UK PACT
GREEN RECOVERY CHALLENGE FUND

UK PACT
(Partnering for Accelerated Climate Transitions)

National Dissemination Workshop on

Electrification of Public Transport and Intermediate Public Transport in Indian Cities

26th April, 2022

Session 1: PT Electrification Strategy for Ahmedabad

Strategy Formulation for PT and its Electrification

Jeff Turner, ITS, University of Leeds
Vishal Khanama, General Manager, AJL, AMC
Khelan Modi, CRDF, CEPT University

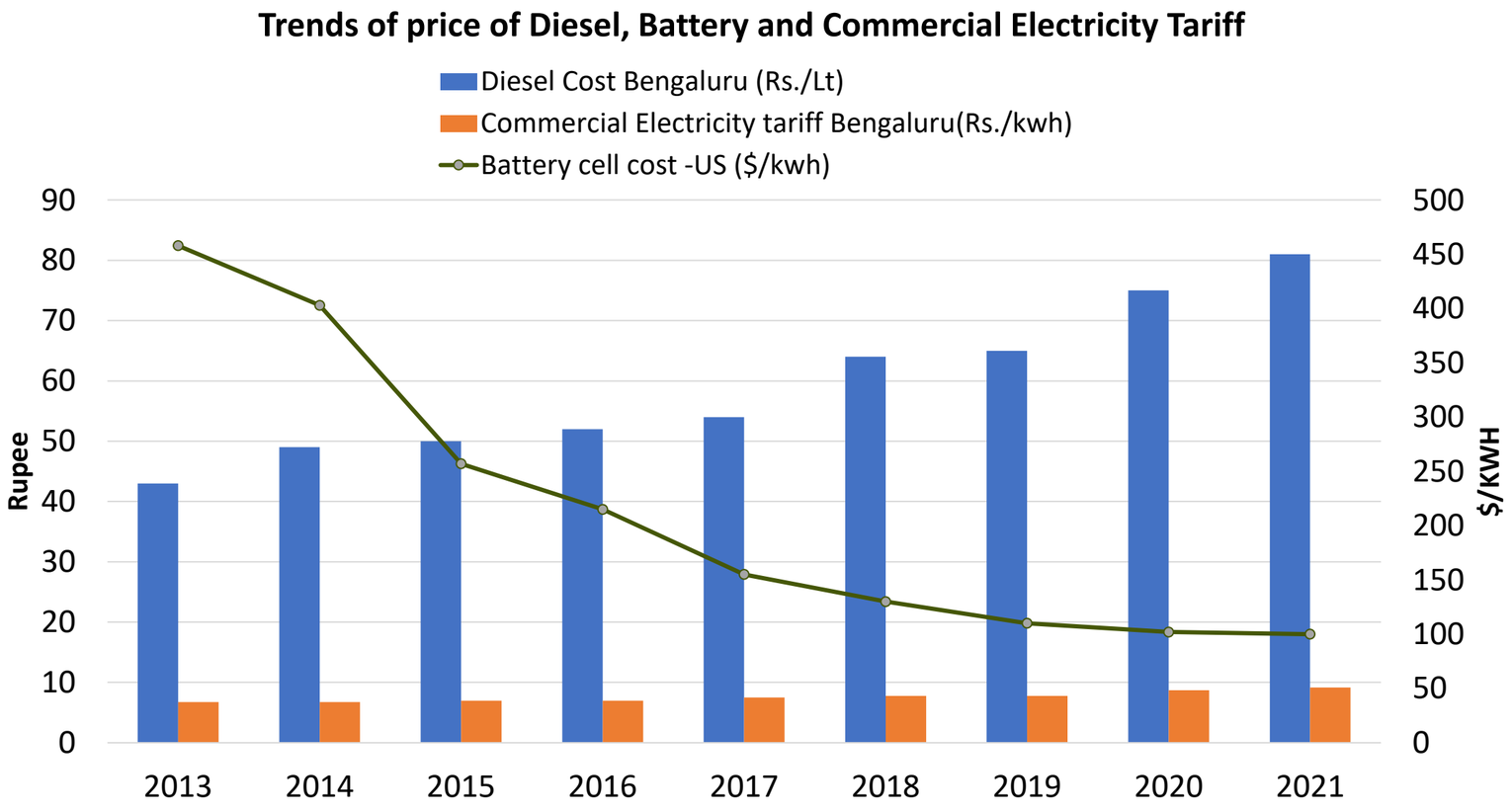
CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION

UNIVERSITY OF LEEDS

Brunel University London

GERMI GUJARAT ENERGY RESEARCH AND MANAGEMENT INSTITUTE

Why Electrification of PT should be prioritised ??



Battery prices – *(Source: BloombergNEF)*

- Technology advances in battery, vehicle platform design etc., are delivering substantial cost reductions for batteries (IEA, 2019)
- CNG bus TCOs is cheaper for buses. However, falling Battery prices and increased CNG prices may alter the equation..!!
- Co2 emission by BS VI CNG bus is 21.09 Tons/year compared to zero emission by electric bus

	2014	2022	CAGR
Battery cell prices (INR per cell)	30900	7575	**-16%**
Diesel prices/ lt.	80	105	**3%**
CNG Prices	46	80	**7%**

UK PACT
GREEN RECOVERY CHALLENGE FUND

Presentation Structure

- ❑ Key learnings from International Cases
- ❑ Future Public Transport Strategy Formulation – Long term
  - ○ PT share – 2031
  - ○ PT electrification target – 2031
  - ○ Impact assessment framework
- ❑ Action Plan – Service standard enhancement
- ❑ Action Plan – E-bus Operations

Success factors from International Experience

Bailey (2020) found the following success factors from European experience:

- Political will
- Need for financial support in order to overcome the initially overcome the high capital cost of e-bus ownership.
- Need for piloting and experimentation
- Innovations in procurement processes – to make bus operations cost-effective.
- Need for integrated planning and design of electric buses, in terms of energy supply, vehicle operation and service delivery.

Operational factors from International Experience

- Local operational context very important for developing optimal bus operational practice and charging strategies.
- Limited generalisable research on best charging strategies and electric bus operational practice
- However, a few studies found that fast charging facilities, including and curbside or ‘opportunity’ fast charging, coupled with more conventional overnight charging exhibited some of the most desired operational performance.

What should be PT share of Ahmedabad in 2031 ??

Year	Population (Ahmedabad City)
2011	5.55 mn
2021	7.20 mn
2031	8.61 mn

Year	PT share
2011	22% (IMP Study, 2011)
2021	13% (Based on existing ridership of AMTS & BRTS)
2031	IMP Study (2011) target – 35% Metro phase II study target – 35% to 40%

What should be the target for 2031?

BAU

PT Share – **13%**

Fleet req. – **1060***

Buses / Lakh Population – **13** (LoS 4)

Scenario 1

PT Share – **20%**

Fleet req. – **2010****

Buses / Lakh Population – **20** (LoS 4)

Scenario 2

PT Share – **30%**

Fleet req. – **3020****

Buses / Lakh Population – **31** (LoS 3)

Suggested by Task Force Group in Draft Strategy Action Plan workshop (20th Oct 2021)

Scenario 3

PT Share – **40%**

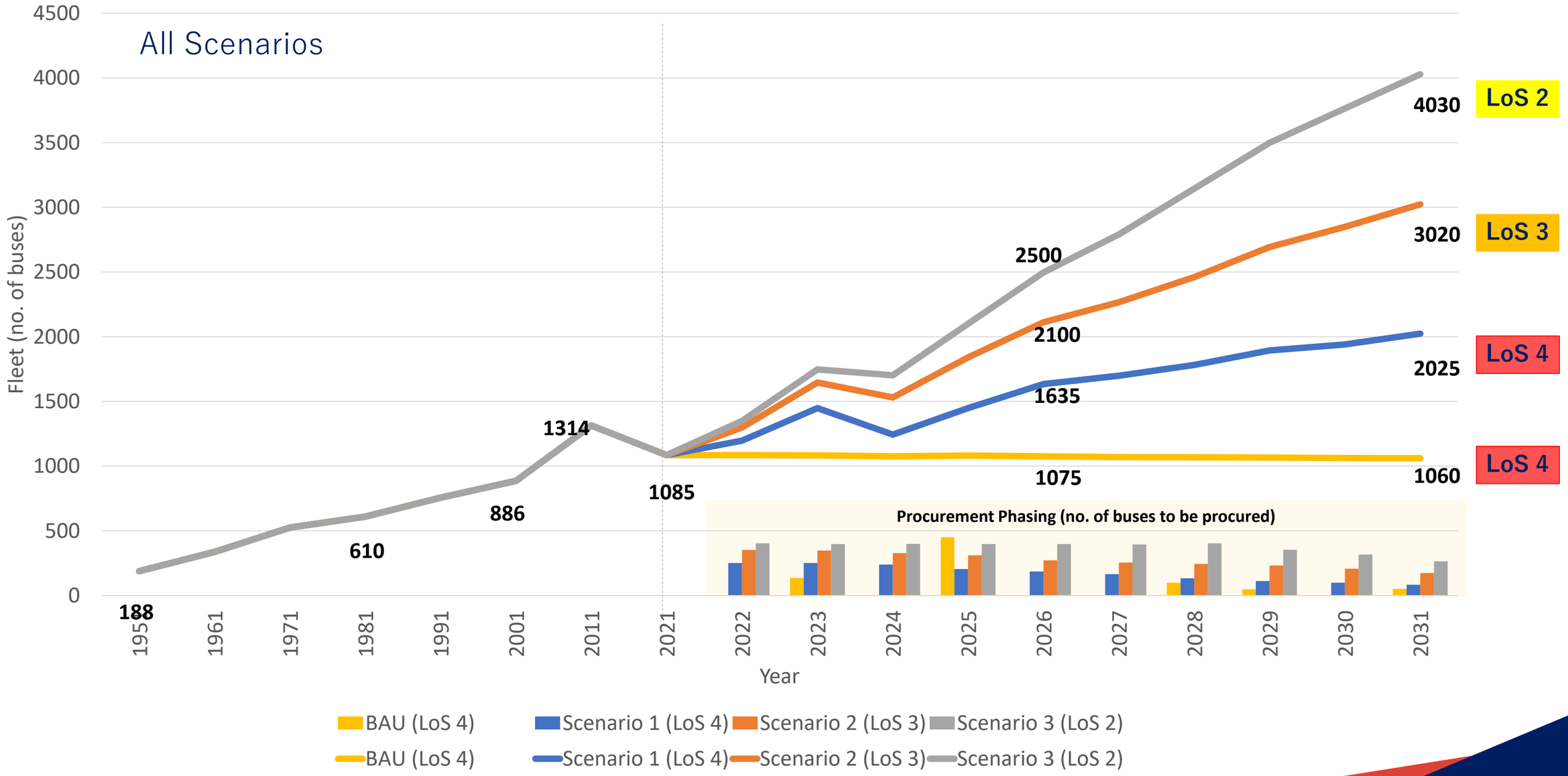
Fleet req. – **4030****

Buses / Lakh Population – **41** (LoS 2)

** For BAU, fleet required is estimated considering 535 pax/bus/day, same as base situation*

***Fleet Requirement for other scenarios has been estimated considering all standard buses with 700 pax per bus per day*

Fleet Procurement Trajectory & Phasing



UK PACT
GREEN RECOVERY CHALLENGE FUND

What should be the target for Electric buses – 2031 ??

"The government intends to have EV sales penetration of 30% for private cars, 70% for commercial vehicles, **40% for buses,** and 80% for two and three-wheelers by 2030" - *Nitin Gadkari, Minister of Road Transport and Highways, GoI 31 August 2021*

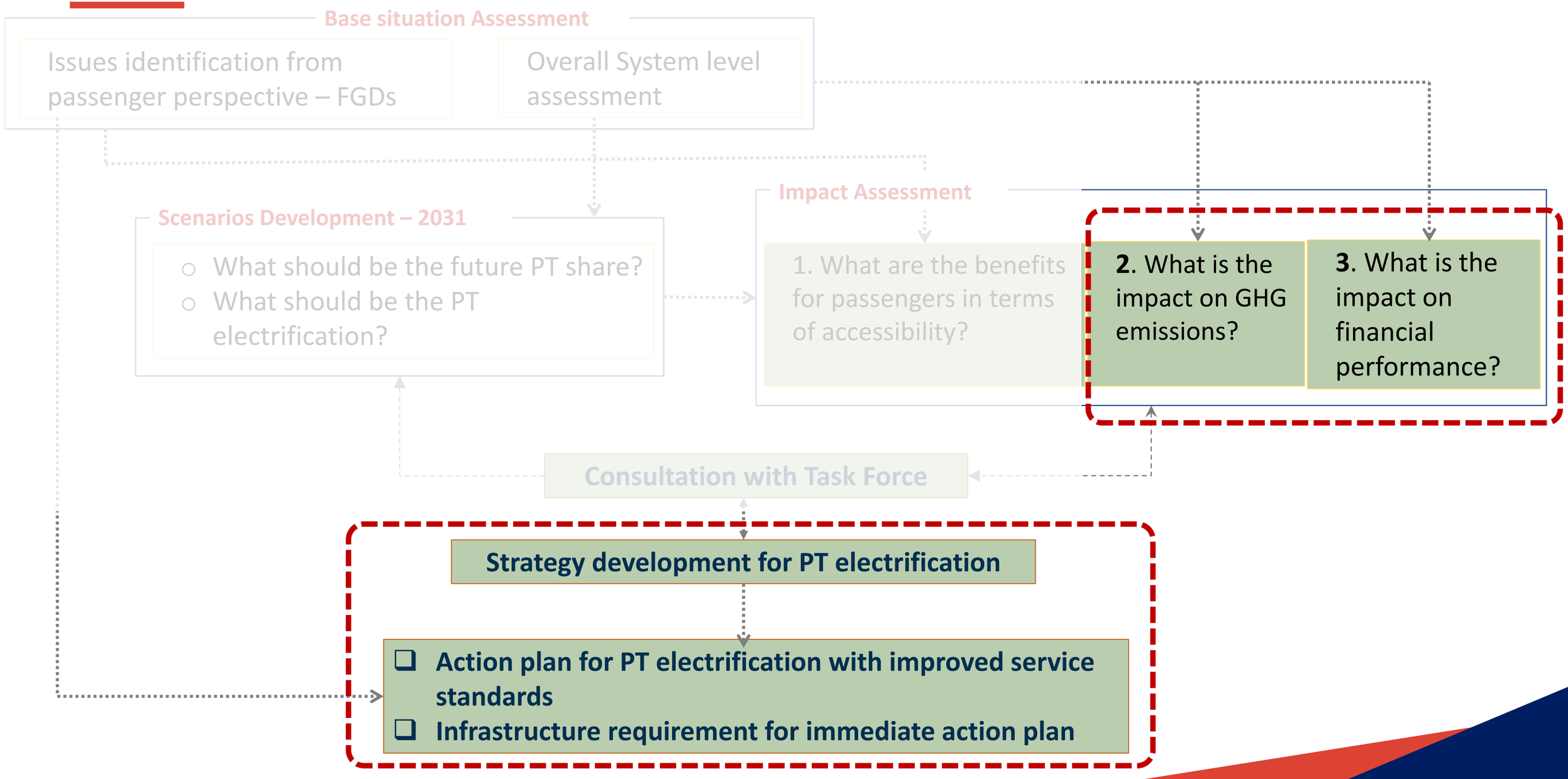
Electric buses requirement

% share of Electric Fleet For year 2031	BAU PT Share 8% 1060 buses	Scenario 1 PT Share 20% 2010 buses	Scenario 2 PT Share 30% 3020 buses	Scenario 3 PT Share 40% 4030 buses
40%	425	810	1210	1612
75%	795	1520	2265	3023
100%	1060	2010	3030	4030

Existing **electric bus share is 202 buses (18%)** of total **1085 buses**

UK PACT
GREEN RECOVERY CHALLENGE FUND

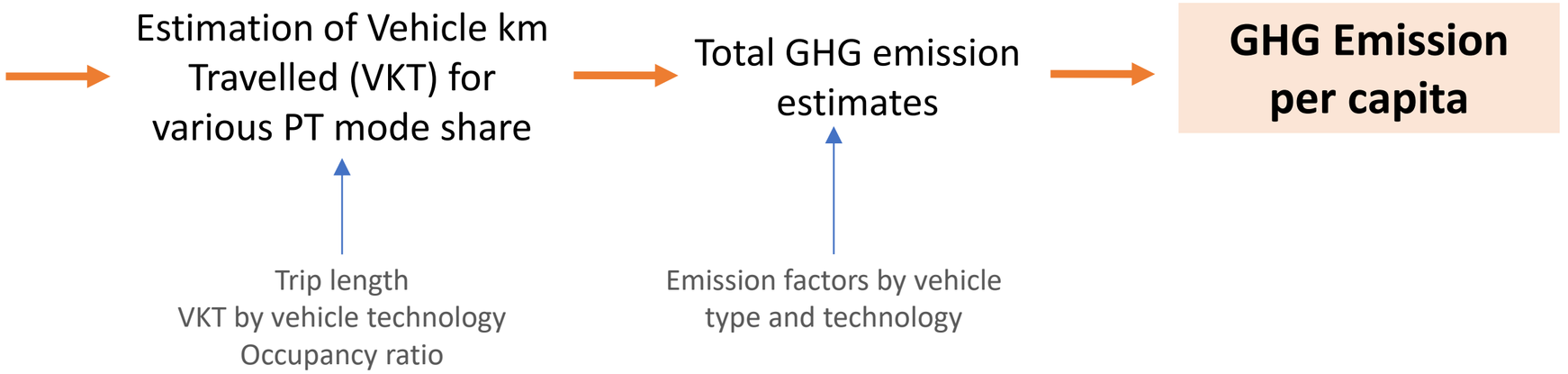
Study Approach



GHG Emission Estimates

GHG Emission Estimates – Estimates of total GHG emission and per capita GHG emission for future year from transport sector in the city.

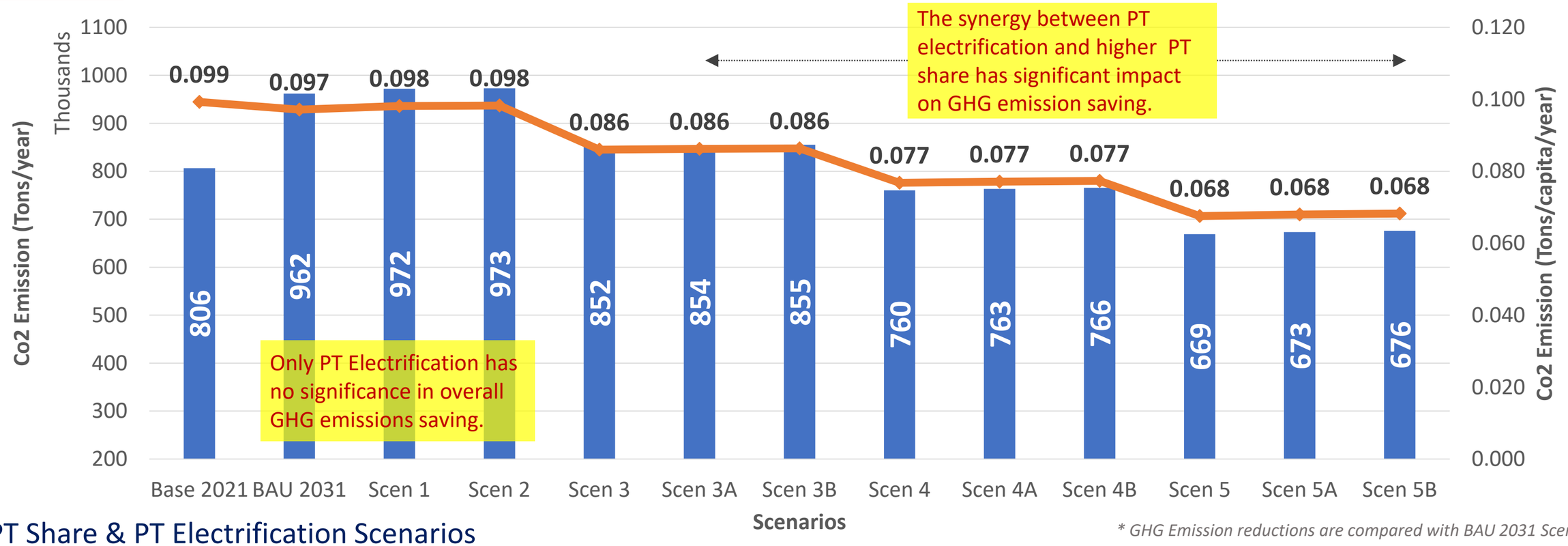
- Existing and future mode share
- Existing and future fleet requirement based on mode share



A spreadsheet based tool developed which estimates the GHG emission for future year. It only requires minimum strategic level inputs from the authority.

UK PACT
GREEN RECOVERY CHALLENGE FUND

GHG Emission Estimates – 2031



PT Share & PT Electrification Scenarios

** GHG Emission reductions are compared with BAU 2031 Scenario*

	Base 2021	BAU 2031	Scen 1	Scen 2	Scen 3	Scen 3A	Scen 3B	Scan 4	Scen 4A	Scen 4B	Scen 5	Scen 5A	Scen 5B
% PT Share	13%	13%	13%	13%	20%	20%	20%	30%	30%	30%	40%	40%	40%
% Electric - PT	19%	19%	40%	75%	40%	75%	100%	40%	75%	100%	40%	75%	100%
GHG Emission reductions		0%	+1%	+1%	-12%	-12%	-12%	-23%	-23%	-23%	-36%	-36%	-36%

Electrification of PT along with improved ridership would reduce the GHG emissions significantly. Only PT electrification has not much impact on GHG reduction.

Financial Impact Assessment

Financial Performance – Assessment of operational viability and sustainability by computing Total Cost of Ownership (TCO) for different fleet size and mix. Also estimates the revenue and compares the cost recovery for each scenario.

Fleet procurement phasing plan by scenario (Fleet size and mix)

→

TCO break-up by different cost components

Revenue estimates based on different PT share/ ridership

→

Financial performance

Total cost of ownership

EPKM/ CPKM

Cost/ pass.km

Operating ratio

A spreadsheet based tool on TCO analysis and revenue estimates has been developed which analyses all the financial parameter and enables scenario comparison.

UK PACT
GREEN RECOVERY CHALLENGE FUND

Impact Assessment Framework – GHG Savings and Financial Performance

	BAU-A	BAU-B	BAU-C	Scen-2A	Scen-2B	Scen-2C	Scen-3A	Scen-3B	Scen-3C	Scen-4A	Scen-4B	Scen-4C
% PT Share	13%	13%	13%	20%	20%	20%	30%	30%	30%	40%	40%	40%
% Electric - PT	19%	40%	75%	40%	75%	100%	40%	75%	100%	40%	75%	100%
GHG Emissions Reduction (WTW)		1%	1%	-12%	-12%	-12%	-23%	-23%	-23%	-36%	-36%	-36%
	Financial Assessment											
CPKM (Rs.)	62.9	61.2	58.5	69.6	66.3	65.8	67.0	63.3	60.6	68.7	64.7	61.9
EPKM / CPKM	95%	97%	101%	86%	91%	92%	97%	102%	107%	93%	99%	103%
Operating Ratio (Fare revenue/ Operating cost)	1.06	1.12	1.22	1.02	1.13	1.20	1.19	1.34	1.48	1.17	1.32	1.46
Cost/ pax km (100% LF)	1.43	1.39	1.33	1.61	1.53	1.52	1.56	1.47	1.41	1.61	1.51	1.45

All the costs are escalated cost at constant prices.

- ❑ Even though E-Bus scenarios has higher upfront costs, the Total Cost of Ownership (Capex + Opex) is cheaper for E-Bus compared to CNG buses.
- ❑ 100% E-Bus scenario is approximately 10% cheaper compared to 40% E-Bus scenario.

UK PACT
GREEN RECOVERY CHALLENGE FUND

Summary – Long term strategy

- **Electrification without fleet enhancement has no major impact on GHG emissions reduction**
- **Electrification of buses as a means to improve public transport – an integral component of PT strategy 2031**
  - Improved fleet size along with improved service quality such as accessibility, waiting time, quality of services, comfort would help attracting more ridership – E-Buses can contribute to quality and comfortable services
- **E-buses seem more economically viable in future:**
  - No significant change in unit rate of electricity observed
  - Rapid rate of increase in price of CNG/Diesel fuels

UK PACT
GREEN RECOVERY
CHALLENGE FUND

Action Plan – Part A

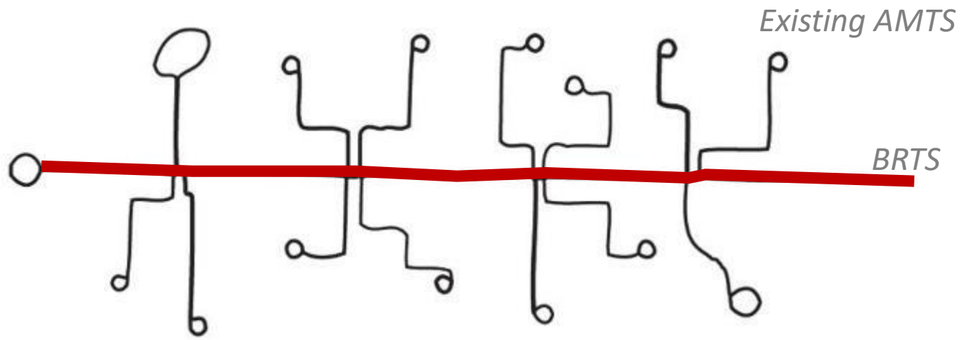
Service Quality Enhancement – AJL Initiatives

Route proposal options have been developed to addresses the issues identified in Users' perception FGDs. All the additional buses required for service improvement, will be electric buses to create the good image for larger visibility in the society.

PT Service Improvement Strategy

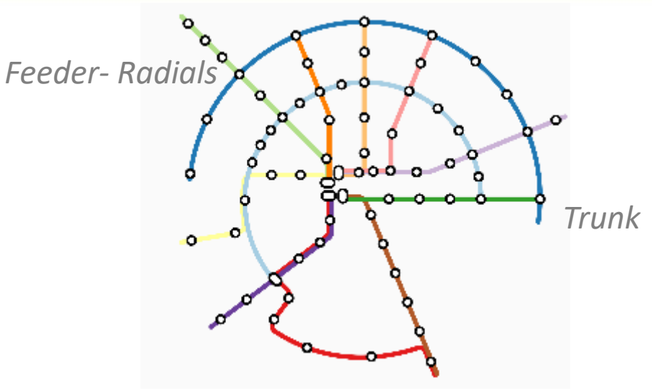
Option 01

ABC (AMTS-BRTS Connect) routes: Identifying existing AMTS routes to integrate to BRTS with minimum interventions



Option 02

Radial routes: Proposing new radial routes to improve the high frequency network and connecting new areas in the city



For Users

- Experiences seamless transfers
- Provides feeder to high-frequency BRTS services
- Ensures overall high-frequency coverage
- Improves connectivity to low-income settlement

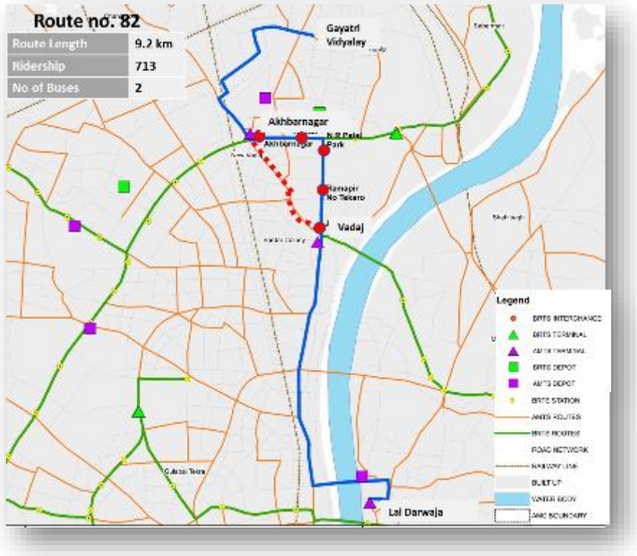
For Transit Agencies

- Creates opportunity for physical and fare integration
- Helps in improving the ridership

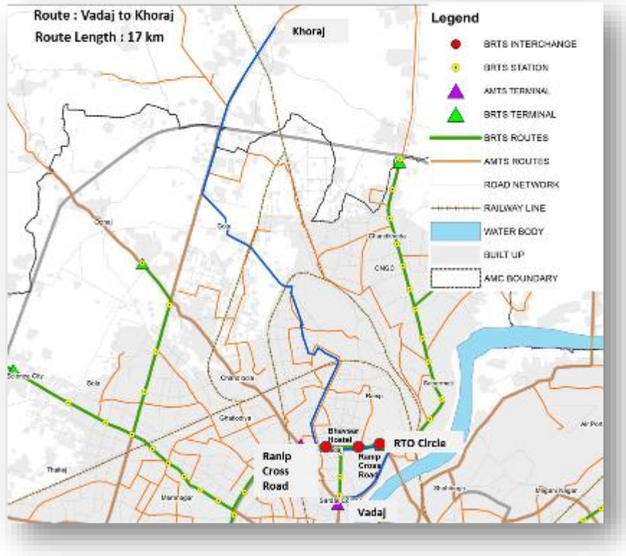
How Service Standards can be Enhanced?

Objectives:

- ❑ Ensure high-frequency service coverage
- ❑ Enhance connectivity based on demand pattern identified in FGD



Option 1: Existing A-B Connect Route



Option 2: New Radial Route

No. of Routes Recommended	20
Fleet Size	**189** buses

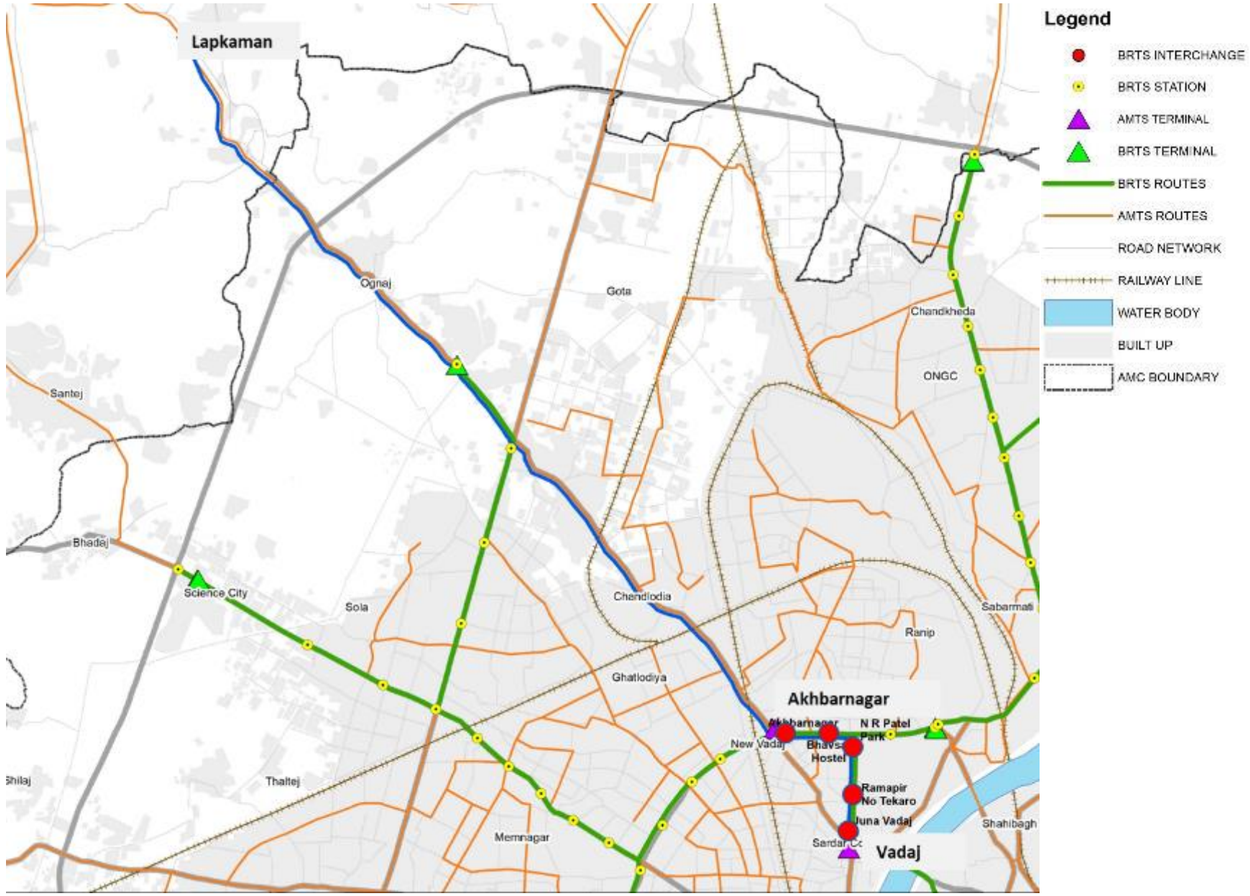
No. of Routes Recommended	12
Fleet Size	**128** buses

How Service Standards can be Enhanced?

Option 1: Existing A-B Connect Route

	Existing route	High frequency route
Length (km)	9.2	9.2
Headway (min)	60	10
Fleet (no. of buses)	2	7

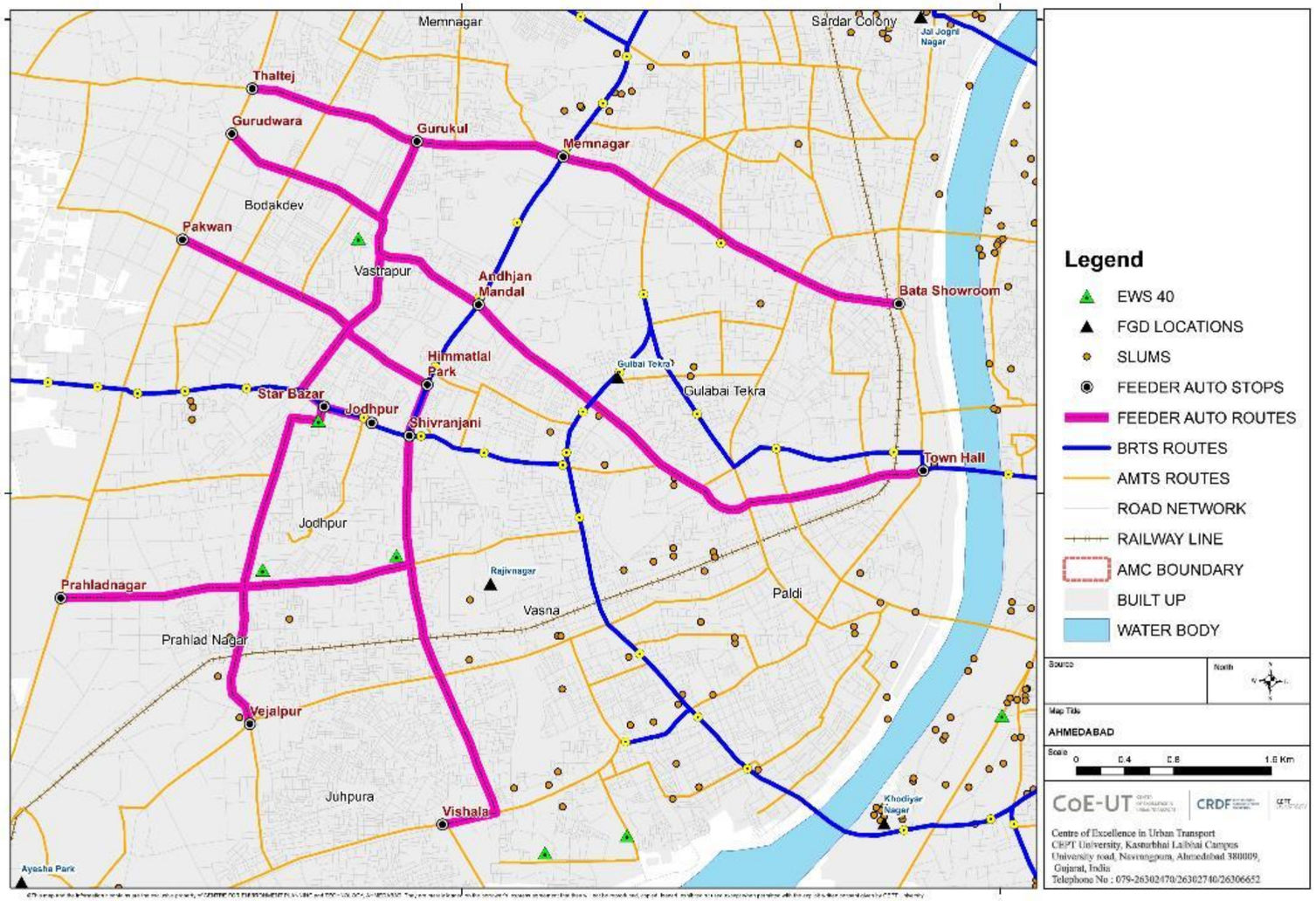
Option 2: New Radial Route

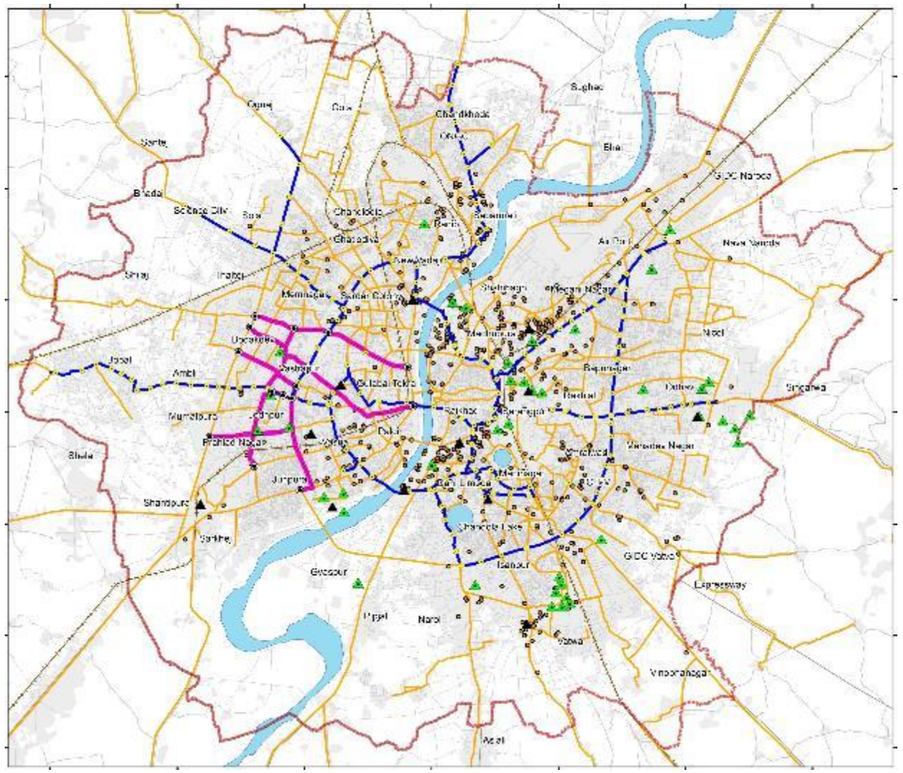


Route Name	Nava Vadaj to Adani Shantigram
Route Length (in kms)	12
Headway	10 min
Fleet Required	**10**

UK PACT
GREEN RECOVERY CHALLENGE FUND

Last Mile Connectivity Improvement





- Initiative has been taken by AJL to provide E-Rickshaw as feeder to BRTS on western part of the city.
- The accessibility to low-income communities have improved from 80% to 98% with **E-SAVARI**.
- Being affordable, frequent and accessible services, **E-SAVARI** is demonstrating good response from commuters.

AJL has started 10 routes with 60 E-Rickshaw as pilot, and there is plan to expand this at city level with 600 E-Autos. The brand name is **E-SAVARI**

Summary – Action Plan (Service Standard Enhancement)

- Option 1 and Option 2 both improve accessibility to services which was one of the major issues identified in FGDs.
- There is a need to provide good pedestrian access to bus stops infrastructure and routes information at the bus stops on the suggested routes (Option 1 or Option 2) which would also address other issues came out from FGDs.
- There is a need to install surveillance camera around bus stops and in these new buses which would ensure safety for passengers – mainly for women passengers.
- E-SAVARI has received good response from commuters because of affordability, frequent and accessible services. It should be expanded pan city as last mile connectivity as short-term action.

UK PACT
GREEN RECOVERY
CHALLENGE FUND

City's Experience and Key Learnings

Observations

UK PACT
GREEN RECOVERY CHALLENGE FUND

City's Experience – E-Bus Operations

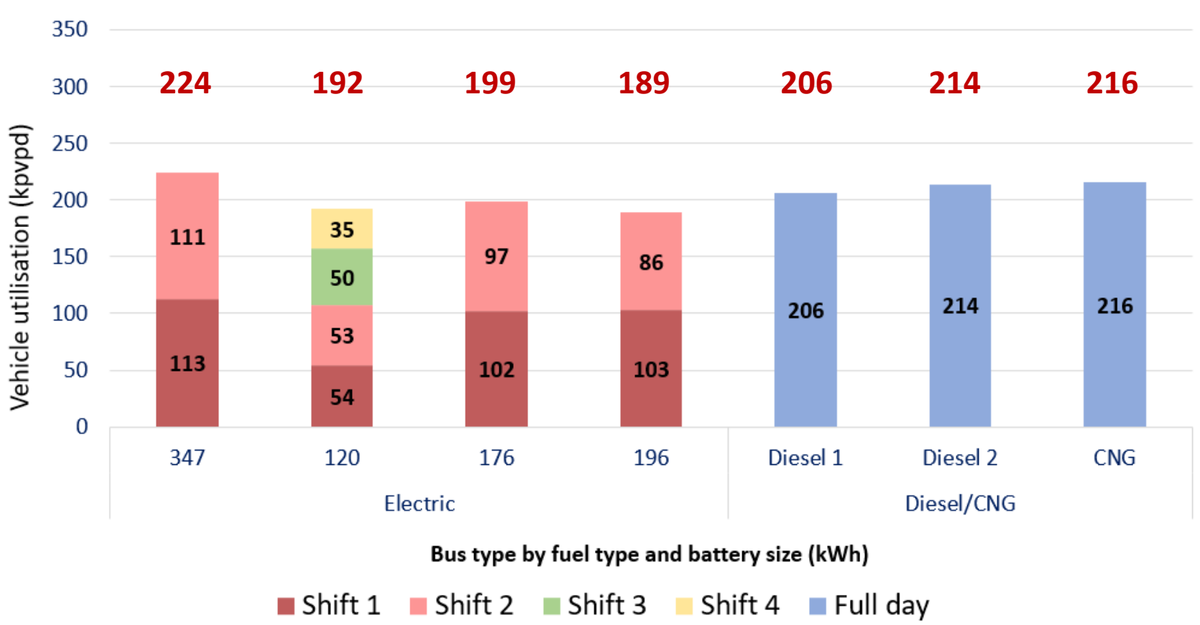
Four different types of E-Buses are in operations.

	2018	2019	2019	2021	2022
E-bus type	**64 kWh**	**120 kWh**	**347 kWh**	**196 kWh**	**176 kWh**
Fleet size	Discontinued in 2019 and replaced with 120kWh plug-in buses	18	33	90	60
Weight (tons)		12	17	10	11
Energy efficiency (kWh/km)		1.1	1.4	0.9	0.9
Range (km)		**90**	**245**	**215**	**195**
Range (km) At 20% SOC		**75**	**185**	**160**	**140**

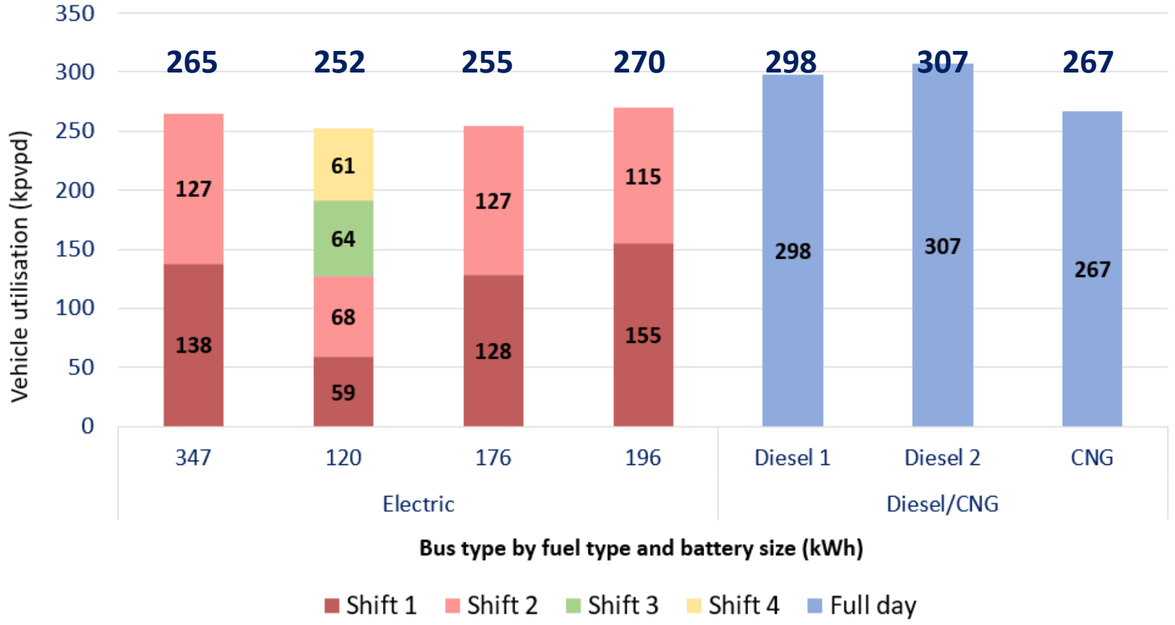
Each type of bus has its own characteristic in terms of its operational performance.

Vehicle Utilisation – E-Bus

Average Vehicle Utilisation



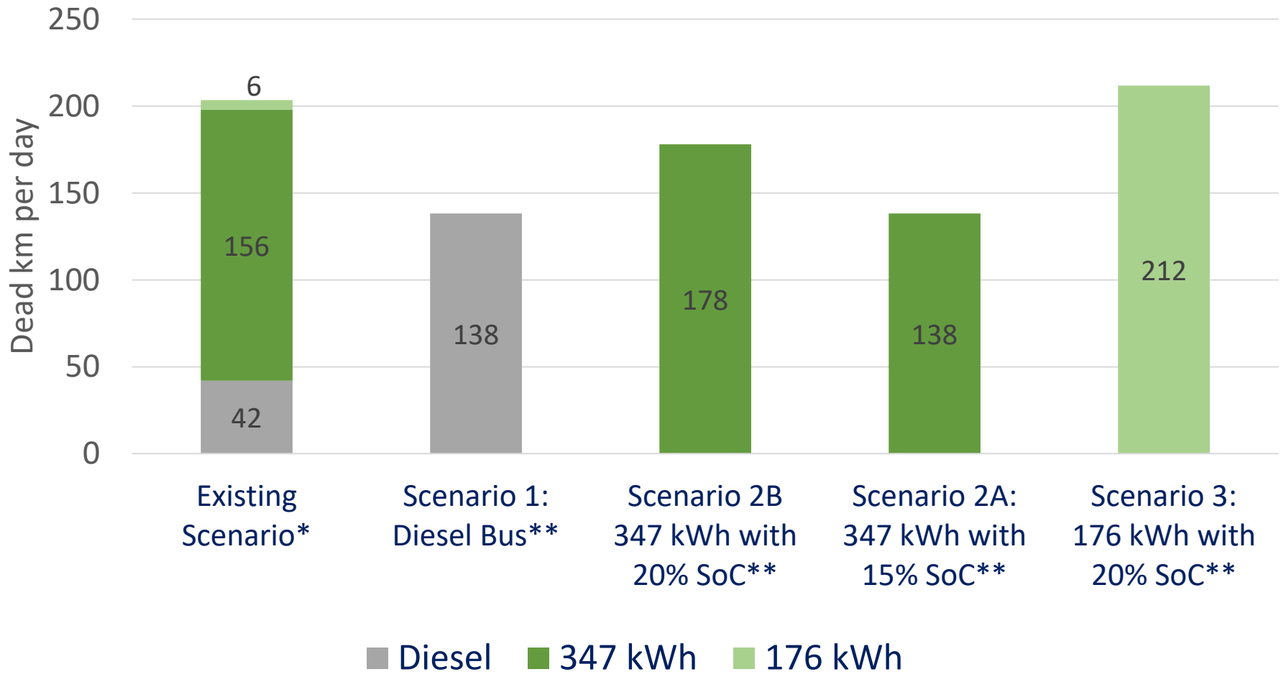
Maximum Vehicle Utilisation



- 200 km is considered as average vehicle utilisation for city bus services in India.
- Irrespective of Battery sizes, AJL is able to manage average vehicle utilisation as per contract.

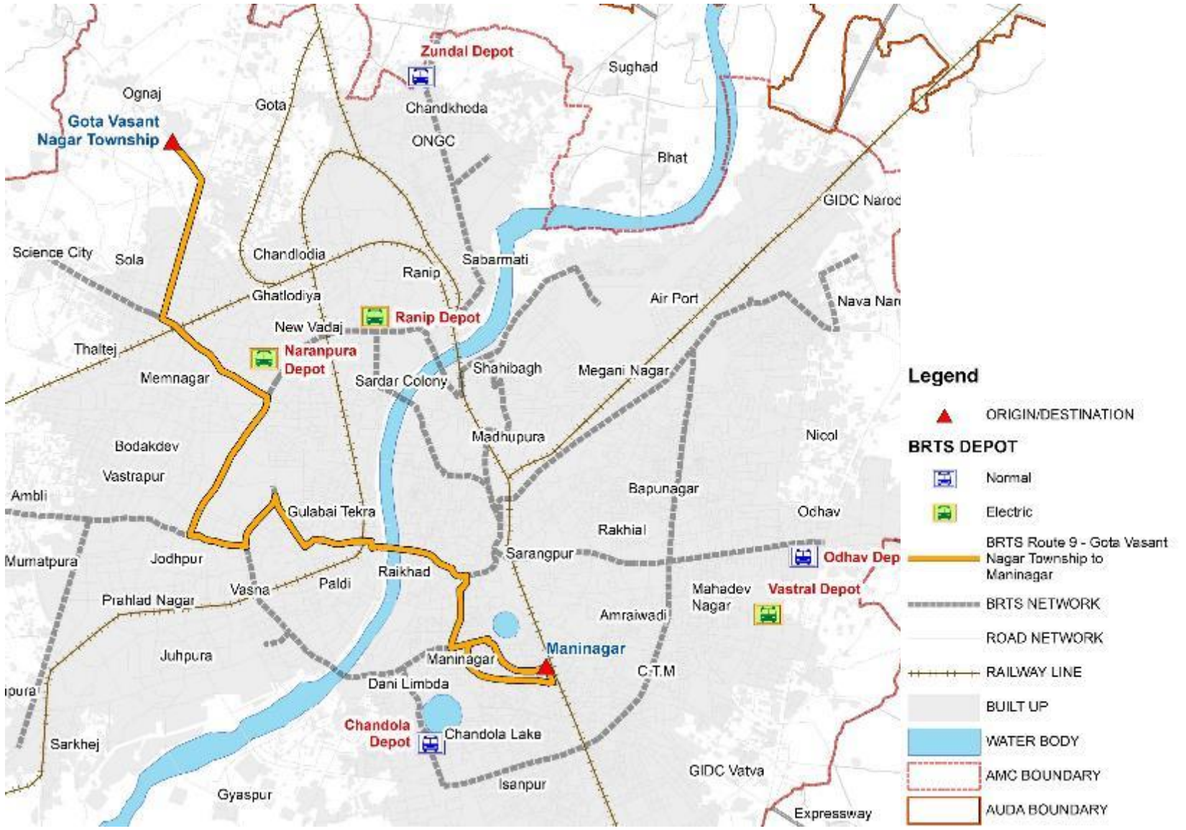
Comparison of Dead km (Non-revenue km)

For a specific route and depot location, varying battery size would impact on dead km because of opportunity charging requirement.



**Presently, Electric and Diesel Buses are operating from Naranpura and Chandola depot respectively*

*** Assuming all 26 buses are operating from Naranpura depot*

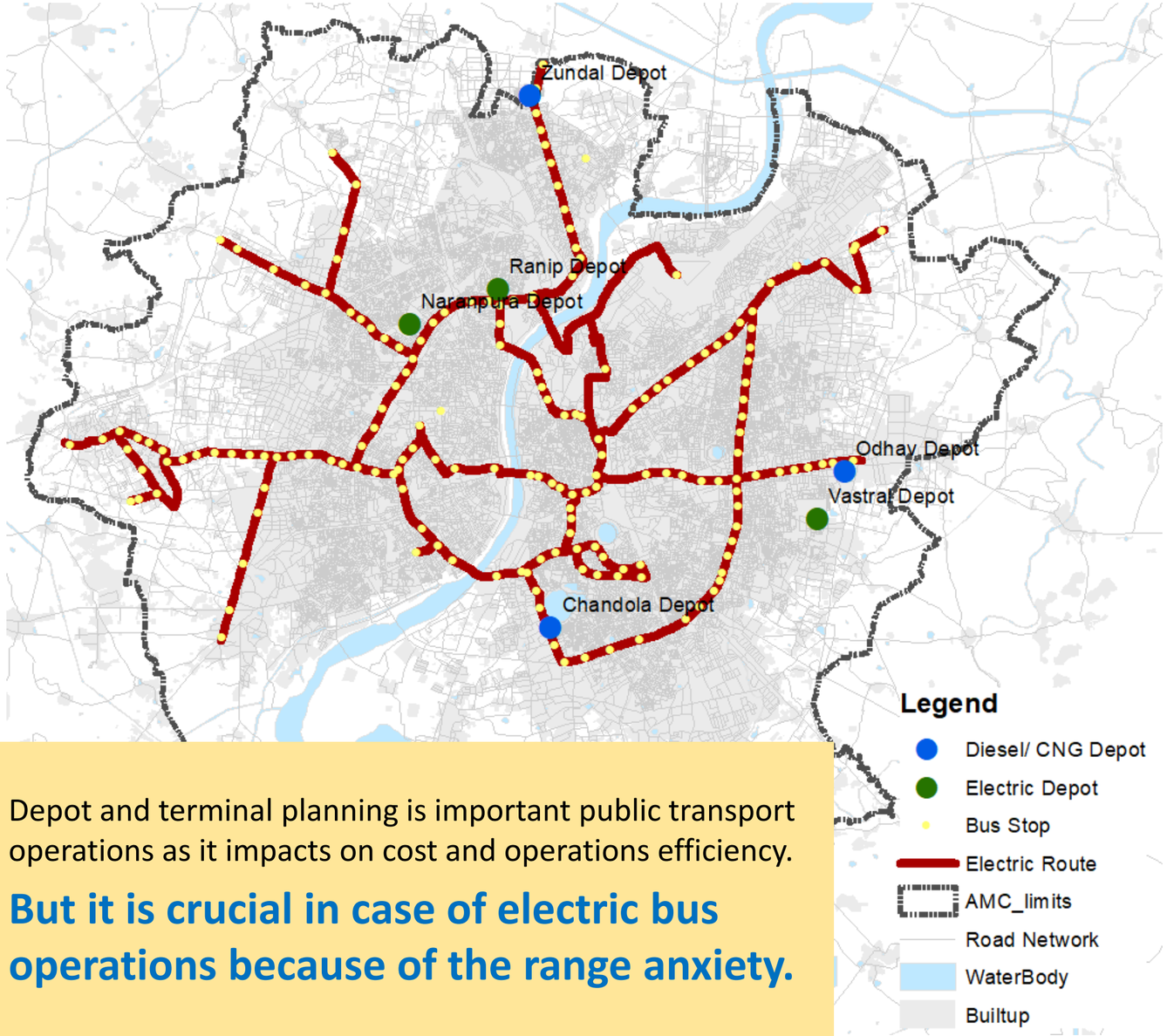


Route 9: Maninagar – Gota Vasant Nagar Township

Fleet Size : 26

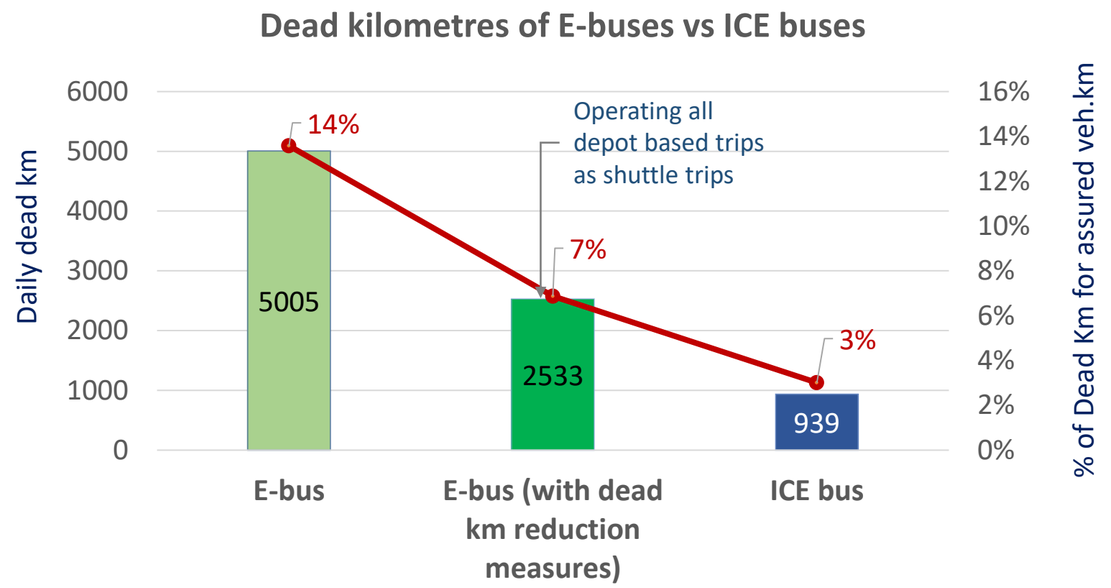
UK PACT
GREEN RECOVERY CHALLENGE FUND

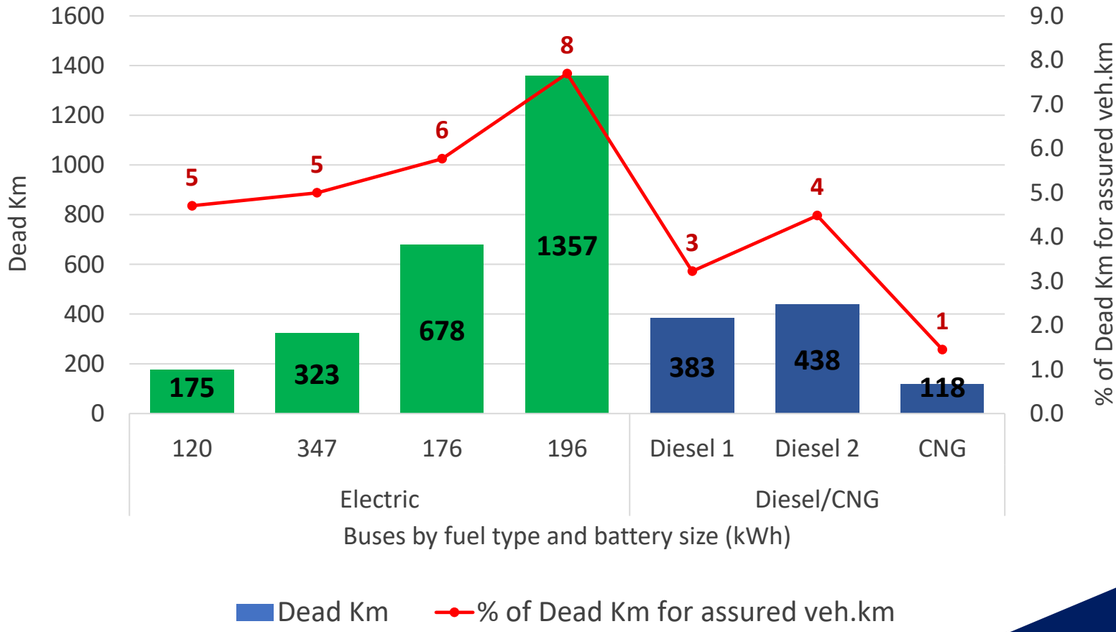
Depot Location for E-Buses



Depot and terminal planning is important public transport operations as it impacts on cost and operations efficiency.

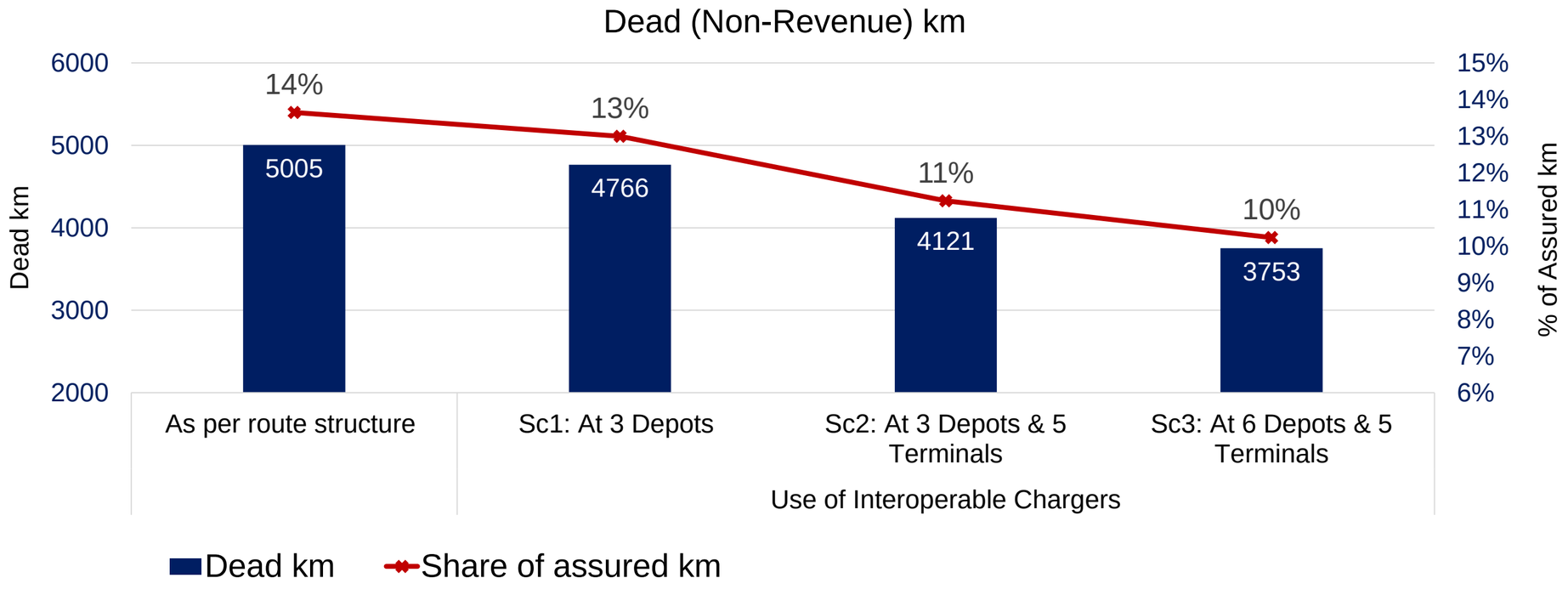
But it is crucial in case of electric bus operations because of the range anxiety.



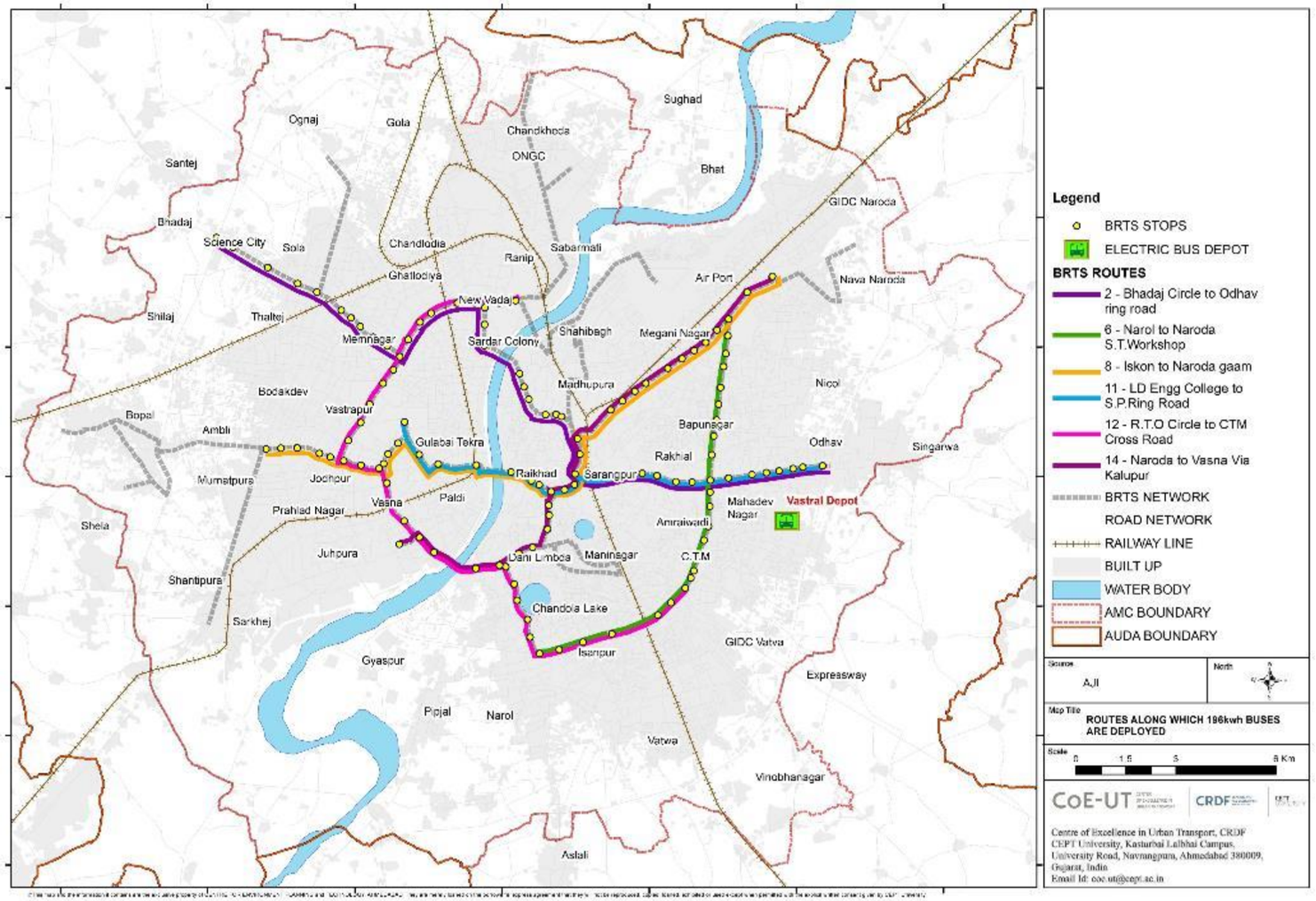


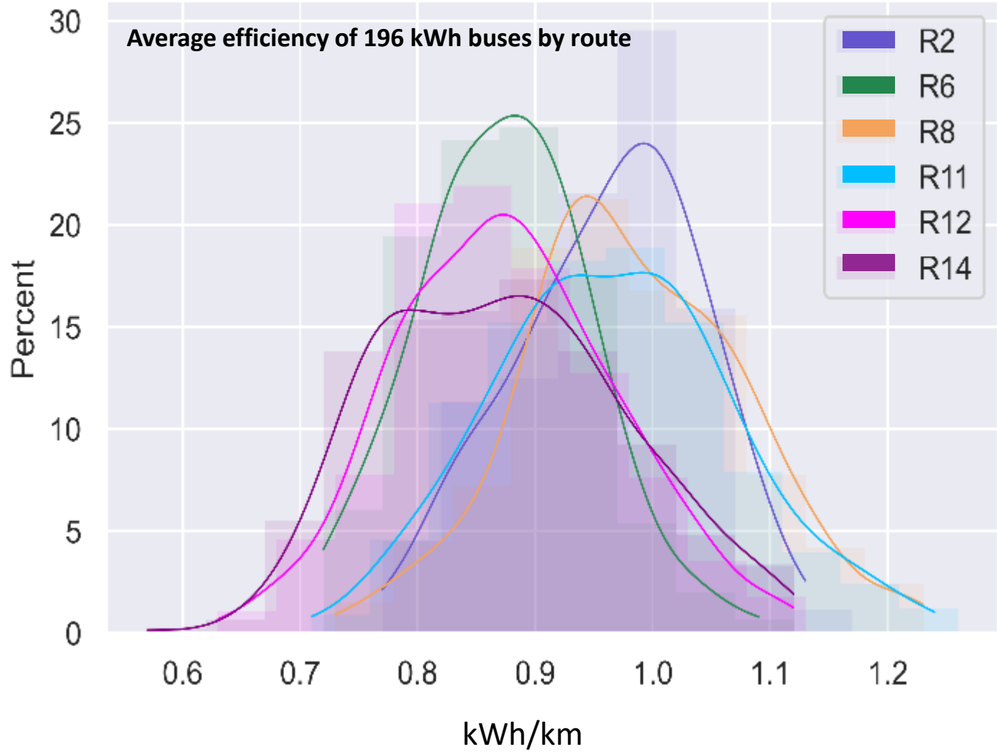
Dead km reduction measures – Scenarios

- **Scenario 1** – Assuming interoperability among the chargers for all three existing depots
- **Scenario 2** – Existing three depots plus additional five terminals where existing electric bus routes terminate with charging infrastructure.
- **Scenario 3** – Other three ICE depots are available for opportunity charging during mid-day plus five terminals same as Scenario 2.



Route and Energy Efficiency





R. no	Avg Energy Efficiency	Normal Distribution	Significance
2	0.96	Yes	Yes
6	0.87	Yes	Yes
8	0.98	Yes	Yes
11	0.97	Yes	Yes
12	0.88	Yes	Yes
14	0.87	Yes	Yes

Route alignment has significant relation with energy efficiency.

UK PACT
GREEN RECOVERY CHALLENGE FUND

Summary – Observations

- **Having range anxiety is a critical aspect, prior Depot location planning is essential to bring the efficiency in operation – Depot location is preferably close to terminal.**
- **Terminal based opportunity charging and interoperability of chargers would improve the schedule flexibility and ultimately increase the revenue km.**
- **Mixed battery size fleet:**
  - Mixed battery size fleet would reduce down the overall cost, however, requires prior planning of routes and infrastructure.
  - Achieving assured vehicle km i.e. about 200km is possible with mixed battery size fleet, however the dead km may be higher in lower battery size.
- **Energy efficiency:**
  - Some routes are more favorable for electric bus deployment in terms of energy efficiency. This fact should be considered while piloting E-Buses.
  - Driving behavior impacts on energy efficiency, driver training is recommended to improve the efficiency.

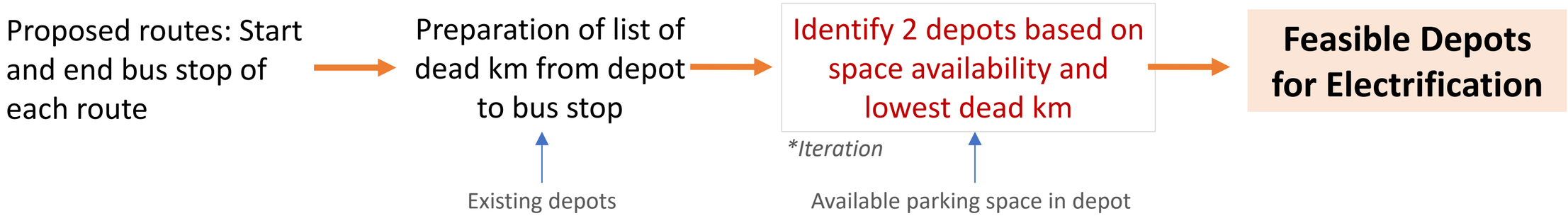
UK PACT
GREEN RECOVERY
CHALLENGE FUND

Action Plan – Part B

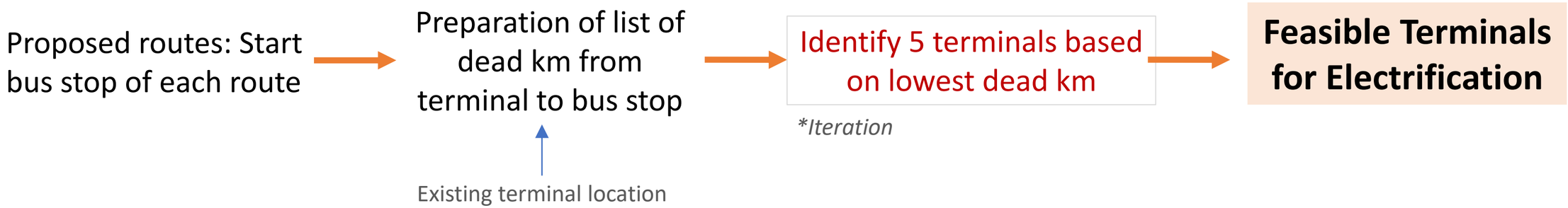
Infrastructure Requirement for Action Plan – Part A

Selection of Feasible Depots and Terminals

1. Identification of Depots – Provides feasible existing bus depots for allocation of electric bus of proposed routes

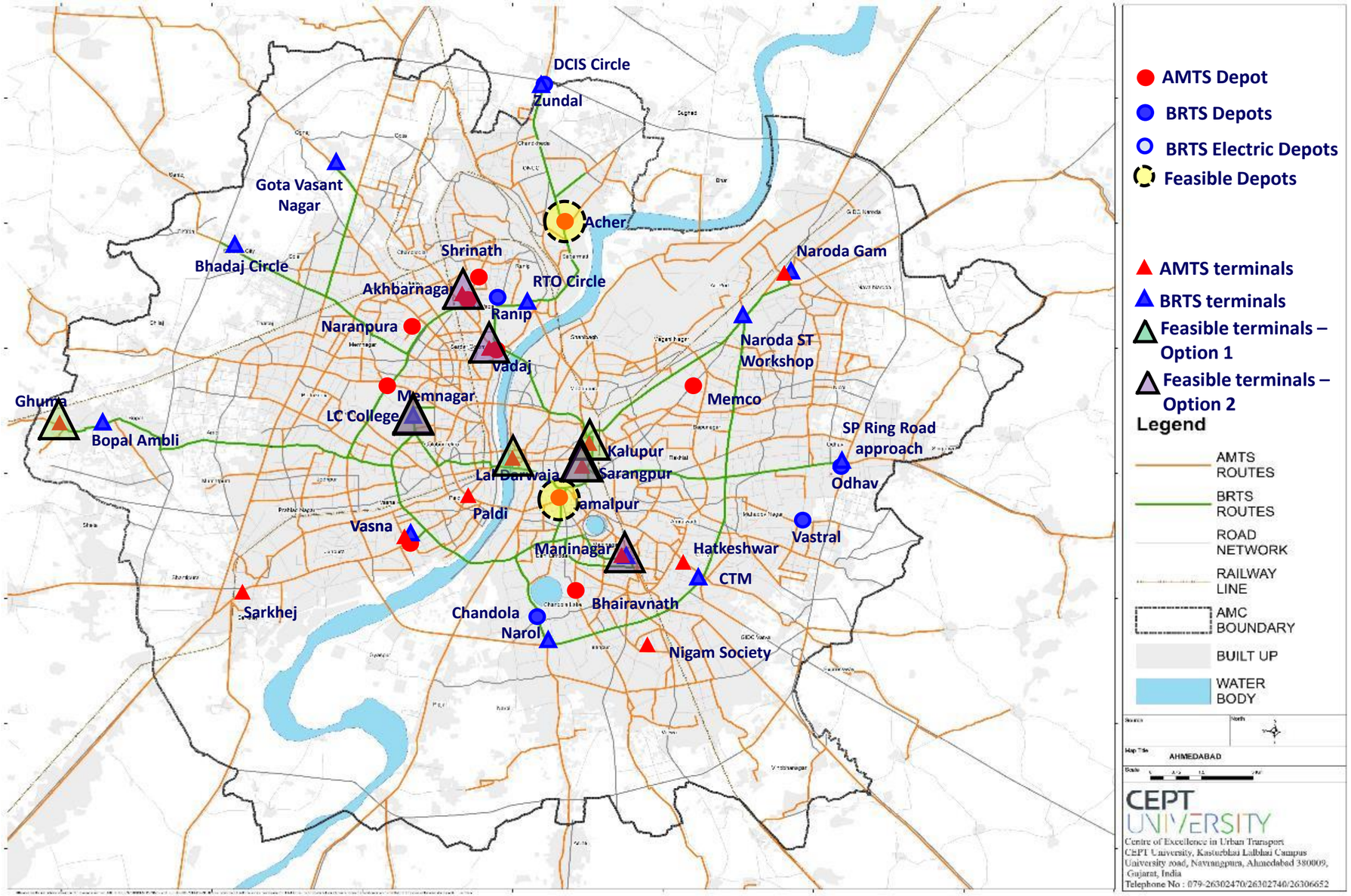


2. Identification of Terminals – Provides feasible existing terminal locations for setting up charging units for conducting opportunity charging



A spreadsheet based tool on the allocation of electric buses of proposed routes to depot and terminals is developed based on the dead km and space availability.

Depot and Terminal Facilities



Feasible Depots

Option 1 – AB Connect	Option 2 – Radial Routes
Jamalpur Acher	Jamalpur Acher
Dead km - 2484	**Dead km - 2228**

Feasible Terminals

Option 1 – AB Connect	Option 2 – Radial Routes
LD College Ghuma Kalupur Lal Darwaja Sarangpur	LD College Akbarnagar Sarangpur Vadaj Maninagar
Dead km - 1020	**Dead km - 216**

UK PACT
GREEN RECOVERY
CHALLENGE FUND

Thank You