PROJECT TITLE

“Transition from CEV to EV by Enabling E-Infra & Electric vehicles for Promoting E-Mobility in Bhopal”

Under the Guidance of Mentors

Prof. Shivanad Swami  Dr. PC Sehgal

Manish Chaube & Zeeshan Khan
Bhopal Introduction

Bhopal, capital of M.P.- City of Lakes.
Combination of old & modern urban planning.
Municipal Area - 413.5 Sq Km
Population - 21.23 Lac
Length of Urban Roads - 647.00 Km
BCLL

- **Special Purpose Vehicle (SPV)** created to manage city bus operations successfully.
- Incorporated with shareholding of Bhopal Municipal Corporation and BDA.
- Formed under Indian Companies Act 1956.
- BCLL is devoted to growth of sustainable urban transport with clear focus on moving people not vehicles by providing smooth public transport system.
- SPV functions on self-sustainable mode by generating resources to meet its revenue expenses.

**Vision:**

To provide **Reliable, Organized, Safe and Efficient public transport System for a Sustainable Urban Mobility.**
City Bus Operations

**2006**
- 39 Star Buses
- Under PPP Model
- 04 Routes
- Bad Experience
- Close down in 2008

**2010**
- 150 Low Floor Non AC Buses
- Under JnNURM Scheme
- Operational since Nov 2010
- Operation on 08 Routes

**2013**
- 20 Low Floor AC buses
- 55 Low floor NON AC buses
- Under JnNURM Scheme
- Operation since Sept 2013
- BRT Route

**2017**
- 62 Midi Buses
- Under AMRUT Scheme
- Operational April

**2019- ELECTRIC BUS PLANNING**
Public Transport Routes

Route Rationalization

2010
- Bus Route: 04
- Standard Routes: 08
- Complementary Routes: 10
- Magic Route: 03
- Trunk Routes: 10
- Standard Routes: 08
- Route Rationalization

2017
- Rectification in Old Bus Routes
- Midi Bus: 10
- Magic Route: 03
- Standard Route: 10
- Trunk Routes: 03
- Midi Route: 10

2019 - NEW 5 No. ELECTRIC BUS ROUTES PLANNING
Bus Service

- 237* Buses
- 16 Routes
- 401 KM Route Length
- 900 Daily Trips
- 46937 Daily KM's
- 1.55 Lacs Daily Ridership

Smart Mobility

- Automatic Vehicle Location System
- Passenger Information System in Buses & Bus Stops
- On board Electronic Ticketing System
- Off Board Automated Fare Collection System
- Revenue Management System
- Video Surveillance System
- Management Information System
- Mobile Application for Bus Tracking
- Application for Bus Pass and Ticketing

PIS in Buses
- Route Name
- Destination
- Next Stop

PAS in Buses
- Next Stop to be reached
- Destination of the Bus

PIS at Bus Stops
- 231 Bus Stops
- Route Name
- Route wise Destination Stop
- ETA of bus

GPS Enabled Buses
Real Time Bus Tracking
Current Locations, Speed
Vehicle Status
Monitoring through Call Center
Access to Bus Operators

Automatic Vehicle Location System

231 Bus Stops

Real Time Bus Tracking
Current Locations, Speed
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Access to Bus Operators

Automatic Vehicle Location System
ITS - Video Surveillance/AFC at BRT Bus Stop

- 2 Cameras each Bus
- Video data storage in Bus DVR
- Data Transfer over Wi-Fi when bus reached in Depots
- All depots connected with Command Center.
- T+1 day basis video are downloaded.

Benefits:
- Passenger have faith.
- Feels more secure while travelling.
- Caught 100+ pick pockets, resolved missing people, lost & found cases.

Tripod at Exit  ATVM  Flap Gates
Smart Mobility Pass

Benefits

- Ridership increased more than 100%
- From 80k to 2.00 lakhs.
- Passengers Reliability.

Rs 800 / Month

Subsidized Monthly pass system
Subsidy is shared by BMC
Unlimited travel during a month.
Concession to Students is 62.50% (Rs 300/Mnt)
Disabled / BMC Employee is 75% (Rs 200/Mnt)
Ladies/Senior Citizens/Govt. etc is 50%.
1,50,000 ++ Pass Users*
28,000 Average Monthly Regular Pass Users.*
Issuance of Passes through 10 POS Centers

- In Bhopal, My Bus is lifeline for commuters. To make City Transport more attractive and effective & User Friendly BCLL has Launched Mobile App for Live Bus Tracking.
- Components of Mobile Application:

<table>
<thead>
<tr>
<th>Details</th>
<th>Current Scenario</th>
<th>Benefits of App</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Info</td>
<td>Commuter has to Call to Call Center.</td>
<td>Live bus tracking with live arrival time at your bus stop Live Buses on Map.</td>
</tr>
<tr>
<td>Fare Details</td>
<td>Previous Experience or while Travelling.</td>
<td>Correct Fare Display in App.</td>
</tr>
<tr>
<td>Trip Plan</td>
<td>wait for Bus at Bus Stop and Check ETA.</td>
<td>Fastest trip and waiting time can be reduced.</td>
</tr>
<tr>
<td>Route Plan</td>
<td>Ask conductor or other commuters.</td>
<td>Locate nearby public transport points, such as bus stops, railway stations, etc.</td>
</tr>
<tr>
<td>Route Info</td>
<td>Website or call center.</td>
<td>Trip Planner. Users can also share their estimated time of arrival and live location with contacts.</td>
</tr>
</tbody>
</table>

*In Bhopal, My Bus is lifeline for commuters. To make City Transport more attractive and effective & User Friendly BCLL has Launched Mobile App for Live Bus Tracking.

Components of Mobile Application:

- Bus Info:
  - Commuter has to Call to Call Center.
- Fare Details:
  - Previous Experience or while Travelling.
- Trip Plan:
  - Fastest trip and waiting time can be reduced.
- Route Plan:
  - Locate nearby public transport points, such as bus stops, railway stations, etc.
- Route Info:
  - Trip Planner. Users can also share their estimated time of arrival and live location with contacts.
MoUHA, GOI SUPPORTED & WORLD BANK FUNDED GEF-5 ESCBS PROJECT OF Efficient and Sustainable City Bus Service, The modules include:-

- Depot Management
- Schedule Planning
- Fleet Management and Maintenance
  - Route & Crew Management
  - Bus Maintenance Management System
  - Fuel Management System
  - Driver Performance management
  - Tyre Management System
- Contract Management
  /Concessionaire
- Contract Operations Control
- Revenue Management

Analytics Reports for Service Planning
Bhopal Smart City Mobility Solutions

a) Intelligent Transport System (PIS/PAS/Real Time Monitoring)
   Buses equipped with GPS based AVLs connected with Central Control and Command Centre. A 16 ft x 6 ft Video Wall comprising of 8 Nos. of High Resolution LED Panels tracks and monitors the movement in real time. Additionally, the Bus Stops are connected with Command Centre reflecting Expected Time of Arrival (ETA) on Passenger Information System (PIS).

b) Automatic Fare Collection System
   Installed at the bus stops to automate the integrated ticketing system.

c) Intelligent Street Poles
   Wi-Fi zoning through Wi-Fi Hot Spots
   Safety of citizens
   Energy efficient Solar based LED Street lighting
   Environmental Sensors for quality, temperature, humidity
   Electronic Vehicle charging points

d) E-Rickshaw (Last Mile Connectivity)
   E-rickshaws with docking station facilities provides last mile connectivity in environmentally sustainable and cost effective manner.

e) Public Bicycle Sharing
   500 Light weight modern Cycles at 50 fully Automated Bicycles in first phase. The Cycle sharing system will also be integrated with the mobile application for a seamless experience.

f) Dedicated Cycle Lane
   Providing a safe and welcoming cycling environment with proper markings and biking surface.
After the Launch of BRTS in 2013 the Air Quality of Bhopal is improved as per the trend shown in the years 2013-2016.

*Data available since 2011
Source: Computed by CSE from CPCB air quality data submitted to Rajya Sabha for 44 cities and CPCB the ENVIS centre
Transportation is one of the leading sectors in the emission of greenhouse gases, which in turn is the leading cause of global warming.

To reduce greenhouse gas emissions and reverse the warming trend, nations must decarbonize their transportation sector (as well as other sectors, such as electricity production, agriculture, and industrial activity).

Electrification of transportation, i.e., replacing ICE vehicles with EVs, is on the critical path toward deep decarbonization.

Every EV needs charging. This work is about the need for public infrastructure EV charging, current impediments to its widespread deployment, and practical solutions to accelerating EV adoption by enhancing infrastructure deployment.

To induct 100 Pure Electric Standard size (9 M) Low Floor AC Buses in Bhopal for operation on BRTS & city routes. DHI recently sanctioned 100 No. of electric buses under fame II scheme to Bhopal.

The word “bus” shall mean a bus powered exclusively by an Electric Motor whose traction energy is supplied exclusively by traction battery installed in the vehicle suitable for operations in city conditions in the city.
The Service and Business Plan for Electric Bus services is being prepared so that the document presents a workable plan that meets the actual needs of the organization.

The Business Plan for Electric Buses is being prepared, which shall include the long term, (beyond 5 years) development strategy besides the short term (in next 5 years) action plan.

A detailed ‘Implementation Plan’ is being prepared for operationalizing the short term action plan.

The Plan shall clearly bring out recommended strategy to implement the plan, including timelines, deployment of resources and inter relationship with other agencies involved for “Transition from Combustion Engine Vehicles to Electric Vehicles by Enabling E-Infra & Electric Buses for Promoting E-Mobility.

Considering the deployment of EV’s in the city of Bhopal the planning of various aspects is required which are below mentioned:-

✓ Analyze electricity distribution infrastructure of the city and availability of adequate Electric feeder connection.

✓ Identify the best possible locations for installing EV’s charging infrastructure for buses as well as other vehicles within the city of Bhopal.

✓ Identify depot space for EV’s and proper design of parking.
Review of existing public transport passenger flow movement; demand pattern study and bus routes for city.
Modification of existing routes according to market segmentation and passenger flow movement.
Identification of new routes for Electric Buses as per market segments.
Estimation of ridership on modified/new routes (Requisite Minimum frequency on Weekdays/Weekends/ Holidays).
Identification of minimum service standards.
Allocation of buses on routes as per minimum service standards. Optimize the usage of existing resources.
To assess the gap to suggest augmentation of Electric bus fleet.
Assess the frequency of buses on specific routes and optimize accordingly.
Provide the analysis tool/software for route optimization and rationalization with requisite MIS reports, with capacity to do basic tweaking according to changed frequency of service/amendment in routes.
To assess fare/non fare revenue flows in order to assess the revenue gap & Key performance indicators and Associated Infrastructure Plan for Electric Bus services.
Clearly articulate BCLL’s vision and value proposition for Electric Bus services.
Preparation of Fare tables for Electric Bus services & Rationalize fare structure for enhancing revenues for Electric Buses. Develop delivery structure for Electric Bus services.
Identify financial models to operate the service, Capital investment program, Operational cost forecast, Financial analysis, Risk Management strategy and Performance and service quality development plan along with IT and ITS applications for Electric Buses services.
Identify complementary assets needed for delivery of identified services for Electric Buses.
Determine cost & financial model for Electric Bus services. Identify assets and costs with intent to maximize the revenue and minimize the cost.
Government Supported Initiatives on Charging Infra

- **INDIA** - DHI Sanctioned 100 No. of Electric buses to Bhopal under fame II. DHI has sanctioned 100% grant for installation of EV charging infrastructure in Govt premises which can also be used under public charging.

- **CHINA** - Pilot in 88 cities, State Grid constructing fast charging plazas under plan to build 500k total public chargers by 2020

- **UK** - Highways England to install chargers every 20 miles along major roads; Residential area 75% cost of h/w covered

- **GERMANY** - Subsidies for public charging infra (10,000 level 2 and 5,000 DC fast)

- **US** - Grants for funding public charging infra Several utilities investing for a business opportunity
In India 390 buses operate in 11 cities with funding under FAME-I Scheme.

Based on experience of FAME-I and inputs from stakeholders DHI formulated Phase II of FAME (FAME-II)

DHI has approved 5595 electric buses to 64 cities / State Govt. entities / STUs for intracity and intercity operation under FAME-II Scheme.

Vehicle fitted with ‘advanced batteries’ are eligible

Demand incentive is based on the battery capacity in kWh

With the emphasis of environment friendly public transport scheme

Adequate public charging infrastructure to instil confidence among EV users

Charging infrastructure to be established as per MoP notification dated 1st October 2019 “Charging Infrastructure for Electrical Vehicles – Guidelines and Standards”

DHI EoI for establishment of 1000 public charging stations

Funding to the extent of 100% of the cost depending upon the project proposal
MoP has issued Charging Guidelines in Dec’18
Setting up of public charging stations (PCS) de-licensed activity, as long as they conform to technical standards
Discom to provide connectivity to anyone setting up PCS on priority; Phase I rollout in Mega Cities with 4M+ population
Charger models recognized:
At least one PCS in 3km x 3km grid, and one PCS to be set up every 25 km on both sides of highways/roads
Every State Govt to nominate a nodal agency, e.g. DISCOM/PSUs
Mandated to use a mix of 3 standards - that there should be at least three fast charging points in public charging stations -- one each of the CCS (min 50kW), CHAdeMO(min 50 kW) and Type 2 AC (min 22kW) configuration.
Since the charging for buses will be a captive use (private space) and chargers would be of a higher rating, one can opt with only single type of standard i.e European CCS2 out of GB/T, CCS-2 for electric buses.
Utilities will need to plan for distribution system upgrades as may be required for fast charging stations in dense urban areas.

EV charging is a potential new source of revenue and load growth.

Cost per km of charging infrastructure and/or network upgrades is low.

Assuming 30 fast chargers in a depot serving 100 buses, total investment needed for a new substation ~Rs 10 Crores i.e. system upgradation cost ~ Rs. 0.8/km.

If all 100 buses in Bhopal are electric, 30 fast chargers (~300kW each) would need an investment of ~ Rs.8 - 10 crores.

<table>
<thead>
<tr>
<th></th>
<th>Baseline charger (70 kW)</th>
<th>Fast Charger (320 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to charge 1 bus (battery size 320 kW)</td>
<td>4.6 hrs</td>
<td>1 hr</td>
</tr>
<tr>
<td># of buses sharing a charger</td>
<td>1</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Charging infra cost (Rs./km)</td>
<td>2.5</td>
<td>3.8 to 2.28</td>
</tr>
</tbody>
</table>

Role of Power Utilities is critical
ADVANTAGES:

- Zero emission (at point of operation)
- Lower energy consumption (20% due to regenerative braking)
- High(er) performances
- Longer life cycles (due to technique)
- Silent drive. Better comfort for driver and passengers.
- Less pollution (Nox, particles, etc).

“Electric energy is the only energy we can generate clean from renewable sources, without environmental impacts”

CHALLENGES:

- Quite new Technology for PT Although:
- Upstream Elect. Infrastructure
- Power Grids needed
- Life cycle of Battery component?
- Implementation of many pilot-models
- Upgradation of Existing electrical infrastructure
### General Comparison of Diesel Bus & Electric Buses

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ICE Bus</th>
<th>Electric Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Source</td>
<td>Diesel</td>
<td>Electricity</td>
</tr>
<tr>
<td>Power Generator</td>
<td>IC Engine</td>
<td>Battery</td>
</tr>
<tr>
<td>Costs</td>
<td>20-60 Lakhs</td>
<td>2 Crs</td>
</tr>
<tr>
<td>Fuel Efficiency</td>
<td>2.2-3.3 Km/L</td>
<td>1.5 Kwh/Km</td>
</tr>
<tr>
<td>Fuel Tariff</td>
<td>65 INR/L</td>
<td>6.95 INR/Kwh</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>INR 15-23 /Km</td>
<td>INR 10/Km</td>
</tr>
<tr>
<td>Emissions</td>
<td>High</td>
<td>Zero (Local)</td>
</tr>
<tr>
<td>Noise</td>
<td>High (baseline)</td>
<td>Minimum (at slow speeds)</td>
</tr>
<tr>
<td>Components</td>
<td>ICE propulsion system, transmission, power accessories, body</td>
<td>EV propulsion system, transmission, battery charging system, power accessories, body</td>
</tr>
<tr>
<td>Moving Parts</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Highest</td>
<td>Lowest</td>
</tr>
<tr>
<td></td>
<td>Frequent Oil Change, Filter Replacement, Periodic Tune up, Engine Overhauling, Water Pump, Fuel Pump Repair &amp; Alternator Replacement</td>
<td>Electronic Devices without moving parts, little or no maintenance</td>
</tr>
<tr>
<td>Model</td>
<td>Diesel Bus (AC)</td>
<td>Electric Bus (AC)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Seats</td>
<td>44</td>
<td>31</td>
</tr>
<tr>
<td>Length</td>
<td>12 m</td>
<td>12 m</td>
</tr>
<tr>
<td>Width</td>
<td>2.5 m</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Height</td>
<td>3.2 m</td>
<td>3.49 m</td>
</tr>
<tr>
<td>Gross Weight</td>
<td>16200 kg</td>
<td>18 500 Kg</td>
</tr>
<tr>
<td>Costs (INR)</td>
<td>75 Lakh</td>
<td>2 Crs</td>
</tr>
<tr>
<td>Fuel Efficiency</td>
<td>1.8 Km/L</td>
<td>1.5 Kwh/Km</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>INR 15/Km</td>
<td>INR 10/Km</td>
</tr>
<tr>
<td>Range (Km)</td>
<td>288</td>
<td>200</td>
</tr>
<tr>
<td>Fuel Tank size</td>
<td>160 L</td>
<td>---</td>
</tr>
<tr>
<td>Charging Time</td>
<td>3-6 hrs</td>
<td></td>
</tr>
<tr>
<td>Max Power</td>
<td>245 HP</td>
<td>180 Kw</td>
</tr>
<tr>
<td>Max Torque</td>
<td>685 Nm</td>
<td>700 Nm</td>
</tr>
<tr>
<td>Battery Type</td>
<td>-</td>
<td>Li-ion 300 Kwh</td>
</tr>
<tr>
<td>Emission Standards</td>
<td>BS VI</td>
<td>Zero Tail Pipe Emission</td>
</tr>
</tbody>
</table>

Source: Electric buses in India: Technology, Policy and Benefits Global Green Growth & CSTEP
ELECTRIC BUS DRIVELINE

BASIC PRINCIPLE

- Energy storage
- Traction electrics
- Electric motor

ANALYSIS OF THE OPERATIONAL NEEDS ON THE E-BUS TECHNOLOGY

- Battery size
- Auxiliary consumption
- Recharging power
- Vehicle Mass
- Energy/km
- Charging time
- Time saving solutions?
  - Avoid additional buses
  - Improve dynamic charging?
- Passengers
- Vehicle and trip properties
- Driveline bus technology
- Km's between charge points
- Design grid charge points

ELECTRIC BUSES: OPTIONS FOR CHARGING OF VEHICLES

- Continuous charging
  - Expensive infrastructure
  - Loses flexibility
- Overnight charging
  - Heavy vehicles
  - Reduced capacity
- Inductive charging
  - Expensive vehicles
  - Magnetic shielding
  - Expensive installation
  - Low energy transfer efficiency
- Conductive charging
  - Expensive infrastructure
  - Loses operational flexibility?
Business Model Options – Why Gross Cost?

- Induction of Electric Buses under GCC Model...a preferred approach for Indian Cities.
- **Gross Cost Contract**
- Provision of depots
- Provision of power load
- Guaranteed on time payments
- Provide for inflation indexation of manpower and electricity cost

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### Business Model Options – Why Gross Cost?

**Net Cost**
- Revenue
- Profit
- Cost
- Funding
- Operator

**Gross Cost**
- Revenue
- Profit
- Cost
- Funding
- Operator

- Full transfer of **REVENUE RISK** to operator.
- Windfall gain if regulator increases fares/state owned buses underperform/demand rises.
- Bidders factor-in a variety of risks apart from operating risks in price-quotes

- Full transfer of only **OPERATING RISK** on the operator.
- Regulatory & operational flexibility to add routes, change frequencies and redeploy resources.
- Absence of market risk lowers govt’s payout on account of concessionaire’s price-quotes.
Project Structure: Need for GCC in Electric

- The project structure must mirror the technical and operational challenges that come with the introduction of battery buses:
- Battery buses are still limited in their autonomy and range, which directly impacts operational aspects.
- Battery buses are still an immature technology. This applies to at least some components such as batteries or power electronics.
- Battery buses are a fast evolving technology. Both authorities and operators are still in a learning phase and battery buses are to some extent a paradigm shift in bus operation.
- Standards, especially communication protocols are still underdevelopment.
- **Vehicle and charging infrastructure specifications**: Specifications can be functional or more technical. In GCC contracting option the focus is on a functional specification which gives following advantages to the Authority:
  - Functional specifications provide more flexibility for the manufacturers.
  - Functional specifications leave the technical responsibility completely with the manufacturers.
- **Charging Infrastructure: Ownership & responsibility or maintenance** and repairs- Under GCC, the responsibility will lie with the owner. The charging devices are also owned by the contractor (s) for the bus operation.
<table>
<thead>
<tr>
<th>Monthly Equal Payment for Capital Cost (a)</th>
<th>1,05,000</th>
<th>1,20,000</th>
<th>1,35,000</th>
<th>1,50,000</th>
<th>1,51,800</th>
<th>1,65,000</th>
<th>1,80,000</th>
<th>1,95,000</th>
<th>2,10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly discount rate in decimals; ie 10.5/1200 (r)</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td><strong>0.01</strong></td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Contract period in months (n)</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td><strong>120</strong></td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Formula ( \frac{1-1/((1+r)^n)}{r} )</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td><strong>0.65</strong></td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
</tr>
<tr>
<td>L-1 Total Operational CPKM @ Rs/Km</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td><strong>50.6</strong></td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>Assured Monthly Km</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
<td>6,000.00</td>
</tr>
<tr>
<td>Calculated Cost of Bus = ( \frac{a}{r} \left( \frac{1-1/((1+r)^n)}{r} \right) )</td>
<td>77,81,525</td>
<td>88,93,171</td>
<td>1,00,04,817</td>
<td>1,11,16,464</td>
<td><strong>1,12,49,861</strong></td>
<td>1,22,28,110</td>
<td>1,33,39,757</td>
<td>1,44,51,403</td>
<td>1,55,63,049</td>
</tr>
<tr>
<td>Subsidy @ 40 % from DHI per Bus</td>
<td>31,12,610</td>
<td>35,57,268</td>
<td>40,01,927</td>
<td>44,46,586</td>
<td><strong>44,99,945</strong></td>
<td>45,00,000</td>
<td>45,00,000</td>
<td>45,00,000</td>
<td>45,00,000.00</td>
</tr>
<tr>
<td>Overall Total Expenditure per Bus</td>
<td>2,52,00,000</td>
<td>2,88,00,00,000</td>
<td>3,24,00,00,000</td>
<td>3,60,00,00,000</td>
<td><strong>3,64,32,000</strong></td>
<td>3,96,00,00,000</td>
<td>4,32,00,00,000</td>
<td>4,68,00,00,000</td>
<td>5,04,00,00,000</td>
</tr>
<tr>
<td>Net Total Expenditure after deducting subsidy @40 % from DHI per Bus</td>
<td>2,20,87,390.15</td>
<td>2,52,42,731.60</td>
<td>2,83,98,073.05</td>
<td>3,15,53,414.50</td>
<td><strong>3,19,32,055.47</strong></td>
<td>3,51,00,000.00</td>
<td>3,87,00,000.00</td>
<td>4,23,00,000.00</td>
<td>4,59,00,000.00</td>
</tr>
<tr>
<td>Assumed Anticipated EPKM deducting RC Manpower cost @ Rs/Km per Bus</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td><strong>25</strong></td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Assumed Anticipated Total Revenue collected per Bus</td>
<td>1,80,00,00,000</td>
<td>1,80,00,00,000</td>
<td>1,80,00,00,000</td>
<td>1,80,00,00,000</td>
<td><strong>1,80,00,00,000</strong></td>
<td>1,80,00,00,000</td>
<td>1,80,00,00,000</td>
<td>1,80,00,00,000</td>
<td>1,80,00,00,000</td>
</tr>
<tr>
<td>Gross Total Expenditure to be incurred after deducting subsidy &amp; RC per Bus</td>
<td>40,87,390</td>
<td>72,42,732</td>
<td>1,03,98,073</td>
<td>1,35,53,415</td>
<td><strong>1,39,32,055</strong></td>
<td>1,71,00,000</td>
<td>2,07,00,000</td>
<td>2,43,00,000</td>
<td>2,79,00,000</td>
</tr>
<tr>
<td>Gross Total Expenditure to be incurred after deducting subsidy &amp; RC for 100 no. Buses</td>
<td>40,87,39,015</td>
<td>72,42,73,160</td>
<td>1,03,98,07,305</td>
<td>1,35,53,41,450</td>
<td><strong>1,39,32,05,547</strong></td>
<td>1,71,00,00,000</td>
<td>2,07,00,000,000</td>
<td>2,43,00,000,000</td>
<td>2,79,00,000,000</td>
</tr>
</tbody>
</table>
**EV Component Development**

### Electric Motor
- High efficiency
- Performance
- Durability

### Battery
- Safety (Mechanical, Thermal & Electrical Abuse)
- BMS
- Cycle Life

### Charger Tester
- Simulates Electric Vehicle environment for offline testing of Charging Station.
- Load bank is charged by charger.
- Automated testing, Fault simulation and Data logging.
- Useful for testing Charging Stations according to AIS138.

### Load simulator for design validation and certification testing of Charging Station functions:
- System Inspections, verification and validation.
- System verification (Protocol validation)
- EVSE power ready recognition
- EVSE connected to vehicle function (Locking mechanism check)
- EVSE charge delivery function
- EVSE Control Pilot Signal communication test
- Power Failure Check.
- Automatic data logging and Report generation

### Shock Protection
- Unintended Vehicle Movement
- Low Energy "Stranding"

### REESS Rupture Resistance & Toxic Gas Management

### REESS Installation Integrity/Protection

### Environmental Chamber To Test Lithium-ion Cells Of Traction Battery

### E-motor Test Bed 150kW and 250 kW

### Cell Level Lithium Ion Battery Test System

### Pack Level Lithium Ion Battery Test System

### Battery Emulator, 100kW, 160 kW, 250 kW
FACILITIES TO BE DEVELOPED AT BUS DEPOTS FOR ELECTRIC BUSES

CURRENT SPECTRUM OF ACTIVITIES

- Li-ion Battery Testing
  - Cell level with Env. Chamber
  - Pack Level
  - Abuse Testing
  - Combined Temp/Vibration
  - Half/Hass
- Battery Emulator
  - 100 kW
  - 250 kW
- Li-ion Space to Auto.
- E-motor Test Bed
  - 150 kW
  - 220 kW
- 2W/3W/4W EV Chassis Dyno Testing
- HCV Chassis Dyno for electric bus testing
- Construction and Functional Safety
- Charger Testing
- EMC
  - Component level
  - 2/3 Wheeler
  - BMS
- Simulation in EV/HEV Technology
  - Comp Simulation & Parameterisation
  - Vehicle Config, & Comp Sizing
  - Plant Modeling & HIL
  - xEV Real Time Simulator
- Chassis Design and Development for Electric City Bus
- Rear Module Packaging
- Steering Kinematic Simulation
- Strength Prediction
- Bump Steer Prediction
- Rechargeable Energy Storage System (REESS)
- Evaluation using CAE
- Material Characterisation for Li-Ion Battery
  - XRD
  - TGA
  - SEM
- Structural Dynamics for EV & Comp
  - Road Simulation
  - Environmental Simulation
  - Suspension
  - Evaluation
  - MAST

Component Sizing and specification

Vehicle Calibrated

System Integration

Control System Development

Microcontroller Board (MCB)

• MBD Tool Chain
  • V-Model Process

• Configuration Design
  • Component Layout
  • Harness Design
  • Packaging
100 kW & 220 kW Electric Motor Test Bed

- Electric motor test beds facilitate complete development, testing, verification and validation environment for electric drives
- 600V, 100/150/220 kW e-motor test beds to test all vehicle types
- Performance and Characterization Test as per AG 944 and ECE R65 and in particular,
  - Reliability, durability and overload capacity
  - Dynamic behavior and dynamic measurements
  - Evaluation of torque speed characteristics of electric motors, torque analysis
  - Power and efficiency mass of electric motors and converters/Motor Controller
  - Cold start performance measurement
  - Testing of regenerative braking
  - Braking loss
  - Mechanical characteristics
  - Overload Capacity

Environmental Chamber to Test Lithium-Ion Cells of Traction Battery

- Environmental chamber is suitable for testing battery reliability under extreme temperature changes. It is suitable for temperature cycling tests as per IEC, UL, and AS standards
  - IEC 62133 – Temp. cycling
  - UL 1648 – Temp. cycling
  - UL 1433 – Temp. cycling
  - Humidity
  - Safety/Ablaze Test
  - Thermal Abuse
  - Thermal Stability
  - Insulated temperature storage
  - Rapid Charge/Discharge
  - Internal shock cycling

150 kW Specifications
- Rated Power: 150 kW
- Rated Torque: 300 Nm
- Max Speed: 15000 RPM
- Rated Speed for rated performance: 1000 to 6000 RPM
- Overload Factor: 1.2 (Max 60 Sec)
- 160 kW Battery Emulator/DC Power supply: 800/600A with Environment Chamber: -40°C to +180°C, 10% to 95% RH, 1500A Capacity

220 kW Specifications
- Rated Power: 220 kW
- Rated Torque: 500 Nm
- Max Speed: 13000 RPM
- Rated Speed for rated performance: 1000 to 6000 RPM
- Overload Factor: 1.2 (Max 60 Sec)
- 250 kW Battery Emulator/DC Power supply: 800/600A with Environment Chamber: -40°C to +180°C, 10% to 95% RH, 1500A Capacity

Cell Level Traction Battery Performance Test System

- Bi-directional Power supply, which acts as source and sink during charge/discharge of batteries
- Individual cells (18/50 Prismatic type) can be tested. System has 26 channels with different current capacities from 2 A, 25 A, 50 A, 100 A, 200 A which can be paralleled together to get higher charge/discharge currents
- Integration and Emulation of Battery Management System (BMS) through Controller Area Network (CAN) bus interface
- Performance and Characterization Test
  - Measurement of Static capacity
  - Constant power discharge
  - Hybrid pulse power (low and high current levels) characterization
  - Self-discharge
  - Internal resistance testing of batteries
  - Charge sustaining energy efficiency
  - Charge-discharge efficiency
  - Perform charge/discharge cycling of batteries to obtain charge and discharge capacity, energy and DC internal resistance
  - Recycle Cooling/Heating
  - Start-Up testing
  - Life Test
  - Map-based cycle life at various DOD (depth of discharge) and current (Ampere) test conditions
- Battery Cycle life testing and Calendar Life Test
- Reference performance testing
- Electrical Abuse Test
  - Overcharge/Over voltage
  - Over-discharge

Specifications:
- Temperature Control Range:
  - -40°C to 100°C
- Humidity Control Range: 20 to 90% RH 15°C to 60°C or better
- Temperature change rate: 5°C/min
- Safety system to prevent fire and explosion
- Test Area: 1.0 x 1.2 x 3.0 m
- CANbus interface for control and monitoring
- 0V to 18V DC
- Battery Channels: 4, 8, 16, 24, or 32 channels
Approach towards Selection of Routes for Operation for Electric Buses

- Routes selected which are yet to be bid out.
- Depots earmarked for Electric Buses out of available options after examining feasibility of estimated power load based on capacity.
- Distance of terminal points of each route from allocated depots estimated and routes with minimum dead km have been selected to prepare a depot-centric new route cluster.
- Depots/ terminals near node point of routes are duly earmarked for keeping option for fast charging during mandatory break of driver and/or shift changeover of crew at terminal.
- The dead mileage of operation of Electric Buses is minimised/optimised.
- No of deployment of buses: >10 buses/ route (Medium and High demand routes).
• GUIDING CRITERIA WHILE PLANNING SUBSTATION LOCATION
  ➢ Location Of Sub Station Should Ensure No Overhead Cables Are Coinciding.
  ➢ The Underground Cable Should Have Minimum Length For Voltage Drop
  ➢ Location Of Substation Should Be Planned Near Existing Electric- Panel Room / Transformer. Bends And
    Turns Should Be Avoided
  ➢ It Should Be As Far As Possible From Workshop
  ➢ Load Assessment at Parent Depots For Feasibility assessment, a 50KW
  ➢ charger per bus at depot is assumed at each Parent Depot.
  ➢ At Host Depots there is a paucity of space – with 1500-2000sqm available at each Host Depot

• OTHER PLANNING CRITERIA
  ➢ 500 Sqm Area Required For Sub Station
  ➢ 1400 Sqm Area Required For Charging 15 Buses And 500 Sqm Area Required For Sub Station
  ➢ Single Slot May Charge 2 Buses At Periphery And 4 Buses In Case Of Island Charging.
  ➢ 1.5m Space To Be Kept Between Two Buses.
<table>
<thead>
<tr>
<th>Name of Parking Depot</th>
<th>Available Area for EV</th>
<th>Area Location / Landmark</th>
<th>Parking Space for Buses</th>
<th>Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawarkar Setu Near Habibganj</td>
<td>2 Acre</td>
<td>Near Railway Over Bridge</td>
<td>20</td>
<td>On the main Road connecting AIIMS &amp; Habibganj RLYST, ISBT. Visible location to public. Connecting 3 Routes, Dead running Km shall be minimized. Electric Infra Available. 11/33 KVA available, line extension not required near to BRTS corridor.</td>
</tr>
<tr>
<td>Bairagarh Depot</td>
<td>5 Acre</td>
<td>Indore Bhopal Main Road/BRTS Start point</td>
<td>40</td>
<td>On the main Indore Bhopal Highway, Connecting 2 routes, hence minimizing dead Km. Existing electrical infra available 33KVA. Upgradation and additional can be installed. Visible to public.</td>
</tr>
<tr>
<td>ISBT</td>
<td>2 Acre</td>
<td>ISBT</td>
<td>40</td>
<td>Existing electrical infra available 33KVA. Upgradation and additional can be installed. Visible to public, as it works as a major bus stand in Bhopal. Connecting 4 routes, Dead running Km will be minimized.</td>
</tr>
</tbody>
</table>
Proposed Layout Plan for Charging Station

HCV dynamometer for Electric Bus Testing

- Heavy commercial dynamometer is required to testing electric, hybrid-electric, fuel cell buses
- Emission measurement: Fuel consumption of xEV heavy commercial vehicles in which traction is through two power trains, i.e. engine and motor
- Performance and Characterization Test such as:
  - Electrical Energy Consumption as per AIS D89 and ECE R101
  - Electric Range measurement as per AIS 040 and ECE R101
  - Power at Wheels as per AIS 041

HCV Specifications

- Power Nominal Rating during Motoring & Absorption: 1500hp [1119kW]
- Tractive Force Nominal Rating during Motoring & Absorption: 4500N
- Vehicle inertia range: 3500 to 50000 Kg
- Roller Diameter: 2500mm
- Torque & Inertia Response time <100ms
<table>
<thead>
<tr>
<th>S.No</th>
<th>Location</th>
<th>Bhopal (Bairagarh), On BRTS corridor</th>
<th>Bhopal (ISBT)</th>
<th>Bhopal (Sawarkar Setu)/Nearby BRTS Corridor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of buses</td>
<td>40 no.-9mtr</td>
<td>40no. -9mtr</td>
<td>20 no.-9 mtr</td>
</tr>
<tr>
<td>2</td>
<td>Input power</td>
<td>11 KW/ 22 KV/33 KV line</td>
<td>11 kv/33 kv Available</td>
<td>11 kv/33 kv Available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HT Line distance/ Line Extention 200 mts from Charging place</td>
<td>Sub station with in 30 mtr</td>
<td>100 mts from Charging place</td>
</tr>
<tr>
<td>3</td>
<td>Unit cost Rs.</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>4</td>
<td>Power Req</td>
<td>2400 KVA</td>
<td>2400</td>
<td>1200</td>
</tr>
<tr>
<td>5</td>
<td>kms per day</td>
<td>200-220</td>
<td>200-220</td>
<td>200-220</td>
</tr>
<tr>
<td>6</td>
<td>Depot</td>
<td>No</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>Bairaghar</td>
<td>ISBT</td>
<td>Sawarkar</td>
</tr>
<tr>
<td>7</td>
<td>Depot Plan</td>
<td>With Infrastructure</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>W/o Infrastructure</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>8</td>
<td>Available (in acre)</td>
<td>Constructed</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>9</td>
<td>Parking area</td>
<td>Adequate</td>
<td>Adequate</td>
<td>Adequate</td>
</tr>
<tr>
<td>10</td>
<td>Boundry Wall</td>
<td>complete</td>
<td>complete</td>
<td>fence with iron Grills</td>
</tr>
<tr>
<td>S.no</td>
<td>Source / Via</td>
<td>Destination</td>
<td>Km</td>
<td>Rt in min</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>Bhauri (Indore Bypass, Chirayu Hospital, Sehore Naka BRTS Corridor, Lalghati, New Market, Board Office, Misrod, 11 Miles, Samardha)</td>
<td>Mandideep</td>
<td>44</td>
<td>115</td>
</tr>
<tr>
<td>2</td>
<td>Salliya (Aakriti Eco City, Shahpura Thana, Aashiyana Aangan, Baba Nagar, Nehar Tiraha, Chuna Bhatti, Kolar Tiraha, Patrakar Colony, MANIT, Mata Mandir, New Market, Jehangirabad, Lady Hospital, Bharat Talkiz, Alpana Tira, Bus Stand, Bhopal Talkiz, Sindhi Colony, Putlighar)</td>
<td>Putlighar</td>
<td>18</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>ISRO (Nizamuddin, Indrapuri, ITI Tira, ISBT, Habibganj Naka, Sagar Public school, AIIMS, Baghmugaliya, Arvind Vihar, 80 Ft Road,</td>
<td>Aashima Mall</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Laxmipati College Khajuri Kalan Gopal Nagar, Vijay Market, Barkheda Pathani, AIIMS, Sagar Public School, Ganesh Mandir, Board Office</td>
<td>Vallabh Bhavan</td>
<td>19</td>
<td>65</td>
</tr>
<tr>
<td>5</td>
<td>Chirayu Hospital (Sehore Naka- BRTS Corridor, Lal Ghati, Royal Market, Bhopal Talkiz, Bus Stand, Bharat Talkiz, Jehangirabad, Purani Jail, New Court, Board Office, Career College, ITI, Jubilee Gate-BHEL, Piplani Petrol Pump, Anand Nagar, TIT College, Kokta)</td>
<td>Kokta</td>
<td>26</td>
<td>75</td>
</tr>
</tbody>
</table>
Bhauri to Mandideep
### EXISTING AVAILABLE DEPOT EQUIPMENT’S FOR BCLL BUSES PROCURED UNDER WORLD BANK GEF 5 PROJECT

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment’s</th>
<th>Qty</th>
<th>BAIRAGARH</th>
<th>ISBT</th>
<th>JAWAHAR CHOWK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheel Alignment Machine</td>
<td>2</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Wheel Balancer Machine</td>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Fully Automatic Tire Changer Hydraulic Type</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Nitrogen Tire Inflator</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Head Light Beam Aligner</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Pneumatic Impact Wrench &amp; Socket</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Automatic Bus Washing</td>
<td>2</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Heavy Duty Vacuum Cleaner</td>
<td>9</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Silent Generators – 125 KVA /45 KVA</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### ADDITIONAL DEPOT EQUIPMENT UNDER PROCUREMENT FROM WORLD BANK GEF 5 PROJECT

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment’s</th>
<th>Qty</th>
<th>S.N</th>
<th>Equipment’s</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 Post Mobile Column Lift</td>
<td>3</td>
<td>11</td>
<td>Heavy Duty Arc Welding Machine</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Stationary Jack Set Of Two</td>
<td>3</td>
<td>12</td>
<td>Tools Trolleys</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>High Pressure Compressor Of 25</td>
<td>3</td>
<td>13</td>
<td>Depot Yard Cleaning Machine</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Hydro-Pneumatic Trolley Jacks (12/25 Ton)</td>
<td>6</td>
<td>14</td>
<td>Ride On Bus Parking Floor Sweeper Machine</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Heavy Duty Engine/Jib Crane 2t Manual-Hydraulic</td>
<td>3</td>
<td>15</td>
<td>Ride on Floor Scrubbing Machine</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Portable Oil Dispensing System</td>
<td>3</td>
<td>16</td>
<td>Automatic Bus Washing Plant With ETP</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Portable Greasing System With Heavy Duty Trolley,</td>
<td>3</td>
<td>17</td>
<td>Pit Trolleys</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>Heavy Duty Truck/Bus Steel Drain With Manual Rotary Pump</td>
<td>6</td>
<td>18</td>
<td>Working Tables</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>Battery Charger</td>
<td>3</td>
<td>19</td>
<td>Ultra Sonic Cleaner</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Brake Lining Riveting Machine For 8mm Solid</td>
<td>3</td>
<td>20</td>
<td>High Pressure Bus Washer</td>
<td>3</td>
</tr>
</tbody>
</table>
Silent Generators

Bairagarh Depot

ISBT Depot

Paint Booth at Bairagarh Depot
Depot Equipment's
Key Implementation Challenges

- Development of charging infrastructure in the depots/Terminals
- Development of Upstream Electric Infrastructure
- Electric drive line technical specifications-type of motor
- Selection of charging infrastructure technologies
- Type of Battery/ Battery chemistry
- Charging Time
- Energy consumption per km
- Sustainability of the solution over 10-12 years-Infrastructure / Vehicles
- Reliability / performance / life expectancy of the batteries.
- Maintenance of vehicles/ infrastructure
- Weight of the batteries vs Number of passengers
Key Learnings

- Key for induction of EVs is Charging Infrastructure.
- Day Charging-higher operating cost. As such night charging preferred.
- New depots for EVs constructed in first phase.
- Old depots upgraded in 2nd phase.
- Unladen weight of Bus-Light weight Body for EVs
- Cooling System for Batteries-upgraded to meet operating conditions.
- Floor mounted Batteries preferred than roof mounted Batteries
- Route Category-wise charging strategy was worked out.
- Replacement of Battery set during mid of contract period planned in contract.
Thanks

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