Leaders Program in Urban Transport Planning and Management- 7

PROJECT TITLE

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

Under the Guidance of Mentors

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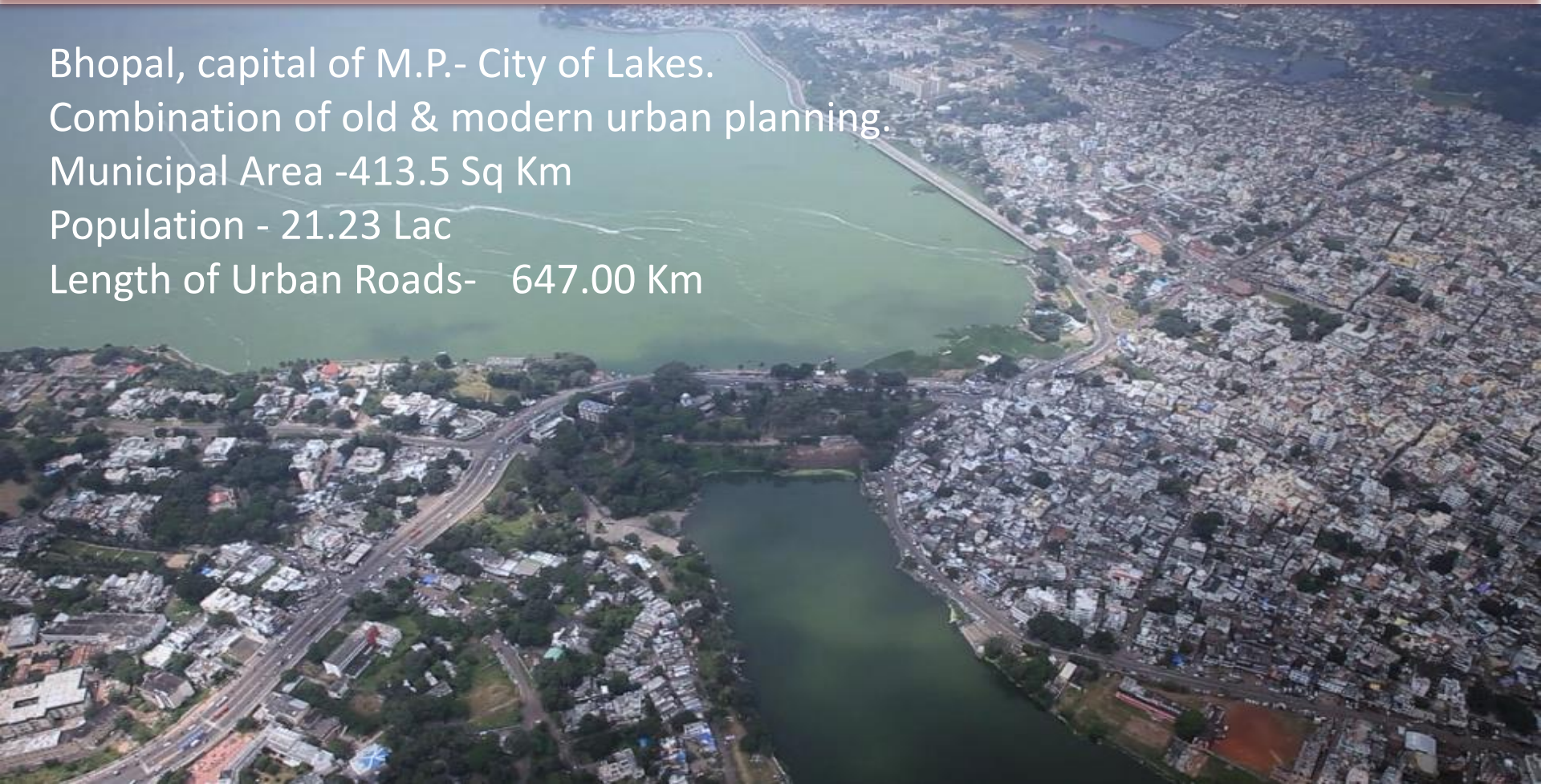
Bhopal Introduction



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.

MYBUS

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 Apr

2019- ELECTRIC BUS PLANNING

Public Transport Routes

Route Rationalization

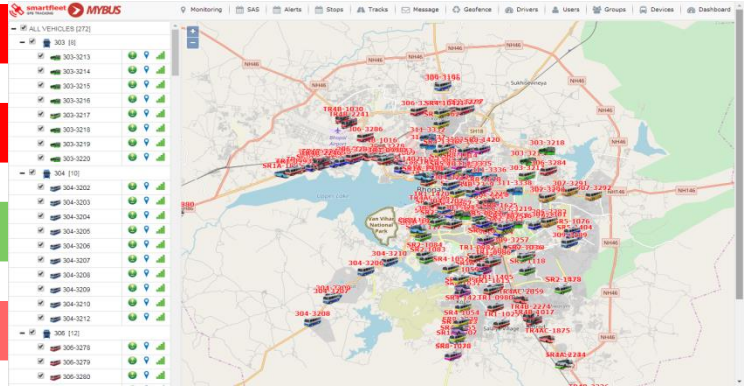
2010	2017
Bus Route	Mini Bus
Magic Route	Rectification in Old Bus Routes
Midi Bus	
Trunk Routes 04	Standard Routes 08
Complementary Routes 10	IPT Routes 10
Trunk Routes 03	Standard Routes
Midi Routes 10	

2019- NEW 5 No. ELECTRIC BUS ROUTES PLANNING

Bus Service

Smart Mobility

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



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

Automatic Vehicle Location System

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

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 → Mobile Application for Bus Pass and Ticketing

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

Rs 800 / Month

Benefits

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

- 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

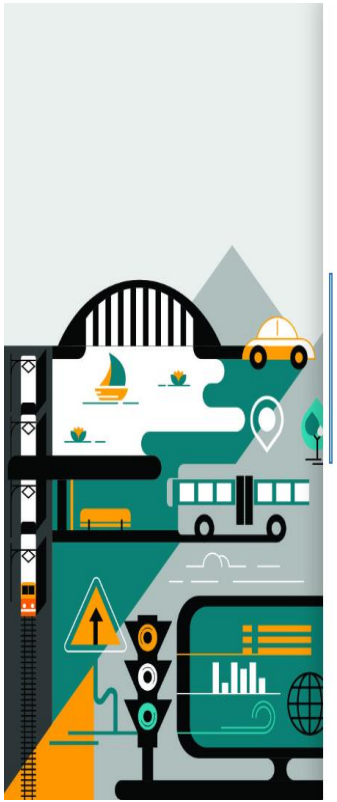
- In Bhopal, My Bus is lifeline for commuters. To make City Transport more attractive and effective & User Friendly BCLL has Launched Mobile App for Live Bus Tracking.
- **Components of Mobile Application:**

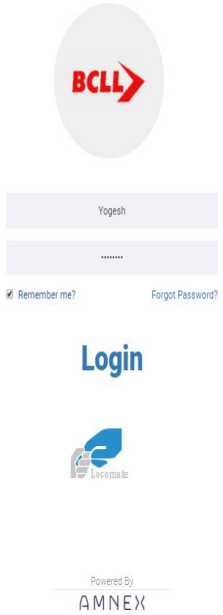
Details	Current Scenario	Benefits of App
Bus Info	Commuter has to Call to Call Center.	Live bus tracking with live arrival time at your bus stop Live Buses on Map.
Fare Details	Previous Experience or while Travelling.	Correct Fare Display in App.
Trip Plan	wait for Bus at Bus Stop and Check ETA.	Fastest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

Management Information System (MIS)- for Bus Operations

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)

All the buses are equipped with 4 Nos. of PIS in buses and passenger announcement system. Destination and next bus stop information, Public messages and announcement.

b AUTOMATIC FARE COLLECT

Automatic Fare Collection System installed at the bus stops to automate the integrated ticketing system

BUS PRIORITY SYSTEM

Installed at the intersection to improve service, enhance safety and reduce delays

c INTELLIGENT STREET POLES

- Wi-Fi zoning through Wifi 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

e PUBLIC BICYCLE SHARING

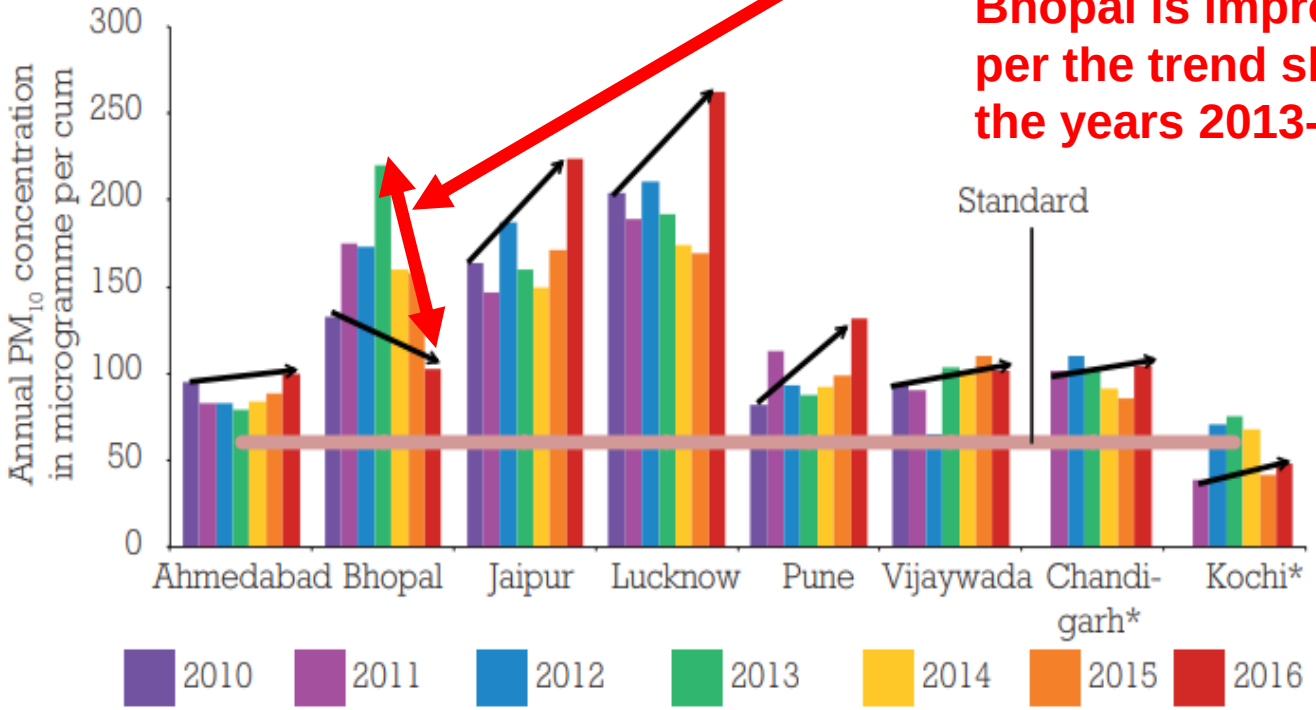
500 Light weight modern Cycles at 50 fully Automated Bicycles in first phase
The Cycle sharing system will also be inte-

f DEDICATED CYCLE LANE

Providing a safe and welcoming cycling environment with proper markings and biking surface

Graph 15: Air quality trends

PM_{10} concentration in metropolitan cities



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

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

- 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.*

BATTERY ELECTRIC BUS

Project Planning, Objectives &Scope:-

- 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.

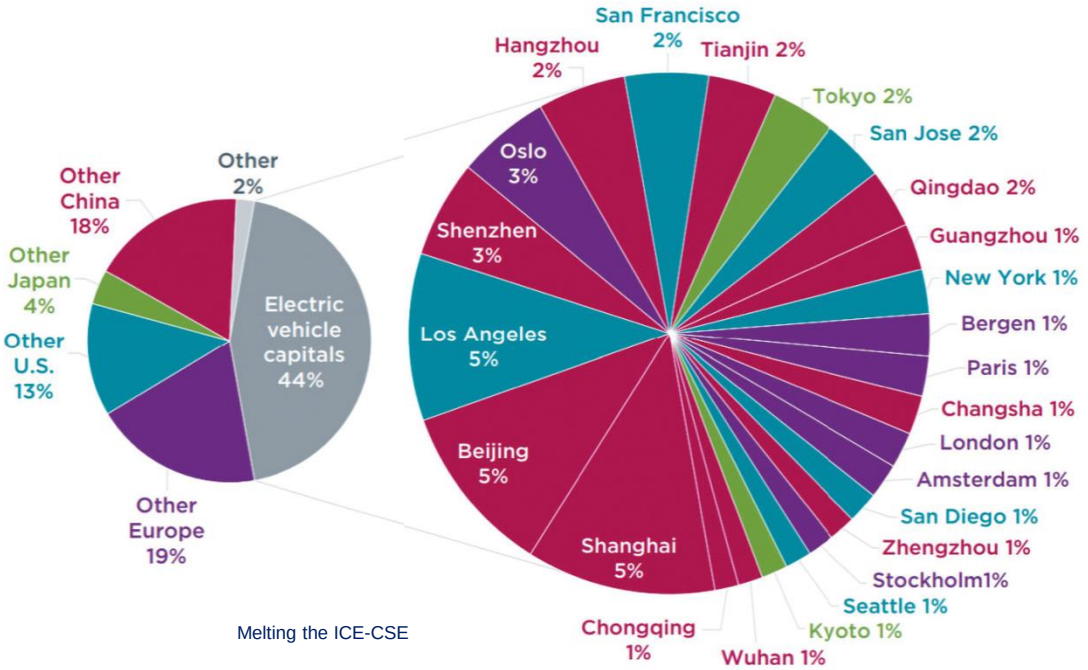
Implementation Plan, Road map &Deliverables:- Part (I)

- 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.

Implementation Plan, Road map &Deliverables:- Part (II)

- 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.

EV Market Shares in Select Cities Worldwide



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

EV Scenario–Government of India Initiatives for Electric Buses

- 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
- Adequatepublicchargeinginfrastructuretoinstilconfidenceamong EVusers
- Charginginfrastructuretobeestablishedasper MoPnotificationdated1stOctober2019"ChargingInfrastructureforElectricalVehicles–GuidelinesandStandards"
- DHI EoI for establishment of1000 public charging stations
- Funding to the extent of 100% of the cost depending upon the project proposal

Guidelines from MoP

- 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.

Role of Power Utilities is critical

- 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

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

ELECTRIC DRIVE LINE versus regular drive lines with a **COMBUSTION ENGINE**

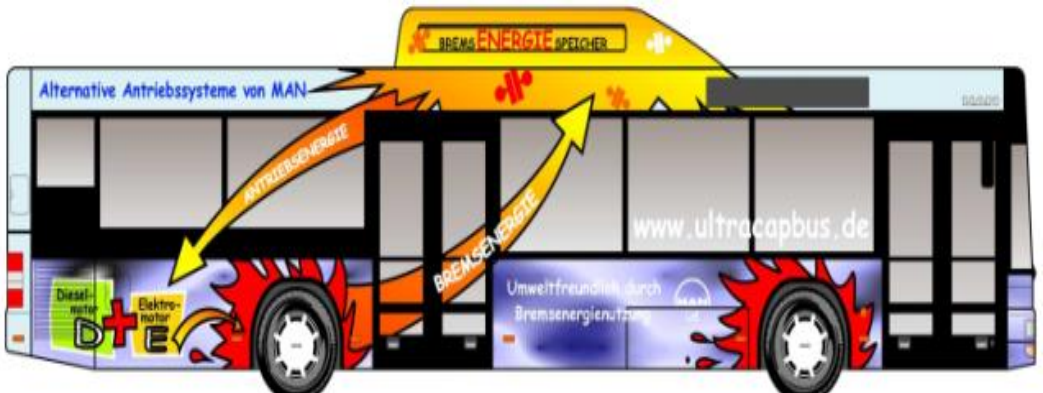
ADVANTAGES:

- ✓ 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

Parameters	ICE Bus	Electric Bus
Power Source	Diesel	Electricity
Power Generator	IC Engine	Battery
Costs	20-60 Lakhs	2 Crs
Fuel Efficiency	2.2-3.3 Km/L	1.5 Kwh/Km
Fuel Tariff	65 INR/L	6.95 INR/Kwh
Fuel Cost	INR 15-23 /Km	INR 10/Km
Emissions	High	Zero (Local)
Noise	High (baseline)	Minimum (at slow speeds)
Components	ICE propulsion system, transmission, , power accessories, body	EV propulsion system, transmission, battery charging system, power accessories, body
Moving Parts	More	Less
Maintenance	Highest	Lowest
	Frequent Oil Change, Filter Replacement, Periodic Tune up, Engine Overhauling, Water Pump, Fuel Pump Repair & Alternator Replacement	Electronic Devices without moving parts, little or no maintenance

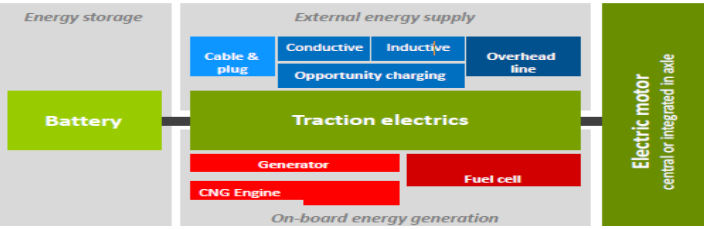
General Comparison of Diesel Bus & Electric Buses

Model	Diesel Bus (AC)	Electric Bus (AC)
Seats	44	31
Length	12 m	12 m
Width	2.5 m	2.5 m
Height	3.2 m	3.49 m
Gross Weight	16200 kg	18 500 Kg
Costs (INR)	75 Lakh	2 Crs
Fuel Efficiency	1.8 Km/L	1.5 Kwh/Km
Fuel Cost	INR 15/Km	INR 10/Km
Range (Km)	288	200
Fuel Tank size	160 L	---
Charging Time		3-6 hrs
Max Power	245 HP	180 Kw
Max Torque	685 Nm	700 Nm
Battery Type	-	Li-ion 300 Kwh
Emission Standards	BS VI	Zero Tail Pipe Emission

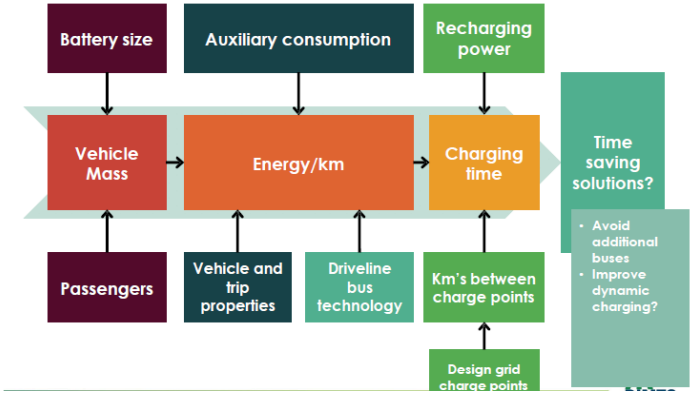
Source: Electric buses in India: Technology, Policy and Benefits Global Green Growth & CSTEP

ELECTRIC BUS DRIVELINE

BASIC PRINCIPLE



ANALYSIS OF THE OPERATIONAL NEEDS ON THE E-BUS TECHNOLOGY



ELECTRIC BUSES: OPTIONS FOR CHARGING OF VEHICLES

Continuous charging

- Expensive infrastructure
- Loses flexibility

Overnight charging

- Heavy vehicles
- Reduced capacity

Opportunity charging

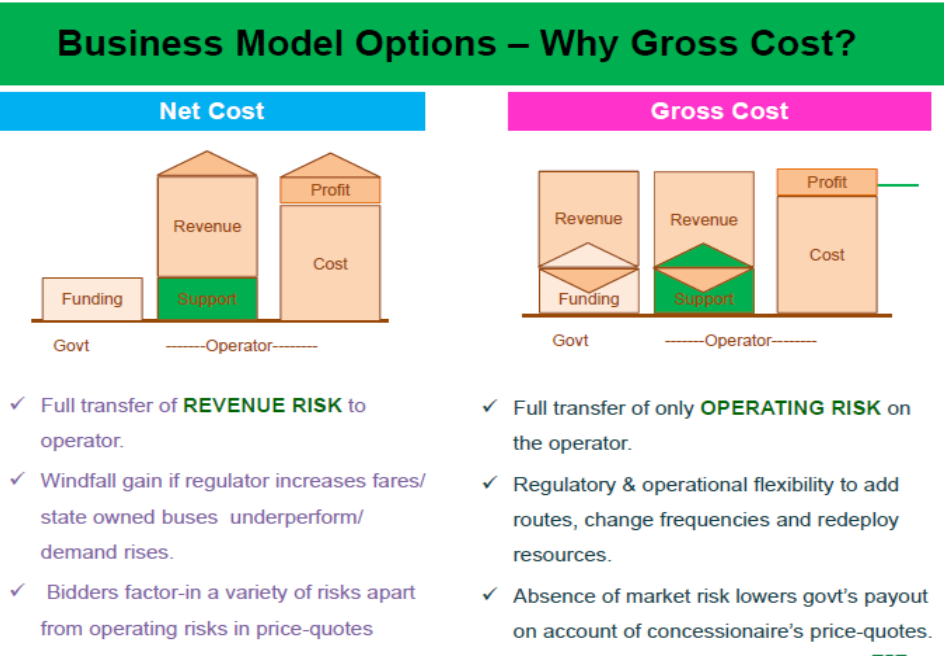
Inductive charging

- 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

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.

OVERALL COST VS EXPENDITURE DETAILS FOR 100 NO. OF ELECTRIC BUSES OF BHOPAL FOR BCLL AS PER SUBSIDY FROM DHI									
Monthly Equal Payment for Capital Cost (a)	1,05,000	1,20,000	1,35,000	1,50,000	1,51,800	1,65,000	1,80,000	1,95,000	2,10,000
Monthly discount rate in decimals; ie 10.5/1200 (r)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Contract period in months (n)	120	120	120	120	120	120	120	120	120
Formula {1-1/(1+r)^n}	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
L-1 Total Operational CPKM @ Rs/Km	35	40	45	50	50.6	55	60	65	70
Assured Monthly Km	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00
Calculated Cost of Bus = [a/r*{1-1/(1+r)^n}]	77,81,525	88,93,171	1,00,04,817	1,11,16,464	1,12,49,861	1,22,28,110	1,33,39,757	1,44,51,403	1,55,63,049
Subsidy @ 40 % from DHI per Bus	31,12,610	35,57,268	40,01,927	44,46,586	44,99,945	45,00,000	45,00,000	45,00,000	45,00,000.00
Overall Total Expenditure per Bus	2,52,00,000	2,88,00,000.00	3,24,00,000	3,60,00,000	3,64,32,000	3,96,00,000	4,32,00,000	4,68,00,000	5,04,00,000
Net Total Expenditure after deducting subsidy @40 % from DHI per Bus	2,20,87,390.15	2,52,42,731.60	2,83,98,073.05	3,15,53,414.50	3,19,32,055.47	3,51,00,000.00	3,87,00,000.00	4,23,00,000.00	4,59,00,000
Assumed Anticipated EPKM deducting RC Manpower cost @ Rs/Km per Bus	25	25	25	25	25	25	25	25	25
Assumed Anticipated Total Revenue collected per Bus	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00	1,80,00,000.00
Gross Total Expenditure to be incurred after deducting subsidy & RC per Bus	40,87,390	72,42,732	1,03,98,073	1,35,53,415	1,39,32,055	1,71,00,000	2,07,00,000	2,43,00,000	2,79,00,000
Gross Total Expenditure to be incurred after deducting subsidy & RC for 100 no. Buses	40,87,39,015	72,42,73,160	1,03,98,07,305	1,35,53,41,450	1,39,32,05,547	1,71,00,00,000	2,07,00,00,000	2,43,00,00,000	2,79,00,00,000

Electric Motor

- High efficiency
- Performance
- Durability

Charging Stations

- Safety / Weatherproof
- Communication
- Interoperability
- Rollout

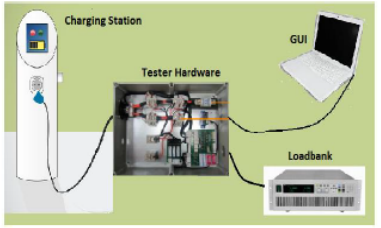
EV Component Development

Battery

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

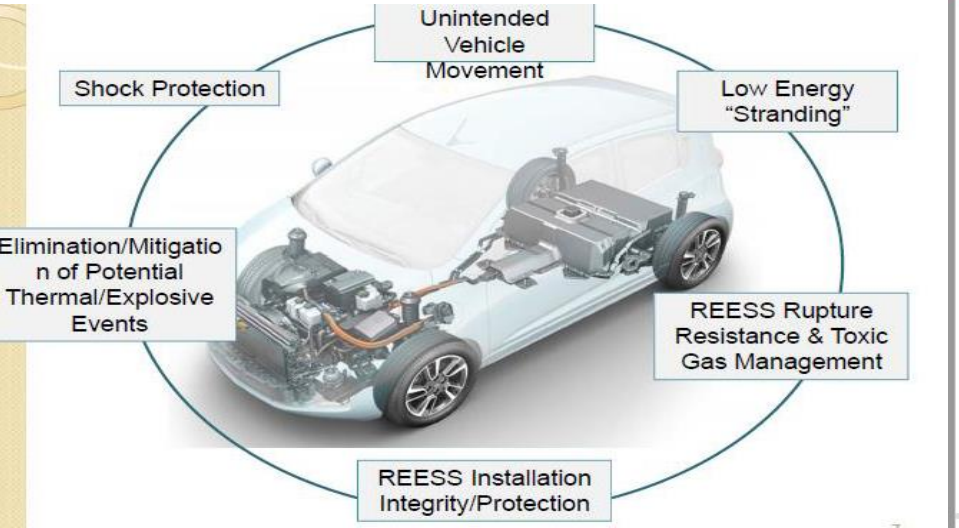
Charger Tester:

- 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



Environmental Chamber To Test Lithium-ion Cells Of Traction Battery

Cell Level Lithium Ion Battery Test System

Pack Level Lithium Ion Battery Test System

E-motor Test Bed 150kW and 250 kW

Battery Emulator, 100kW, 160 kW, 250 kW

FACILITIES TO BE DEVELOPED AT BUS DEPOTS FOR ELECTRIC BUSES

CURRENT SPECTRUM OF ACTIVITIES

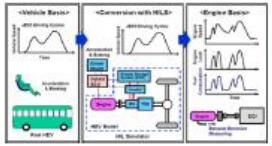
- **Li-ion Battery Testing**
  - -Cell level with Env. Chamber
  - -Pack Level
  - -Abuse Testing
  - -Combined Temp/Vibration
  - -Halt/Hass
- Battery Emulator
  - -100 kW
  - -250 kW
- Li-ion Space to Auto.

- 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



- Domain Expertise
- Simulation and Modeling Tool Chain

- MBD Tool Chain
- V – Model Process

Component Sizing and specification

Control System Development

Vehicle Calibration

System Integration

- Chassis Dyno. calibration
- Vehicle Parameterization

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
- 800V, 600A, 150/220 kW E-motor test beds to test all vehicle types
- Performance and Characterization Test as per AIS 041 and ECE R85 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 maps of electric motors and converters/Motor Controller
  - Cold start performance measurement
  - Testing of regenerative braking
  - Blocking tests
  - Thermal Characteristics
  - Overload Capacity

Coolant Conditioner

Power Meter

150 kW Specifications

- Rated Power: 150 kW
- Rated Torque: 400 Nm
- Max Speed: 15000 RPM
- Speed Range for rated performance: 4000 to 8000 RPM
- Overload Factor: 1.2 (Max 60 Sec)
- 160 kW-Battery Emulator/DC Power supply: 800V/600A With Environment Chamber: -40°C to + 180°C, 10% to 95% RH, 1500L Capacity

220 kW Specifications

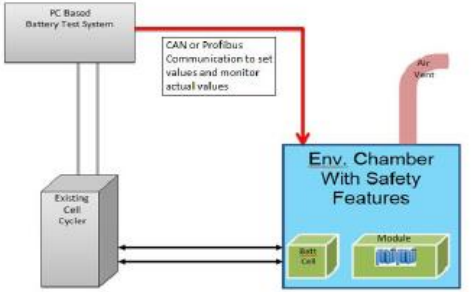
- Rated Power: 220 kW
- Rated Torque: 500 Nm
- Max Speed: 12000 RPM
- Speed Range for rated performance: 3000 to 8000 RPM
- Overload Factor: 1.2 (Max 60 Sec)
- 250 kW-Battery Emulator/DC Power supply: 800V/600A With Environment Chamber: -40°C to + 180°C, 10% to 95% RH, 1500L Capacity

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 SAE standards.
  - IEC 62133 – Temp. cycling
  - UL 2054 – Temp. cycling
  - UL 1642 – Temp. cycling
  - Halt/Hass
- Safety/ Abuse Test
  - Thermal Abuse
  - Thermal stability
  - Elevated Temperature Storage
  - Rapid Charge/Discharge
  - Thermal Shock Cycling

Specifications:

- **Temperature Control Range:**
- **-40° C to 100° C**
- **Humidity Control Range: 10 to 98% RH 15°C to 90 °C or better**
- **Temperature change rate: 5 °C/min,**
- **Safety system to prevent fire and Explosion**
- **Test Area: 1.0 × 1.0 × 1.0 m3**



Cell Level Traction Battery Performance Test System

- Bi-directional Power cyclers, which acts as source and sink during charge/discharge of batteries
- Individual cells (18650, Prismatic etc) can be tested. System has 26 channels with different current capacities from 2 A, 25A, 50 A, 100A, 300A which can be paralleled together to get higher charge/discharged 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
  - Cold cranking testing of batteries
  - Charge sustaining energy efficiency
  - Charge depleting energy efficiency
  - Perform charge/ discharge cycling of batteries to obtain charge and discharge capacity, energy and DC internal resistance
  - Reserve Capacity Testing
  - Start/Stop testing
  - Cycle 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:

- **Voltage 0V to 18V DC for each channel**
- **System with each channel independently capable of both source, and sink operation throughout the voltage range of 0 to 18V DC**
- **Battery Channels**
  04 Channels ± 2 A
  08 Channels ± 25 A
  08 Channels ± 50 A

Approach towards Selection of Routes for Operation for Electric Buses

- **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).

DESIGN PRINCIPLES FOR PLANNING OF PARENT DEPOT

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

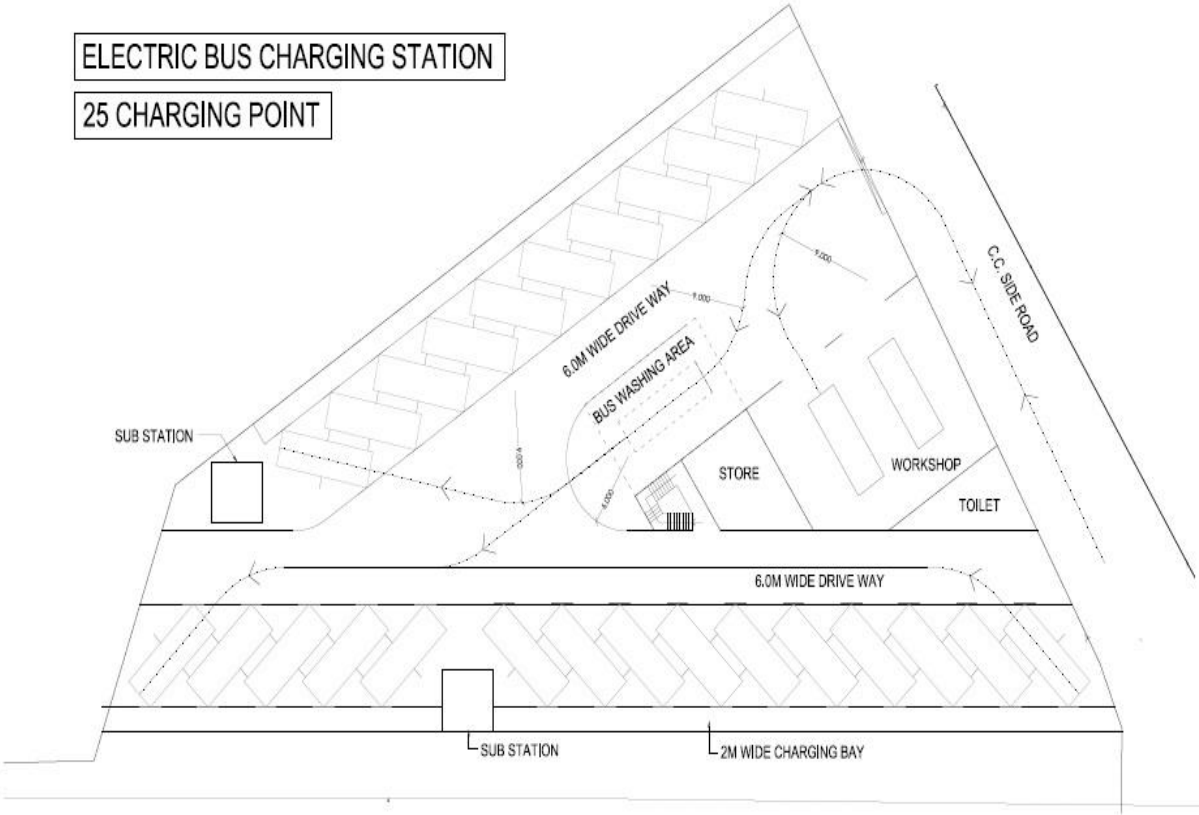
OTHER PLANNING CRITERIA

- 500 Sqm Area Required For Sub Station **D**
- 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.

Identified Depot Spaces for Electric Bus Parking

Name of Parking Depot	Available Area for EV	Area Location / Landmark	Parking Space for Buses	Selection Criteria
Sawarkar Setu Near Habibganj	2 Acre	Near Railway Over Bridge	20	On the main Road connecting AIIMS & 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.
Bairagarh Depot	5 Acre	Indore Bhopal Main Road/BRTS Start point	40	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.
ISBT	2 Acre	ISBT	40	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

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 039 and ECE R101
  - Electric Range measurement as per AIS 040 and ECE R101
  - Power at Wheels as per AIS 041

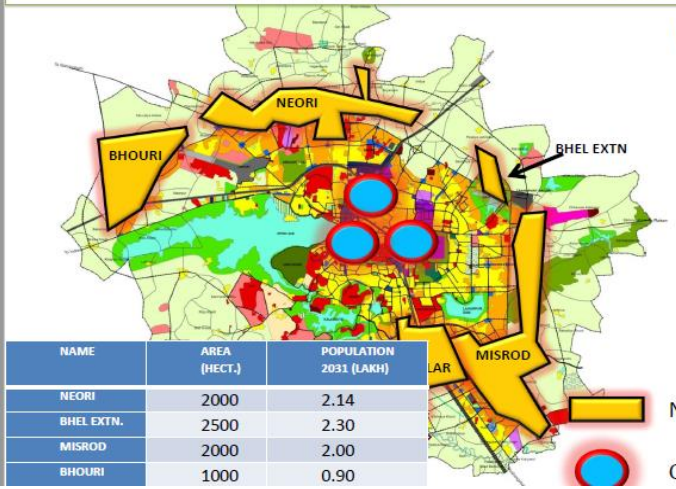
HCV Specifications

- Power Nominal Rating during Motoring & Absorption: 1500Hp (1119kW)
- Tractive Force Nominal Rating during Motoring & Absorption : 45000N
- Vehicle inertia range : 3500 to 50000 Kg
- Roller Diameter : 2500mm
- Torque & Inertia Response time <100ms

S.No	Location		Bhopal (Bairagarh), On BRTS corridor	Bhopal (ISBT)	Bhopal (Sawarkar Setu)/ Nearby BRTS Corridor
1	No. of buses		40 no.-9mtr	40no. -9mtr	20 no.-9 mtr
2	Input power	11 KW/ 22 KV/33 KV line	11 kv/33 kv Available	11 kv/33 kv Available	11 kv Available
		HT Line distance/ Line Extention	200 mts from Charging place	Sub station with in 30 mtr	100 mts from Charging place
3	Unit cost Rs.		6.7	6.7	6.7
4	Power Req	KVA	2400	2400	1200
5	kms per day		200-220	200-220	200-220
6	Depot	No	1	1	1
		Location	Bairaghar	ISBT	Sawarkar
7	Depot Plan	With Infrastructure	a	a	X
		W/o Infrastructure			a
8	Available (in acre)	Constructed	a	a	a
9	Parking area		Adequate	Adequate	Adequate
10	Boundry Wall		complete	complete	fence with iron Grills

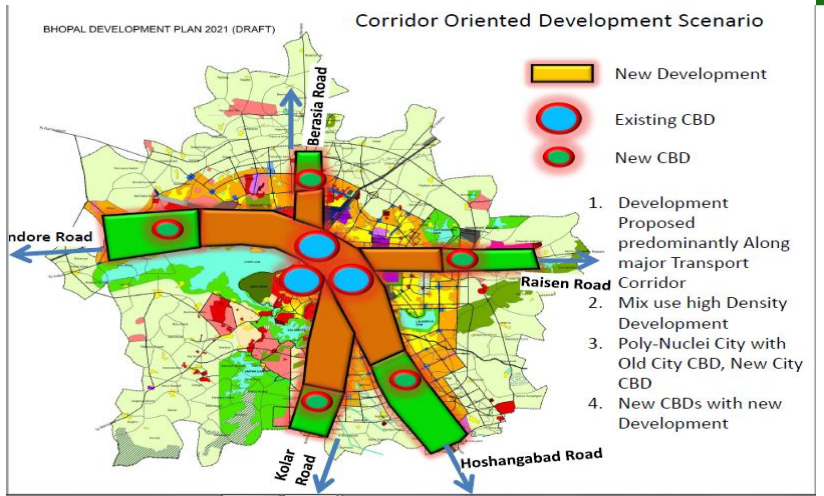
Master Plan Scenarios

- **Based on various land use distribution : Proposed Developments**

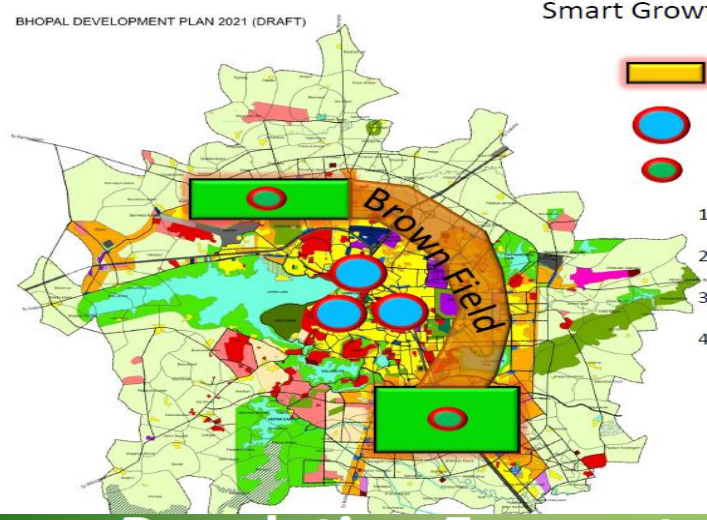


1. Development Proposed predominantly in North and South City

NAME	AREA (HECT.)	POPULATION 2031 (LAKH)
NEORI	2000	2.14
BHEL EXTN.	2500	2.30
MISROD	2000	2.00
BHOURI	1000	0.90



1. Development Proposed predominantly Along major Transport Corridor
2. Mix use high Density Development
3. Poly-Nuclei City with Old City CBD, New City CBD
4. New CBDs with new Development

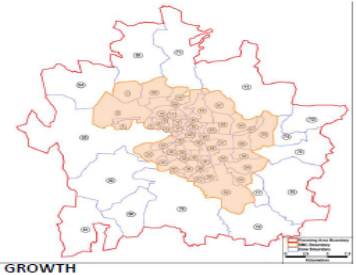


1. Mix use high Density Development-Green Field
2. Brown Field Development in Existing Areas
3. Poly-Nuclei City with Old City CBD, New City CBD
4. New CBDs with new Development

CMP

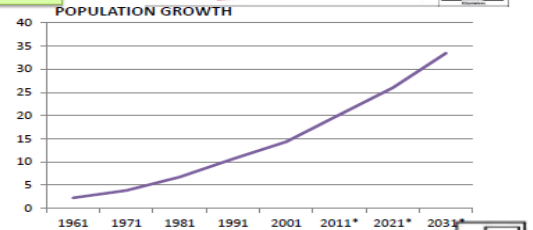
Population Forecast

Year	Population (in lakhs) (Municipal Area)	Population (in lakhs) (Outskirts)	Total	Decadal Growth Rate
1961	2.22		2.22	
1971	3.84		3.84	72.62%
1981	6.71		6.71	74.35%
1991	10.62		10.62	58.38%
2001	14.33		14.33	34.93%
2011	17.96	2.22	20.18*	40.82%
2021	23.0	3.0	26.0*	28.84%
2031	29.0	4.5	33.5*	28.85%



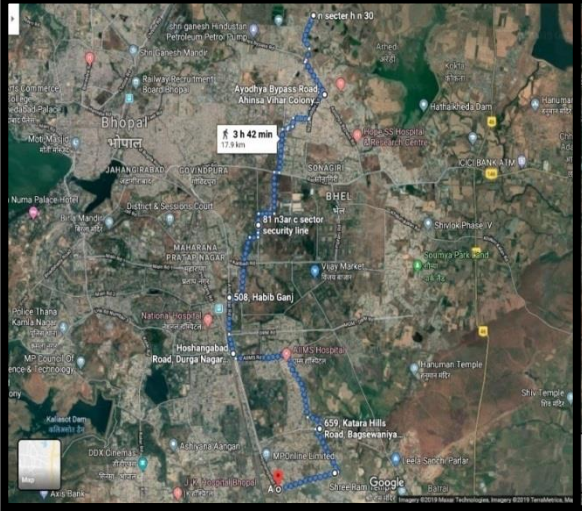
** Includes population in Planning Area, beyond Municipal Area*

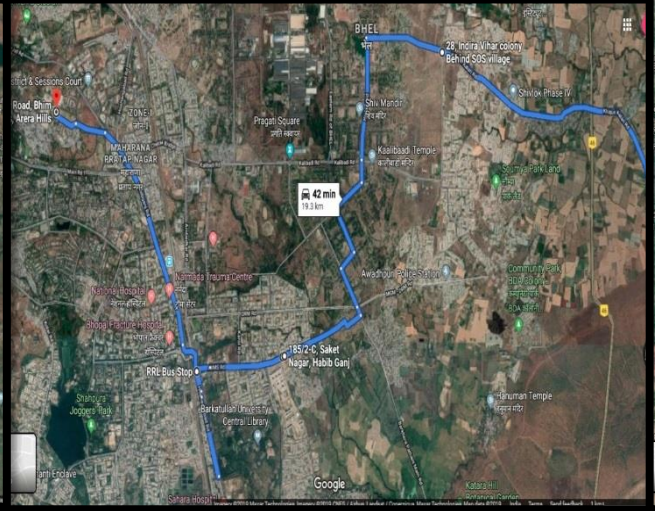
Population for 2021 and 2031 have been projected

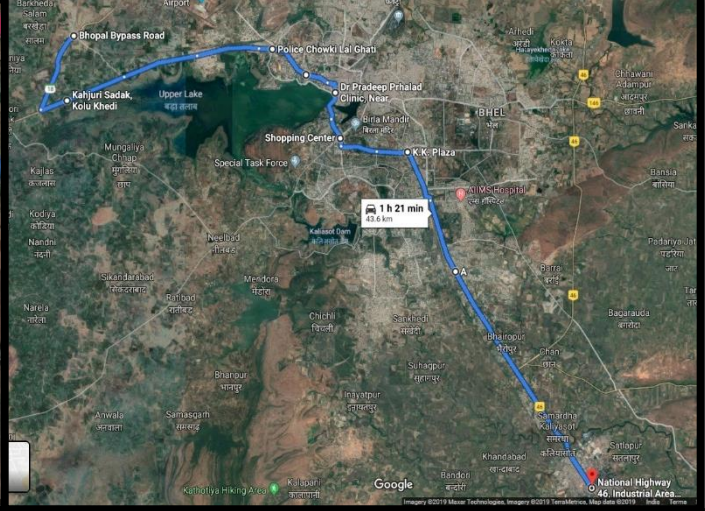


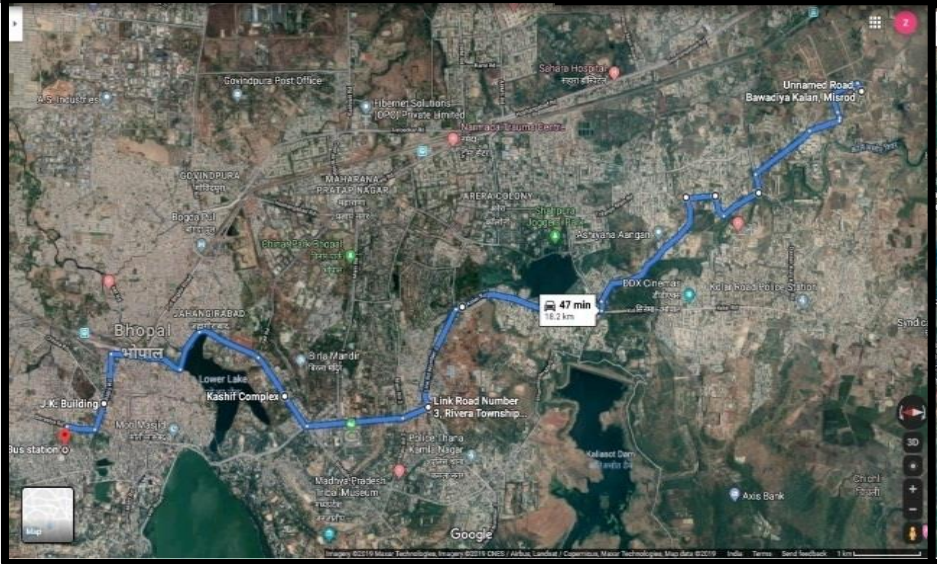
Identified Routes for Electric Buses

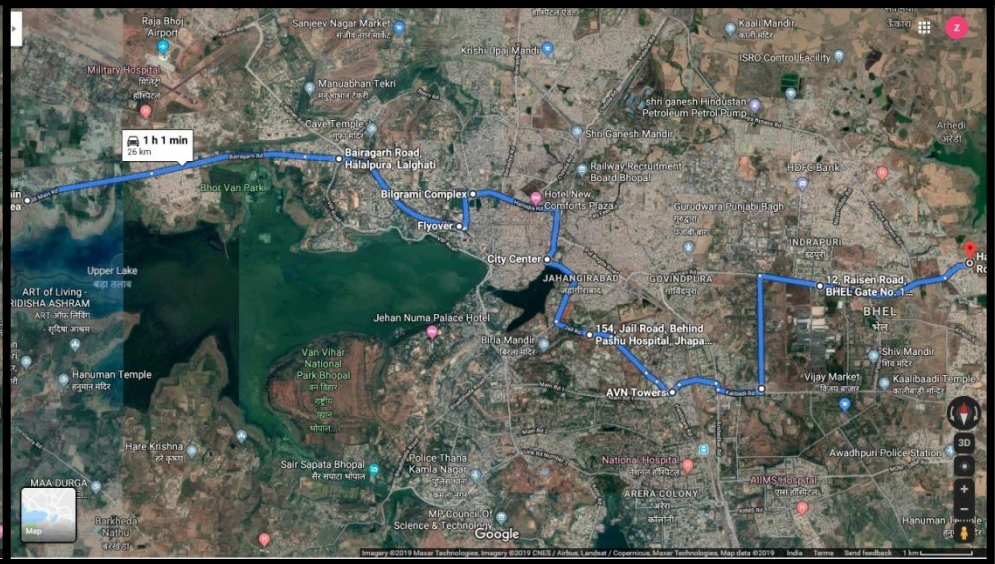
S.no	Source / Via	Destination	Km	Rt in min	No. of Buses
1	Bhauri (Indore Bypass, Chirayu Hospital, Sehore NakaBRTS Corridor, Lalghati, New Market, Board Office, Misrod, 11 Miles, Samardha)	Mandideep	44	115	28
2	Salliya (Aakriti Eco City, Shahpura Thana, Aashiyana Aangan, Baba Nagar, Nehar Tiraha, Chuna Bhatti, Kolar Tiraha, Patrakar Colony, MANIT, Mata Mandir, New Market, Jehangirabad, Lady Hospital, Bharat Talkiz, Alpana Tiraha, Bus Stand, Bhopal Talkiz, Sindhi Colony, Putlighar)	Putlighar	18	64	18
3	ISRO (Nizamuddin, Indrapuri, ITI Tiraha, ISBT, Habibganj Naka, Sagar Public school, AIIMS, Baghmugaliya, Arvind Vihar, 80 Ft Road,	Aashima Mall	17	50	16
4	Laxmipati College Khajuri Kalan Gopal Nagar, Vijay Market, Barkheda Pathani, AIIMS, Sagar Public School, Ganesh Mandir, Board Office	Vallabh Bhavan	19	65	18
5	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)	Kokta	26	75	20

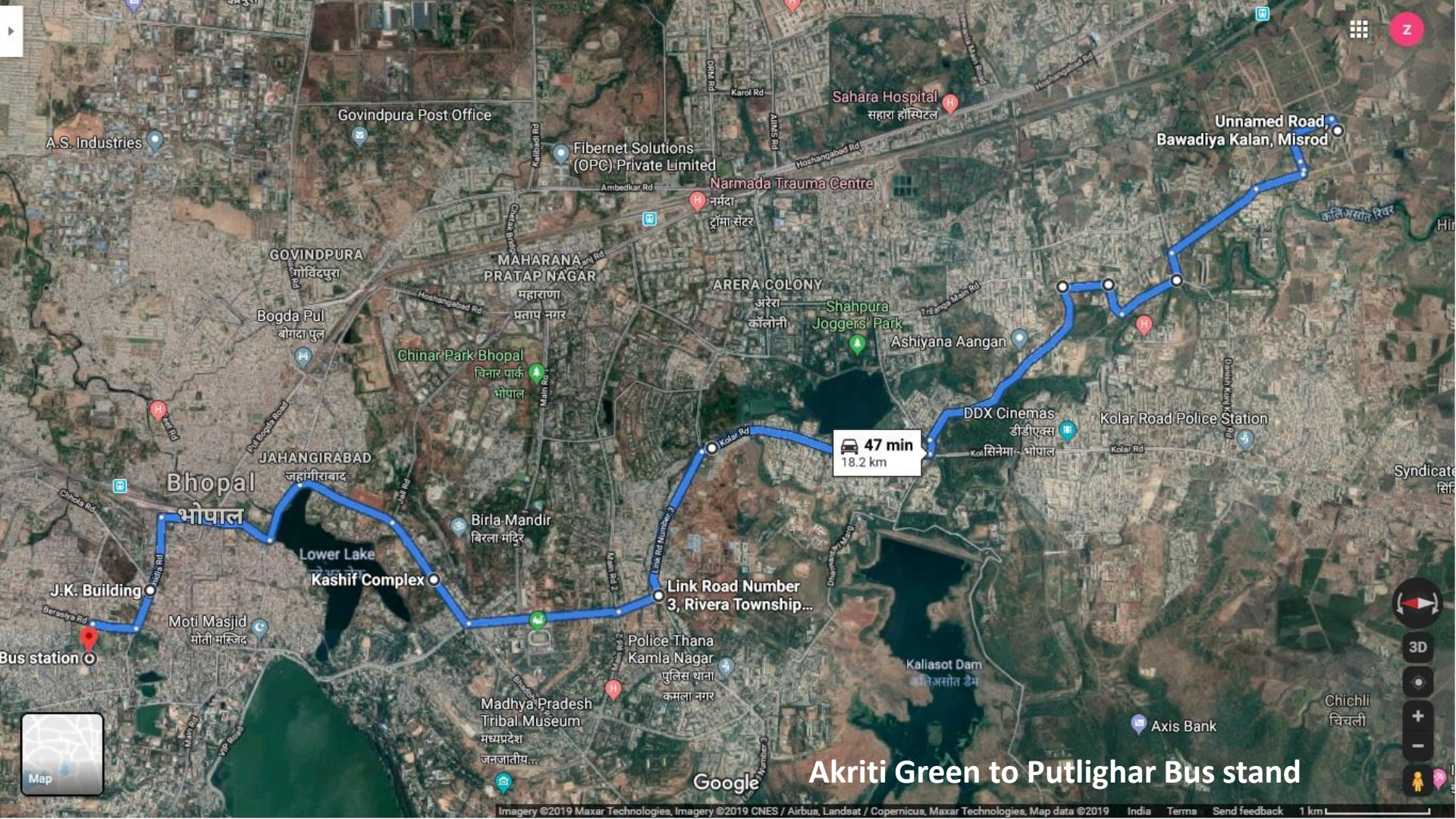

n secter h n 30
Ayodhya Bypass Road
Ahinsa Vihar Colony
3 h 42 min
17.9 km
81 n3ar c sector
security line
508, Habib Ganj
Hoshangabad
Road, Durga Nagar
659, Katara Hills
Road, Bagseweniya...
Bhopal
BHEL
MAHARANA
PRATAP NAGAR
Google

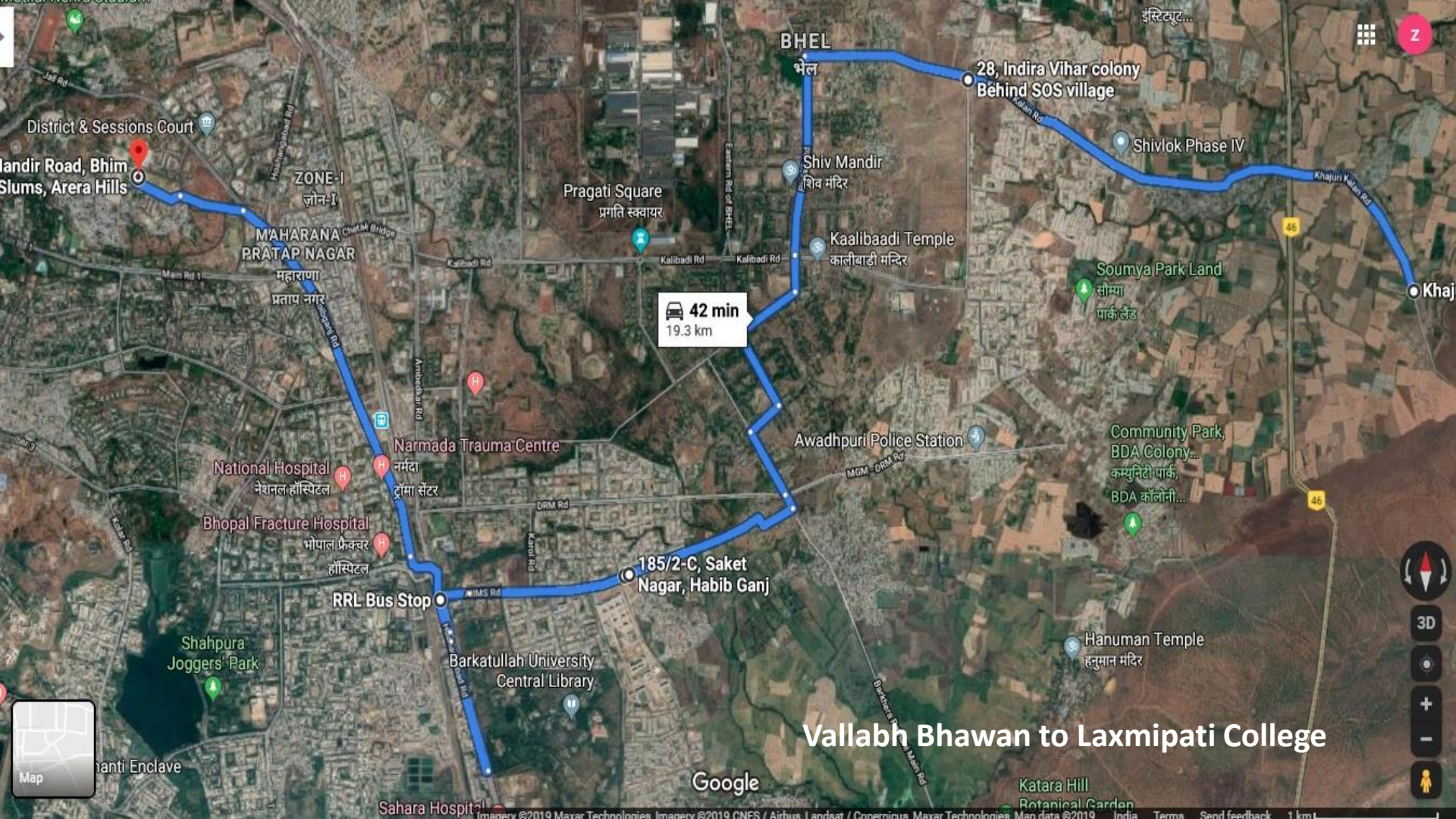

26, Indira Vihar colony
Behind SOS village
42 min
19.3 km
852-C, Saket
Nagar, Habib Ganj
RRL Bus Stop
BHEL
Google


Bhopal Bypass Road
Police Chowki Lal Ghati
Kahjuri Sadak,
Kolu Khedi
Dr Pradeep Prhalad
Clinic, Near
Shopping Center
K K Plaza
1 h 21 min
43.6 km
National Highway
46, Industrial Area
Google


Govindpura Post Office
Unnamed Road,
Bawadiya Kalan, Misrod
47 min
18.2 km
Bhopal
Kashif Complex
Link Road Number
3, Rivera Township...
J.K. Building
Bus station
Google

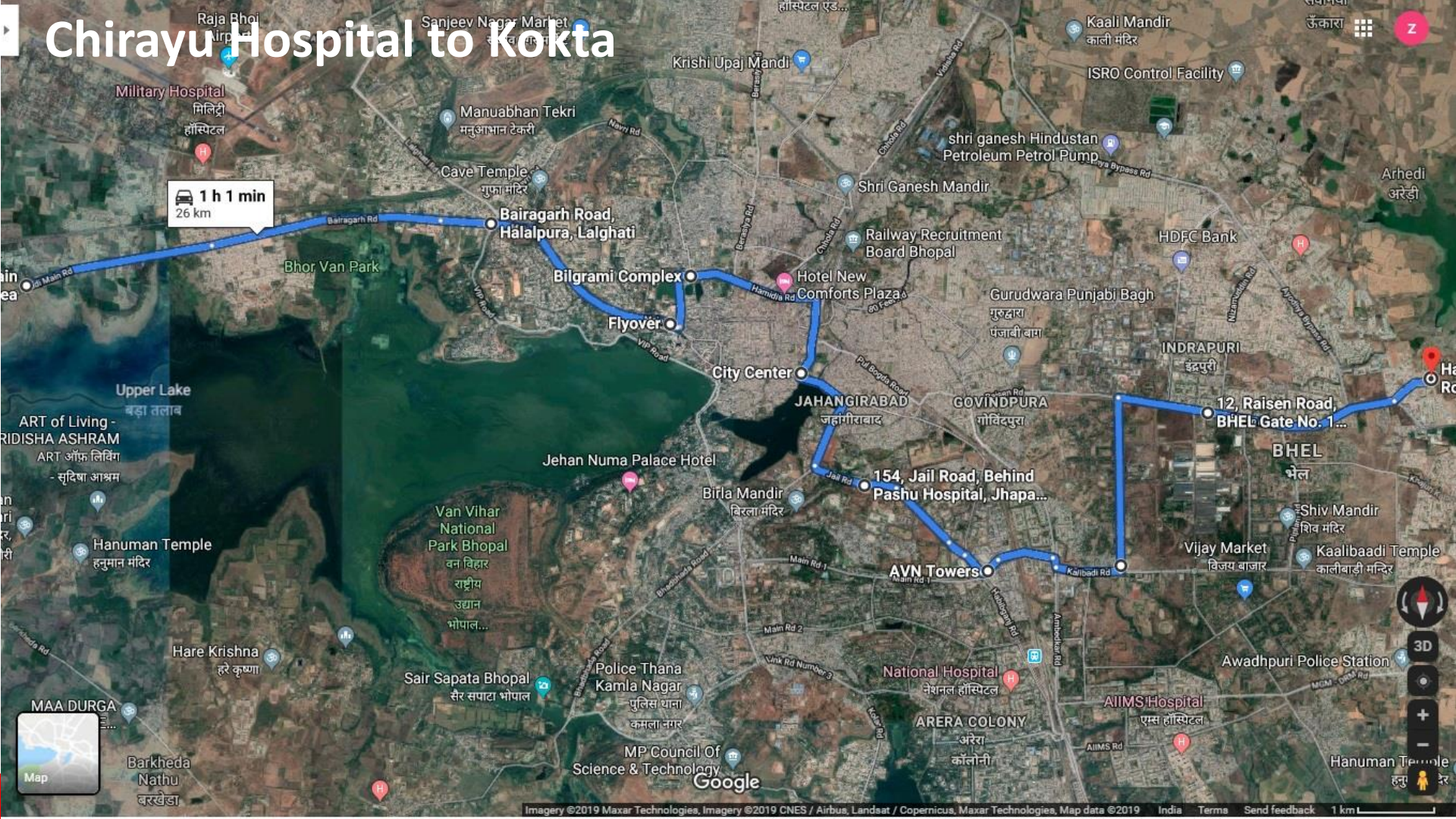

1 h 1 min
26 km
Bairagarh Road,
Halalpura, Lalghati
Bilgrami Complex
Flyover
City Center
12, Raisen Road,
BHEL Gate No. 1...
154, Jail Road, Behind
Pashu Hospital, Jhapa...
AVN Towers
Jehan Numa Palace Hotel
Upper Lake
Van Vihar
National
Park Bhopal
Hanuman Temple
Police Thana
Kamla Nagar
ARERA COLONY
Google

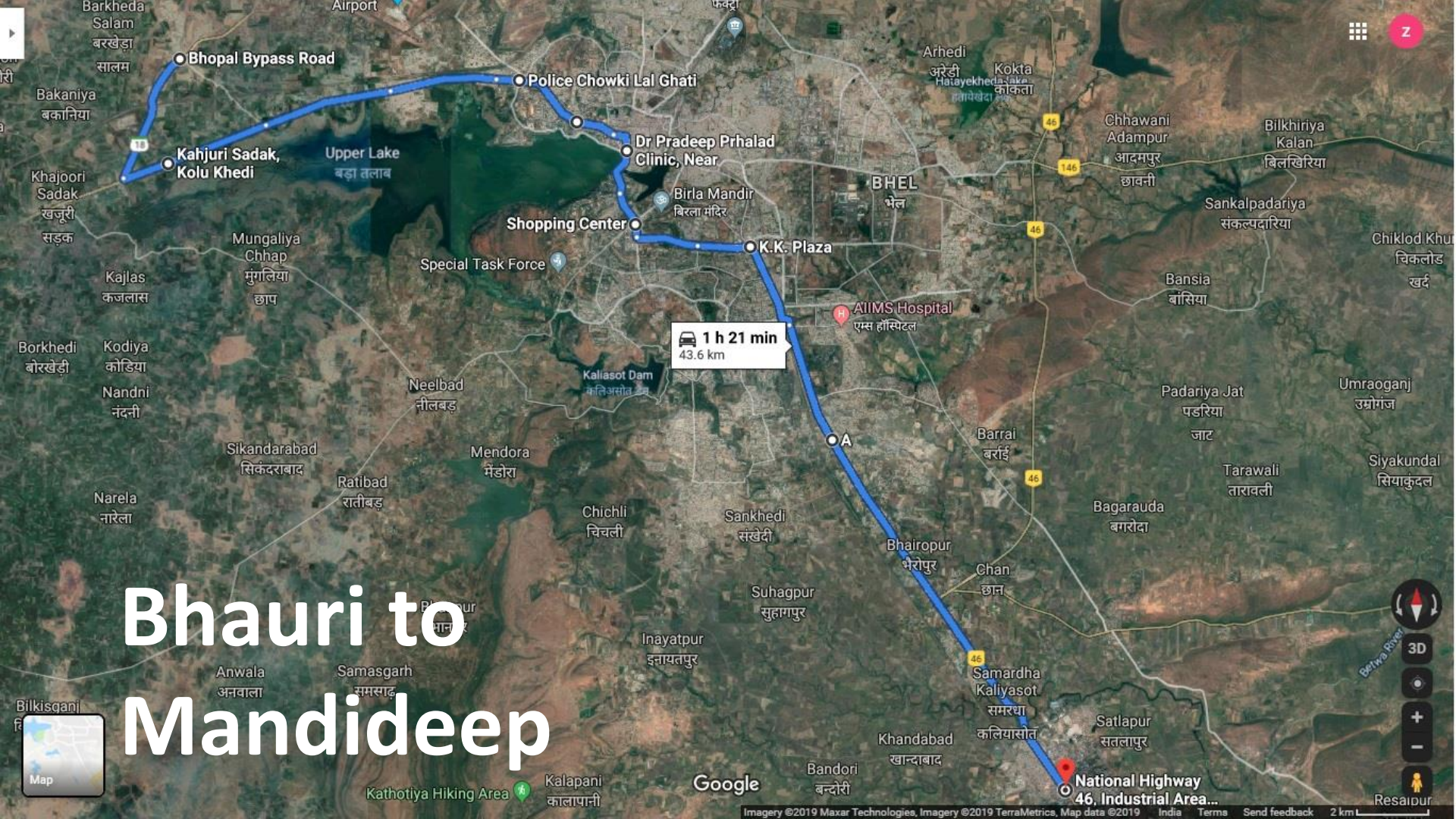

Akriti Green to Putlighar Bus stand
47 min
18.2 km
Unnamed Road
Bawadiya Kalan, Misrod
Sahara Hospital
सहारा हॉस्पिटल
Govindpura Post Office
A.S. Industries
Fibernet Solutions
(OPC) Private Limited
Narmada Trauma Centre
नर्मदा ट्रॉमा सेंटर
GOVINDPURA
गोविंदपुरा
MAHARANA
PRATAP NAGAR
महाराणा प्रताप नगर
ARERA COLONY
अरेरा कॉलोनी
Shahpura
Joggers Park
Ashiyana Aangan
Bogda Pul
बोगदा पुल
Chinar Park Bhopal
चिनार पार्क भोपाल
DDX Cinemas
डीडीएक्स सिनेमा - भोपाल
Kolar Road Police Station
JAHANGIRABAD
जहांगीराबाद
Bhopal
भोपाल
Birla Mandir
बिरला मंदिर
Lower Lake
Kashif Complex
J.K. Building
Link Road Number 3, Rivera Township...
Moti Masjid
मोती मस्जिद
Bus station
Police Thana
Kamla Nagar
पुलिस थाना कमला नगर
Kaliasot Dam
कालिअसोत डैम
Madhya Pradesh
Tribal Museum
मध्यप्रदेश जनजातीय...
Axis Bank
Chichli
चिचली
Google
Map
3D
Imagery ©2019 Maxar Technologies, Imagery ©2019 CNES / Airbus, Landsat / Copernicus, Maxar Technologies, Map data ©2019
India
Terms
Send feedback
1 km


BHEL
भेल
28, Indira Vihar colony
Behind SOS village
Shivlok Phase IV
District & Sessions Court
ZONE-I
ज़ोन-I
Pragati Square
प्रगति स्क्वायर
Shiv Mandir
शिव मंदिर
Kaalibaadi Temple
कालीबाड़ी मन्दिर
Soumya Park Land
सौम्या
पार्क लैंड
MAHARANA
PRATAP NAGAR
महाराणा
प्रताप नगर
42 min
19.3 km
Narmada Trauma Centre
नर्मदा
ट्रॉमा सेंटर
National Hospital
नेशनल हॉस्पिटल
Awadhpuri Police Station
Community Park,
BDA Colony...
कम्युनिटी पार्क,
BDA कॉलोनी...
Bhopal Fracture Hospital
भोपाल फ्रैक्चर
हॉस्पिटल
185/2-C, Saket
Nagar, Habib Ganj
RRL Bus Stop
Shahpura
Joggers' Park
Barkatullah University
Central Library
Hanuman Temple
हनुमान मंदिर
Vallabh Bhawan to Laxmipati College
Google
Katara Hill
Botanical Garden
Sahara Hospital
Map
3D

ISRO to Aashima Mall

Chirayu Hospital to Kokta




Bhauri to Mandideep
Bhopal Bypass Road
Police Chowki Lal Ghati
Dr Pradeep Prhalad Clinic, Near
Kahjuri Sadak, Kolu Khedi
Upper Lake
बड़ा तालाब
Shopping Center
Birla Mandir
बिरला मंदिर
K.K. Plaza
Special Task Force
AIIMS Hospital
एम्स हॉस्पिटल
1 h 21 min
43.6 km
A
BHEL
भेल
Kaliasot Dam
Hathaikheda Lake
Barkheda Salam
बरखेड़ा सालम
Bakaniya
बकानिया
Khajoori Sadak
खजूरी सड़क
Mungaliya Chhap
मुंगलिया छाप
Kajlas
कजलास
Borkhedi
बोरखेड़ी
Kodiya
कोडिया
Nandni
नंदनी
Neelbad
नीलबड़
Sikandarabad
सिकंदराबाद
Ratibad
रातीबड़
Narela
नारेला
Mendora
मेंडोरा
Chichli
चिचली
Sankhedi
संखेदी
Suhagpur
सुहागपुर
Inayatpur
इनायतपुर
Anwala
अनवाला
Samasgarh
समसगढ़
Bilkisganj
Kathotiya Hiking Area
Kalapani
कालापानी
Bandori
बन्दोरी
Khandabad
खान्दाबाद
Satlapur
सतलापुर
Samardha Kaliyasot
समरधा कलियासोत
National Highway 46, Industrial Area...
Resaldur
Arhedi
अरेड़ी
Kokta
कोकता
Chhawani Adampur
आदमपुर छावनी
Bilkhiriya Kalan
बिलखिरिया
Sankalpadariya
संकल्पदारिया
Chiklod Khur
चिकलोड खुर्द
Bansia
बांसिया
Padariya Jat
पडरिया जाट
Umraoganj
उम्रोगंज
Barrai
बर्राई
Tarawali
तारावली
Siyakundal
सियाकुंदल
Bagarauda
बगरोदा
Bhairopur
भैरोपुर
Chan
छान
Google
Map
3D
Imagery ©2019 Maxar Technologies, Imagery ©2019 TerraMetrics, Map data ©2019
India
Terms
Send feedback
2 km

S.No	EXISTING AVAILABLE DEPOT EQUIPMENT'S FOR BCLL BUSES PROCURED UNDER WORLD BANK GEF 5 PROJECT	QTY	BAIRAGARH	ISBT	JAWAHAR CHOWK
1	Wheel Alignment Machine	2	Yes		Yes
2	Wheel Balancer Machine	2	Yes		Yes
3	Fully Automatic Tire Changer Hydraulic Type	3	Yes	Yes	Yes
4	Nitrogen Tire Inflator	3	Yes	Yes	Yes
5	Head Light Beam Aligner	3	Yes	Yes	Yes
6	Pneumatic Impact Wrench & Socket	3	Yes	Yes	Yes
7	Automatic Bus Washing	2	Yes		Yes
8	Heavy Duty Vacuum Cleaner	9	Yes	Yes	Yes
9	Silent Generators – 125 KVA /45 KVA	4	Yes	Yes	Yes

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

Depot equipment Utilization & Benefits: Bus Washing Plant

Jawahar Chowk Depot

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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