UITP ADVANCING PUBLIC TRANSPORT

SHAKTI SUSTAINABLE ENERGY FOUNDATION

REPORT

PERFORMANCE EVALUATION FRAMEWORK

FOR ELECTRIC BUSES IN INDIA

FINAL REPORT

JULY | 2020

PERFORMANCE EVALUATION FRAMEWORK

FOR ELECTRIC BUSES IN INDIA

JULY | 2020

UITP ADVANCING PUBLIC TRANSPORT

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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.

Contact: The Capital Court, 104B/2 Left Wing, 4th Floor, Munirka Phase III, New Delhi 110067, Delhi
Tel: +91 11 47474000 | Fax: +91 11 47474043 Website: www.shaktifoundation.in

About UITP:

International Association of Public Transport (UITP) is a non-profit organisation headquartered in Belgium with a global network of offices, including in Delhi and Bangalore. UITP is the only worldwide platform for cooperation on public transport, with more than 1,800 members from 100+ countries representing public transport authorities, operators, policy decision-makers, scientific institutions, and the public transport supply and service industry. We undertake research, advocacy, and capacity building initiatives and provide networking platforms to advance public transport systems.

Contact: Ninety Ten Eventures Office Space, F-322, Lado Sarai, New Delhi 110030, Delhi
Website: www.uitp.org

Authors:

Christy Ann Cheriyan

Ravi Gadepalli (ravi.gadepalli@uitp.org)

Rupa Nandy (rupa.nandy@uitp.org)

Acknowledgements

We would like to thank Mr. Aman Garg from Foton-PMI, Mr. Naga Satyam from Olectra-BYD and other industry representatives for their valuable feedback and insights, which helped improve the report. We would also like to thank Ruchir Shukla, Vivek Chandran and Chetna Nagpal from Shakti Foundation for their critical inputs during project design and report development.

Disclaimer:

Contents

List of Tables

List of Figures

Abbreviations

ADB	Asian Development Bank
ARAI	Automobile Research Association of India
ASRTU	Association of State Road Transport Undertaking
CAPEX	Capital Expenditure
CARB	California Air Resources Board
CIRT	Central Institute Road Transport
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
COVID-19	Coronavirus disease
CPKM	Cost per kilometre
DHI	Department of Heavy Industries
DISCOM	Electricity Distribution Company
e-bus	Electric bus
EoI	Expression of Interest
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
FTA	Federal Transit Administration
GCC	Gross-Cost Contract
GHG	Greenhouse Gas
GoI	Government of India
GPS	Global Positioning System
HP	Horsepower
HRTC	Himachal Road Transport Corporation
HSD	High-Speed Diesel
ICAT	International Centre for Automotive Technology
ICE	Internal Combustion Engine
ICCT	International Council on Clean Transportation
ICTSL	Indore City Transport Service Limited
IFI	International Financing Institution
IIT	Indian Institute of Technology
INR	Indian Rupee
ITS	Intelligent Transport System
kg	kilogramme

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

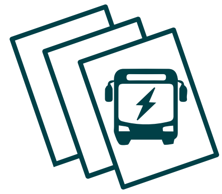
This report focuses on the National Framework for Electric Bus Performance Evaluation, discussing the ecosystem required, the framework's potential applications, and the indicators to be evaluated. The rest of the report is organised as follows:

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[1]. 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:

a. **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 is 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.

b. **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'[2] 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

[1]Measuring public transport performance, Lessons for Developing Countries, SUTP Technical Document #9, GIZ

[2]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

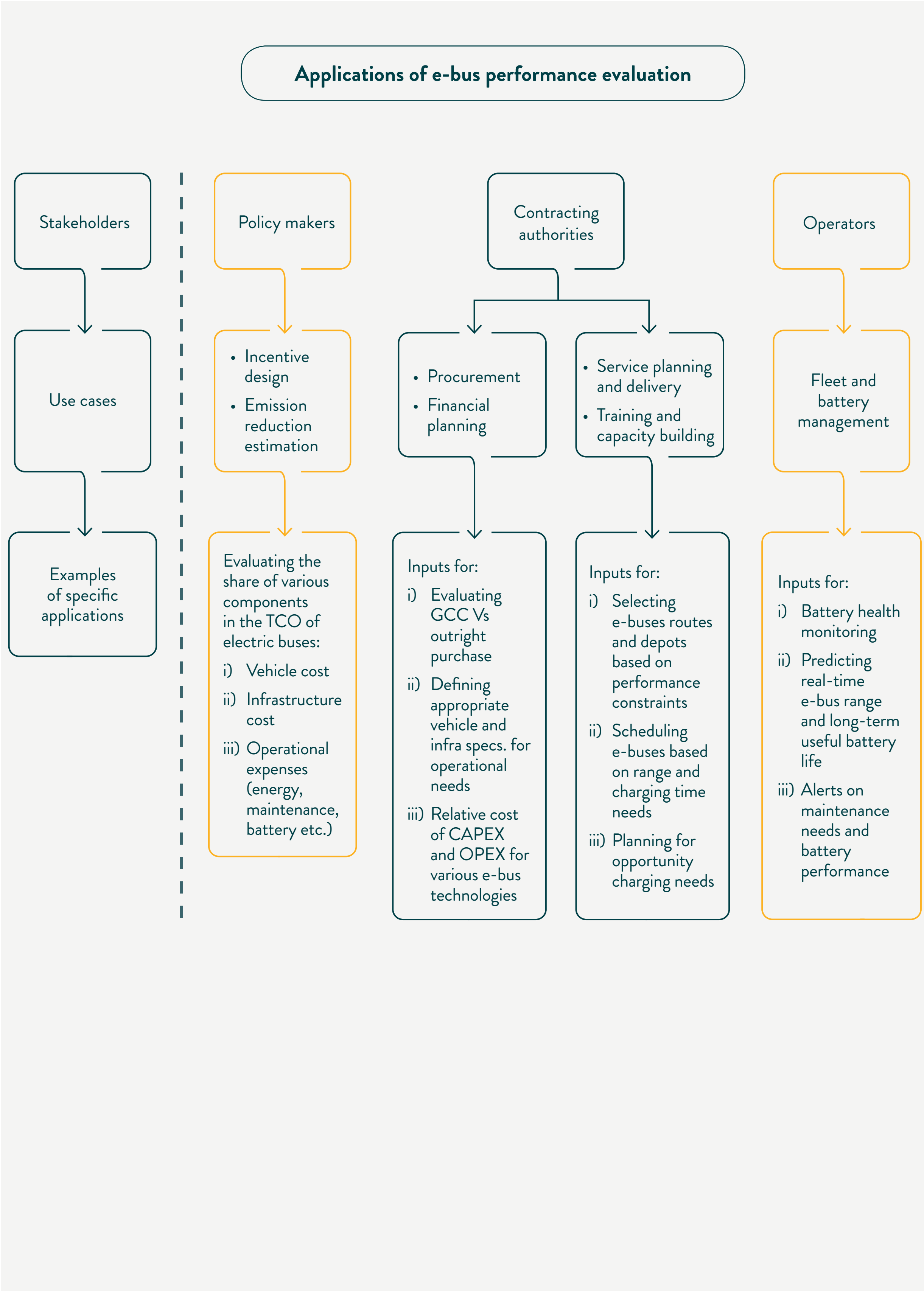
a. Battery health monitoring

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:

- Assessing the impact of current financial and policy incentives for e-bus deployment and learnings for future investments
- 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:

- Effectively monitoring e-bus technical and operational performance against the SLAs outlined in the contract
- Improving service planning and maximising service delivery based on actual e-bus performance
- 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:

- Improving charging and battery management
- Predicting maintenance requirements and associated procurement needs
- 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	• ADB • Shenzhen Urban Transport Planning & Design Institute	TRL	NREL	NREL
Authority commissioning the evaluation	• Independent agencies	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	• Environmental performance • Financial performance	• Buses and infrastructure • Public opinion • Financial performance	• Buses and infrastructure • Operations • Cost • Experience of transit authority • Financial performance	
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 evalutation, 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 • Monthly • Once	• Daily • Monthly • Once	• Daily • Monthly • Once
Data sources	• Manual surveys • GPS • Electronic reports	• Telematics data • Fuel data • Surveys • Pilot information	• GPS • Utility bills • National Transit Database • Maintenance work orders • Battery SoC • Daily service reports • Daily garage activity sheets	• GPS • Utility bills • National Transit Database • Maintenance work orders • Text format data from operators
Stakeholders	Passengers Operators Transport Authorities	Passengers Bus Operators	Manufacturers Operators Transport Authority	• Manufacturers • Operators • 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.

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[3]). 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.

[3] 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

Sl No	INDICATOR	SUB-INDICATOR	DESCRIPTION
BUS SYSTEM DETAILS			
I. BUS SPECIFICATIONS			
1	Total number of buses		
1a		No. of 9m buses	
1b		No. of 12m buses	
III. Operations			
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		
IV. Energy			
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)	

Sl 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. FUNDING AND FINANCIALS			
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

Sl 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

Sl 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)		
IV. Energy			
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)	

Sl 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)		
V. Personnel			
43	No. of drivers		
44	No. of conductors		
45	No. of maintenance staff		
46	No. of contract management staff		
47	Other staff		
D. FUNDING AND FINANCIALS			
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	

Sl 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[4] 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.

[4]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
Financial Performance	
Category I – Total Cost	
a. Personnel Cost	
i. Drivers	
ii. Conductors	
iii. Traffic Supervisory	
iv. Total Traffic Staff	INRper effective-km of operation
v. Workshop & Maintenance	
vi. Admin & Others	
vii. Provident Fund, Welfare, etc.	
viii. Total (i. to vii.)	
b. Material Cost	
i. Fuel	
ii. Lubricants	
iii. Springs	
iv. Spare Auto Parts	INR per effective-km of operation
v. Tyres & Tubes	
vi. Batteries	
vii. General Items	
viii. Reconditioned Items	
ix. Total (i. to viii.)	
c. Taxes	
i. Motor Vehicle Tax	
ii. Passenger Tax	
iii. Special Road Tax	INR per effective-km of operation
iv. Misc. & Other Tax	
v. Total (i. to iv.)	
d. Interest	
i. To Central Govt.	
ii. To State Govt.	INR per effective-km of operation
iii. On Borrowings	
iv. Total (i. to iii.)	

Indicator	Unit
e. Misc. & Others	INR per effective-km of operation
f. Payment for Hired Buses	INR per effective-km of operation
g. Depreciation	INR per effective-km of operation
i. Buses	
ii. Other Assets	
Total Cost (a. to g.)	INR per effective-km of operation
Category II – Total Revenue	
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
Category III – Profit/Loss	
Surplus before Tax	INR per effective-km of operation
Category IV – Financial Ratios	
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	%
Physical Performance	
Category I – Fleet Utilisation	
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
Category II – Capacity Utilisation	
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
Category III – Quality of Service	
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
Category IV – Manpower Productivity	
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
Gearbox oil	kL
i. Top-up	
ii. Oil change	
Springs	kg/lakh km
Retreaded tyres consumed	Units/lakh km
Differential oil	L
i. Top-up	
ii. Oil change	
Engine life	Lakh km
i. New	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
ii. Reconditioned (R/C)	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
iii. Overall	
Crown wheel & pinion life	Lakh km
i. Tata	
ii. Leyland	
iii. Volvo	
iv. Others	
v. Overall	
Fuel injection pump life	Lakh km
i. New	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
ii. R/C	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
iii. Overall	

Indicator	Unit
Gearbox life	Lakh km
i. New	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
ii. R/C	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
iii. Overall	
Piston assembly life	Lakh km
i. Tata	
ii. Leyland	
iii. Volvo	
iv. Others	
v. Overall	
Clutch plate life	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	
Coverage	Multiple cities	London	Foothill Transit	King County
Buses	- Bus lifespan - Vehicle performance	- Number of buses - Bus manufacturer - Bus range on a single charge	- Number of buses - Bus manufacturer/ model - Model year - Length/ width/ height - Curb weight - Wheelbase - Passenger capacity - Motor - Rated power - Energy storage - Accessories - Emission equipment - Transmission - Fuel capacity	- Number of buses - Bus manufacturer - Bus year and model - Length - Motor - Rated power - Energy storage - Accessories
Infrastructure	- Charging typology - Power stations	- Infrastructure type - Breakdown time - Reason for breakdown - Time to repair	- Charging type & location - Maintenance facilities - Vehicle parking and storage facilities	- Charging type & location - Maintenance facilities - Vehicle parking and storage facilities
Operations	- Bus availability - Annual distance driven - Faulty conditions - Reserve SoC - State of charge degradation	- Mileage - Bus start and stop times - Total in-service time - Total out-of-service time - Total scheduled out-of-service time - Total unscheduled out-of-service time - Description of reason for out-of-service bus - Total planner service time - Range on a single refuelling - Vehicle availability - Hours of operation in a typical cycle - Maintenance and reliability	- Route details - In-service speeds - Average monthly operating mileage - Bus use and availability - Breakdowns (Reasons for breakdowns/road calls) - Reasons for unavailability	- Route details - Operating hours - Number of days per week - Amount of fuel - Range - Average bus miles accumulated per month - Bus availability - Reasons for bus unavailability - Battery SoC - Breakdowns (Reasons for breakdowns/road calls)
Energy	- Energy consumption - Fuel cost - Fuel usage - Fuelling data	- Refuelling/recharging - Start time - Amount - End time - Battery SoC at plug in and plug out - Time taken to recharge	- Total energy consumption - Number of charges - Miles driven	- Daily energy use - Monthly fuel economy - Energy cost per mile

Indicator Category	China	Europe	US	
Financials	- Bus and infrastructure investment costs - Energy cost - Staff cost - Spare part cost - Service charges - Investment, charger O&M cost - Maintenance cost	- Infrastructure unit operating costs	- Bus purchase cost - Labour cost - Scheduled maintenance cost per km - Unscheduled maintenance cost per km - Work order maintenance cost per km	- Bus purchase cost - Labour cost - Scheduled maintenance cost per km - Unscheduled maintenance cost per km - Work order maintenance cost per km
Other indicators	- Risks and indirect costs - User and driver satisfaction	- Attitude towards and perception of low emission buses - Ease of integrating bus and infrastructure with the current fleet - Ease of O&M - Perception of bus and infrastructure as a whole		- Previous experience with ZEBs - Roles of organisations - Driver, fleet personnel, and customer perceptions - Special fleet needs - Training

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) 2. Planning for future maintenance for a particular bus type and specific operating conditions 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	
Time interval between maintenance events		new	OEM	MIS-Maintenance	Monthly		
Total number of bus breakdowns		CIRT	Operator	MIS-Maintenance	Monthly	Service planning and delivery; fleet and battery management	
No. of routes		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.
Average route length		CIRT	STU	Schedule Database	Once	Service planning and delivery; procurement and financial planning	
Buses per route		new	STU	Schedule Database	Once	Service planning and delivery	
Stops per route		new	STU	MIS-Operations/ ITS	Once	Service planning and delivery	
Trips per route		new	STU	Schedule Database	Once	Service planning and delivery	
Average speed		new	Operator	GPS	Daily	Service planning and delivery	
Average e-bus Load Factor		CIRT	STU	MIS-Operations/ ITS	Daily	Service planning and delivery	
e-bus energy efficiency (kWh/ km)		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 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 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	
If outright purchase							
	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	
Subsidy amount	(FAME subsidy/ state subsidy amount)	CIRT	STU	STU/Authority Database	Once	Incentive design; procurement and financial planning; TCO estimation	
Source of subsidy		new	STU	STU/Authority Database	Once	Incentive design; procurement and financial planning; TCO estimation	
Source of financing beyond subsidy (Eg. Commercial loans/ grants/ in-house budgets)		new	STU	STU/Authority Database	Once	Incentive design; procurement and financial planning; TCO estimation	
If loan	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	
e-bus earnings per km		new	STU	MIS-Operations/ ITS	Daily	Service planning and delivery; TCO estimation	

This is an official Report of UITP, the International Association of Public Transport. UITP has more than 1,800 member companies in 100 countries throughout the world and represents the interests of key players in this sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport worldwide.

ADVANCING PUBLIC TRANSPORT

JULY | 2020

Rue Sainte-Marie 6, B-1080 Brussels, Belgium | Tel +32 (0)2 673 61 00 | Fax +32 (0)2 660 10 72 | info@uitp.org | www.uitp.org