Outright purchase/ GCC)                             |                                                                  |                                                               |
| 50                               | If GCC                                                              |                                                                  |                                                               |
| 50a                              |                                                                     | CPKM (paid to the operator if GCC)/ Payment paid to the operator |                                                               |
| 50b                              |                                                                     | Conductor CPKM                                                   |                                                               |
| 50c                              |                                                                     | CPKM of traffic supervision staff + admin staff                  |                                                               |
| 50d                              |                                                                     | Energy CPKM                                                      |                                                               |

| SI No | INDICATOR                          | SUB-INDICATOR                                  | DESCRIPTION                                |
|-------|------------------------------------|------------------------------------------------|--------------------------------------------|
| 51    | If outright purchase               |                                                |                                            |
| 51a   |                                    | Cost of bus purchase                           |                                            |
| 51b   |                                    | Cost of charging infrastructure (if available) |                                            |
| 51c   |                                    | Staff CPKM                                     |                                            |
| 51d   |                                    | Maintenance CPKM                               |                                            |
| 51e   |                                    | Energy CPKM                                    |                                            |
| 52    | Subsidy amount                     | FAME subsidy amount                            |                                            |
|       |                                    | State subsidy amount                           |                                            |
| 53    | Source of subsidy                  |                                                |                                            |
| 54    | Source of financing beyond subsidy |                                                | Commercial loans/ grants/ in-house budgets |
| 55    | If loan                            | Loan interest rate                             |                                            |
| 56    |                                    | Loan tenure                                    |                                            |
| 57    | e-bus earnings per km              |                                                |                                            |

## E. OTHER INDICATORS

The other indicators commonly analysed in global evaluations include the attitude and perception of users and drivers. The Indian Institute of Technology (IIT) Delhi<sup>4</sup> study also identified the need to capture data on user perception, which is currently not collected in India. The following specific e-bus performance evaluation indicators are required to assess user perception:

- Attitude towards using e-buses
- Noise levels inside the e-bus
- Comfort of travelling, including riding comfort, in comparison to ICE buses,

These indicators should be collected in addition to the other user perception indicators that an STU/authority is ideally already collecting to assess user perception of public bus transport. The next sub-section discusses the framework for this data collection, including methods, sources, and periodicity.

## 4.2 Data collection methods, sources, and periodicity

Chapter 3 presented the current methods of data collection in Indian STUs. This includes MIS reports (both operation and maintenance), ITS reports, manual data entry, and STU databases on fleets and depots.

In addition, new data collection sources are available for e-buses, such as:

- ITS schedule-wise charging reports
- Electricity bills from DISCOMs and meter readings at depots and chargers
- OEM/operator invoices

The indicators that can be evaluated based on data from these new sources are summarised in Table 7, Table 8, and Table 9.

<sup>4</sup><https://shaktifoundation.in/wp-content/uploads/2016/07/Indicators-to-measure-performance-efficiency-of-bus-systems1.pdf>

Table 7: New Indicators to be collected from schedule-wise charging reports

| Data Source: ITS schedule-wise charging reports |
|-------------------------------------------------|
| Number of charging events                       |
| Charging 1 duration                             |
| SoC at start of Charging 1                      |
| SoC at end of Charging 1                        |
| Distance travelled for Charging 1 (km)          |
| Charging 2 duration                             |
| SoC at start of Charging 2                      |
| SoC at end of Charging 2                        |
| Distance travelled for Charging 2 (km)          |
| Charging 3 duration                             |
| SoC at start of Charging 3                      |
| SoC at end of Charging 3                        |
| Distance travelled for Charging 3 (km)          |

Table 8: New Indicators to be collected from DISCOMs/ related sources

| Data Source: DISCOMs           |
|--------------------------------|
| Bus energy efficiency (kWh/km) |
| Power consumed per day         |
| Energy cost (INR per kWh)      |
| Energy CPKM                    |

Table 9: New Indicators to be collected from OEM/operator invoices to government entities

| Source: Operator/OEM Invoices to SRTUs/Authorities |
|----------------------------------------------------|
| CPKM (payment to the operator)                     |
| Cost of bus purchase (if applicable)               |
| Cost of charging infrastructure (if available)     |

The abovementioned indicators need to be monitored by the authority at a certain frequency, for which the data needs to be collected either daily, monthly, or at the beginning of the evaluation. Accordingly, all indicators are classified based on the periodicity of data collection. The bus system details and infrastructure indicators only need to be collected at the beginning of evaluation, as they should largely remain constant. The bus operations details and energy indicators need to be collected on a daily basis, as these data indicators vary with respect to the specific daily operating conditions. Finally, certain

indicators related to personnel and financing based on the procurement model, utility bills, etc. need to be collected on a monthly basis, as these data are typically provided at the end of each month. The detailed framework of indicators given in Annexure III mentions the periodicity for each indicator.

### 4.3 Responsibility for data collection

The involvement of different stakeholders in the performance evaluation depends on the type of procurement model. The key stakeholders include:



- STUs/contracting authorities
- Operators
- OEMs

Table 9, Table 10, and Table 11 give stakeholder-wise lists of indicators to be collected. The lists are

based on a GCC procurement scenario, as the FAME II subsidy scheme is only applicable to the GCC model. In an outright purchase model with an annual maintenance contract with an OEM, only maintenance-related indicators are the responsibility of OEM, and all other indicators need to be collected by the STU/Authority.

**Table 10: Indicators to be collected by the STU/Contracting Authority**

| Name of the OEM                                                      |
|----------------------------------------------------------------------|
| Total number of buses                                                |
| No. of 9m buses                                                      |
| No. of 12m buses                                                     |
| Date of induction of buses                                           |
| Length/width/height                                                  |
| Gross Vehicle Weight                                                 |
| Wheelbase                                                            |
| Passenger capacity                                                   |
| Rated power (HP)                                                     |
| Average number of on-road buses                                      |
| No. of operational days per month                                    |
| Scheduled km per bus per day                                         |
| Dead km per bus per day                                              |
| Scheduled revenue hours per bus                                      |
| No. of routes                                                        |
| Average route length                                                 |
| Buses per route                                                      |
| Stops per route                                                      |
| Trips per route                                                      |
| Average e-bus LF                                                     |
| Energy cost (INR per kWh)                                            |
| Cost of electric infrastructure (11kV/ 66kV line, transformer, etc.) |
| Number of e-bus depots                                               |
| No. of e-buses per depot                                             |
| Total depot land area available (sq km)                              |
| No. of conductors                                                    |
| No. of contract management staff                                     |
| Other staff                                                          |

| Name of the OEM                                                  |
|------------------------------------------------------------------|
| Business model (Outright purchase/ GCC)                          |
| CPKM (paid to the operator if GCC)/ Payment paid to the operator |
| Conductor CPKM                                                   |
| CPKM of traffic supervision staff + admin staff                  |
| Cost of bus purchase                                             |
| Cost of charging infrastructure (if available)                   |
| Staff CPKM                                                       |
| Maintenance CPKM                                                 |
| Energy CPKM                                                      |
| Subsidy amount                                                   |
| Source of subsidy                                                |
| Source of financing beyond subsidy                               |
| e-bus earnings per km                                            |

**Table 11: Indicators to be collected by the operator**

| Name of the operator                   |
|----------------------------------------|
| Operated km per bus per day            |
| Average odometer reading               |
| Steering hours per bus per day         |
| Time spent at a depot per bus per day  |
| Total cancelled km                     |
| due to staff shortage                  |
| due to bus unavailability              |
| due to bus breakdown during operations |
| due to traffic congestion              |
| due to transmission issues             |
| due to charging issues                 |
| due to battery issues                  |
| due to electric drive issues           |
| due to other reasons                   |
| Total number of bus breakdowns so far  |
| Average speed                          |
| Energy efficiency of buses (kWh/km)    |
| No. of drivers                         |
| Interest rate on loan                  |
| Loan tenure                            |

Table 12: Indicators to be collected by OEMs

| Name of the OEM                                     |
|-----------------------------------------------------|
| Time interval between maintenance events            |
| No. of charging cycles per day                      |
| Charging 1 duration                                 |
| SoC at start of Charging 1                          |
| SoC at end of Charging 1                            |
| Distance travelled for Charging 1 (km)              |
| Charging 2 duration                                 |
| SoC at start of Charging 2                          |
| SoC at end of Charging 2                            |
| Distance travelled for Charging 2 (km)              |
| Charging 3 duration                                 |
| SoC at start of Charging 3                          |
| SoC at end of Charging 3                            |
| Distance travelled for Charging 3 (km)              |
| Power consumed per day                              |
| Charger description                                 |
| Total no. of chargers                               |
| Capacity of depot charging infrastructure (kW)      |
| Capacity of enroute charging facility (if any) (kW) |
| Power supply to the depot (kV)                      |
| No. of maintenance staff                            |

To summarise, e-bus performance evaluation requires a multi-stakeholder approach to ensure comprehensive data collection and fulfil the objectives of all stakeholders. The detailed proposed performance evaluation framework is given in Annexure III.

#### 4.4 National e-bus data-sharing platform

The KPIs proposed for e-bus performance evaluation need to be calculated based on data collected from multiple sources, as listed in Section 4.2, and by multiple stakeholders, as listed in Section 4.3. Furthermore, the performance evaluation needs to be carried out by each city/ state, and the KPIs needs

to be compared with those of other cities and states to benchmark their performance. In addition to helping cities with their operational strategies, such benchmarking will also support DHI in evaluating the performance of e-bus funding through the FAME scheme and designing future subsidies to encourage the best-performing systems.

Given the benefits of adopting a pan-India framework, it is recommended that DHI support the development of a common platform to track the progress of e-bus implementation across the country and benchmark e-bus performance. The following are the key points to consider when developing such a platform:

### 1) Learning from the current performance monitoring platforms

- Performance monitoring of conventional ICE buses is currently carried out using a combination of ITS and MIS based platforms
- The existing ITS and MIS systems in India are typically driven by the vendors providing the software service or those deploying the ITS hardware. As a result, most Indian cities do not have an integrated ITS and MIS platform that helps them monitor their overall performance.
- One of the key reasons for the lack of a comprehensive solution in India is that each city has tried to develop its own platform, even though they do not always possess the required technical and financial resources that are needed for such a system.

### 2) Need and scope for the proposed national platform

- Developing a national platform can help pool resources centrally to develop a good quality solution that works across all states and cities.
- The performance evaluation framework proposed in the previous sections is designed to cover both technology-related performance indicators like energy efficiency, charging time, range, and breakdowns and other indicators covering operations, user perception, and funding and financing.
- Hence, the proposed national platform can either be designed as a part of the wider public bus performance monitoring efforts or with a specific focus on e-bus-specific performance evaluation indicators.
- It is recommended that the platform cater to both ITS based real-time performance monitoring

and MIS/ excel data input based performance evaluation, to ensure that it can be adopted by all states and cities, regardless of their level of technology access in their operations.

- As an interim step towards developing a national ITS/ MIS platform, it is recommended that a simple spreadsheet/ excel based data sharing template be circulated among cities implementing e-buses. The template can adopt the framework proposed in this report.
- The national platform can initially compile and compare e-bus performance data across cities based on an excel-based data collection template. Once the excel-based performance monitoring mechanism has been rolled out across India and is operating smoothly, the platform can transition to more advanced methods like MIS and ITS.

### 3) Venue for national performance monitoring platform development and management

- Consistent efforts to develop and sustain the national e-bus performance monitoring platform are of paramount importance to ensure its successful deployment and accrue the benefits of the platform.
- It is recommended that GoI backed centres of excellence such as CIRT, Automobile Research Association of India (ARAI), or the International Centre for Automotive Technology (ICAT), Manesar are entrusted with the responsibility of developing and maintaining the platform, with support from external agencies such as UITP, International Council on Clean Transportation (ICCT), or consulting firms specialising in the topic. These agencies have the technical competence to adopt both the excel-based monitoring and the more advanced MIS/ ITS systems.



## 5. Way forward



Electric bus implementation has been initiated through the FAME I scheme and has now picked up momentum through FAME-II and various state-level initiatives focused on promoting clean mobility technologies. As cities selected for the FAME II subsidy and others prepare for the deployment of e-buses, it is important to ensure that they have a framework for carrying out comprehensive performance evaluation to improve their implementation efficiency and inform future procurement efforts. To this end, this report presented potential applications of e-bus performance evaluation, performance evaluation indicators, and an overall framework for data collection and performance evaluation.

It is important to include e-bus specific KPIs in existing institutional mechanisms to ensure a smooth transition to e-bus performance evaluation. This can be done by retaining the KPIs from ICE buses for operational and financial indicators, while adding in e-bus-specific KPIs such as energy consumption and battery and charging infrastructure performance.

Furthermore, implementing agencies and policy makers need to ensure that data is collected effectively. Accordingly, the following next steps are recommended to help Indian cities benefit from the proposed performance evaluation framework:

**1. Incorporate the proposed performance evaluation framework into the DHI guidelines for STUs/ city authorities** deploying e-buses. DHI has already proposed e-bus performance evaluation in its Expression of Interest (EoI) inviting cities to undertake e-bus operations. Therefore, the framework proposed in this report and the detailed steps outlined for the adoption of performance evaluation by respective implementing agencies can form the basis for the data sharing mandated by DHI.

**2. Pilot the proposed e-bus performance evaluation framework** in cities that have already deployed e-buses. This can be carried out in partnership with the STU, OEM, and operator involved to test the validity of the developed framework and build the capacity of all the stakeholders in order to make performance evaluation a core part of their operations and future decision-making. The pilot can be based on simple data collection processes using manual and excel-based

methods in case the agency does not have access to MIS/ ITS systems.

**3. Develop a national e-bus data sharing platform:** A national data sharing platform needs to be established to help cities implement the proposed performance evaluation framework, so that they can quickly adopt the system instead of developing one on their own, and DHI can efficiently monitor the performance of e-buses subsidised under the FAME scheme. The platform should be maintained by agencies such as CIRT, ARAI, or ICAT, which can quickly build the technical skillsets needed for such a platform. A unified platform will help in standardising data management and sharing protocols, even as the scale of e-bus implementation at the city level progresses from pilots to fleet level deployment. Initially, this platform can use simple excel-based data management templates to ensure its widespread adoption and then gradually introduce more advanced MIS and ITS based data sharing protocols.

**4. Institutionalise performance evaluation in STUs:** The proposed performance evaluation framework needs to be integrated into the STUs'/authorities' continuous monitoring activities to learn from previous experiences and improve operational strategies. This entails incorporating e-bus-specific KPIs, such as e-bus energy efficiency (kWh/km), charging duration, related off-time, etc., into their conventional performance evaluation mechanisms.

**5. Knowledge sharing and capacity building programmes:** As STUs and cities gain experience in e-bus deployment and operations, there need to be opportunities for them to exchange knowledge and learn from each other's experiences. In parallel, capacity building programmes exposing them to the latest trends in e-bus technologies, planning, procurement, and management will ensure the sustainability of their operations and facilitate further scale-up.

**6. Integrate the new e-bus performance evaluation indicators into CIRT and TRW frameworks.** The proposed framework includes new indicators necessary for e-bus performance evaluation; these indicators should be incorporated into the CIRT and TRW frameworks. This will ensure that STUs/authorities collect e-bus indicators for their annual reporting to CIRT and TRW.

## 6. Annexures



### 6.1 Annexure I: CIRT data indicator list

| Indicator                          | Unit                              |
|------------------------------------|-----------------------------------|
| <b>Financial Performance</b>       |                                   |
| <b>Category I – Total Cost</b>     |                                   |
| <b>a. Personnel Cost</b>           | INRper effective-km of operation  |
| i. Drivers                         |                                   |
| ii. Conductors                     |                                   |
| iii. Traffic Supervisory           |                                   |
| iv. Total Traffic Staff            |                                   |
| v. Workshop & Maintenance          |                                   |
| vi. Admin & Others                 |                                   |
| vii. Provident Fund, Welfare, etc. |                                   |
| viii. Total (i. to vii.)           |                                   |
| <b>b. Material Cost</b>            | INR per effective-km of operation |
| i. Fuel                            |                                   |
| ii. Lubricants                     |                                   |
| iii. Springs                       |                                   |
| iv. Spare Auto Parts               |                                   |
| v. Tyres & Tubes                   |                                   |
| vi. Batteries                      |                                   |
| vii. General Items                 |                                   |
| viii. Reconditioned Items          |                                   |
| ix. Total (i. to viii.)            |                                   |
| <b>c. Taxes</b>                    | INR per effective-km of operation |
| i. Motor Vehicle Tax               |                                   |
| ii. Passenger Tax                  |                                   |
| iii. Special Road Tax              |                                   |
| iv. Misc. & Other Tax              |                                   |
| v. Total (i. to iv.)               |                                   |
| <b>d. Interest</b>                 | INR per effective-km of operation |
| i. To Central Govt.                |                                   |
| ii. To State Govt.                 |                                   |
| iii. On Borrowings                 |                                   |
| iv. Total (i. to iii.)             |                                   |



| Indicator                                 | Unit                              |
|-------------------------------------------|-----------------------------------|
| <b>e. Misc. &amp; Others</b>              | INR per effective-km of operation |
| <b>f. Payment for Hired Buses</b>         | INR per effective-km of operation |
| <b>g. Depreciation</b>                    |                                   |
| i. Buses                                  | INR per effective-km of operation |
| ii. Other Assets                          |                                   |
| <b>Total Cost (a. to g.)</b>              | INR per effective-km of operation |
| <b>Category II – Total Revenue</b>        |                                   |
| Traffic Revenue                           | INR per effective-km of operation |
| Reimbursement of Fare Concessions         | INR per effective-km of operation |
| Subsidy                                   | INR per effective-km of operation |
| Non-Traffic Revenue                       | INR per effective-km of operation |
| <b>Category III – Profit/Loss</b>         |                                   |
| Surplus before Tax                        | INR per effective-km of operation |
| <b>Category IV – Financial Ratios</b>     |                                   |
| Total Earning per bus (on-road) per day   | ₹                                 |
| % Return on Capital Employed              | %                                 |
| % Operating Ratio                         | %                                 |
| Total Cost per bus (on-road) per day      | ₹                                 |
| % Return on Capital Invested              | %                                 |
| <b>Physical Performance</b>               |                                   |
| <b>Category I – Fleet Utilisation</b>     |                                   |
| Buses held                                | Count                             |
| Buses off road                            | Count                             |
| No. of spare buses                        | Count                             |
| Buses on road                             | Count                             |
| Fleet utilisation                         | %                                 |
| Scheduled services                        | Count                             |
| Scheduled km                              | Lakh km                           |
| Effective km                              | Lakh km                           |
| Dead km                                   | Lakh km                           |
| Gross km                                  | Lakh km                           |
| Cancelled km                              | Lakh km                           |
| Bus utilisation per day (on-road buses)   | km                                |
| Bus utilisation per day (on buses held)   | km                                |
| <b>Category II – Capacity Utilisation</b> |                                   |
| Seating capacity                          | Count                             |

| Indicator                                  | Unit         |
|--------------------------------------------|--------------|
| No. of standees                            | Count        |
| Seat km                                    | Lakh km      |
| Carrying capacity km                       | Lakh km      |
| Passenger km                               | Lakh km      |
| Occupancy Ratio                            | %            |
| Load Factor                                | %            |
| Passenger lead/ trip length                | km/passenger |
| Passengers carried                         | Count        |
| Passengers per bus on road per day         | Count        |
| <b>Category III – Quality of Service</b>   |              |
| Trips to be operated                       | Count        |
| Actual trips operated                      | Count        |
| Regularity                                 | %            |
| Indicators                                 | Unit         |
| No. of breakdowns                          | Count        |
| Breakdown per 10,000 eff. km               | Count        |
| Punctuality of departure & arrival         | %            |
| Fatal accidents                            | Count        |
| Major & serious accidents                  | Count        |
| Minor accidents                            | Count        |
| Total accidents                            | Count        |
| Accidents per lakh eff. kms.               | Count        |
| No. of persons injured                     | Count        |
| No. of fatalities                          | Count        |
| No. of public complaints                   | Count        |
| <b>Category IV – Manpower Productivity</b> |              |
| Traffic staff                              | Count        |
| Workshop and maintenance staff             | Count        |
| Administration and other staff             | Count        |
| Staff ratio per bus                        | Staff/bus    |
| i. Drivers                                 |              |
| ii. Conductors                             |              |
| iii. Checkers & traffic supervisory staff  |              |
| iv. Workshop & maintenance                 |              |
| v. Administration                          |              |
| vi. Others                                 |              |

| Indicator                                       | Unit                           |
|-------------------------------------------------|--------------------------------|
| Manpower productivity per day                   | km                             |
| Avg. salary/employee/day                        | ₹                              |
| Eff. km/staff member/day                        | km                             |
| Category V – Operational Information            |                                |
| Total No. of Schedules                          | Count                          |
| Classification of Schedules                     | Count                          |
| A. Earning more than total cost                 |                                |
| B. Earning between variable cost and total cost |                                |
| C. Earning less than variable cost              |                                |
| No. of Depots                                   | Count                          |
| No. of Bus Stations                             | Count                          |
| Total No. of Routes                             | Count                          |
| Average Route Length                            | km                             |
| % of Total km                                   | %                              |
| No. of Bus Shelters/Stops                       | Count                          |
| Material Performance                            |                                |
| High-Speed Diesel (HSD)                         | kilolitres (kL)                |
| Compressed Natural Gas (CNG)                    | km/kilogramme (kg)             |
| Kilometre per Litre (KMPL)                      | km/litre                       |
| i. Tata                                         |                                |
| ii. Leyland                                     |                                |
| iii. Volvo                                      |                                |
| iv. Others                                      |                                |
| Engine oil used /oil change                     | kL or Lakh km (for oil change) |
| i. Tata                                         |                                |
| ii. Leyland                                     |                                |
| iii. Volvo                                      |                                |
| iv. Others                                      |                                |
| Engine oil top-up                               | kL or Lakh km (for oil top-up) |
| i. Tata                                         |                                |
| ii. Leyland                                     |                                |
| iii. Volvo                                      |                                |
| iv. Others                                      |                                |
| New tyres consumed                              | Units/lakh km                  |
| Engine oil KMPL                                 | km/L                           |
| Battery life                                    | Months/ lakh km                |

| Indicator                            | Unit          |
|--------------------------------------|---------------|
| <b>Gearbox oil</b>                   | kL            |
| i. Top-up                            |               |
| ii. Oil change                       |               |
| Springs                              | kg/lakh km    |
| Retreaded tyres consumed             | Units/lakh km |
| <b>Differential oil</b>              | L             |
| i. Top-up                            |               |
| ii. Oil change                       |               |
| <b>Engine life</b>                   | Lakh km       |
| i. New                               |               |
| a. Tata                              |               |
| b. Leyland                           |               |
| c. Volvo                             |               |
| d. Others                            |               |
| <b>ii. Reconditioned (R/C)</b>       |               |
| a. Tata                              |               |
| b. Leyland                           |               |
| c. Volvo                             |               |
| d. Others                            |               |
| <b>iii. Overall</b>                  |               |
| <b>Crown wheel &amp; pinion life</b> | Lakh km       |
| i. Tata                              |               |
| ii. Leyland                          |               |
| iii. Volvo                           |               |
| iv. Others                           |               |
| v. Overall                           |               |
| <b>Fuel injection pump life</b>      | Lakh km       |
| <b>i. New</b>                        |               |
| a. Tata                              |               |
| b. Leyland                           |               |
| c. Volvo                             |               |
| d. Others                            |               |
| <b>ii. R/C</b>                       |               |
| a. Tata                              |               |
| b. Leyland                           |               |
| c. Volvo                             |               |
| d. Others                            |               |
| <b>iii. Overall</b>                  |               |

| Indicator                   | Unit    |
|-----------------------------|---------|
| <b>Gearbox life</b>         | Lakh km |
| <b>i. New</b>               |         |
| a. Tata                     |         |
| b. Leyland                  |         |
| c. Volvo                    |         |
| d. Others                   |         |
| <b>ii. R/C</b>              |         |
| a. Tata                     |         |
| b. Leyland                  |         |
| c. Volvo                    |         |
| d. Others                   |         |
| <b>iii. Overall</b>         |         |
| <b>Piston assembly life</b> | Lakh km |
| i. Tata                     |         |
| ii. Leyland                 |         |
| iii. Volvo                  |         |
| iv. Others                  |         |
| v. Overall                  |         |
| <b>Clutch plate life</b>    | Lakh km |
| i. Tata                     |         |
| ii. Leyland                 |         |
| iii. Volvo                  |         |
| iv. Others                  |         |
| v. Overall                  |         |

## 6.2 Annexure II: Indicators identified in global review

| Indicator Category    | China                                                                                                                                                                                             | Europe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | US                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Coverage</b>       | Multiple cities                                                                                                                                                                                   | London                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Foothill Transit                                                                                                                                                                                                                                                                                                                                                                                                | King County                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Buses</b>          | <ul style="list-style-type: none"> <li>- Bus lifespan</li> <li>- Vehicle performance</li> </ul>                                                                                                   | <ul style="list-style-type: none"> <li>- Number of buses</li> <li>- Bus manufacturer</li> <li>- Bus range on a single charge</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                             | <ul style="list-style-type: none"> <li>- Number of buses</li> <li>- Bus manufacturer/ model</li> <li>- Model year</li> <li>- Length/ width/ height</li> <li>- Curb weight</li> <li>- Wheelbase</li> <li>- Passenger capacity</li> <li>- Motor</li> <li>- Rated power</li> <li>- Energy storage</li> <li>- Accessories</li> <li>- Emission equipment</li> <li>- Transmission</li> <li>- Fuel capacity</li> </ul> | <ul style="list-style-type: none"> <li>- Number of buses</li> <li>- Bus manufacturer</li> <li>- Bus year and model</li> <li>- Length</li> <li>- Motor</li> <li>- Rated power</li> <li>- Energy storage</li> <li>- Accessories</li> </ul>                                                                                                                                             |
| <b>Infrastructure</b> | <ul style="list-style-type: none"> <li>- Charging typology</li> <li>- Power stations</li> </ul>                                                                                                   | <ul style="list-style-type: none"> <li>- Infrastructure type</li> <li>- Breakdown time</li> <li>- Reason for breakdown</li> <li>- Time to repair</li> </ul>                                                                                                                                                                                                                                                                                                                                                                         | <ul style="list-style-type: none"> <li>- Charging type &amp; location</li> <li>- Maintenance facilities</li> <li>- Vehicle parking and storage facilities</li> </ul>                                                                                                                                                                                                                                            | <ul style="list-style-type: none"> <li>- Charging type &amp; location</li> <li>- Maintenance facilities</li> <li>- Vehicle parking and storage facilities</li> </ul>                                                                                                                                                                                                                 |
| <b>Operations</b>     | <ul style="list-style-type: none"> <li>- Bus availability</li> <li>- Annual distance driven</li> <li>- Faulty conditions</li> <li>- Reserve SoC</li> <li>- State of charge degradation</li> </ul> | <ul style="list-style-type: none"> <li>- Mileage</li> <li>- Bus start and stop times</li> <li>- Total in-service time</li> <li>- Total out-of-service time</li> <li>- Total scheduled out-of-service time</li> <li>- Total unscheduled out-of-service time</li> <li>- Description of reason for out-of-service bus</li> <li>- Total planner service time</li> <li>- Range on a single refuelling</li> <li>- Vehicle availability</li> <li>- Hours of operation in a typical cycle</li> <li>- Maintenance and reliability</li> </ul> | <ul style="list-style-type: none"> <li>- Route details</li> <li>- In-service speeds</li> <li>- Average monthly operating mileage</li> <li>- Bus use and availability</li> <li>- Breakdowns (Reasons for breakdowns/road calls)</li> <li>- Reasons for unavailability</li> </ul>                                                                                                                                 | <ul style="list-style-type: none"> <li>- Route details</li> <li>- Operating hours</li> <li>- Number of days per week</li> <li>- Amount of fuel</li> <li>- Range</li> <li>- Average bus miles accumulated per month</li> <li>- Bus availability</li> <li>- Reasons for bus unavailability</li> <li>- Battery SoC</li> <li>- Breakdowns (Reasons for breakdowns/road calls)</li> </ul> |
| <b>Energy</b>         | <ul style="list-style-type: none"> <li>- Energy consumption</li> <li>- Fuel cost</li> <li>- Fuel usage</li> <li>- Fuelling data</li> </ul>                                                        | <ul style="list-style-type: none"> <li>- Refuelling/recharging</li> <li>- Start time</li> <li>- Amount</li> <li>- End time</li> <li>- Battery SoC at plug in and plug out</li> <li>- Time taken to recharge</li> </ul>                                                                                                                                                                                                                                                                                                              | <ul style="list-style-type: none"> <li>- Total energy consumption</li> <li>- Number of charges</li> <li>- Miles driven</li> </ul>                                                                                                                                                                                                                                                                               | <ul style="list-style-type: none"> <li>- Daily energy use</li> <li>- Monthly fuel economy</li> <li>- Energy cost per mile</li> </ul>                                                                                                                                                                                                                                                 |



| Indicator Category      | China                                                                                                                                                                                                                                                                  | Europe                                                                                                                                                                                                                                                                       | US                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                        |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Financials</b>       | <ul style="list-style-type: none"> <li>- Bus and infrastructure investment costs</li> <li>- Energy cost</li> <li>- Staff cost</li> <li>- Spare part cost</li> <li>- Service charges</li> <li>- Investment, charger O&amp;M cost</li> <li>- Maintenance cost</li> </ul> | <ul style="list-style-type: none"> <li>- Infrastructure unit operating costs</li> </ul>                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>- Bus purchase cost</li> <li>- Labour cost</li> <li>- Scheduled maintenance cost per km</li> <li>- Unscheduled maintenance cost per km</li> <li>- Work order maintenance cost per km</li> </ul> | <ul style="list-style-type: none"> <li>- Bus purchase cost</li> <li>- Labour cost</li> <li>- Scheduled maintenance cost per km</li> <li>- Unscheduled maintenance cost per km</li> <li>- Work order maintenance cost per km</li> </ul> |
| <b>Other indicators</b> | <ul style="list-style-type: none"> <li>- Risks and indirect costs</li> <li>- User and driver satisfaction</li> </ul>                                                                                                                                                   | <ul style="list-style-type: none"> <li>- Attitude towards and perception of low emission buses</li> <li>- Ease of integrating bus and infrastructure with the current fleet</li> <li>- Ease of O&amp;M</li> <li>- Perception of bus and infrastructure as a whole</li> </ul> |                                                                                                                                                                                                                                        | <ul style="list-style-type: none"> <li>- Previous experience with ZEBs</li> <li>- Roles of organisations</li> <li>- Driver, fleet personnel, and customer perceptions</li> <li>- Special fleet needs</li> <li>- Training</li> </ul>    |

## 6.3 Annexure III: Detailed framework for proposed e-bus performance evaluation

| Evaluation metric                                   | Sub-metric       | Data already captured (CIRT) or new? | Agency for collection in GCC model | Data collection source and method                       | Data collection periodicity | Data applications                                           | Analysis required                                                             |
|-----------------------------------------------------|------------------|--------------------------------------|------------------------------------|---------------------------------------------------------|-----------------------------|-------------------------------------------------------------|-------------------------------------------------------------------------------|
| Name of the OEM                                     |                  | CIRT                                 | STU                                | STU/Authority Fleet database                            | Once                        | -                                                           |                                                                               |
| Total number of buses                               |                  | CIRT                                 | STU                                | STU/Authority Fleet database                            | Once                        | Incentive design                                            | Pan-India compilation to decide on future incentives                          |
|                                                     | No. of 9m buses  | CIRT                                 | STU                                | STU/Authority Fleet database                            | Once                        | Incentive design                                            |                                                                               |
|                                                     | No. of 12m buses | CIRT                                 | STU                                | STU/Authority Fleet database                            | Once                        | Incentive design                                            |                                                                               |
| Date of induction of buses                          |                  | CIRT                                 | STU                                | STU/Authority Fleet database                            | Once                        | -                                                           |                                                                               |
| Length/width/height                                 |                  | CIRT                                 | STU, from OEM                      | STU/Authority Fleet database / OEM product portfolio    | Once                        | Incentive design                                            |                                                                               |
| Gross Vehicle Weight                                |                  | CIRT                                 | STU, from OEM                      | STU/Authority Fleet database/ OEM product portfolio     | Once                        |                                                             |                                                                               |
| Wheelbase                                           |                  | CIRT                                 | STU, from OEM                      | STU/Authority Fleet database/ OEM product portfolio     | Once                        |                                                             |                                                                               |
| Passenger capacity                                  |                  | CIRT                                 | STU, from OEM                      | STU/Authority Fleet database/ OEM product portfolio     | Once                        |                                                             |                                                                               |
| Rated power (HP)                                    |                  | CIRT                                 | STU from OEM                       | STU/Authority Fleet database/ OEM product portfolio     | Once                        |                                                             |                                                                               |
| Charger description                                 |                  | new                                  | OEM                                | STU/Authority Electrical database/OEM product portfolio | Once                        | Service planning and delivery; fleet and battery management | Evaluation of the operational suitability of a particular charging technology |
| Total no. of chargers                               |                  | new                                  | OEM                                | STU/Authority Electrical database/OEM product portfolio | Once                        | Service planning and delivery; fleet and battery management |                                                                               |
| Capacity of depot charging infrastructure (kW)      |                  | new                                  | OEM                                | STU/Authority Electrical database/OEM product portfolio | Once                        | Service planning and delivery; fleet and battery management |                                                                               |
| Capacity of enroute charging facility (if any) (kW) |                  | new                                  | OEM                                | STU/Authority Electrical database/OEM product portfolio | Once                        | Service planning and delivery; fleet and battery management |                                                                               |
| Power supply to the depot (kV)                      |                  | new                                  | OEM                                | STU/Authority Electrical database/OEM product portfolio | Once                        | Service planning and delivery; fleet and battery management |                                                                               |

| Evaluation metric                       | Sub-metric                             | Data already captured (CIRT) or new? | Agency for collection in GCC model | Data collection source and method | Data collection periodicity | Data applications                                                      | Analysis required                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------|----------------------------------------|--------------------------------------|------------------------------------|-----------------------------------|-----------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Number of e-bus depots                  |                                        | new                                  | STU                                | STU/Authority Database            | Once                        | Total cost of ownership estimation; procurement and financial planning |                                                                                                                                                                                                                                                                                                                                               |
| No. of e-buses per depot                |                                        | new                                  | STU                                | MIS/ITS                           | Once                        | TCO estimation; procurement and financial planning                     |                                                                                                                                                                                                                                                                                                                                               |
| Total available depot land area (sq km) |                                        | CIRT                                 | STU                                | STU/Authority Database            | Once                        | TCO estimation; procurement and financial planning                     |                                                                                                                                                                                                                                                                                                                                               |
| Average number of on-road buses         |                                        | CIRT                                 | STU                                | MIS/ITS                           | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| No. of operational days per month       |                                        | CIRT                                 | STU                                | MIS/ITS                           | Monthly                     | Service planning and delivery                                          | 1. Percentage of cancelled km against scheduled km, to be used in future scheduling (reasons for cancellation to assess the nature of repetition)<br>2. Planning for future maintenance for a particular bus type and specific operating conditions<br>3. Assessment of the battery health, to predict the actual range of buses in real time |
| Scheduled km per bus per day            |                                        | CIRT                                 | STU                                | Schedule Database                 | Daily                       | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Dead km per bus per day                 |                                        | CIRT                                 | STU                                | MIS/ITS                           | Daily                       | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Operated km per bus per day             |                                        | CIRT                                 | Operator                           | MIS/ITS                           | Daily                       | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Average odometer reading                |                                        | CIRT                                 | Operator                           | MIS/ITS                           | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Steering hours per bus per day          |                                        | CIRT                                 | Operator                           | MIS/ITS                           | Daily                       | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Scheduled revenue hours per bus         |                                        | CIRT                                 | STU                                | STU/Authority Schedule            | Daily                       | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Time spent at a depot per bus per day   |                                        | CIRT                                 | Operator                           | MIS- Operations/ ITS              | Daily                       | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
| Total cancelled km so far               |                                        |                                      | Operator                           | MIS- Operations/ ITS              | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
|                                         | due to staff shortage                  | new                                  | Operator                           | MIS- Operations/ ITS              | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
|                                         | due to bus unavailability              | new                                  | Operator                           | MIS- Maintenance                  | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
|                                         | due to bus breakdown during operations | new                                  | Operator                           | MIS- Maintenance                  | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
|                                         | due to traffic congestion              | new                                  | Operator                           | MIS- Operations/ ITS              | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |
|                                         | due to transmission issues             | new                                  | Operator                           | MIS- Operations/ ITS              | Monthly                     | Service planning and delivery                                          |                                                                                                                                                                                                                                                                                                                                               |

| Evaluation metric                               | Sub-metric                   | Data already captured (CIRT) or new? | Agency for collection in GCC model | Data collection source and method                                                     | Data collection periodicity | Data applications                                                                 | Analysis required                                                                                                                                                                                                              |
|-------------------------------------------------|------------------------------|--------------------------------------|------------------------------------|---------------------------------------------------------------------------------------|-----------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                 | due to charging issues       | new                                  | Operator                           | MIS-Maintenance                                                                       | Monthly                     | Service planning and delivery; fleet and battery management                       |                                                                                                                                                                                                                                |
|                                                 | due to battery issues        | new                                  | Operator                           | MIS-Maintenance                                                                       | Monthly                     | Service planning and delivery; fleet and battery management                       |                                                                                                                                                                                                                                |
|                                                 | due to electric drive issues | new                                  | Operator                           | MIS-Maintenance                                                                       | Monthly                     | Service planning and delivery; fleet and battery management                       |                                                                                                                                                                                                                                |
|                                                 | due to other reasons         | new                                  | Operator                           | MIS-Maintenance                                                                       | Monthly                     | Service planning and delivery; fleet and battery management                       |                                                                                                                                                                                                                                |
| <b>Time interval between maintenance events</b> |                              | new                                  | OEM                                | MIS-Maintenance                                                                       | Monthly                     |                                                                                   |                                                                                                                                                                                                                                |
| <b>Total number of bus breakdowns</b>           |                              | CIRT                                 | Operator                           | MIS-Maintenance                                                                       | Monthly                     | Service planning and delivery; fleet and battery management                       |                                                                                                                                                                                                                                |
| <b>No. of routes</b>                            |                              | CIRT                                 | STU                                | Schedule Database                                                                     | Once                        | Service planning and delivery                                                     | 1. Identification of constraints along particular route based on a particular technology. This will also help in future selection of routes and depots, e-bus scheduling, and assessment of the need for opportunity charging. |
| <b>Average route length</b>                     |                              | CIRT                                 | STU                                | Schedule Database                                                                     | Once                        | Service planning and delivery; procurement and financial planning                 |                                                                                                                                                                                                                                |
| <b>Buses per route</b>                          |                              | new                                  | STU                                | Schedule Database                                                                     | Once                        | Service planning and delivery                                                     |                                                                                                                                                                                                                                |
| <b>Stops per route</b>                          |                              | new                                  | STU                                | MIS-Operations/ITS                                                                    | Once                        | Service planning and delivery                                                     |                                                                                                                                                                                                                                |
| <b>Trips per route</b>                          |                              | new                                  | STU                                | Schedule Database                                                                     | Once                        | Service planning and delivery                                                     |                                                                                                                                                                                                                                |
| <b>Average speed</b>                            |                              | new                                  | Operator                           | GPS                                                                                   | Daily                       | Service planning and delivery                                                     |                                                                                                                                                                                                                                |
| <b>Average e-bus Load Factor</b>                |                              | CIRT                                 | STU                                | MIS-Operations/ITS                                                                    | Daily                       | Service planning and delivery                                                     |                                                                                                                                                                                                                                |
| <b>e-bus energy efficiency (kWh/km)</b>         |                              | new                                  | Operator/OEM                       | Power consumed by all chargers from electric meter readings over the total km covered | Monthly                     | Service planning and delivery; TCO estimation; procurement and financial planning | 1. Identification of the range of buses in actual operating conditions<br>2. Estimation of the energy cost for future financial planning                                                                                       |

| Evaluation metric              | Sub-metric                             | Data already captured (CIRT) or new? | Agency for collection in GCC model | Data collection source and method          | Data collection periodicity | Data applications                                                           | Analysis required                                                                                                                                                                                                                                                      |
|--------------------------------|----------------------------------------|--------------------------------------|------------------------------------|--------------------------------------------|-----------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| No. of charging cycles per day |                                        | new                                  | OEM                                | MIS- Operations/ ITS                       | Daily                       | Service planning and delivery; fleet and battery management                 | 1. Estimation of the actual steering hours in the operating scenario, to facilitate e-bus scheduling based on range and charging requirements<br>2. Evaluation of the cost of energy and extra fleet required to cover the time lost in charging and estimation of TCO |
|                                | Charging 1 duration                    | new                                  | OEM                                | ITS/Schedule-wise charging reports         | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | SoC at start of Charging 1             | new                                  | OEM                                | Battery SoC-Schedule-wise charging reports | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | SoC at end of Charging 1               | new                                  | OEM                                | Battery SOC-Schedule-wise charging reports | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | Distance travelled for Charging 1 (km) | new                                  | OEM                                | ITS/Schedule-wise charging reports         | Daily                       | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                                                                                                                                                        |
|                                | Charging 2 duration                    | new                                  | OEM                                | ITS/Schedule-wise charging reports         | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | SoC at start of Charging 2             | new                                  | OEM                                | Battery SoC-Schedule-wise charging reports | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | SoC at end of Charging 2               | new                                  | OEM                                | Battery SoC-Schedule-wise charging reports | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | Distance travelled for Charging 2 (km) | new                                  | OEM                                | ITS/Schedule-wise charging reports         | Daily                       | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                                                                                                                                                        |
|                                | Charging 3 duration                    | new                                  | OEM                                | ITS/Schedule-wise charging reports         | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | SoC at start of Charging 3             | new                                  | OEM                                | Battery SoC-Schedule-wise charging reports | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | SoC at end of Charging 3               | new                                  | OEM                                | Battery SoC-Schedule-wise charging reports | Daily                       | Service planning and delivery; fleet and battery management                 |                                                                                                                                                                                                                                                                        |
|                                | Distance travelled for Charging 3 (km) | new                                  | OEM                                | ITS/Schedule-wise charging reports         | Daily                       | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                                                                                                                                                        |

| Evaluation metric                       | Sub-metric                                                       | Data already captured (CIRT) or new? | Agency for collection in GCC model | Data collection source and method                      | Data collection periodicity | Data applications                                                           | Analysis required                                                                                                              |
|-----------------------------------------|------------------------------------------------------------------|--------------------------------------|------------------------------------|--------------------------------------------------------|-----------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Power consumed per day                  |                                                                  | new                                  | OEM                                | Depot electric meter reading                           | Daily                       | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                |
| Energy cost (INR per kWh)               |                                                                  | new                                  | STU                                | DISCOM website                                         | Once                        | TCO estimation; procurement and financial planning                          |                                                                                                                                |
| No. of drivers                          |                                                                  | CIRT                                 | Operator                           | MIS-Operations/ ITS                                    | Daily                       | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                |
| No. of conductors                       |                                                                  | CIRT                                 | STU                                | STU/Authority Database                                 | Daily                       | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                |
| No. of maintenance staff                |                                                                  | CIRT                                 | OEM                                | MIS-Operations/ ITS                                    | Monthly                     | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                |
| No. of contract management staff        |                                                                  | CIRT                                 | STU                                | STU/Authority Database                                 | Monthly                     | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                |
| No. of other staff                      |                                                                  | CIRT                                 | STU                                | STU/Authority Database                                 | Monthly                     | Service planning and delivery; fleet and battery management; TCO estimation |                                                                                                                                |
| Business model (Outright purchase/ GCC) |                                                                  | new                                  | STU                                | STU/Authority Database                                 | Once                        | Incentive design; procurement and financial planning                        | Assessment for future procurement model selection                                                                              |
| IF GCC                                  |                                                                  |                                      |                                    |                                                        |                             |                                                                             |                                                                                                                                |
|                                         | CPKM (paid to the operator if GCC)/ Payment paid to the operator | new                                  | STU                                | GCC contract, Monthly invoice/ payment to the operator | Once/ Monthly               | Incentive design; procurement and financial planning; TCO estimation        | Evaluation of TCO, its various components, and relative CAPEX and OPEX costs to decide on procurement models, incentives, etc. |
|                                         | Conductor CPKM                                                   | CIRT                                 | STU                                | STU/Authority Staff cost per km                        | Monthly                     | Incentive design; procurement and financial planning; TCO estimation        |                                                                                                                                |
|                                         | CPKM of traffic supervision staff + admin staff                  | CIRT                                 | STU                                | STU/Authority Staff cost per km                        | Monthly                     | Incentive design; procurement and financial planning; TCO estimation        |                                                                                                                                |

| Evaluation metric                                                                          | Sub-metric                                     | Data already captured (CIRT) or new? | Agency for collection in GCC model | Data collection source and method | Data collection periodicity | Data applications                                                    | Analysis required |
|--------------------------------------------------------------------------------------------|------------------------------------------------|--------------------------------------|------------------------------------|-----------------------------------|-----------------------------|----------------------------------------------------------------------|-------------------|
|                                                                                            | Energy CPKM                                    | new                                  | STU                                | DISCOM electricity bills          | Monthly                     | Incentive design; procurement and financial planning; TCO estimation |                   |
| <b>If outright purchase</b>                                                                |                                                |                                      |                                    |                                   |                             |                                                                      |                   |
|                                                                                            | Cost of bus purchase                           | new                                  | STU                                | OEM Invoice                       | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
|                                                                                            | Cost of charging infrastructure (if available) | new                                  | STU                                | OEM Invoice                       | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
|                                                                                            | Staff CPKM                                     | CIRT                                 | STU                                | STU/Authority Staff cost per km   | Monthly                     | Incentive design; procurement and financial planning; TCO estimation |                   |
|                                                                                            | Maintenance CPKM                               | CIRT                                 | STU                                | STU/Authority Staff cost per km   | Monthly                     | Incentive design; procurement and financial planning; TCO estimation |                   |
|                                                                                            | Energy CPKM                                    | new                                  | STU                                | DISCOM electricity bills          | Monthly                     | Incentive design; procurement and financial planning; TCO estimation |                   |
| <b>Subsidy amount</b>                                                                      | (FAME subsidy/ state subsidy amount)           | CIRT                                 | STU                                | STU/Authority Database            | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
| <b>Source of subsidy</b>                                                                   |                                                | new                                  | STU                                | STU/Authority Database            | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
| <b>Source of financing beyond subsidy (Eg. Commercial loans/ grants/ in-house budgets)</b> |                                                | new                                  | STU                                | STU/Authority Database            | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
| <b>If loan</b>                                                                             | Loan interest rate                             | new                                  | Operator/ OEM                      | STU/Authority Database            | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
|                                                                                            | Loan tenure                                    | new                                  | Operator/ OEM                      | STU/Authority Database            | Once                        | Incentive design; procurement and financial planning; TCO estimation |                   |
| <b>e-bus earnings per km</b>                                                               |                                                | new                                  | STU                                | MIS-Operations/ ITS               | Daily                       | Service planning and delivery; TCO estimation                        |                   |



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