REPORT

Framework for Performance Evaluation of Electric Buses in India

FINAL REPORT

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About Shakti:

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support renewable energy, energy efficiency and the adoption of sustainable transport solutions. We would like to thank Vivek Chandran and Chetna Nagpal from Shakti for their valuable feedback in developing this report.

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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. We're 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, public transport supply and service industry. We undertake research, advocacy, capacity building initiatives and provide networking platforms to advance public transport systems.

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Disclaimer:

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Abbreviations

ASRTU	:	Association of State Road Transport Undertaking
CIRT	:	Central Institute Road Transport
CPKM	:	Cost per km
DHI	:	Department of Heavy Industries
DISCOM	:	Distribution Company
EoI	:	Expression of Interest
EV	:	Electric Vehicles
FAME	:	Faster Adoption and Manufacturing of Electric Vehicles
GCC	:	Gross Cost Contract
GoI	:	Government of India
HRTC	:	Himachal Road Transport Corporation
ICE	:	Internal Combustion Engine
ICTSL	:	Indore City Transport Service Limited
ITS	:	Intelligent Transport Systems
KSRTC	:	Kerala State Road Transport Corporation
LCTSL	:	Lucknow City Transport Service Limited
MIS	:	Management Information Systems
MoRTH	:	Ministry of Road Transport Highways
NMMT	:	Navi Mumbai Municipal Transport
O&M	:	Operation and Maintenance
OEM	:	Original Equipment Manufacturing
PTA	:	Public Transport Authority
SSEF	:	Shakti Sustainable Energy Foundation
STU/SRTU	:	State Transport Undertaking/State Road Transport Undertaking
TCO	:	Total cost of ownership
TRW	:	Transport Research Wing
UITP	:	International Association of Public Transport

1. Introduction

1.1 Electric buses in India-the story so far

Electric 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) of electric vehicles. The FAME-I scheme sanctioned a total of 390 buses to be deployed across 11 cities. Coinciding with the end of FAME-I, Government of India (GoI) announced the phase II of the scheme in April 2019. The FAME II scheme is rolled out with an outlay of INR 10,000 crores spread over three years i.e. between 2019-20 and 2021-22, to provide demand incentives for Electric Vehicles (EVs). 35% of the total FAME II scheme outlay is allocated to e-bus procurement across cities. Within this, the Department of Heavy Industries (DHI) has selected 64 cities across India to receive financial incentives for the deployment of 5595 e-buses. In addition to the FAME scheme urban bus providers in Ahmedabad, Pune and Bangalore and State Transport Undertakings (STUs) like Himachal Pradesh Road Transport Corporation (HRTC) are also procuring electric buses (e-buses) through independent efforts.

About 450 buses are currently under operation 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 Covid-19 induced delay in procurement and financing, India is likely to have at least 3,000 e-buses operating across the country over the next one year.

1.2 Need for an e-bus performance evaluation framework

Introduction of electric buses (e-buses) is ushering in a new era of bus service provision in India. Firstly, e-buses themselves are an expensive new technology which vary significantly in operations, planning and maintenance compared to 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 buses that are already deployed to **improve their operational performance** and **inform our future procurement choices**. In addition to the technology switch, many bus agencies are also witnessing a switch in business models. State Transport Undertakings (STUs), responsible for operation public buses in India, have traditionally owned and operated their buses. However, they are moving towards the Gross Cost Contract (GCC) model of procurement under FAME-II where-in the technology risk and investment for the buses is brought in by the service provider while the contracting authority takes up service planning, delivery and the

revenue risk. Performance monitoring of service providers is crucial for 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 procurements**: Develop a comprehensive understanding of the performance of different e-bus technologies under varying operating conditions and business models which can be applied to improve decision making criteria for future procurements and at the same time inform OEMs on vehicle technology improvement needs.
- **Peer to peer learning to improve performance of deployed buses**: Facilitate peer to peer learning across cities through standardised data management and sharing practices. This will help them in adopting the best operational practices for the available bus technologies thereby improving the longevity of e-bus, battery and charging infrastructure performance
- **Monitoring operations and contract management**: Review the performance of the e-bus operators against the Service Level Agreements (SLAs) listed in their contracts to ensure success of the contract and to provide timely inputs to improve efficiency of the e-bus service delivery

DHI has already created the necessary ecosystem for such a National level performance evaluation framework mandating all agencies receiving FAME II subsidy to create an online platform for performance monitoring and data sharing. However, specific actions to operationalize the performance monitoring efforts haven't been taken up yet.

This report fills in the gap in the available literature to provide guidance to contracting authorities and service providers deploying e-buses to evaluate their performance across alternative 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 the project on "Creating enabling mechanisms to scale-up adoption of electric buses in Indian cities". The project focussed on providing knowledge support on financial incentives and alternative approaches for procurement of electric buses.

Further, as some cities have deployed e–buses under FAME-I and many others are gearing up for roll-out under FAME-II, it is an opportune time to inform them on best practices to carry out performance evaluation of these e-buses. In this context, UITP has undertaken the current exercise with the following objectives:

- To develop a National level framework for performance monitoring and evaluation mechanisms for e-buses
- To support State Transport Undertakings (STUs) and other agencies deploying e-buses in their performance monitoring and evaluation practices

Accordingly, this report is prepared as part of the objective I summarizing

- the importance of performance evaluation for successful roll-out and scale-up of e-buses in India
- learnings from current practices globally and in India for bus performance evaluation
- proposal for the e-bus performance evaluation in India

1.4 Outline of the report

This report is prepared as the National Framework for Electric Bus Performance Evaluation discussing on the ecosystem required, its 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 for e-bus performance evaluation and compares them with Indian practices for electric and ICE based buses.

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

2. Applications and beneficiaries of e-bus performance evaluation

2.1 Applications of performance evaluation

Performance evaluation refers to specific monitoring and analysis processes to determine how well policies, programs and projects perform with regard to their intended goals and objectives[1]. Globally, public transport agencies use performance evaluation and monitoring to:

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

Towards meeting the e-bus technology evaluation, peer to peer learning and contract management objectives outlined in Chapter 1, performance evaluation can contribute towards following specific applications:

1. **Total Cost of Ownership (TCO):** The Total Cost of Ownership (TCO) of electric buses over their life of 10 to 15 years includes Capital Expenditure (CAPEX) for the vehicles and charging infrastructure while supporting civil and power infrastructure cost is amortised over their life of 25-30 years. Operational Expenses (OPEX) for staff, energy, vehicle and battery maintenance, tax, insurance and other miscellaneous costs together form the majority of the TCO. Performance evaluation of deployed e-bus in varied operating contexts can give accurate estimates of various components of the TCO thereby helping cities identify the least TCO alternative for their operating conditions. The TCO analysis can in-turn help in the following:

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

   a. **Incentive design:** The current incentives for electric buses under FAME II and other state level subsidies are designed as CAPEX subsidy on the vehicle cost for both Gross Cost Contract (GCC) models of procurement. CAPEX on vehicles is typically is a minor component of the TCO of bus systems as staff, energy and maintenance costs together form the majority of the cost. An accurate estimation of each of these TCO components can help evaluate the FAME II incentive mechanism and propose alternative incentive designs for the future
   b. **Procurement planning and business model selection**: The performance evaluation of the deployed buses could provide inputs to identify the best business model for procurement based on the TCO analysis i.e. outright purchase Vs GCC based on the performance delivery. The vehicle and infrastructure specifications which are appropriate for the specific operational requirements based on data from ongoing operations
2. **Service planning and delivery:** Bus agencies have experience in operating typical Internal Combustion Engine (ICE) based buses which typically operate for the entire day with just 5-10 minutes of fuelling time. In case of e-buses, buses need to spend more time for charging-thereby reducing their 'up-time' for operations. The time for charging varies between buses based on their battery size, energy efficiency and consequently their maximum range per charge. Performance evaluation can provide a comprehensive evaluation of the operational constraints of e-buses thereby helping in addressing the following concerns:
   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 in determining the performance of e-buses. Performance evaluation can help detect scope for improvement in these areas and help in identifying areas for training and capacity building needs for staff
4. **Battery management:** Batteries are the most expensive asset of electric buses and are at the heart of ensuring sustainability of e–bus operations. Therefore, performance evaluation of e-buses can assist the OEMs/Operators in
   a. Battery health monitoring
   b. Prediction of range of buses real-time and useful life of batteries for the contract period
   c. Provision of alerts on maintenance needs and battery performance
5. **Emission reduction estimates:** It is understood that the adoption of e- buses will help reduce emissions from buses. Performance evaluation will help develop accurate estimations of the air pollution and Green House gas (GHG) impacts of e-bus deployment thereby making a stronger case of electrification of buses. This is a continuous process of evaluation over the lifecycle of bus operations.

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

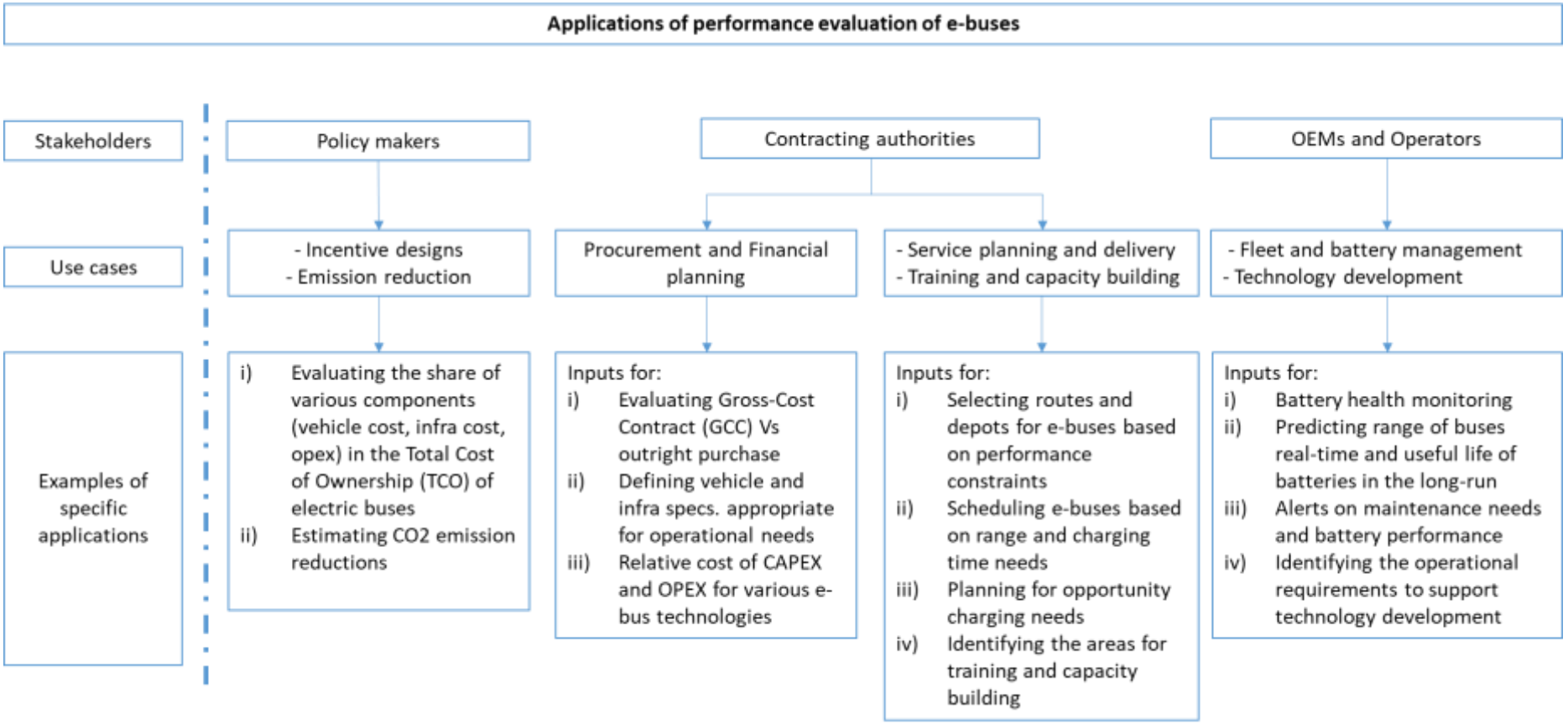

Figure 1 Application of performance evaluation framework

2.2 Stakeholder-wise benefits of performance evaluation

The performance evaluation of e-buses requires a collaborative approach from all key stakeholders to shape their decision making towards improved operations and future procurements. The key benefits of e-bus performance evaluation accrued to various categories of stakeholders can be outlined as follows:

1. **Policy makers and financing institutions**
   Policy makers and agencies involved in funding and financing of e-buses like DHI, state governments and International Financing institutions (IFIs) will benefit from performance evaluation of e-buses 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 towards global commitments of emission reduction

2. **Public transport Authorities**
   STUs and Special Purpose Vehicles (SPVs) that outsource e-bus services or purchase them are categorized as public transport authorities. e-bus performance evaluation benefits these authorities in both short and long term decision making:
   - To effectively monitor e-bus technical and operational performance against the Service Level Agreements (SLAs) outlined in the contract
   - To improve service planning and maximise service delivery based on real-world performance of e-buses
   - To inform future procurement and financial planning decisions
3. **Service Providers**
   Performance evaluation helps bus service providers minimise their cost of operations while meeting SLAs by:
   - Improving charging and battery management
   - Predicting maintenance requirements and allied procurements
   - Planning for battery replacements

4. **Manufacturers**
   The e-bus technology is still in its nascent stage and is still evolving. Hence, learning from real world performance helps OEMs identify improvements that can be incorporated in product development for the future. A performance snapshot of e-buses will also enable manufacturers in demand projection based on which model works in what condition.

3. Current performance evaluation practices

We reviewed various global examples of e-bus performance evaluation and the current practices in India to derive necessary learnings for an e-bus performance evaluation framework specific to India.

3.1 Global practices

Globally, around 0.42 million (4.2 lakh) e-buses are operational, 99% of which is in China. It is expected that the number would increase to around 18 million by 2020 (BNEF, 2018). China, Europe and the United States of America (USA) are the three regions with 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 are given in Table 1**Error! Reference source not found.**. While the transit agencies in these cities may be carrying out more comprehensive performance evaluation, only data available for the current project is explained in this report.

Table 1 Overview of documents reviewed for 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	United States of America (USA)	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	National Renewable Energy Laboratory	2016

The following sub-sections present the review of the international practices listed above covering their strategic priorities, methods for data collection and indicators of performance evaluation.

3.1.1 Agencies and objectives for performance evaluation

Globally, performance evaluation of e-buses is mainly commissioned by transit authorities, government agencies and also independent entities in many cases. In Europe and the USA Government entities such as Transport for London (TfL) and Federal Transit Administration Research (FTA) commissioned studies to provide guidance on future procurement and to evaluate e-bus performance against their intended targets. In Shenzhen, China performance evaluation was undertaken by Asian Development Bank (ADB) in association with Shenzhen Urban Transport Planning and Design Institute. ADB has also conducted an independent evaluation in partnership with Grutter consulting across multiple Chinese cities with large scale fleet operations. Most of the remaining studies are focussed on a specific city. However, independent evaluation exercises in China weren't as comprehensive as the reviews commissioned by the government authorities in Europe and USA.

A summary of the strategic objectives, scale and timelines is given in the Table 2**Error! Reference source not found.**. The objectives, scale and timelines of evaluation varied across the cases reviewed according to their applications. In terms of objectives, while financial performance and cost implications are evaluated by all studies, the evaluation in London also included user feedback and perception on e-buses. The duration of the evaluation also varied significantly amongst the cases with London having the longest duration of evaluation which started in 2017 and is still continuing.

The applications of performance evaluation also varied with respect to the strategic objective of the authority commissioning the evaluation. The major purposes of performance evaluation of e-buses globally are:

- To estimate the emission reductions from e-buses- The performance evaluation of e-buses in Chinese cities focussed on the emissions reduced through e-bus deployment
- To evaluate the TCO of e-buses- US cities conducted performance evaluation to estimate the TCO of e-buses and hence to plan for further deployment strategies
- To identify the training and capacity building needs- Chinese and US cities conducted performance evaluation also for identifying training and capacity building requirements

- To establish the further improvement needs of e-buses: All the reviewed conducted the performance evaluation to identify the further improvement requirement needs of e-buses. The key areas for future improvements include operations planning, infrastructure deployment, and procurement strategies, the real-world performance of e-buses and further improvements in operations and technology.

Table 2 Comparison of approach for performance evaluation of e-buses among global practices

Indicator	China	Europe	USA	
Coverage	Multiple cities	London	Foothill Transit	King County
Review undertaken by	• ADB • Shenzhen Urban Transport Planning & Design Institute	Transport Research Laboratory (TRL)	National renewable Energy Laboratory (NREL)	National renewable Energy Laboratory (NREL)
Authority commissioning the evaluation	• Independent initiatives	Transport for London	Federal Transit Administration Research (FTA)	California's Air Research Board (CARB) and FTA
Objective	To evaluate real-world performance of e-buses in China	To provide guidance on future Low Emission Bus (LEB) adoption	To evaluate performance of e-buses against their targets	To share early experience of advanced technology
Scale	Large e-bus fleets	Large e-bus fleets	Pilot evaluation	Large e-bus fleets
Categories of evaluation	• Environmental performance • Financial performance	• Buses • Infrastructure • Opinion	• Buses and infrastructure • Operational information • Cost parameters • Past experience of transit authority	
Duration	Until 2017	2017 onwards	July 2014-May 2015	April 2016-March 2017

3.1.2 Indicators for performance evaluation

All the reviewed cases followed a very comprehensive data collection exercise including a documentation of the base-line scenario through collection of bus system characteristics and infrastructure facilities. The major categories of data collection include:

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 costs
3. Other indicators
    a. Attitude and perception
    b. Driver satisfaction

Bus specifications and infrastructure details are captured at the beginning as it is important to analyse the base line information. Bus operations data captured details of route, daily operated kms, energy consumptions etc. These data indicators can provide insights to reliability of e-buses, battery performance, and range of e-buses in each operating scenario. In cases of full-fledged performance evaluation for a longer duration, data variation across time period and temperature were also analysed. Cities in the USA also conducted in-depth analysis of breakdowns and bus availability to estimate reliability of e-buses. Energy consumption and driving range is collected by all reviewed cases as this relates to energy consumption per km.

Both initial investment costs and operating & maintenance costs are collected in detail in all cases. US performance evaluation collected detailed maintenance data to differentiate the cost with ICE buses and to establish the reasons for higher initial maintenance cost of e-buses. Work order maintenance cost is also analysed in US cities to estimate each vehicle part related cost of operations of e-buses

Two additional parameters collected across the reviewed cases include user and driver satisfaction and ability of the organization to deliver quality bus services and the previous experience with ZEBs. These parameters consider e-bus service delivery in a comprehensive manner by capturing perception of end users and service operators. The summary of the indicators of performance evaluation is given in Annexure-II.

3.1.3 Methods and periodicity of data collection

The reports published by the independent agencies and authorities are based on collaborative efforts of different stakeholders. In most cases, the agency which

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 collected data frequently on a daily basis. In most cases, the data collection was based on the current monitoring practices of transit agencies and these agencies/authorities already had an extensive performance evaluation mechanism in place.

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

Table 3 Methods and periodicity of data collection among global practices

Description	China	Europe	USA	
Agency which collected data	ADB, Shenzhen	TRL	Online data from manufacturers collected by NREL	NREL
Frequency of data collection	-Once	- Daily - Monthly - Once	- Daily - Monthly - Once	- Daily - Monthly - Once
Sources of data	- Manual surveys - GPS - Electronic reports	- Telematics data - Fuel data - Survey based data - Pilot information	- GPS Information - Utility bills - National Transit Database - Maintenance work orders - Battery SOC - Daily service reports - Daily garage activity sheets	- GPS Information - 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. Performance evaluation of e-buses being initiated by decision-makers like transit authorities or other Government agencies is a key feature of the more comprehensive evaluation exercises
2. The major applications for which performance evaluation was conducted include:
    a. Emission reduction estimates
    b. Evaluation of TCO
    c. Identification of training and capacity building needs
    d. Identification of further improvements needed in operation

3. Transit agencies, bus operating companies and manufacturers need to collaborate to ensure data availability for the evaluation and efficiency in its collection.

4. In majority of the reviewed cases, performance evaluation data was collected from standard data logs maintained by transit agencies rather than as a separate data collection exercise

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 Cost and financials
        ii. Operation and maintenance costs
    c. Other indicators
        i. Attitude and perception
        ii. Driver satisfaction

6. The evaluation exercise needs be undertaken using the same indicators consistently over a few years to establish robust performance results

3.2 Current practices in India

Performance evaluation of bus based public transport systems in India is typically conducted using Key Performance Indicators (KPIs) established by the Central Institute of Road Transport (CIRT), Government of India (GoI). Some STUs adopt different variations of CIRT indicators according to their local contexts and operating models. However, the data collection and KPI reporting practices vary widely within India- with many States and Cities not even collecting adequate data to generate the KPIs proposed by CIRT (IIT Delhi,

2016[2]). At the same time, there's a significant scope for improvement in KPIs recommended by CIRT when compared International best practice examples in performance monitoring such as Transport for London (TfL). Massachusetts Bay Transportation Authority (MBTA). It is in this context of inadequate performance evaluation and management of conventional buses that electric buses are being implemented in India.

This section discusses on the current practices of bus performance evaluation in India in two categories. Firstly, to understand the evaluation mechanisms for most commonly adopted Internal Combustion Engine (ICE) buses and their framework. Secondly, to review the performance evaluation mechanism for already deployed electric buses.

The public bus transport services in India are managed by STUs or Special Purpose Vehicles (SPVs). In most cases, the performance evaluation is undertaken by the respective STU on a daily basis for the entire fleet and is not linked to policy making, transport planning, decision making etc. Some STUs use the Key Performance Indicators (KPI) 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 of public bus systems in India.

3.2.1 Categories of indicators

The published data of SRTUs comprises indicators on financial and physical performance of the SRTUs. The financial performance indicators are grouped into

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

Physical performance indicators are categorised into

- Category I: Fleet utilization- count of buses and total kms served by the SRTUs

[2] 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.

- Category II: Capacity utilization in terms of 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, category of each staff
- Category V: The material performance indicators which include consumption of fuel and other materials like lubricants, engine oil, tyres etc.

Further, SRTUs also maintain the data categorized based on the manufacturers, spare parts etc. The detailed indicator list for current ICE buses is given in the Annexure-I.

3.2.2 Methods and periodicity of data collection

The annual reports published by CIRT are based on the data indicators supplied by SRTUs quarterly in a pre-defined format. The data is collected from almost 53 reporting SRTUs and SPVs across the country which includes both urban and rural services. Further, bus transport in India is also governed by SPVs created at city level and most SPVs are not part of the regular data collection process. Therefore, the annual compilation exercise by CIRT or TRW includes only evaluation for reporting STUs and few SPVs.

The SRTUs typically monitor their operational performance schedule wise at a depot level. This data is compiled at the SRTU level to submit to CIRT. The typical operational information- Management Information Systems (MIS) are collected through manual methods or by using Intelligent Transport System (ITS) in case of advanced SRTUs. The operational and maintenance data at a depot level are collected on a daily basis while financial performance indicators are evaluated typically on a monthly basis.

In case of outsourced operations, the frequency of data reporting may also depend on the frequency of payment which typically is linked to key performance indicators (KPI). Therefore, the SRTUs which practice performance monitoring already collect these data either from manual or ITS sources.

3.3 Performance evaluation practices of Indian e-bus operators

India currently has about 600 e-buses out of which 560 buses can be considered as public transport fleets (at least 10 buses) which are deployed by 11 bus agencies 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 FAME I subsidy. While these agencies continue to collect bus operations related KPIs such as fleet availability, vehicle utilisation, punctuality e-bus vehicle technology specific KPIs such as energy consumption, charger and battery performance etc. aren't captured in much detail. Most agencies just collect the electricity consumption data across all the buses without measuring bus, charger and route –wise performances. Hence, Indian bus agencies need to improve their performance evaluation practices to track their own e-

bus performance and to compare themselves with other agencies. A standardised set of KPIs across agencies can improve operational efficiency and can inform future procurement decisions.

*Table 4 Overview of current e-buses fleets deployed across 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 fleet of e-buses (at least 10 buses) operating as public bus services. Additionally, there are various niche applications and trials across India such as one bus operating in Thane, e-buses operating in tarmac operations in Delhi, Chennai and Hyderabad airports, private intercity buses in Maharashtra and others that aren't covered here.

4. Performance evaluation framework for e-buses

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

As explained in chapter 2 many Indian states and cities have poor data management and ITS practices which won't allow them to carry out real time performance monitoring. We propose that a periodic performance evaluation of the identified KPIs is 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 period data collection processes. The same indicators can easily be incorporated into real-time monitoring systems where available. Further these indicators have been presented in two stages: Stage 1 comprises of essential indicators specific to electric buses that all e-bus implementing agencies are advised to collect to ensure successful operations, while 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' to make the evaluation more comprehensive. Both essential and recommended indicators can be generated by moth traditional/ manual methods of data collection and advanced ITS/ MIS based data collection systems.

4.1 Proposed indicators for e-bus performance evaluation

The proposed indicators for electric bus performance evaluation are categorized 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. Attitude and perception of users

The indicators are compared with CIRT indicator list to identify if it is being already collected and then new indicators are suggested which are necessary for electric buses. The indicator list and its comparison with CIRT indicators are given in Annexure-III.

Table 5 presents the essential indicators that ought to be collected by all bus agencies implementing e–buses. These are recommended to be collected for both Gross Cost Contract (GCC) and outright purchase based procurement as these indicators are essential to monitor the e-bus performance and adopt efficiency improvement strategies for operating buses and procurement specifications for planned e-bus deployments.

Table 5 Essential indicators for e-bus performance evaluation

Sl No	INDICATORS	SUB-INDICATORS	DESCRIPTION
A. BUS SYSTEM DETAILS			
I. BUS SPECIFICATIONS			
1	Number of buses - Total, of which:		
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		Time spent including charging, cleaning, routine maintenance
9	Total cancelled km so far		
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	Energy efficiency of buses (KWH/KM)		Total energy consumed (KWH) to the total distance travelled
12	KWH capacity of charger		

Sl No	INDICATORS	SUB-INDICATORS	DESCRIPTION
13	No. of times of charging per day		
14a	Charging 1	Duration of each charging event	
14b		State of charge at start of Charging 1	
14c		State of charge at end of Charging 1	
14d		Km travelled for charging 1	
15a	Charging 2	Duration of each charging event	
15b		State of charge at start of Charging 2	
15c		State of charge at end of Charging 2	
15d		Km travelled for charging 2	
16a	Charging 3	Duration of each charging event	
16b		State of charge at start of Charging 3	
16c		State of charge at end of Charging 3	
16d		Km travelled for charging 3	
17	Power consumed per day(KWH)		Total power consumed for 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 operator	
20b		CPKM of conductor	
20c		CPKM of traffic supervision staff + admin staff	
20d		CPKM of energy	
21	If outright purchase		
21a		Cost of bus purchase	
21b		Cost of charging infrastructure (if available)	
21c		CPKM of staff	
21d		CPKM of maintenance	
21e		CPKM of energy	
22	Earnings per km on electric buses		

Table 6 presents the 'recommended indicators' for e-bus performance evaluation that expands of the 'essential indicators' covered in Table 5. It includes a total of 57 Key Performance Indicators (KPIs) identified to monitor and evaluate electric bus performance. The bus system details, manpower, part of infrastructure and bus operations include CIRT indicators that are typically collected. The main new indicators proposed includes those related to charging infrastructure specifications, energy consumptions and financing pattern for new procurement models. The detailed definition of each indicator and any formula associated is given in Annexure-II.

Table 6 Recommended indicators for e-bus performance evaluation

Sl No	INDICATORS	SUB-INDICATORS	DESCRIPTION
C. BUS SYSTEM DETAILS			
I. BUS SPECIFICATIONS			
1	Name of the OEM		Name of the manufacturer
2	Number of buses - Total, of which:		
2a		No. of 9m buses	
2b		No. of 12m buses	
3	Date of induction of buses		Date of induction of each lot of bus
4	Length/width/height		Technical specifications of the e-buses
5	Gross vehicle Weight		
6	Wheelbase		
7	Passenger capacity		
8	Rated power (hp)		
II. INFRASTRUCTURE SPECIFICATIONS			
9	Charger description		
10	Total no. of chargers		
11	KW capacity of depot charging infrastructure		Capacity provided at the depot
12	KW of enroute charging (if any)		
13	KV of power to the depot		
14	Number of depots of electric bus operation		
15	electric buses per depot		
16	Total Depot Land Area Available (sq KM)		Specified as land per depot

Sl No	INDICATORS	SUB-INDICATORS	DESCRIPTION
III. Operations			
17	Average number of buses on-road		
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 the routes
21	Operated km per bus per day		Average operated km across the routes
22	Average odometer reading		
23	Steering hours per bus per day		
24	Scheduled revenue hours per bus		
25	Time spent at a depot per bus per day		Time spent including charging, cleaning, routine maintenance
26	Total cancelled km so far		
26a		due to *crew shortage*	
26b		due to *unavailability of bus*	
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 so far		
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 Load Factor (LF) of electric buses		
IV. Energy			

Sl No	INDICATORS	SUB-INDICATORS	DESCRIPTION
36	Energy efficiency of buses (KWH/KM)		Total energy consumed (KWH) to the total distance travelled
37	No. of times of charging per day		
38a	Charging 1	Duration of each charging event	
38b		State of charge at start of Charging 1	
38c		State of charge at end of Charging 1	
38d		Km travelled for charging 1	
39a	Charging 2	Duration of each charging event	
39b		State of charge at start of Charging 2	
39c		State of charge at end of Charging 2	
39d		Km travelled for charging 2	
40a	Charging 3	Duration of each charging event	
40b		State of charge at start of Charging 3	
40c		State of charge at end of Charging 3	
40d		Km travelled for charging 3	
41	Power consumed per day		Total power consumed for 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 cost of upstream electricity infrastructure cost
49	Business model (Outright purchase/ GCC)		
50	If GCC		

Sl No	INDICATORS	SUB-INDICATORS	DESCRIPTION
50a		CPKM (paid to the operator if GCC)/ Payment paid to operator	
50b		CPKM of conductor	
50c		CPKM of traffic supervision staff + admin staff	
50d		CPKM of energy	
51	If outright purchase		
51a		Cost of bus purchase	
51b		Cost of charging infrastructure (if available)	
51c		CPKM of staff	
51d		CPKM of maintenance	
51e		CPKM of energy	
52	Subsidy amount	(FAME Subsidy/ State subsidy/	
53	Source of subsidy		
54	Source of financing beyond subsidy	(Commercial loans/ grants/ in-house budgets)	
55	In case of loan	Rate of interest of loan	
56		Loan tenure	
57	Earnings per km on electric buses		

E. OTHER INDICATORS

The other indicators mainly collected by global practices include attitude and perception of users and drivers. The IIT Delhi[2] study also identified the need for capturing user perception which is currently absent in India. In this scenario, the specific performance evaluation indicators for e-buses as given below are required to assess the user perception.

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

These indicators are in addition to the other user perception indicators ideally an STU/authority shall collect for assessing user perception of public bus transport. The next sub-section discusses on framework for this data collection including method, sources and responsibility for data collections.

4.2 Method, sources and periodicity of data collection

Chapter 3 presented the current methods of data collection in Indian STUs. This includes Management Information Systems (MIS) reports (both operation and maintenance), ITS reports, manual entry data and STU data base for fleet and depot information.

Additionally, new methods and sources of data are available for e-buses such as:

- Schedule wise charging reports of ITS
- Utility bills, electricity readings at depots and at chargers available from electricity Distribution Companies (DISCOMs)
- OEM/Operator Invoices

The new indicators which can be collected through each of these new methods identified methods are given in Table 7, Table 8 and Table 9.

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

Data Source: Schedule wise charging reports using ITS
Number of charging events
Duration of each charging event 1
State of charge at start of Charging 1
State of charge at end of Charging 1
Km travelled for charging 1
Duration of each charging event 2
State of charge at start of Charging 2
State of charge at end of Charging 2
Km travelled for charging 2
Duration of each charging event 3
State of charge at start of Charging 3
State of charge at end of Charging 3
Km travelled for charging 3

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

Data Source: DISCOMs
Energy efficiency of buses (KWH/KM)
Power consumed per day
Energy cost (INR per kwh)
CPKM of energy

Table 9 New Indicators to be collected from Invoices to authority

Source: Invoice to SRTU/Authority
CPKM (payment to the operator)
Cost of bus purchase (if applicable)
Cost of charging infrastructure (if available)

Further, the 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 evaluation. Accordingly, all indicators are classified based on the periodicity of data collection. The bus system details and infrastructure indicators need to be collected only at the beginning of evaluation as they would mainly remain constant. The bus operations details and energy indicators need to be collected on a daily basis. These data indicators vary with respect to the specific operating conditions and hence it is important they are collected daily. Finally, certain indicators related to personnel and financing based on the procurement model, utility bills etc. need to be collected monthly as these indicators are typically notified at the end of each month. The detailed framework of indicators given in Annexure-III explains the periodicity for each indicator.

4.3 Responsibility for data collection

The stakeholders involved for the performance evaluation is generally dependent on the type of procurement model. The key stakeholders include:

- STU/contracting authority
- Operator
- OEM

Table 10, Table 11 and

Table **12** give stakeholder wise list of indicators to be collected. The tables are considering a procurement through gross cost contract as FAME-II subsidy scheme of Government of India is only for GCC model. In an outright purchase model with an annual maintenance contract with 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 STU/Contracting Authority

Name of the OEM
Number of buses - Total, of which:
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 buses on-road
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 Load Factor (LF) of electric buses
Energy cost (INR per kwh)
Cost of electric infrastructure (11KV/ 66KV line, transformer etc.)
Number of depots of electric bus operation
electric buses per depot
Total Depot Land Area Available (sq KM)
No. of conductors
No. of contract management staff
Other staff
Business model (Outright purchase/ GCC)
CPKM (paid to the operator if GCC)/ Payment paid to operator
CPKM of conductor
CPKM of traffic supervision staff + admin staff
CPKM of energy
Cost of bus purchase
Cost of charging infrastructure (if available)
CPKM of staff
CPKM of maintenance
CPKM of energy
Subsidy amount
Source of subsidy
Source of financing beyond subsidy
Earnings per km on electric buses

Table 11 Indicators to be collected by 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 so far
due to *crew shortage*
due to *unavailability of bus*
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
Rate of interest of loan
Loan tenure

Table 12 Indicators to be collected by OEMs

OEM
Time interval between maintenance events
No. of times of charging per day
Duration of each charging event
State of charge at start of Charging 1
State of charge at end of Charging 1
Km travelled for charging 1
Duration of each charging event
State of charge at start of Charging 2
State of charge at end of Charging 2
Km travelled for charging 2
Duration of each charging event
State of charge at start of Charging 3
State of charge at end of Charging 3
Km travelled for charging 3
Power consumed per day
Charger description
Total no. of chargers
KW capacity of depot charging infrastructure
KW of enroute charging (if any)
KV of power to the depot
No. of maintenance staff

To summarize, the performance evaluation of e-buses needs a multi stakeholder approach for a comprehensive data collection to fulfil the objectives of all stakeholders. The detailed framework of proposed performance evaluation is given in Annexure-III.

4.4 National level data sharing platform for e-buses

The KPIs proposed for the performance evaluation of e-buses 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. Further, the performance evaluation needs to be carried out by each city/ state for themselves and also needs to be compared with other cities and states to benchmark their performance. In addition to helping cities with their operational strategies, such benchmarking will also support DHI is evaluating the performance of the e-bus funding through the FAME scheme and in designing the future subsidies to encourage the best performing systems.

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

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

- Performance monitoring of conventional ICE based buses is currently carried out using a combination of Intelligent Transport Systems (ITS) and Management Information Systems (MIS) based platforms
- The existing ITS and MIS systems in India are typically drive by the vendors providing the software service or the one's deploying the ITS hardware. As a result, most Indian cities don't have an integrated ITS and MIS platform that helps monitor their overall performance
- One of the key reasons of the lack of a comprehensive solution in India is that it each city tried to develop their own platform even though they possess the required technical and financial resources that are needed for such a system

2) **Need and scope for the proposed National-level platform**

- Developing a National level platform can help pool-in resources centrally to develop a good quality solution that can work across 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, breakdowns etc. and other indicators covering operations, user perception, funding and financing
- Hence, the proposed National level platform can either be designed as a part of the wider performance monitoring efforts for the bus systems or to just focus on the performance evaluation indicators specific to e-bus technology

- It is recommended that the platform shall cover both ITS based real-time performance monitoring and MIS/ excel data input based performance evaluation to ensure that it is adopted by various states and cities at various levels of technology maturity in their operations
- As an interim step towards developing a National-level ITS/ MIS platform, it is recommended that simple spreadsheet/ excel based data sharing template is circulated among cities implementing e-buses. The template can adopt the framework proposed by this report
- The National level platform can initially compile and compare e-bus performance across cities based on excel based data collection template. Once the excel based performance monitoring is stabilised, these can be transitioned to more advanced methods like MIS and ITS systems.

3) **Venue for development and management of the National platform for e-bus monitoring**

- Consistent efforts to develop and sustain the e-bus monitoring platform are of paramount importance to ensure the successful deployment and to accrue the benefits of the National platform for e-bus performance monitoring and evaluation
- It is recommended that Government of India (GoI) backed centres of excellence such as Central Institute for Road Transport (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, 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 focussed on promoting clean mobility technologies. As cities selected for FAME II subsidy and others brace for deployment of e-buses, it is important to ensure that they carry out comprehensive performance evaluation to improve their efficiency of implementation and to inform future procurement efforts. Towards this, the report presented potential applications of performance evaluation of e-buses, indicators for e-bus performance evaluation and an overall framework for data collection and performance evaluation.

It is important that e-bus specific KPIs are included into 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 applications such as operational and financial indicators while adding e-buses specific KPIs such as energy, battery and charging infrastructure performance.

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

1) **Incorporate the proposed performance evaluation framework as part of the DHI guidelines to STUs/ city authorities** while deploying e-buses. DHI has already proposed the performance evaluation of e-buses in its EoI inviting cities for 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 case cities which 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 to build capacity of all the stakeholders towards making performance evaluation a core part of their operations and decision making for the future. The pilot can be based on simple data collection processes using manual and excel based methods in case the agency doesn't have access to MIS and ITS based methods.

3) **Develop a National-level e-bus data sharing platform**: A National level data sharing platform need to be established to help cities implement the proposed performance evaluation framework such that cities can quickly adopt the system instead of rebuilding one for themselves and also to enable DHI to monitor performance of the e-buses subsidised through the FAME scheme. The platform shall 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 levels progresses from pilots to a fleet level deployment. Even this platform can start using simple excel based data management templates for wider adoption followed by 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/authority's continuous monitoring practices to learn from the previous experiences and improve the operational strategies for the future. This would involve adding KPIs specific to electric buses such as energy efficiency of the bus (kwh/km), charging duration related off-time etc. in addition to their conventional performance evaluation practices

5) **Knowledge sharing and capacity building programs**: As STUs and cities gain experience in e-bus deployment and operations, there need be adequate venues for them to exchange knowledge and learn from each other's experiences. Simultaneously capacity building programs aimed at helping them understand the latest trends in e-bus technologies, planning, procurement and management will ensure sustainability of their operations and a further scale up

6) **Integrate the new e-bus performance evaluation indicators within CIRT and TRW indicators**. The proposed framework identified new indicators necessary for e-bus performance evaluation. This would ensure that e-bus indicators are collected along with the annual reporting of STUs/authorities to CIRT and TRW

6. Annexures

6.1 Annexure-I: CIRT data indicator list

Indicators	Unit
Financial Performance	
Category I – Total Cost	
a. Personal Cost	₹ (in Lakhs) or Ps./eff. km
i. Drivers	
ii. Conductors	
iii. Traffic Supervisory	
iv. Total Traffic Staff	
v. W/shop1 & Maintenance	
vi. Admin & Others	
vii. P.F., Welfare, etc.	
viii.Total (i. to vii.)	
b. Material Cost	₹ (in Lakhs) or Ps./eff. km
i. Fuel	
ii. Lubricants	
iii. Springs	
iv. Auto Spare Parts	
v. Tyres & Tubes	
vi. Batteries	
vii. General Items	
viii. Reconditioned Items	
ix. Total (i. to viii.)	
c. Taxes	₹ (in Lakhs) or Ps./eff. km
i. M.V. Tax	
ii. Passenger Tax	
iii. Special Road Tax	
iv. Misc. & Other Tax	
v. Total (i. to iv.)	
d. Interest	₹ (in Lakhs) or Ps./eff. km
i. To Central Govt.	
ii. To State Govt.	
iii. On Borrowings	
iv. Total (i. to iii.)	
e. Misc. & Others	₹ (in Lakhs) or Ps./eff. km
f. Payment to Hired Buses	₹ (in Lakhs) or Ps./eff. km
g. Depreciation	₹ (in Lakhs) or Ps./eff. km
i. On Buses	

Indicators	Unit
ii. On Other Assets	
Total Cost (a. to g.)	₹ (in Lakhs) or Ps./eff. km
Category II – Total Revenue	
Traffic Revenue	₹ (in Lakhs) or Ps./eff. km
Reimbursement of Fare Concessions	₹ (in Lakhs) or Ps./eff. km)
Subsidy	₹ (in Lakhs) or Ps./eff. km
Non-traffic Revenue	₹ (in Lakhs) or Ps./eff. km
Category III – Profit/Loss	
Surplus before Tax	₹ (in Lakhs) or Ps./eff. km
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 – Utilization of Fleet	
Buses held	Count
Buses off road	Count
No. of spare buses	Count
Buses on road	Count
Fleet Utilization	%
Scheduled services	Count
Scheduled kms.	Lakhs km
Effective kms.	Lakhs km
Dead kms.	Lakhs km
Gross kms.	Lakhs km
Cancelled kms.	Lakhs km
Bus utilization per day on buses on road	Km
On buses held	
Category II – Capacity Utilization	
Seating capacity	Count
No. of standees	Count
Seat kms.	Lakhs km
Carrying capacity kms.	Lakhs km
Passenger kms.	Lakhs km
Occupancy Ratio	%
Load factor	%
Passenger lead	Km/passenger
Passengers carried	Count

Indicators	Unit
Passengers per bus on road per day	Count
Category III – QOS	
Trips to be operated	Count
Actual trips operated	Count
Regularity	%
Indicators	Unit
No. of breakdowns	Count
Breakdown per 10,000 eff. kms.	Count
Punctuality Departure Arrival	%
Fatal accidents	Count
Major & serious accidents	Count
Minor accidents	Count
Total accidents	Count
Accidents per lakh eff. kms.	Count
No. of person 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	
Manpower Productivity per day	Km
Avg. salary/employee/day	₹
Eff.kms./crew 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

Indicators	Unit
% of Total Kms	%
No. of Bus Shelters/Stops	Count
Material Performance	
HSD (High-speed Diesel)	Kiloliters
CNG (Compressed Natural Gas)	Km/kg
KMPL (Kilometre per Liter)	Km/liter
i. Tata	
ii. Leyland	
iii. Volvo	
iv. Others	
Engine oil used /oil change	Kiloliters / Lakhs km (for oil change)
i. Tata	
ii. Leyland	
iii. Volvo	
iv. Others	
Engine oil top-up	Kiloliters or Lakhs km (for oil change)
i. Tata	
ii. Leyland	
iii. Volvo	
iv.Others	
New tyres consumed	Units/lakh km
Engine oil KMPL	Km/liter
Battery life	Months/ lakh km
Gearbox oil	Kiloliters
i. Top-up	
ii. Oil change	
Spring	Kg/lakh km
Retreaded tyres consumed	Units/lakh km
Differential oil	Liters
i. Top-up	
ii. Oil change	
Engine Life	Lakhs km
i. New	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
ii. Reconditioned (R/C)	
a. Tata	
b. Leyland	
c. Volvo	

Indicators	Unit
d. Others	
iii. Overall	
Crown wheel & pinion life	Lakhs km
i. Tata	
ii. Leyland	
iii. Volvo	
iv. Others	
v. Overall	
Fuel injection pump life	Lakhs km
i. New	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
ii. R/C	
a. Tata	
b. Leyland	
c. Volvo	
d. Others	
iii. Overall	
Gearbox life	Lakhs 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	Lakhs km
i. Tata	
ii. Leyland	
iii. Volvo	
iv. Others	
v. Overall	
Clutch plate life	Lakhs km
i. Tata	
ii. Leyland	

Indicators	Unit
iii. Volvo	
iv. Others	
v. Overall	

6.2 Annexure-II: Indicators identified from global review

Indicator Category	China	Europe	US	
Coverage	Multiple cities	London	Foothill Transit	King County
Buses	- Life span of buses - Vehicle performance	- Number of buses - Bus manufacturer - Range of bus in a single charge	- Number of buses - Bus manufacturer/ model - Model year - Length/ width/ height - Curb weight - Wheel base - 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 - Breakdown reason - 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 state of charge - State of charge degradation	- Mileage - Bus start time and stop time - In-service time total - Out-service time total - Scheduled out of service time total - Unscheduled out of service time total - Description of bus out of service reason - Planner service time total - Range on 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 unavailability of bus - Battery State of Charge - 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

Financials	- Bus and infrastructure investment costs - Energy cost - Staff cost - Spare parts cost - Service Charges - Investment, operation and maintenance of chargers - 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 LEBs - Ease of integrating bus and infrastructure with current fleet - Ease of maintenance and operation - Perception of bus and infrastructure as a whole		- Previous experience with zero emission buses - Roles of organizations - Driver, fleet personnel and customer perception - Special fleet needs - Training

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

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
Name of the OEM		CIRT	STU	STU/Authority Fleet data base	Once	--	
Number of buses - Total, of which:		CIRT	STU	STU/Authority Fleet data base	Once	Incentive design	Compilation across the country to decide on future incentives
No. of 9m buses	No. of 9m buses	CIRT	STU	STU/Authority Fleet data base	Once	Incentive design	
No. of 12m buses	No. of 12m buses	CIRT	STU	STU/Authority Fleet data base	Once	Incentive design	
Date of induction of buses		CIRT	STU	STU/Authority Fleet data base	Once	--	
Length/width/ height		CIRT	STU FROM OEM	STU/Authority Fleet data base / OEM product portfolio	Once	Incentive design	
Gross vehicle Weight		CIRT	STU FROM OEM	STU/Authority Fleet data base/ OEM product portfolio	Once		
Wheelbase		CIRT	STU FROM OEM	STU/Authority Fleet data base/ OEM product portfolio	Once		
Passenger capacity		CIRT	STU FROM OEM	STU/Authority Fleet data base/	Once		

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
				OEM product portfolio			
Rated power (hp)		CIRT	STU FROM OEM	STU/Authority Fleet data base/ OEM product portfolio	Once		
Charger description		NEW	OEM	STU/Authority Electrical Database/OEM product portfolio	Once	Service planning and delivery, Fleet and battery management	To evaluate 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	
KW capacity of depot charging infrastructure		NEW	OEM	STU/Authority Electrical Database/OEM product portfolio	Once	Service planning and delivery, Fleet and battery management	
KW of enroute charging (if any)		NEW	OEM	STU/Authority Electrical Database/OEM product portfolio	Once	Service planning and delivery, Fleet and battery management	
KV of power to the depot		NEW	OEM	STU/Authority Electrical Database/OEM product portfolio	Once	Service planning and delivery, Fleet and battery management	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
Number of depots of electric bus operation		NEW	STU	STU/Authority Database	Once	total cost of ownership, procurement and financial planning	
electric buses per depot		NEW	STU	MIS-Operation/ITS	Once	total cost of ownership, procurement and financial planning	
Total Depot Land Area Available (sq KM)		CIRT	STU	STU/Authority Database	Once	total cost of ownership, procurement and financial planning	
Average number of buses on-road		CIRT	STU	MIS-Operation/ITS	Monthly	Service planning and delivery	
No. of operational days per month		CIRT	STU	MIS-Operation/ITS	Monthly	Service planning and delivery	1. Percentage of cancelled kms against scheduled km to be used to plan for future schedules (reasons for cancellation to assess the nature of repetition), 2. To plan for future maintenance activity for a particular bus type and specific
Scheduled km per bus per day		CIRT	STU	Schedule database	Daily	Service planning and delivery	
Dead km per bus per day		CIRT	STU	MIS-Operation/ITS	Daily	Service planning and delivery	
Operated km per bus per day		CIRT	Operator	MIS-Operation/ITS	Daily	Service planning and delivery	
Average odometer reading		CIRT	Operator	MIS-Operation/ITS	Monthly	Service planning and delivery	
Steering hours per bus per day		CIRT	Operator	MIS-Operation/ITS	Daily	Service planning and delivery	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
Scheduled revenue hours per bus		CIRT	STU	STU/Authority Schedule data	Daily	Service planning and delivery	operating conditions, 3. To assess the battery health and hence to predict the range of buses real time
Time spent at a depot per bus per day		CIRT	Operator	MIS-Operation/ITS	Daily	Service planning and delivery	
Total cancelled km so far			Operator	MIS-Operation/ITS	Monthly	Service planning and delivery	
	due to ***crew shortage***	NEW	Operator	MIS-Operation/ITS	Monthly	Service planning and delivery	
	due to ***unavailability of bus***	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-Operation/ITS	Monthly	Service planning and delivery	
	due to **transmission** issues	NEW	Operator	MIS-Operation/ITS	Monthly	Service planning and delivery	
	due to **charging** issues	NEW	Operator	MIS-Maintenance	Monthly	Service planning and delivery, Fleet and battery management	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
	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 so far		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. To identify constraints along particular route based on a particular technology. This will also help in future selection of routes and depots, scheduling of ebuses and 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-Operation/ITS	Once	Service planning and delivery	
Trips per route		NEW	STU	Schedule database	Once	Service planning and delivery	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
Average speed		NEW	Operator	GPS Information	Daily	Service planning and delivery	
Average Load Factor (LF) of electric buses		CIRT	STU	MIS-Operation/ITS	Daily	Service planning and delivery	
Energy efficiency of buses (KWH/KM)		NEW	Operator/OEM	Power consumed by all chargers from Utility readings to the total kms operated	Monthly	Service planning and delivery, total cost of ownership, procurement and financial planning	1. To identify range of buses in actual operating conditions, 2. To predict the energy cost for future financial planning
No. of times of charging per day		NEW	OEM	MIS-Operation/ITS	Daily	Service planning and delivery, Fleet and battery management	1. To estimate the actual steering hours in operating scenario and hence to prepare scheduling of e-buses based on range and charging requirements, 2. To evaluate the cost of energy and extra fleet required to replace the duration lost to charging and hence total cost of ownership
	Duration of each charging event	NEW	OEM	ITS/Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	State of charge at start of Charging 1	NEW	OEM	Battery SOC-Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	State of charge at end of Charging 1	NEW	OEM	Battery SOC-Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	Km travelled for charging 1	NEW	OEM	ITS/Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management, total cost of ownership	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
	Duration of each charging event	NEW	OEM	ITS/Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	State of charge at start of Charging 2	NEW	OEM	Battery SOC-Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	State of charge at end of Charging 2	NEW	OEM	Battery SOC-Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	Km travelled for charging 2	NEW	OEM	ITS/Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management, total cost of ownership	
	Duration of each charging event	NEW	OEM	ITS/Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	State of charge at start of Charging 3	NEW	OEM	Battery SOC-Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	State of charge at end of Charging 3	NEW	OEM	Battery SOC-Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management	
	Km travelled for charging 3	NEW	OEM	ITS/Schedule wise charging reports	Daily	Service planning and delivery, Fleet and battery management, total cost of ownership	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
Power consumed per day		NEW	OEM	Depot electric meter reading	Daily	Service planning and delivery, Fleet and battery management, total cost of ownership	
Energy cost (INR per kwh)		NEW	STU	DISCOM Website	Once	total cost of ownership, procurement and financial planning	
No. of drivers		CIRT	Operator	MIS-Operation/ITS	Daily	Service planning and delivery, Fleet and battery management, total cost of ownership	
No. of conductors		CIRT	STU	STU/Authority Database	Daily	Service planning and delivery, Fleet and battery management, total cost of ownership	
No. of maintenance staff		CIRT	OEM	MIS-Operation/ITS	Monthly	Service planning and delivery, Fleet and battery management, total cost of ownership	
No. of contract management staff		CIRT	STU	STU/Authority Database	Monthly	Service planning and delivery, Fleet and battery management, total cost of ownership	
Other staff		CIRT	STU	STU/Authority Database	Monthly	Service planning and delivery, Fleet and battery management, total cost of ownership	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
Business model (Outright purchase/ GCC)		NEW	STU	STU/Authority Database	Once	Incentive design, procurement and financial planning	To assess the future procurement models
If GCC							
	CPKM (paid to the operator if GCC)/ Payment paid to operator	NEW	STU	GCC contract, Monthly invoice/payment to operator	Once/Monthly	Incentive design, procurement and financial planning, Total cost of ownership	To evaluate the total cost of ownership, its various components, and relative CAPEX and OPEX costs to decide procurement models, incentives etc.
	CPKM of conductor	CIRT	STU	STU/Authority staff cost per km	Monthly	Incentive design, procurement and financial planning, Total cost of ownership	
	CPKM of traffic supervision staff + admin staff	CIRT	STU	STU/Authority staff cost per km	Monthly	Incentive design, procurement and financial planning, Total cost of ownership	
	CPKM of energy	NEW	STU	DISCOM payment bills	Monthly	Incentive design, procurement and financial planning, Total cost of ownership	
If outright purchase							
	Cost of bus purchase	NEW	STU	OEM Invoice	Once	Incentive design, procurement and financial planning, Total cost of ownership	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
	Cost of charging infrastructure (if available)	NEW	STU	OEM Invoice	Once	Incentive design, procurement and financial planning, Total cost of ownership	
	CPKM of staff	CIRT	STU	STU/Authority staff cost per km	Monthly	Incentive design, procurement and financial planning, Total cost of ownership	
	CPKM of maintenance	CIRT	STU	STU/Authority staff cost per km	Monthly	Incentive design, procurement and financial planning, Total cost of ownership	
	CPKM of energy	NEW	STU	DISCOM payment bills	Monthly	Incentive design, procurement and financial planning, Total cost of ownership	
Subsidy amount	(FAME Subsidy/ State subsidy/	CIRT	STU	STU/Authority Database	Once	Incentive design, procurement and financial planning, Total cost of ownership	
Source of subsidy		NEW	STU	STU/Authority Database	Once	Incentive design, procurement and financial planning, Total cost of ownership	
Source of financing beyond subsidy	(Commercial loans/ grants/ in-house budgets)	NEW	STU	STU/Authority Database	Once	Incentive design, procurement and	

Metrics for evaluation	Sub-metric	Data already captured (CIRT) or New	Agency for collection in GCC Model	Source and method of data collection	Periodicity of data collection	Application of data	Analysis required
						financial planning, Total cost of ownership	
If loan	Rate of interest of loan	NEW	Operator/OEM	STU/Authority Database	Once	Incentive design, procurement and financial planning, Total cost of ownership	
	Loan tenure	NEW	Operator/OEM	STU/Authority Database	Once	Incentive design, procurement and financial planning, Total cost of ownership	
Earnings per km on electric buses		NEW	STU	MIS-Operation/ITS	Daily	Service planning and delivery, Total cost of ownership	

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