Technical Assistance for BMTC Transitioning to an all - EV/Clean Fuel Public Transport Fleet

Business Case for Full Electrification of BMTC Fleet

Part 1 – Financial Analysis and Funding

C40 Cities Finance Facility

November 2020

Funding partners:

Implementing agencies:

ABOUT THE C40 CITIES FINANCE FACILITY

The C40 Cities Finance Facility (CFF) is a collaboration of the C40 Cities Climate Leadership Group and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The CFF supports cities in developing and emerging economies to develop finance-ready projects to reduce emissions to limit global temperature rise to 1.5°C and strengthen resilience against the impacts of a warming climate. The CFF is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), the Children's Investment Fund Foundation (CIFF), the Government of the United Kingdom and the United States Agency for International Development (USAID).

Published by:
C40 Cities Finance Facility

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Potsdamer Platz 10
10785 Berlin, Germany

E contact@c40cff.org
W c40cff.org

Author/Responsible/Editor:
GFA/ HEAT GmbH
Habitat, Energy, Application & Technology

Seilerbahnweg 14
61462 Koenigstein, Germany

Bonn, 2020

Funding partners:

Implementing agencies:

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LIST OF ABBREVIATIONS

AC	Airconditioned
Base Year	2021
BAU	Business as usual
BMTC	Bangalore Metropolitan Transport Corporation
BMC	Bangalore Municipal Corporation
BS 1 to 6	Bharat Stage (Euro Equivalent) 1 to 6
CAPEX	Capital Expenditure
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
COP21	The 21st Conference of the 1992 United Nations Framework Convention on Climate Change held in Paris
CPI	Consumer Price Index
CPKM	Cost per kilometre
CSTEP	Centre for Study of Science, Technology and Policy
e-bus	Electric bus
EIA	US Energy Information Administration
EPKM	Earnings per kilometre
EV	Electric Vehicle
FY	Financial year ending March 31
GCC	Gross Cost Contracting
GHG	Greenhouse gases
GoI	Government of India
GoK	Government of Karnataka
HC	Hydrocarbons
ICE	Internal combustion engine
INDC	Intended nationally determined contributions to reduce GHG emissions under COP21
km	Kilometre
kW	Kilo watt
kWh	Kilo-watt-hour
LFP	Lithium Iron Phosphate
LTO	Lithium-titanate
m	Metre
midi	9 m bus

MMBTU	Metric Million British Thermal Unit
MT	Million tonnes
NMC	Lithium Nickel Manganese Cobalt Oxide
NOx	Oxides of nitrogen
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditure
PA/p.a.	Per annum
PM	Particulate matter
PMx	Particulate matter of less than x microns in size
SCC	Social Cost of Carbon
SOx	Oxides of sulphur
Std.	Standard (12 m) bus
STU	State Transport Undertaking
TA	Transit Authority
TCO	Total Cost of Ownership
USD	United States Dollar
WPI	Wholesale price index

EXECUTIVE SUMMARY

Introduction

Bengaluru city is the capital of state of Karnataka, with a total population of over 14 million. Bangalore Metropolitan Transport Corporation (BMTC) along with Bengaluru Metro Rail Corporation Ltd. are the two public transport service providers in the City. As of March 2020, BMTC had a fleet size of 6,697 buses operating over 2,000 routes and running 45 million kms annually catering to 1.2 billion passenger trips per year.

The detailed terms of reference for business case of BMTC full transition to electric/clean fuel technology is guided by the requirements of terms of reference of the topic, reproduced at Annexure 1 of this report.

Emissions from ICE powered motor vehicles are responsible for about two-thirds of air pollution in urban areas (Niti Ayog & World Energy Council, 2018). Since, BMTC buses contribute significant share of diesel consumption in urban areas, BMTC plans to transform its fleet to Electric/CNG fleet over next decade or so and thereby reduce cost of operations as well as contribute towards reduction of emissions, noise pollution and resultant health problems.

Business case analysis adopts the approach of testing for full transition of existing BMTC operations to electric with the objective of checking the viability of capital intensive transition from financial, technology transition and implementation perspective.

Electric mobility emerges as the strategic choice for BMTC on account of the following factors:

1) Electric vehicles have zero tailpipe emissions and overall result is much less emission of carbon dioxide and other pollutants. In the event that the entire fleet of BMTC is converted to e-buses, it is roughly estimated that 51,460 MT of CO_2 emission can be reduced or avoided every year (*Bengaluru - Electric Bus*, 2020).
2) Electricity is produced using mostly domestic resources and diesel is mostly imported. Cost of energy per kilometre is much less for e-buses. The electricity tariffs are stable and increase at a low rate as compared to prices of diesel/CNG which are much more volatile and historically have increased at a much higher rate than electricity. The estimated annual savings in diesel cost for BMTC is INR 52.5 million in addition to saving in equivalent amount of foreign exchange outgo.
3) E-buses are practically noise free and upon full transition the ambient noise levels in Bengaluru is expected to reduce from 73 dB to 50 dB. Other estimated health benefits include 1,325 premature deaths and 1,815 hospital admissions averted, increase in average life expectancy by 32 days and saving of INR 67 million in health care costs per year (C40 Cities, 2020).
4) E-buses have much less moving parts and hence maintenance cost is lower and expected to last longer.
5) Electricity is not prone to pilferage unlike diesel.

Business Case Scenarios

The business case for electric mobility is based on three scenarios:

- Business As Usual (BAU): This scenario assumes all future fleet replacement will be using diesel buses of BS VI standard.
- Base Case Scenario: Electrification of present fleet of 6,697 buses.
- Augmented Fleet Scenario: As per BMTC Vision 2030, an augmented fleet of 16,500 buses, assuming same composition of midi, standard and standard (AC) buses as in present fleet.

The BAU scenario is compared with the scenario in which only electric buses are used for replacing existing diesel fleet from FY 2022 onwards.

Implementation Phases

The entire electrification project is assumed to span over twelve years with primary idea of examining the viability of long term and large scale transition as per existing BMTC vision 2030, with additional two years provisioned for preparation of implementation phase from now. The project implementation is divided into three phases (shown below) in order to take into account ***reduction in costs, technological advancements in EVs***, ***maturity of market players with EVs*** (primarily BMTC, OEMs, energy and charging infrastructure providers) and ***skilled labour availability***.

	Midi (Non-AC)	Standard (Non-AC)	Standard (AC)	Total	%age
Phase 1	582	1164	418	2164	32%
Phase 2	463	1070	274	1807	27%
Phase 3	--	2558	168	2726	41%
Total	1045	4792	860	6697	100%

Business Case Options

The cost of owning and operating electric buses primarily arises from the utilisation (km/day) and life of the bus (years/kms). The daily operating range also dictates the battery size/charging strategy and appurtenant costs. Hence, the implementation options arise from the wide range of kilometres covered by the BMTC buses per day. The relatively high initial and fixed cost of electric buses and low variable cost demand that these are deployed in the longest schedules. However, longer operating ranges come with the requirement of larger batteries and/or investment in opportunity charging infrastructure both of which requires higher initial investment. Inadequate daily operating range may require replacement of a diesel bus by more than one electric bus thus further increasing investments. Thus, the following options are proposed to be evaluated in the business case which optimise Capex, Opex or both.

Option 1: Optimising Capex by electrification of schedules having shortest daily operating kilometres first (and therefore lowest investment in battery/charging infrastructure)

Option 2: Optimising Opex by electrification of schedules having longest daily operating kilometres first

Option 3: A mixed approach viz. electrification of medium range schedules first, followed by longer schedules and then shortest schedules

A comprehensive listing of various assumptions adopted towards development of this Business Case is available at Annexure 2 of this report.

The summary of financial evaluation of the options is presented below:

NPV (in 2021) in (Rs. Billion)	Option 1	Option 2	Option 3
Capex			
New Diesel Buses (BAU)	18.0	18.0	18.0
Electric Buses	46.9	50.6	47.4
Opex			
Diesel Buses (BAU)	172.45	184.21	179.33
Electric Buses	126.22	135.90	131.31
Existing Fleet (prior to replacement)	151.56	125.97	131.62
Total Cash Outflow			
Diesel Buses (BAU)	342.0	328.2	329.0
Electric Buses	324.6	312.4	310.3
Difference (Electric – BAU)	17.3	15.8	18.7
%age of bus-kms using e-bus (2022-32)	37%	48%	46%

It may be seen that although Option 3 results in highest NPV of the difference in cash outflows between diesel (Business As Usual) and electric fleet, other Options 1 and 2 are not very far behind. This indicates whatever be the transition strategy, adoption of early and gradual transition to electric bus makes better business sense than the status quo.

In addition to the financial benefits to BMTC, the electrification project will also benefit the citizens of Bengaluru, India and the world by reducing the emission of particulate matter (by 7335 tonnes p.a.) and noise pollution (by 23 dB), foreign exchange outgo (by USD 175 p.a.) and greenhouse gases (by 0.45 MTPA).

Funding Options

This shows that the **electrification project will be highly beneficial for BMTC as well as the Bengaluru city** but the investment requirement to implement is estimated at Rs. 94,439 million, almost 4 times the total value of fixed assets of BMTC. The year-wise requirement of funds is given below:

(Rs. Million)

Year	Phase 1	Year	Phase 2	Year	Phase 3
2021	834	2026	2,439	2030	5,822
2022	1,547	2027	2,248	2031	7,769
2023	8,024	2028	3,891	2032	26,224
2024	7,938	2029	15,886	--	--
2025	10,785	--	--	--	--
Total	**29,128**	**Total**	**24,464**	**Total**	**39,815**

In view of the sizeable requirement of funds, the following funding scenarios are evaluated:

1. No PPP – All buses are procured and run by BMTC
2. Moderate PPP – 25% of the capital investment (rolling stock, batteries or charging infrastructure) is incurred by private operators
3. Higher PPP – 50% of the capital investment (rolling stock, batteries or charging infrastructure) is incurred by private operators

From the phase-wise financial analysis, it is seen that except phase -1, the electric buses are financially better than diesel buses on life cycle cost basis and hence no grant/subsidy is envisaged in phase 2 and phase 3. The proposed funding structure under the above scenarios is shown below accordingly:

Rs. Million

Source/Financing Scenario	No PPP	Moderate PPP	Higher PPP
Government Subsidy	2,913	2,913	2,913
PPP	--	23,243	46,486
Loans to BMTC	67,870	50,438	33,006
Equity to BMTC	22,623	16,813	11,002
	93,407	93,407	93,407

The GDP of Bengaluru city is approximately Rs. 5000 billion[1] and as such the above funding requirement represents barely 1.9% of it spread over twelve years. Hence the project deserves to be financially supported by the Government of Karnataka/Bengaluru Municipal corporation.

The private funding options to BMTC include gross cost contracting, wet leasing, leasing of batteries, PPP for charging infrastructure etc. The public funding options including loan/equity/grant assistance from Government of Karnataka/ Urban Transport Fund, grant from Government of India, concessional loans from state financing institutions like KUIDFC and bilateral and multilateral organisations. BMTC

1 Comprehensive Mobility Plan for Bengaluru, 2019

can also raise funds by monetising its land assets and activating other revenue sources like parking, public charging, advertising, carbon credits etc.

Risk Assessment and Mitigation

The risks to BMTC in implementation of the electrification project arises mainly from four sources viz. product risk, financing risk, operational risk and revenue risk.

The ***product risks*** can arise on account of technology reliability, price and levels of energy consumption. The fragile financial condition alongside expected Opex escalations, decline in ridership levels and inability to increase fares contribute towards the ***financing risks***. The ***operational risks*** on the other hand can arise from lack of favourable operating conditions due to traffic congestion and consequent delays and trip cancellations. These could potentially bring down, not only the performance levels but ridership levels as well. The revenue levels for BMTC are showing a downward trend and going electric may not directly change that trend. Maintaining a reasonable revenue stream to match, at least the cost of operations, will remain constant challenge for the organisation specially with metro network expansion, road traffic congestion and improving economic conditions of city dwellers. Accordingly, expected ridership and fare levels alongside the extent of fare evasion/pilferage would pose the ***traffic revenue risks***, while ability to tap on ***non-traffic revenue*** potentials can pose another dimension to the revenue related risks.

Annexure 3 of this report elaborates on various risk factors of transitioning to new electric technology based operations and potential measures for mitigation.

Conclusion

Electrification of the fleet will help BMTC to reduce the operating costs significantly. However, the high initial cost of the electric buses together with limited operating range, constraints of creating charging infrastructure etc. constitutes the stumbling blocks in this journey.

The Business Case has looked into these issues in detail and finds that despite the high initial capital requirement, it is financially beneficial to BMTC in addition to the equally significant environment benefits resulting from this transition.

Some of the issues that this report **does not address and need to be dealt** with during the implementation of the project include:

1. Route/Schedule rationalisation for optimum utilisation of the electric bus and diesel bus fleet;
2. Route/fleet rationalisation considering metro expansion;
3. Detailed implementation report for each phase/sub-phase including depot selection, route/schedule allocation, battery size/charging strategy, operational plan;
4. Rationalisation of costs through outsourcing of maintenance and non-core activities, conductor-less fare collection etc.;

5. Organisation restructuring to accommodate operation, supervision and control of operators, operation and maintenance of Electric Buses/charging infrastructure;
6. Detailed financing plan for each phase/sub-phase.

The Business Case report has been prepared in two parts. Part 1 (this report) deliberates on financial analysis, results and broad funding options. Part 2 of the report focuses on procurement strategies and implementation framework for effecting the phased transition.

1. INTRODUCTION

1.1. Background

Bengaluru, the capital of Karnataka state and the third largest city of India has a total population of over 14 million. The City is also considered as the Silicon Valley of the Country. As per the Karnataka Electric Vehicles and Energy Storage Policy, 2017 (Karnataka EV Policy), Government of Karnataka (GoK) intends to make Bengaluru-the Electrical Vehicle Capital of India as well.

Bangalore Metropolitan Transport Corporation (BMTC) along with Bengaluru Metro Rail Corporation Ltd. Are the two public transport service providers in the City. As of March 2020, BMTC had a fleet size of 6,697 buses operating over 2,000 routes and running 45 million kms annually catering to 1.2 billion passenger trips per year. BMTC comprise a significant component of urban mobility systems and has been carrying 40-50%of urban travel demand of Bangalore city through its city-wide route operations. Its ridership constituted 75% of city's total public transport systems demand[2].

1.2. Need for shift to clean fuel technology

The population growth rate of Bengaluru was 3.25% per year in the last decade. The rapid population growth coupled with economic growth and rising income levels has led to a phenomenal growth in the number of personal vehicles, two and four wheelers in Bengaluru city, which in turn is prime reason for majority of mobility problems like congestion, pollution etc. According to a study by Urban Emissions along with researchers from the Centre for Study of Science, Technology and Policy (CSTEP), the estimated PM10 (particulate matter of less than 10 microns in size) pollution may increase by 74% by 2030, led primarily by vehicle exhaust, construction dust, and on-road dust. The PM10 levels increased by 300% and was more wide spread between 2010 and 2017 (The Hindu, 2019). An exponential increase in particulate matter (PM) in the air in Bengaluru city is the main cause for the rise in lung diseases.

The share of transport sector in the total CO_2 emission constitutes about 28% (Guttikunda et al., 2019). Further, emissions from ICE powered motor vehicles are responsible for about two-thirds of air pollution in urban areas (Niti Ayog & World Energy Council, 2018). Since, BMTC buses contribute significant share of diesel consumption in urban areas, the BMTC Vision 2030 plans for transition to clean fuel technologies and thereby contribute towards reduction of the urban emissions and decarbonization of Bengaluru.

1.3. National and State Commitments

In recognition of the growing problem of Climate Change, India has voluntarily committed to cutting its GHG emissions intensity by 33% to 35% percent from 2005 level by 2030 (Government of India, 2015). A study by Indian Institute of Science,

2 Consultant estimate derived from BMTC data, CMP study and BMRCL ridership information

Bengaluru has recently estimated that the pollutant levels would reduce by over 90% if private vehicles and buses would run on electricity only in 2031 (Infrastructure Development Corporation (Karnataka) Limited, 2019).

The National Electric Mobility Mission Plan 2020 has been formulated to provide incentives for faster adoption of electric vehicles, through funding under the ongoing FAME program. It targets to convert 30% of the vehicle population into electric by 2030 and after that allow sale of only electric vehicles. Similarly, the Karnataka EV Policy aims to achieve 100% electric mobility by 2030.

1.4. Terms of Reference

A business case provides justification for undertaking a project, programme or portfolio. It evaluates the benefit, cost and risk of alternative options and provides a rationale for the preferred solution. The terms of reference for this business case is placed as Annexure 1.

1.5. Data Sources

This business case relies on the information collected from the following sources:

- Historical data related to financial and operational information, received from BMTC;
- Administration Reports of BMTC for FY 2016-17, 2017-18 and 2018-19;
- Literature survey as listed out in References;
- Market study by consultant team;
- Discussions with BMTC Officials.

2. BMTC'S CHOICE OF FUEL OPTIONS

The relative advantages/disadvantages of various fuel options for BMTC is discussed in the following paragraphs.

2.1. Diesel Buses

i. As per the Government of India regulations, only buses compliant with BS-VI emission standard equivalent to Euro VI standards can be sold in the country after April 1, 2020. Market study by consultant team reveals that the BS-VI buses are expected to cost about 15-20% more than the incumbent BS-IV buses procured between 2017-2020 in addition to fuel/consumables consumption being more than earlier[3]. These buses are expected to reduce emissions of particulate matter (PM) by 50 to 67% and NOx emissions by 87 to 89% as compared to BS IV buses (International Council on Clean Transportation, 2016). However, there isn't much change expected in the carbon dioxide (CO_2) emissions, in fact the BS VI buses are even said to be less fuel efficient to their predecessors, however, at present there is no operating data available on the same.

ii. The World Bank estimates that the petroleum prices are expected to increase by 21% whereas US Energy Information Administration projects an increase by 75% by 2030 as compared to 2019) in dollar terms (Knoema, n.d.). Rupee depreciation and any increase (or decrease) in taxes and duties will also impact diesel prices. Rupee has depreciated by about 5% p.a. from Rs. 46.23/USD August 5, 2010 to Rs. 75.09/USD on August 4, 2020. Accordingly, the price of diesel in India could be as high as 3 times of the present levels.

iii. The cost of maintenance of diesel buses is estimated to be roughly double that of electric buses (Neil Quarles et al., 2020) excluding the economic cost of the incremental downtime of the diesel bus.

iv. Unlike CNG or electric energy sources, diesel is prone to pilferage.

2.2. CNG Buses

i. Similar to diesel buses, CNG buses would reduce emissions but not eliminate them. In a recent study of on-road bus emission comparison for operating conditions in Zhenjiang, China, it has been found that CNG buses emit slightly more than EURO 4 buses whereas CNG buses have been found to be emitting 2 times Carbon-monoxide, hydrocarbons (HC) and almost 3.5 times Nox as compared to Euro V buses in real road conditions (Chao Wang et al., 2020).

3 Source: Consultant Team from discussions with various OEMs/Operators

ii. The cost of CNG is expected to increase significantly in medium to long term. The World Bank expects the cost of natural gas to increase by almost 60% from USD 2.57 in 2019 to USD 4 in 2030 per MMBTU (Knoema, 2020) and may be by over 100% in rupee terms given that rupee has depreciated by more than 60% in the last 10 years[4].

iii. Similar to diesel buses, the maintenance cost of CNG buses are expected to be much higher than the electric buses.

iv. Bengaluru has a very fledgling CNG network. As of February 2020, there were only 16 CNG stations with another 40 under implementation as compared to Delhi-NCR which has 520 CNG stations and public transport operates only on CNG.

2.3. Electric Buses

i. Electric buses have no tail pipe emissions (hence the name Zero Emission Buses or e-buses) and are practically noiseless. Considering that, emissions from ICE powered motor vehicles are responsible for about two-thirds of air pollution in urban areas (Niti Ayog & World Energy Council, 2018), switching over to 100% electric mobility seem to be the only solution to make a significant difference in emission levels within the city.

ii. India has committed to an INDC target of 40% electricity generation from non-fossil fuel sources by 2030 (Government of India, 2015) but is aiming for even more ambitious target of 57% by 2027 in Central Electricity Authority's strategy blueprint (Michael Safi, 2016). In September 2019, India's total renewable electricity capacity was 35.7% of the total installed capacity (Bajaj, 2019). India has come a long way in this direction and can therefore be expected to meet its stated goals. Data for the monsoon period of the year 2019 (May to September) shows over 75 per cent penetration of clean power in the state of Karnataka (ET Energy World, 2020). Further, renewable power has achieved grid parity in terms of cost per unit and soon dispatchable or round the clock (RTC) renewable power will achieve grid parity[5].

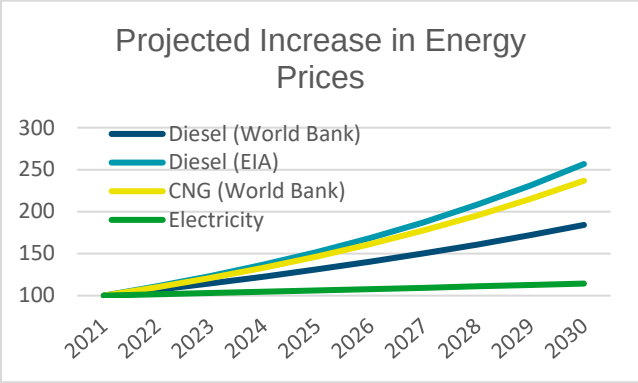
With India's aggressive plans to adopt renewable energy sources for power generation, high penetration of renewable power in Karnataka and availability of dispatchable renewable energy in the horizon, it is conceivable that BMTC will be able to source most of its energy requirements for running the electric buses through zero emission sources given supportive open access policies. Hence, e-buses won't merely shift the emissions out of urban areas but would actually reduce on overall basis to a great extent.

4 As per rates retrieved from www.rbi.org.in for August 5, 2010 and for August 4, 2020 from https://fbil.org.in - the Rupee depreciated from 46.23 to 75.09 to an American Dollar

5 In a recent auction, RTC solar power is quoted at Rs. 2.90/kWh (USD 0.04/kWh) (Business Standard, 2020).

iii. In contrast to actual and expected steep increases in both Diesel and CNG prices, electricity tariffs India have been very stable with an average annual increase of 1.5% between 2012-13 and 2019-20[6]. With increasing share of the energy coming from renewable sources, the energy prices are expected to remain stable as these sources have mostly up-front fixed costs and very little variable cost that increases with inflation. In fact, by 2030, the cost of wind and solar energy in India are expected to fall further to Rs. 2.26 and Rs. 1.90 /kWh respectively (ET Energy World, 2019). ***Interestingly, greener the electricity cheaper it is.***

Figure 1: Expected comparative movement of energy prices

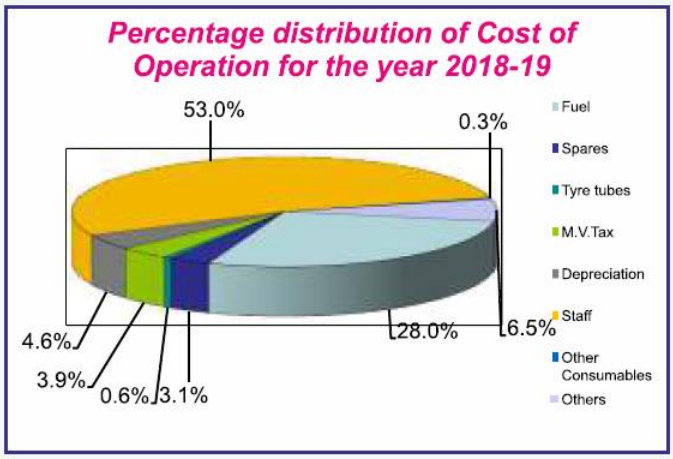


iv. Electric buses are less expensive to maintain since :

a) due to the regenerative braking the electric bus brakes wear out slower than the diesel bus brakes,
b) the e-bus doesn't need the regular change of motor-oil, oil-filter, diesel filter, oil-rotor seal, air-filter or gear-box oil and
c) electric motors have less wearing parts than diesel-motors and the most costly faults for diesel buses are in the motors.

For BMTC, almost a third of the costs arise from fuel and maintenance. Diesel prices are subject to both variations in international crude oil prices as well as foreign exchange rates since India imports 82% of its oil requirements. Electric buses have much lower cost of energy, dependent on domestically produced coal and renewable energy. Hence electricity prices are more stable than diesel. Both these aspects of electric buses support the operating environment of BMTC where it is difficult to increase fares

Figure 2: Distribution of BMTC operating cost (2018-19)



6 Office of the Economic Adviser, Department for Promotion of Industry and Internal Trade (www.eaindustry.nic.in)

in line with the increase in costs and as result it has been incurring losses since 2012-13 (except for a small profit in 2015-16).

Accordingly, switching to electric buses is considered the most preferred strategic choice for BMTC and BMTC's vision of 100% electrification by 2030 is a step in the right direction. In addition to direct beneficial impact, this will set the tone as an example not only within Bengaluru or Karnataka but for citizens and organisations all over the country.

3. BUSINESS CASE

The business case for transition to electric bus technology is prepared to examine viability of transition for BMTC's existing array of operations. *The business case working accordingly presents a roadmap, covering various nuances of transition that BMTC may need to undergo during the implementation period.*

3.1. Business Case Setting

BMTC runs three types of fleet viz. Standard (12 m non-airconditioned), Standard-AC (12 m air-conditioned) and Midi (9 m buses mostly non-airconditioned). It runs various types of services as summarised in Table 1.

Table 1: BMTC Services

Route Type	Average Route Length (km)	No. of Routes	No. of Schedules	Average daily effective km[7]
VAJRA (AC)	31.8	73	594	180
Airport Service (AC)	52.5	17	123	338
Vajra Metro Feeder (AC)	17.2	4	26	127
Feeder	16.3	6	7	160
Metro Feeder	14.7	21	79	169
Trunk Route	17.8	6	22	161
Peak Hour Service	21.8	9	9	203
Big Connect	10.5	8	23	192
K R Market	34.0	2	21	236
Kempegowda Bus Station	30.7	10	192	182
Atal Saarige	9.6	5	11	148
Circular Route	25.2	13	25	164
Others	24.5	2022	5053	198
Total/Average		**2196**	**6185**	**209**

Source: Consultant Team based on BMTC data

7 Excluding dead kilometers and cancellations

BMTC operates largest fleet of Volvo luxury buses in the country mainly servicing passengers to the airport as well as work force to and from the IT centres in and around the city. With the expansion of the metro rail services, BMTC is planning to augment its metro feeder services. Except, the above, majority of the BMTC's fleet operate non-airconditioned (ordinary) services.

3.2. Business Case Scenarios

The business case analyses the following scenarios:

1) Electrification of current diesel fleet (Base Case Scenario)
2) Electrification of an expended fleet of 16,5000 buses (Augmented fleet Scenario)
3) Business as usual scenario where the existing fleet are replaced with comparable diesel fleet and augmented fleet is also based on diesel fuel.

For evaluation, both the base case and augmented fleet scenarios are compared with the business as usual (BAU) scenario.

3.3. Project Phasing

As per the available BMTC's Vision Plan 2030, its entire fleet will be operating on clean fuel by 2030. Further, it has indicated for no procurement of any diesel buses after 2022. As per the depreciation policy of BMTC, the useful life of buses is considered to be **10 years or 5,60,000 kms**, whichever is earlier. As per BMTC's annual report for financial year 2018-19, it considers the useful life of non-AC buses as **11 years/850,000 kms** and 15 years/10,50,000 for AC buses (mainly Volvo make).

Even as per this lenient policy, 20% of the non-AC fleet was overaged both by kms and by years as on March 31, 2020. The age and use profile of BMTC fleet as of March 2020 is shown in Table 2.

Table 2: Ageing profile of BMTC Fleet

Age (years)	0- 1	1- 2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11+	Total
Midi (non-AC)	--	48	198	75	17	40	58	17	1	--	--	--	454
Standard (non-AC)	348	393	924	38	54	179	585	408	492	55	862	1045	5383
Standard (AC)	10	--	83	72	--	3	107	75	49	43	132	286	860
Total	358	441	1205	185	71	222	750	500	542	98	994	1331	6697
%Total	5.3	6.6	18.0	2.8	1.1	3.3	11.2	7.5	8.1	1.5	14.8	19.9	100.0

Source: BMTC Engineering Cell

Accordingly, the replacement schedule of the fleet predicated by the present age of the fleet and superimposed by BMTC Vision Plan provides the schedule of electrification of BMTC's fleet as shown in Table 3: Fleet Replacement Schedule. In the event, that BMTC wishes to accelerate the electrification of the fleet, it will have to scrap the vehicles before the end of economic life or sell at a loss (considering that BMTC's fleet is of outdated BS-II/III/IV standards). Similarly, operating the fleet beyond their economic life will involve reconditioning/refurbishment and higher operating costs. Hence neither accelerating nor deferring replacement of vehicles is advisable.

Table 3: Fleet Replacement Schedule

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Midi (non-AC)	0	1	17	58	40	17	75	198	48	0	0	454
Std Non-AC	1962	492	408	585	179	54	38	924	393	348	0	5383
Std AC Buses	46	22	218	132	43	49	75	107	3	0	165	860
Total	2008	515	643	775	262	120	188	1229	444	348	165	6697
% of Total	30.0	7.7	9.6	11.6	3.9	1.8	2.8	18.4	6.6	5.2	2.5	100.0

Source: Consultant Team based on BMTC data

BMTC currently operates **152 schedules for metro feeder** services and it is estimated that by the time the Metro rail phase 2 is completed, the requirement of feeder services will increase to 698 schedules. Accordingly, the midi bus fleet is expected to increase from 454 to 1045 and the standard non-AC bus fleet is reduced by the same extent to reflect reduction in services to avoid overlap with Metro rail services.

The entire electrification project is assumed to span over 12 years, considering existing diesel fleet replacement as per available BMTC policy and vision plan. However, the project is divided into three phases in order to take into account ***reduction in costs, technological advancements in EVs***, ***maturity of market***

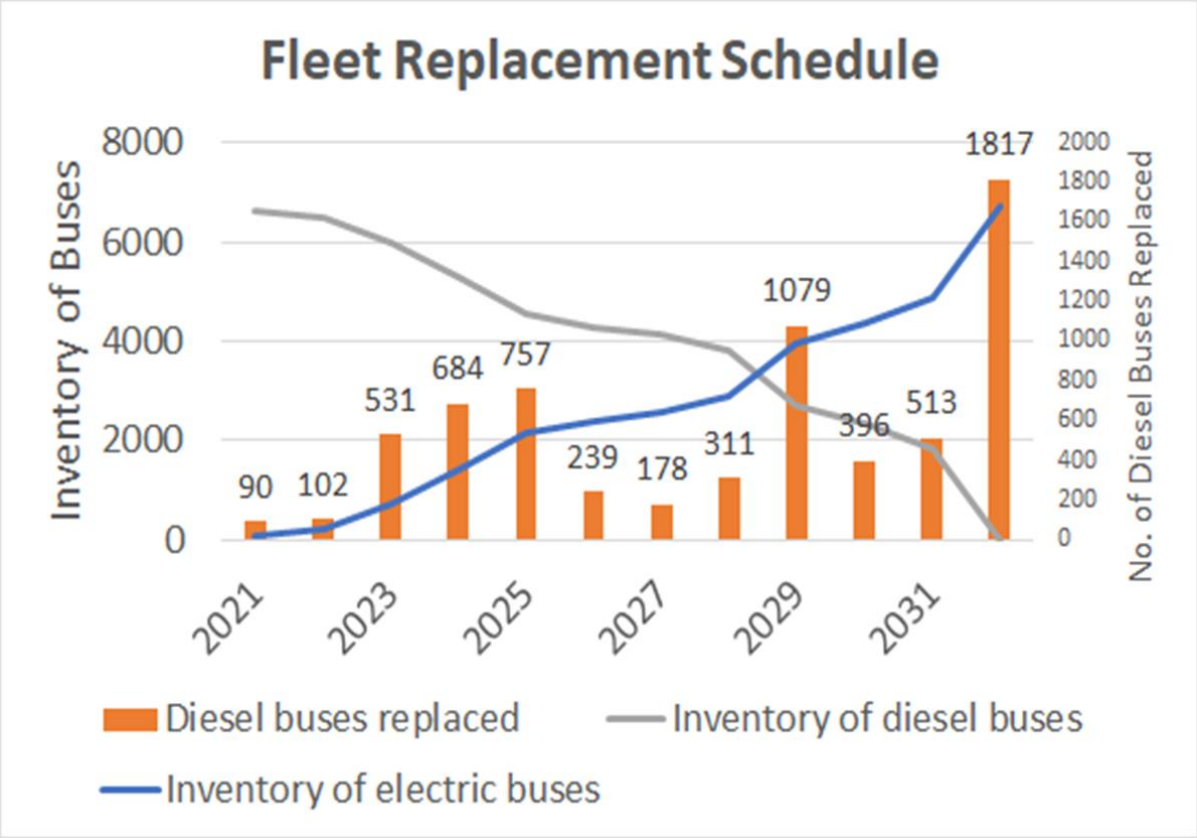
players (primarily OEMs, energy and charging infrastructure providers) and ***skilled labour availability***. Phased diesel bus replacement with electric buses is shown in Table 4 and Figure 3.

Table 4: Phasing of Induction of Electric buses

	Years	Midi (Non-AC)	Standard (Non-AC)	Standard (AC)	Total	% of Total
Phase 1	2021-25	582	1164	418	2164	32%
Phase 2	2026-29	463	1070	274	1807	27%
Phase 3	2030-32	0	2558	168	2726	41%
Total		1045	4792	860	6697	100%

Source: Consultant Team

Figure 3: Fleet Replacement Schedule



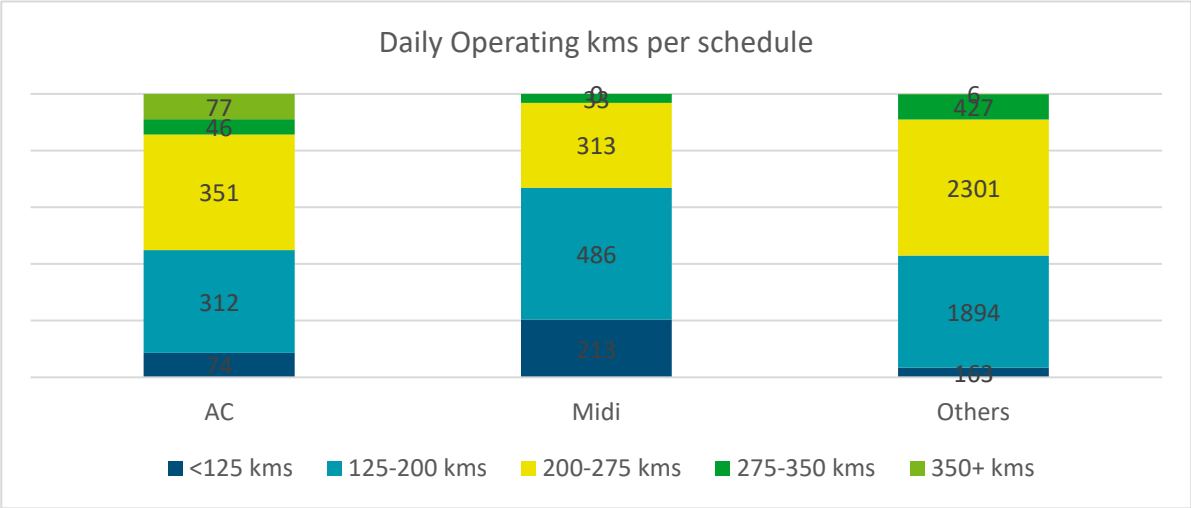
3.4. Business Case Options

The buses are utilised to operate schedules. Each schedule represents the path followed by the bus from the time it leaves the depot and returns at the end of the day. Each schedule may ply on multiple routes. The schedules are allocated to depots and each depot manages the schedules from the fleet of vehicles allocated to it. Each schedule is given an identification number based on the route(s), the schedule mainly

operates in. Thus, total fleet equals the number of schedules operated plus maintenance reserves. In March 2020 (pre-COVID), BMTC operated 6,185 schedules and had a fleet of 6,697 vehicles, thus the maintenance reserves work out to 8.3%.

The cost of owning and operating electric buses is primarily dependent on the utilisation (km/day) and life of the bus (years/kms). The daily operating range also dictates the battery size/charging strategy and appurtenant costs. Hence, the implementation options arise from the wide range of kilometres covered by the BMTC's fleet as shown in Figure 4: Daily Operating Kms per Schedule. The relatively high initial and fixed cost of electric buses and low variable cost warrant that these are deployed in the longest schedules. However, longer operating ranges come with the requirement of larger batteries and/or investment in opportunity charging infrastructure both of which requires higher initial investment. Inadequate operating range may mean more than one electric bus is needed to substitute a diesel bus) leading to higher capital and operating expenses.

Figure 4: Daily Operating Kms per Schedule



The following considerations have been used to determine the possible implementation options of transition to electric fleet:

1. A two-year postponement in full electrification as compared to the stated objective of completion by 2030 due to COVID-19 related adverse financial impact on GoK, GoI, BMTC, OEMs and prospective operators.
2. The Vision Plan anticipates requirement of additional fleet considering increasing congestion levels and population. However, since detailed study on future requirements, network and route, ridership levels etc. has not been carried out, the base case scenario of the business plan covers electrification of the present fleet assuming no significant change in route/ operating characteristics. The base case is then extrapolated to show the key financial requirements and outcomes in a scenario with 16,500 buses envisaged in the Vision Plan.
3. The cost of batteries is likely to reduce significantly in near to medium term. Technological development in batteries is also likely to increase energy densities.

Further, batteries based on NMC/LTO/NMCA chemistry will become economical in medium to long term making faster charging possible and will extend operating ranges for a given battery size and reduce battery costs.

In view of the foregoing, the following options have been evaluated:

Option 1: Minimising Capex by electrification of schedules covering least daily operating kilometres first and longer schedules in subsequent phases. Bloomberg New Energy Finance, 2018 expects by 2030, the battery pack in the average e-bus should only account for around 8% of the total e-bus price – down from 26% in 2016. It further asserts that by reducing the battery size, the cost parity with diesel buses can be achieved earlier than with larger battery sized e-buses. Shorter schedules run with lower battery sizes in the initial years would require lesser investment in charging infrastructure as well. Therefore, deferment of e-bus adoption for longer schedules will minimise overall investment in battery/charging infrastructure.

Table 5: Selection of Schedules for Option 1

Phase	Type of Bus	Units	Schedule km/day	Battery (kWh)	Op Range* (km/day)	Replacement Ratio
I	Midi (Non-AC)	540	<170	125	256	1.00
	Standard (Non-AC)	1206	<175	150	242	1.00
	Standard (AC)	418	<210	175	225	1.00
II	Midi (Non-AC)	505	170-280	125	293	1.00
	Standard (Non-AC)	1028	175-205	150	272	1.00
	Standard (AC)	274	210-245	175	252	1.00
III	Midi (Non-AC)	N/A	N/A	N/A	N/A	N/A
	Standard (Non-AC)	2558	>205	150	321	1.00
	Standard (AC)	168	>245	324	360	**1.06**

Source: Consultant Team

Option 2: Minimising Opex by electrification of schedules having most daily operating kilometres first and shorter schedules in subsequent phases. Even excluding the cost of battery and charging infrastructure, the cost of e-buses is higher than conventional diesel/CNG buses and lower utilisation of the assets results in higher fixed costs of operation per km. Further, an increase of 1 kWh in battery size results in increase of about 2000 kms in operations during the lifetime of the battery all other costs remaining the same. Even at a cost of $250/kWh, this works out to a cost of less than INR 10 per additional km and thereby reducing the overall cost per km. Hence, higher utilisation of the e-buses, will tend to increase the operational viability despite higher CapEx.

Table 6: Selection of Schedules for Option 2

Phase	Type of Bus	Units	Schedule km/day	Battery (kWh)	Op Range* (km/day)	Replacement Ratio
I	Midi (Non-AC)	540	>170	175	290	1.00
	Standard (Non-AC)	1206	>240	324	315	1.00
	Standard (AC)	418	>215	324	293	**1.09**
II	Midi (Non-AC)	505	<170	125	293	1.00
	Standard (Non-AC)	1028	215-240	175	272	1.00
	Standard (AC)	274	155-215	175	252	1.00
III	Midi (Non-AC)	N/A	N/A	--	N/A	N/A
	Standard (Non-AC)	2558	<215	175	321	1.00
	Standard (AC)	168	<155	175	298	1.00

Source: Consultant Team

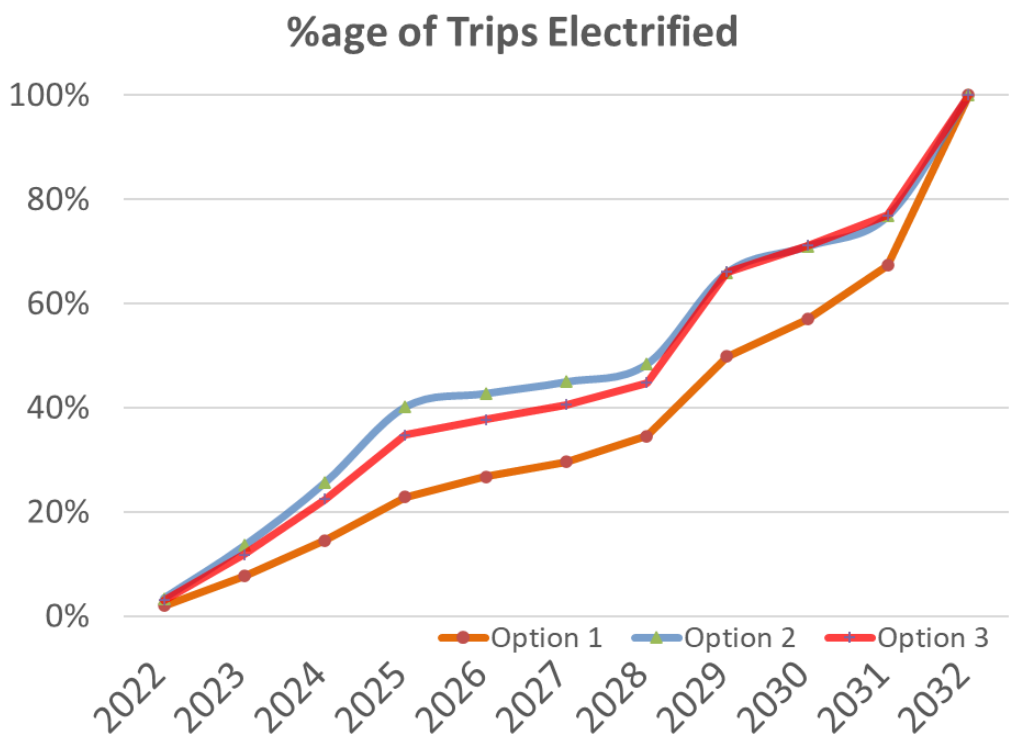
Option 3: Optimising Capex and Opex: A mixed approach i.e. electrification of medium range schedules first, followed by longer schedules and then shortest schedules.

Table 7: Selection of Schedules for Option 3

Phase	Type of Bus	Units	Schedule km/day	Battery (kWh)	Op Range* (km/day)	Replacement Ratio
I	Midi (Non-AC)	540	>170	125	256	**1.02**
	Standard (Non-AC)	1206	215-245	175	242	**1.01**
	Standard (AC)	418	155-230	175	225	**1.01**
II	Midi (Non-AC)	505	<170	125	293	1.00
	Standard (Non-AC)	1028	>245	200	285	**1.03**
	Standard (AC)	274	>230	324	318	**1.09**
III	Midi (Non-AC)	N/A	N/A	N/A	N/A	N/A
	Standard (Non-AC)	2558	<215	135	309	1.00
	Standard (AC)	168	<155	175	263	1.00

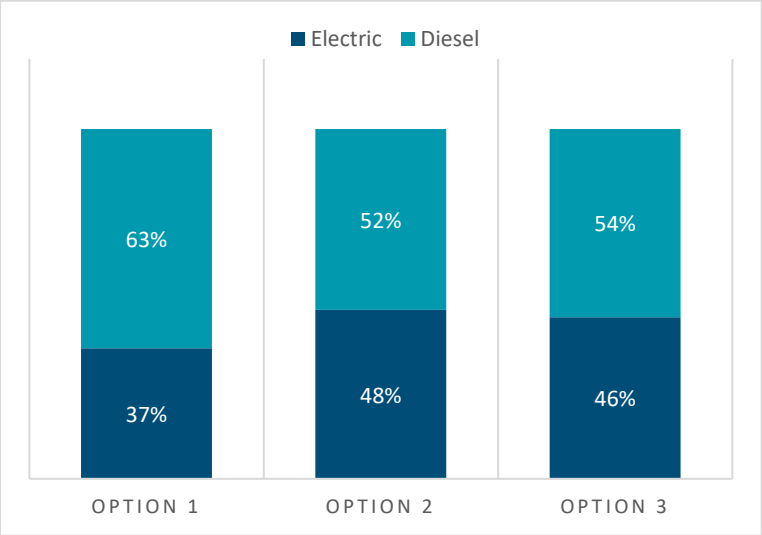
Source: Consultant Team

Figure 5: Comparison of Options - %age kms electrified



The induction schedule of the e-buses is determined by the replacement cycle of the existing fleet. However, depending on the option chosen for electrification, the %age of trips electrifies varies as shown in Figure 5. Option 2 has the highest %age of kms electrified between 2021 and 2032 but Option 3 isn't far behind. By 2032, all trips are electrified in each option.

Figure 6: Total Kilometre Operated by Fuel Type (2021-2032)



4. FINANCIAL ANALYSIS

4.1. Capital Expenditure

The capital expenditure for implementation of the electric bus system comprises of the following elements:

1. Procurement cost of electric bus fleet: The cost of an electric bus can be bifurcated into cost of a) chassis/body and b) the battery. The size of the battery has a bearing on the total cost of the bus, operating range, charging infrastructure requirements and battery life/replacement cost. The life of the battery depends on the number of charging cycles. Hence, a smaller battery charged 2-3 times a day through a faster charger is expected to last less and replaced earlier than a larger battery mostly charged once a day through slow charging. Other than the type and size of the battery, the procurement cost of electric bus also depends on:

    a. **Air conditioning**: Air conditioned buses are more expensive.

    b. **Size of the bus:** length of bus may vary from sub 7 m to 24 m. For present business case, midi (9 m) and standard (12 m) fleet have been considered.

    c. **Height of the bus floor** – most of BMTC fleet is high floor (1050 mm) with some semi-low floor (650 mm) whereas the AC bus fleet is low floor (400 mm). The high floor buses are less passenger friendly but substantially cheaper than the low floor models. Further, there is a preference for the low floor buses by Government as well as passengers. The e-buses available in the Indian market are mostly low floor ones (as per UBS-II) which provide superior value as compared to

high floor buses but effect of the same is not considered in the business case.

d. **Other specifications** like traction power, construction (monococ vs ladder type chassis), interiors etc.

Table below lists out the cost breakup of different bus types adopted for business case analysis here.

Table 8: Cost of Buses

(Rs. million/Unit in 2021)

Bus Type	Chassis/ Body	Battery Size (kWh)	Battery Cost	Gross Cost	Equivalent Diesel Bus
Midi Non-AC	5.66	125	2.34	8.00	2.53
Standard (Non-AC)	11.14	250	4.69	15.83	3.57
Standard-AC	12.38	300	5.62	18.00	11.12

Source: Consultant Team

2. Charging Infrastructure: This includes:
   a. **Cost of slow chargers** to be deployed at the depot for overnight charging of the buses.
   b. **Cost of fast chargers** to be deployed at bus terminals and other strategic locations like airports, metro stations for opportunity charging.
   c. **Cost of feeder lines from nearest substation and switchgear**. Based on discussions with BESCOM and BMTC, cost of Rs. 10 million per depot is assumed. An additional 20 million is provided for the opportunity charging infrastructure at the terminals.
3. **Depot Infrastructure:** The charging infrastructure would utilise depot space reducing the number of buses that a depot can cater to. Accordingly, either construction of additional parking/charging space would be needed or new depot would have to be constructed. Accordingly, a provision of 20% additional depot space is assumed in the business case.
4. **Cost of Diesel Buses**: For the business as usual scenario, the cost of the diesel buses has been assumed based on past trends, discussions with BMTC and OEMs. ***The cost of BS VI buses is considered to be 15% higher than the BS IV*** buses based on market study. Since *no increase in fleet strength is considered for the base case, the current depot and terminal infrastructure is considered to suffice.*

The following considerations has been taken into account while estimating the future capital expenditure requirements:

- Cost of battery for electric buses will reduce by 8.25% p.a. (Bloomberg New Energy Finance, 2018).

- Chassis/Body cost of electric buses will decrease for first 5 years due increasing economies of scale and then increase as per WPI due to increase in input prices[8].
- Cost of diesel buses for BAU will increase as per WPI.
- At least 1 hour of opportunity charging will be feasible.
- Capex will be funded using 75% debt with a tenure of 8 years and 9% p.a. rate of interest.

A detailed list of assumptions regarding capital expenditure is placed at Annexure 2. The estimated total capital expenditure for BAU and various options over the period 2021-32 is as given below:

Table 9: Total Capital Expenditure

Expenditure Head	Option 1	Option 2	Option 3
	(Rs. Million)		
E-Bus (Chassis/Body)	68,145	68,145	68,145
Battery	14,225	19,882	15,208
Charging Infra	6,765	6,172	6,070
Power Connection	1,579	1,579	1,579
Depot Infrastructure	3,409	3,409	3,409
Salvage Value (Old fleet)	-1,004	-1,004	-1,004
Net Capex	93,119	98,183	93,407
Capex in BAU (Existing fleet replaced with diesel buses)			31,123

Source: Consultant Team

4.2. Operating Expenditure

The operating expenditure (Opex) for city bus operations can be broadly divided into two categories viz.

1. Expenses dependent on fleet type (Variable Operating Cost): This relates to expenses which need to be differently estimated for diesel fleet (BAU) and electric fleet and include
   - annual motor vehicle tax[9]
   - fleet maintenance (consumables, spares, tyres & tubes)
   - fuel/energy cost
   - replacement of batteries (e-bus only)
   - charging infrastructure
   - engine reconditioning (Diesel only)
   - depreciation, and

8 Consultant team, Market study.

9 There is exemption of MV Tax on electric vehicles in Karnataka.

- interest

These costs are calculated based on input costs and operating parameters such as specific energy consumption (litres/kWh) consumed per kilometre, capital expenditure, interest on borrowed funds etc. divided over annual operating kilometres to obtain CPKM.

2. Expenses independent of fleet type (Fixed Operating Cost): These include
   - operating staff cost (drivers, ticket issuers, supervisory staff etc)
   - depot overheads
   - corporate overheads, legal expenses etc.

For the purpose of this business case, it is assumed that other than replacement of diesel fleet with electric buses, nature of operations in all other respects remain the same. These are estimated based on cost per kilometre (CPKM) incurred during financial year 2019-20 and past trends.

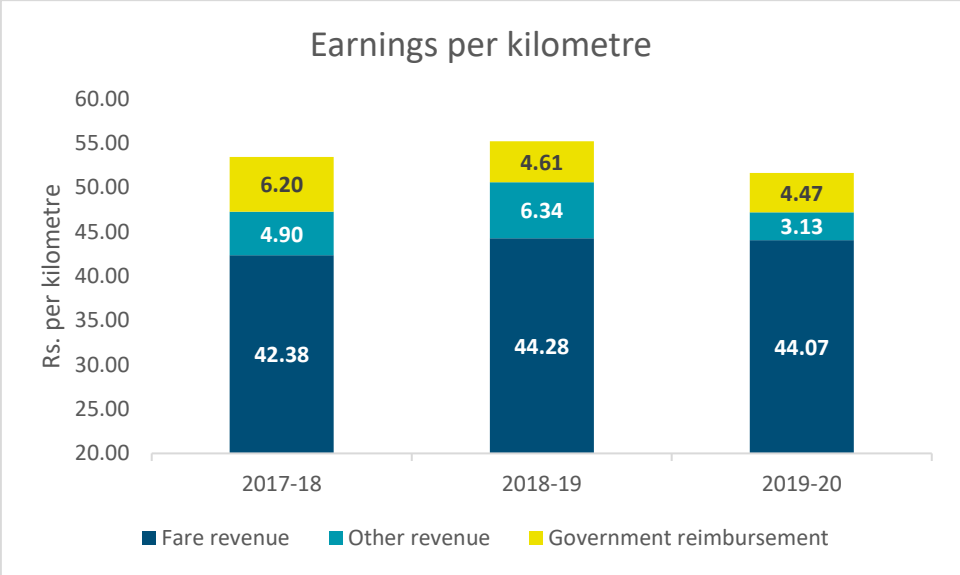
4.3. Revenue

Revenue accrues to BMTC from fare and non-fare sources. In addition, BMTC also receives reimbursement for concessional fares/passes provided to certain category of riders. Such revenue is expected to grow at the same rate as fare-box revenue.

1. Fares: During 2019-20, BMTC earned Rs. 42.37/km in non-Ac services and Rs. 63.81/km in case of AC services on an average. It is envisaged that BMTC will not charge different fares for deploying electric bus-based services. Hence same fares will be applicable for both electric buses and BAU scenarios. Fare escalations in future years is assumed to increase to cover the increase in costs in BAU scenario i.e. 30% due to fuel inflation, 50% due to increase in salary and 20% WPI.

2. Ridership: With better quality of buses and increase in population, it is expected that more riders will provide their patronage to public transport. However, since the fleet is not being augmented to cater to the increased ridership, a conservative growth of 1% p.a. is assumed.

Figure 7: BMTC Earnings per kilometre



3. Non-Fare Revenue: Almost 9.0%[10] of BMTC's total income arises from non-fare sources such as rent, parking fee, concession fees, freight charges etc. BMTC has converted its bus terminals into Traffic Transit Management Centres (TTMCs) and has created commercial spaces for offices, shops, vendors etc. Similarly, redevelopment of the depots for electrification may give rise to land value capture opportunities. However, a detailed study and planning exercise is required for estimating the extent of revenues. Hence, in the business case it is assumed that such revenues would help BMTC raise capital to meet its equity requirements for the project rather than augmenting the revenue.

4. BMTC will also have the opportunity to utilise its depot space and charging infrastructure for charging other vehicles during lean periods. The viability of this business needs to be assessed in details and hence to be on conservative side, the business case does not assume any revenue from the same.

A detailed list of assumptions regarding operating expenditure and revenue is placed as Annexure 2.

4.4. Investment Appraisal – Base Case Scenario

The evaluation of the fleet electrification projects is undertaken in two parts: the first part shows viability of the additional investment in the electric buses and related infrastructure vis-à-vis the savings resulting from it as compared to BAU and the second part shows viability of the overall project considering operating revenues of BMTC and cashflows towards the acquisition and operation of the electric fleet. The

10 Average for FY 2018, 2019 and 2020

second part shows the overall viability of operating electric buses vis-à-vis the projected revenue levels of BMTC.

4.4.1. Comparative Viability of Electric Fleet

The project is undertaken in three phases and cashflows of each phase under each of the three options and each of the three scenarios are evaluated independently. A summary of results is presented below:

Table 10: Comparison of BAU and Project Options in terms of NPV

NPV (in 2021) (Rs. Billion)	Option 1	Option 2	Option 3
Capex			
New Diesel Buses (BAU)	18.0	18.0	18.0
Electric Buses	46.9	50.6	47.4
Opex			
Diesel Buses (BAU)	172.45	184.21	179.33
Electric Buses	126.22	135.90	131.31
Existing Fleet (prior to replacement)	151.56	125.97	131.62
Total Cash Outflow			
Diesel Buses (BAU)	342.0	328.2	329.0
Electric Buses	324.6	312.4	310.3
Difference (Electric – BAU)	17.3	15.8	**18.7**
%age of bus-kms using E-Bus (2022-32)	**37%**	**48%**	**46%**

Source: Consultant Team

It is evident that all the three options of electric bus transition indicate positive net present value, with Option 3 offering maximum returns on the additional investment made in electric buses. Option 3 optimises the investment in buses as well as utilisation of the fleet. In Option 1, the investment is lowest as larger battery sized buses are procured later but the utilisation of the fleet is also less. In option 2, the utilisation of the fleet is most but so is the Capex.

Comparison of net present value (NPV) and financial IRR and for each type of bus is shown in Figure 8 and Figure 9 respectively. It is seen that the IRR for Standard (AC) buses are very high, starting from phase 1 itself. This is because the difference between purchase cost of Diesel luxury AC buses (Volvo and equivalent) and electric AC buses is about 50-60% whereas the cost of the non-AC electric buses are about 4-5 times that of their diesel counterparts. Further the savings in fuel cost per km as well as utilisation of the buses is higher than other bus types.

Figure 8: FIRR for various Phases by Electric bus type

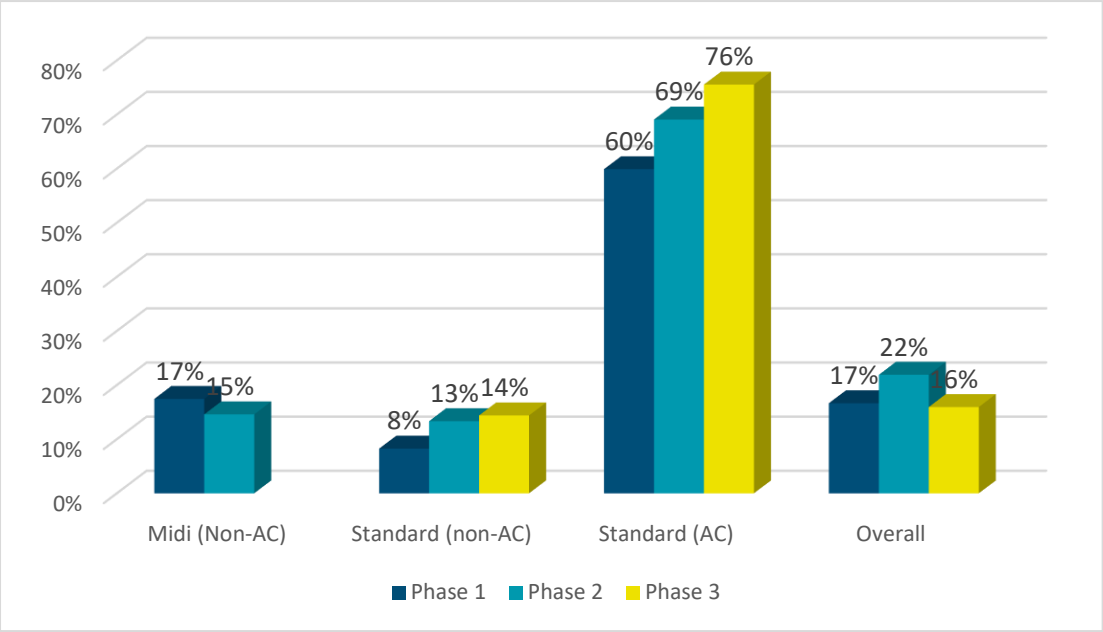
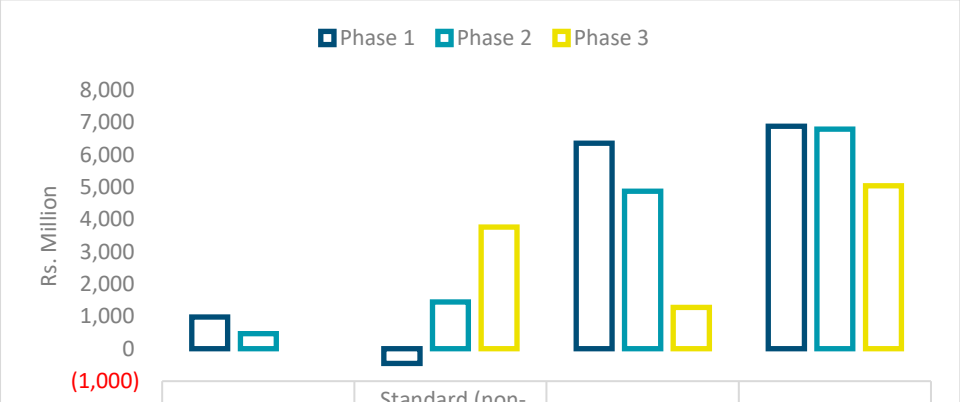


Figure 9: NPV for different Electric bus types and Phases



	Midi (Non-AC)	Standard (non-AC)	Standard (AC)	Overall
Phase 1	980	(454)	6,349	6,875
Phase 2	464	1,450	4,867	6,781
Phase 3		3,758	1,276	5,034

The Midi and Standard (non-AC) buses are expected to require a subvention from government in the form of CapEx/ OpEx grants to achieve parity with equivalent diesel buses from the point of view of BMTC's cost of operations.

4.4.2. Stand-alone Viability of the Electric Fleet

From the above analysis, it is clear that Option 3 presents the best business case and the same is evaluated for ascertaining overall viability as shown in Table 11.

Table 11: NPV of revenue and outflows

(Rs. Million)

	Phase 1	Phase 2	Phase 3	Total
Revenue	65,529	50,563	49,831	165,923
Capex	20,243	12,354	14,753	47,351
Opex	53,629	37,930	39,747	131,305
Surplus/(Deficit)	(8,343)	279	(4,669)	(12,733)

Even though the electric fleet operation is financial better in comparison to BAU scenario for BMTC, yet from assessment of revenue as per current operating environment, it is unlikely that BMTC would be able to breakeven unless urgent measures are taken for bridging the gap between revenue and cost of operations.

4.5. Augmented Fleet Scenario

As per BMTC's Vision Plan, by 2030 it would need to augment its fleet to 16,500 buses due to increase in congestion levels as well as increase in population of Bengaluru. Transitioning from a current fleet of under 7,000 vehicles to 16,5000 vehicles require significant changes – not only at operational level such as rationalisation of routes/fleet/schedules, service planning but also revenue generation. Anticipating all such changes is outside the scope of this business case report.

Nevertheless, the results of the base case can be extrapolated to get a sense of the scale of investments and viability gap in terms of order of magnitude. The composition of the fleet in terms of percentage share of various types of vehicles is assumed to be same as in base case in this scenario. The overall fleet size is increased by 8.5% p.a. from 2022 so as to reach 16,500 by 2032. The additional infrastructure needs in terms of depot space, charging infrastructure etc. is also computed accordingly.

The summary results of this scenario are presented in the form of investments needed till 2032 and projected financial statement for FY 2033 in Table 12.

Table 12: Financial Snapshot for Augmented Fleet Scenario: FY 2033

(Rs. Billion)

	Diesel (BAU)	Electric
Total Capex (2022-2032)	105.330	257.399
EPKM[11] *(Rs/Km)*	66.7	66.7
Million kms/year	1058.5	1058.5
Total Fare Revenue	70.556	70.556
Other Revenue	13.053	13.053
Total Revenue	83.609	83.609
CPKM (Rs/Km)	113.41	95.02
Total Cost	120.040	100.577
Net Profit/(Loss)	-36,431	-16,969

Source: Consultant Team

11 BMTC Vision Plan 2030

5. EXPECTED BENEFITS

Switching to electric fleet will result in many benefits to BMTC as well as the community. These benefits are enumerated below:

5.1. Reduction in Emission of Green House Gases

About 44% of the GHG emissions in Bengaluru is from transport. Each litre of diesel burnt produces 2.66 Kg of CO_2 (Natural Resources Canada, 2014). Considering average current fuel efficiency of BMTC fleet of 3.74 litres/km, the fleet produces 0.71 Kg of CO_2 per km on Tank to Wheel basis (TTW). Accounting for the Well to Tank factor of 30 gm of CO_2/MJ, the CO_2 produced per km for BMTC works out to 1 kg/km. As per BMTC's Vision plan 2030, BMTC would need to operate 1.06 billion kilometres per year by 2030 thereby resulting in total GHG emission of 1.06 MT of CO_2 p.a.

On the other hand, the emission factor of grid electricity is trending downwards with increase in renewable energy composition in the overall electricity mix of India. As per Central Electricity Authority of India, 2019, 1154 MT of CO_2 is expected to be emitted in 2029-30 in producing 2.4 trillion units of electricity. Adding the transmission and distribution losses of 10%, the CO_2 emission for each unit of electricity consumed in charging of EVs works out to 0.53 kg/kWh.

Table 13: Estimated GHG Emissions from BMTC Fleet in 2032

Parameters	Unit	Base Case	Augmented Fleet Case
No. of buses		6,697	16,500
KMs/year	million	437	1059
Diesel Fleet			
CO_2 emission (Well to Wheel)	Kg/km	1.00	
Total CO_2 emission/year	MTPA	0.44	1.06
Electric Fleet			
Units Consumed/year	Million kWh	473	1147
Emission Factor of Grid Power	kg/kWh	0.53	
Total CO_2 emissions	Million tons	0.25	0.61
Emission reduction	**Million tons**	**0.18**	**0.45**
Value of Emission Reduction[12]	USD m p.a.	22.12	53.59
	Rs. million	2837	6874

Source: Consultant Team

12 According to Ricke et al. (2018), India is one of the 4 countries that incur large fractions of the global cost consistently other than China, Saudi Arabia and the United States and India's SCC is the highest in the world estimated at USD 86/ton in 2013. Using a discount rate of 2%, the estimated value for 2030 will be US$ 120/t.

Thus, the SCC of emission reduction due to electrification of BMTC fleet is estimated at Rs. 2,837 m in the base case and Rs. 6,874 in the augmented fleet scenario in 2032. Considering generation/procurement of green energy for BMTC electric buses to the extent of 15% of the energy requirement, the benefits from emission reduction will increase to Rs. 3,421 m and Rs. 8288 m respectively.

5.2. Reduction in Emission of Particulate Matter

Bengaluru's annual concentration of fine particulate matter (PM2.5) is 43 µg/m3, which is more than the national standard (40 µg/m3) and four times above the World Health Organisation (WHO) guidelines. An estimated 1.2 million premature deaths in India are due to air pollution. About 25% of the PM2.5 emissions come from transport sector in Bengaluru and may double by 2030. The benefits from electrification of BMTC fleet is estimated as under:

Table 14: Emission reduction benefits

		Base Case	Augmented Fleet Case
Annual kms	million p.a.	439	1,059
Nox, HC, PM emissions	gms/km	6.93	
Total emission	tons p.a.	3,039	7,335
Cost of emission[13]	Rs./ton	2,50,000	
Total cost of emission saved	Rs. Million/year	760	1,834

5.3. Reduction in Import Cost and Foreign Currency Outgo

India imports 82% of its crude oil requirements. Considering a crude oil value of $98.29/barrel in 2030 as projected by US Energy Industry Administration, the savings in foreign exchange outgo due to electrification of BMTC's fleet is estimated to be US$ 72 million in base case and US$ 175 million in augmented fleet case (scenarios 2).

Table 15: Saving in import cost

		Base Case	Augmented Fleet Case
Diesel Consumed	Mil litres	117	283
Import cost	USD million	72	175

5.4. Reduction in Noise

According to an OECD report (1995), there are mainly four categories of impact from land transport noise in urban areas (Kumar et al., n.d.):

13 Rs. 100,000 in 2014-15 as per Central Pollution Control Board of India

i. Productivity losses due to poor concentration, communication difficulties/fatigue due to insufficient rest
ii. Health care costs to rectify loss of sleep, hearing problems or stress
iii. Lowered property values
iv. Loss of psychological well-being.

As per CSTEP, 2018, the average noise levels of a standard diesel and electric buses are estimated at 73.56 dB and 50.79 dB respectively and the incremental economic benefit of the reduction in noise level is estimated at Rs. 22,127 million per year in 2030.

5.5. Value for Money Analysis

It is noted from Table 11 that adoption of electric buses is financially beneficial for BMTC. Further in the above paragraphs, we also see that the electric buses also provide substantial socio-economic benefits. The overall value for money of the electric buses is summarised below:

Table 16: Value for Money Analysis

NPV in 2021 (Rs. million)	Total
Change in Capex	(29,339)
Change in Opex	48,019
Change in GHG Emissions	12,564
Change in Health Costs	3,352
Overall Value for Money (VfM)	34,596

Table 9. As per the Annual Financial Statements of BMTC, the total value of fixed assets was Rs. 26,426 million as at March 31, 2019. In comparison, the investment requirement is almost four times. The year-wise requirement of funds is given below:

Table 17: Year-wise investment requirement

Year	Phase 1	Year	Phase 2	Year	Phase 3
2021	834	2026	2,439	2030	5,822
2022	1,547	2027	2,248	2031	7,769
2023	8,024	2028	3,891	2032	26,224
2024	7,938	2029	15,886	--	--
2025	10,785	--	--	--	--
Total	**29,128**	**Total**	**24,464**	**Total**	**39,815**

5.6. Private Funding Sources

The Government of India has been encouraging STUs to adopt public private participation in city bus operations in the lines of Transport for London. Cities like Delhi have achieved almost 50% privatisation over the last decade. However, Bengaluru has so far preferred the owner-operator model. It has, however, initiated engagement towards PPP and is in the process of tendering 390 electric buses on gross cost contracting model in which the operator is required to incur all capital and operating costs for electric buses including charging infrastructure. Given the large capital commitments required for electric bus operations, BMTC will benefit by allowing private sector to supplement its resources. However, BMTC has a current manpower strength of 34,000 and hence the extent of private operations would require gradual decrease in manpower. In view of the foregoing, the following 3 scenarios are evaluated:

- No PPP – All buses are procured and run by BMTC;
- Moderate PPP – 25% of the capital investment (rolling stock, batteries or charging infrastructure) is incurred by private operators;
- Higher PPP – 50% of the capital investment (rolling stock, batteries or charging infrastructure) is incurred by private operators.

From the phase-wise financial analysis shown in Figure 8, it is seen that except phase -1, the electric buses are financially better than diesel buses on life cycle cost basis and hence no grant/subsidy is envisaged in Phase 2 and Phase 3. However, during initial years of Phase 1, it is seen that a subvention of 10% of capital cost of electric buses is required in order to achieve positive NPV as compared to diesel buses. The proposed funding structure under the above scenarios is shown in

Table 18 accordingly.

Table 18: Funding Pattern

(Rs. Million)

Source/Financing Scenario	No PPP	Moderate PPP	Higher PPP
Government Subsidy	2,913	2,913	2,913
PPP	0	23,243	46,486
Loans to BMTC	67,870	50,438	33,006
Equity to BMTC	22,623	16,813	11,002
	93,407	93,407	93,407

BMTC has the option of out-sourcing the investment requirements to third parties using the following contractual mechanism:

1. Gross Cost Contracting (Opex model) – Operator procures and maintains the buses/charging infrastructure and operates for fixed rate per km.
2. Wet-lease – Counterparty procures and maintains the assets but BMTC operates

3. Dry lease – Financier only provides financing like a loan. BMTC has to pay the lease instalments, operates and maintains the assets
4. Charging Infrastructure on Opex model
5. Leasing of batteries from the manufacturer – BMTC pays only for the bus body/chassis up-front but batteries are paid on usage basis over the life of the contract. Manufacturer maintains and replaces batteries as needed.

5.7. Public Funding Sources:

The GDP of Bengaluru city is approximately Rs. 5000 billion[14] and as such the above funding requirement represents barely 1.9% of it spread over 12 years. Other than outsourcing the investment requirements through the above-mentioned arrangements, BMTC may look at raising the requisite resources through the following ways:

(a) **Government of Karnataka:** During the FY 2021, the Government of Karnataka has budgeted an assistance of Rs. 7,000 million spread-over 7 years for procurement of 1,500 diesel buses. This practically covers the entire debt service requirement for BMTC if it finances the buses 100% through debt. Similarly, the Government has also allocated Rs. 1,000 million for procurement of 500 electric buses i.e. @ Rs. 2 million/bus. This is in addition to the subsidy of Rs. 5.0 million per bus for 90 midi electric buses from Bengaluru Smart City Corporation and Rs. 5.5 million per standard bus assured to BMTC from Government of India under Fame-2 scheme. Thus, the current allocations for electric buses aggregate to about Rs. 3,100 million.

In addition to the grant support, Government of Karnataka also need to support BMTC by way of equity infusion as well as supporting the debt servicing obligations, should the operational cashflows of BMTC are inadequate. In this regard, Government of Karnataka collects about Rs. 7,500 million each year by way of 10 per cent cess plus 1 per cent additional cess on motor vehicle tax for transport infrastructure and state transport fund, and surcharge on stamp duty at the rate of 2 and 3 per cent for urban local bodies and rural local. The CMP, 2019 has proposed increase in the tax base and rates to generate additional funds to support the strengthening of urban mobility infrastructure of Bengaluru.

(b) **Government of India:** BMTC has received approval for a grant of Rs. 5.5 million per bus for 300 standard electric buses under FAME-2 scheme of GoI in GCC mode. In addition, for future procurements, BMTC may seek from GoI facilitation for loans at concessional terms from multilateral and bilateral development agencies.

(c) **Land Value Capture:** In addition to external funds, BMTC also needs to exploit its real estate assets to generate additional income. Presently, only 9% of BMTC's income accrues from non-fare sources. This should be enhanced at

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least to 25% especially considering the difficulties faced in raising fare levels. The depots post electrification may be used for parking and charging other EVs.

(c) **Green Cess/Tax/Levy –** BMTC's investment in environment friendly electric buses would benefit all citizens of Bengaluru and such socio-economic benefit should be captured thorough a green cess and passed on to BMTC in lieu of it making the investments. Bengaluru Municipality may also be able to collect congestion fee by making suitable amendments to the Karnataka Municipal Corporation Act, 1976 and the Karnataka Motor Vehicle Taxation Act, 1957. This will not only help funding of infrastructure facilities but also reduce congestion and promote use of public transport, both will help improve the viability of BMTC.

(e) **Bus-Stop and Terminal Naming Rights –** Metro rail corporations including Delhi Metro have been able to raise significant revenues by granting naming rights and advertisement spaces to various brands and the same can be replicated by BMTC.

6. RISK ASSESSMENT AND MITIGATION

The risks to BMTC in implementation of the electrification project arises mainly from four sources viz. product risk, financing risk, operational risk and revenue risk. The above risks are explained in the following paragraphs:

6.1. Product Risk

This risks arises from the differences between Diesel and Electric buses and are as follows:

a. **Technology Risk**: Electric mobility technology is quite mature now, however, there is lack of experience of application in the Indian context. High day time temperatures, occasional flooding of streets, thefts, vandalism etc. pose threat to the high capital investment in the e-buses. Such risks can be mitigated by contracting out the operation/maintenance to third parties/manufacturers.
b. **Price Risk**: The business case assumes reduction of electric bus/battery prices, availability of batteries suitable for faster charging, higher diesel and lower electricity prices. Any adverse changes in these parameters during the implementation phases. A long-term procurement programme for buses as well as energy with assured cost reductions may alleviate some of these risks.
c. **Useful life:** The total cost of operation and financial indicators are dependent on longer life of electric buses as compared to diesel buses. A long-term maintenance contract with OEMs may mitigate this risk. The OEMs would also train/advise the bus drivers/maintenance staff on proper usage/routine check-up/maintenance of the assets.
d. **Energy Consumption:** The main advantage of electric buses arises from lower energy consumption. However, in case the energy consumption in actual may be higher. Such risk can be wholly/partly contracted out to OEM/concessionaire.

6.2. Financing Risk:

The biggest hurdle to BMTC in implementing the electrification project is the financing risk, especially considering its fragile financial health. It used to be one of the few profits making STUs in the world. However, its profitability has taken a nose dive since 2012-13 mainly due to gradual increase in cost of operations, decreasing ridership and inability to increase fare.

6.3. Operating Risk:

BMTC is not only India's largest STU with 6,448 buses (in 2015-16), it also lost the least money (Rs 1.01 billion) over six years to 2016 among eight metropolitan bus systems (Business Standard India, 2018). Hence, operating risks internal to BMTC may be considered minimal. However, BMTC is subjected to external operating risks such as

a. Congestion which reduces its daily operating kilometre/bus and thus earnings.

b. Cancellation of trips: Due to delays, it often needs to cancel trips. During April 2019 to February 2020, it has to cancel 13.4% of the trips. The main reasons for cancellation are road blocks/congestion/late arrivals (43%), shortage of staff (25%) and vehicle breakdown/unavailability (29%).
c. Due to increased transit time and unreliability the ridership base is also adversely affected which is shifting to private vehicles or metro rail.

6.4. Revenue Risk:

The revenue levels for BMTC are showing a downward trend and going electric may not directly change that trend. Maintaining a reasonable revenue stream to match, at least the cost of operations, will remain constant challenge for the organisation specially with metro network expansion, road traffic congestion and improving economic conditions of city dwellers. Accordingly expected ridership and fare levels alongside the extent of fare evasion/pilferage would pose the traffic revenue risks, while ability to tap on non-traffic revenue potentials can pose another dimension to the revenue related risks.

As mentioned, some of the above risks may be reduced by outsourcing. However, excessive transfer of risks to concessionaire may result in failed tenders or poor implementation outcomes.

BMTC has attempted to procure 300 electric buses through gross cost contracting (GCC), however, most potential participants did not submit bids owing to apprehension of excessive contractual risks. Hence a fair risk-reward mechanism is essential for PPP involvement in city bus operations.

Similarly, improved customer satisfaction, enhanced infrastructure support and skill development can potentially support risk factors within control of BMTC/Government.

A comprehensive list of risks affecting electric bus concessions is presented as Annexure 3.

7. COMMUNICATION STRATEGY

In addition to promoting sustainable infrastructure in cities, one of the directives of the government of Karnataka is to create greater awareness among public on choices of mode they can opt for commuting (like use of public transport, carpooling, cycling, use of electric vehicles, etc.) and carbon footprints they leave when using different commuting modes, which in the long-term are necessary to bring about behavioural changes in commuters.

While BMTC has already formulated its vision 2030 for adopting electric mobility which is duly supported by the Karnataka EV Policy and the National policy on E-Mobility, the program will necessitate many changes to “business as usual scenario”. Commuters are familiar to the operation of diesel buses and feel safe to use it. There may be some concerns regarding the “silent” electric buses which store large amount of electrical energy on-board.

Further, due to adoption of GCC mode of procurement, there may be apprehension amongst staff regarding continuation of their employment. The maintenance staff composition also needs to undergo some change and new manpower of suitable qualifications will have to be recruited and existing manpower need to be retrained.

BMTC would need substantial funding from Government as well as private sources to implement the program. Hence it is critical to communicate the strength, ability and resolve of BMTC towards electrification program. Any actions seemingly deviant from the stated policy of electrification needs to be clarified e.g. purchase of some diesel buses during initial years.

While communicating the importance of the fleet electrification program, the following facts may be highlighted:

- Reduction in carbon emissions by up to 0.45 million tonnes per year or by 42% as compared to ICE engine buses;
- Reduction in particulate matter by 7,335 tonnes per year;
- Reduction in fuel costs;
- Reduction in total cost of operation;
- Reduction in noise from diesel buses from 76 dB to 50 dB.

The communication plan must be implemented throughout the program, especially during the preparation period. Therefore, users will be aware of the system’s functioning and will be more willing to accept it once it is launched. Important milestones such as arrival of each batch of bus, official launch event and information dissemination every time a route is implemented need timely communication for effective support.

8. CONCLUSION AND RECOMMENDATIONS

Bengaluru is a fast-growing city and it has is already become third largest cosmopolitan city of India. In addition to being the Silicon Valley of India, it aspires to be Electric Vehicle Capital of India as well. *Given the growing air pollution levels in the city and commitments of national and state governments to reduce dependence on fossil fuels, a gradual shift to clean fuel/electric vehicles is envisaged. In this context, it is not surprising to note that available BMTC Vision Document 2030 has put forward a mission to fully convert diesel fleet into clean fuel/electric fleet over the next decade.*

BMTC is one of the most progressive State Transport Undertakings in India. It used to be one of the most profitable STUS and still retains the position of the least loss-making STU in India. Electrification of the fleet will help it to reduce the operating costs significantly. However, the high initial cost of the electric buses together with limited operating range, constraints of creating charging infrastructure etc. constitute the stumbling blocks in this journey.

The Business Case has looked into these issues in detail and finds that despite the high initial capital requirement, gradual transition to electric bus technology is financially beneficial to BMTC in addition to the equally significant environmental and health benefits resulting from this transition. *Going forward, this business case working and analysis provides a strategic background and roadmap for BMTC towards adoption of a large scale transition to electric bus based operations.*

Some of the issues that this report does not address and need to be dealt with during the implementation of the project include:

1. Route/Schedule rationalisation for optimum utilisation of the electric bus and diesel bus fleet.
2. Route/fleet rationalisation considering metro expansion.
3. Detailed implementation report for each phase/sub-phase including depot selection, route/schedule allocation, battery size/charging strategy, operational plan.
4. Rationalisation of costs including through outsourcing of maintenance and non-core activities, conductor-less fare collection etc.
5. Organisation restructuring to accommodate operation, supervision and control of operators, operation and maintenance of electric buses/charging infrastructure.
6. Detailed financing plan for each phase/sub-phase.

The Business Case report has been prepared in two parts. Part 1 (this report) deliberates on financial analysis, results and broad funding options. Part 2 of the report focuses on procurement strategies and implementation framework for effecting the transition over next decade.

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10. ANNEXURES

Annexure 1. Terms of reference

Task 2.2 Business Case and Financial Model

Activity 2.2.1 Business Case

The Service Provider shall prepare a Business Case the transition to a full electric busses fleet, containing a business justification for the entire project duration. The Business Case shall clearly investigate if the project is desirable, viable and achievable, and therefore worthwhile for the city and/or private investors to invest the amounts needed. The Business case shall also include a communication strategy which is shared between SPE and city to have convincing arguments when communicating with media, civil society, private sector etc. At a minimum, the Business Case shall include the following components:

• A strategic case – the background of the project and why it is needed;

• An options appraisal – what options have been considered and which has been chosen (not forgetting the 'do nothing' option and possible tranches);

• Expected benefits – the benefits that will arise from the work and any unavoidable dis-benefits;

• Commercial aspects – the costs, investment appraisal and funding arrangements;

• A 'Value for money' appraisal in relation to BMTC's expenditure;

• A risk assessment – the major risks and their impact on the business case;

• Timescales – a summary of the delivery of outputs and realisation of benefits.

• Two Workshops with the PIU at the beginning and at the end of the activity.

Activity 2.2.2 Draft Financial Model

The Service Provider shall prepare a draft financial model for each subproject. This financial model shall be reasonably accurate to portray the economic and financial feasibility of each phase of the project under a variety of scenarios and assumptions. The Financial Model shall cover to a reasonable detail as a minimum:

Development Costs; • CAPEX (Capital Expenditures); • OPEX (Operational Expenditures); • Financing Costs; • Insurance Costs; • Taxes;	Tariffs; • Legal Fees; • Sources and Uses of Funds; • Cash Flows; Loan repayments (if needed); and • Pro Forma Financial Statements.

The Financial Model shall be a working model. It has to be presented in a workshop to the PIU.

Annexure 2. Assumptions

C40 CITIES FINANCE FACILITY

Assumptions for the Financial Model

Capital Expenditure

Capex Cost/Bus (Rs./Unit in 2021)	Excl. Battery	Battery Size	Battery Cost	Gross Cost	Eqv Diesel Bus
E Bus - Midi Non-AC	5,656,250	125	2,343,750	8,000,000	2,550,000
E Bus - Standard	11,137,500	250	4,687,500	15,825,000	3,550,000
E Bus - Standard-AC	12,375,000	300	5,625,000	18,000,000	11,100,000
Cost of Charger/kW	18,750				
Battery Cost	$250	/kWh			

It is assumed that all overaged stabdard-AC buses as on 31/3/2020 will be replaced with BS VI Diesel buses during FY 2021

Depot Development/Electrification	No of Buses	Acres/Unit	Cost/Unit
1 depot would be required for every	150	3	300,000,000
Cost of development		100,000,000	Rs. /Acre
Cost of electrification/depot (including cost of opp charging		30,000,000	Rs. /Acre
Extra Depot Space required for electrification		20%	
Total Midi Fleet in FY 2025 onwards	698		
Midi Electric buses procured in 2021	90		
Bus End of Life Scrap Value	3%		

Change in Prices	Chargers	Battery	Buses (Body+Chassis)	
Increase/(Decrease) per year	-2.5%	-8.25%	-2.5%	p.a.
Decrease for	5	5	5	years
Thereafter	2%	-8.25%	1.80%	p.a.
Battery Life	7	years		
Repurposing cost of old battery	$49	/kWH (2021)		
MV Factor for old battery	60%	(100 kWh bttery will be valued as 60 kWh less repurposing costs)		

Financing Assumptions

Loan Tenure	8.00	years
Subsidy/Equity	25%	
Debt	75%	
Average rate of Interest (For TCO)	9.0%	
Discounting Rate	9%	

Project Phasing

Phase	Years	Mid-year	Charger Rating Fast	Charger Rating Slow	of Bus/Battery Cost)
Phase 1	2022-2025	2024	120	60	14.1%
Phase 2	2026-2029	2028	150	75	12.9%
Phase 3	2030-2032	2031	200	100	12.9%

Funding partners:

Federal Ministry for Economic Cooperation and Development
CHILDREN'S INVESTMENT FUND FOUNDATION
UK Government
USAID FROM THE AMERICAN PEOPLE

Implementing agencies:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
C40 CITIES

C40 CITIES FINANCE FACILITY

Operating Assumptions

Dead Km	3.40%			
Cancelled kms	5.00%			
Charger Maintenance Cost	5%	of Capex		
Spare Fleet	8.3%	BMTC		
Base Year	FY: 2021			
Diesel Cost	77.88	Rs./litre	FY: 2021	
Cost of Grid Power/kWh	5.45	(Rs. 5 + 9% tax)	FY: 2021	
Cost of Solar Power (Rooftop)	3.5	Rs./kWh		
%age of Rooftop solar power	15%			
Average Cost of power	5.16	Rs./kWh		
Charging efficiency	90%			
Battery Degradation Factor	0.8	Fast Charging Time	1 Hour	/bus/day
Charger utilisation (hours/day)	Fast	5 Hour	Slow	6 Hour
Minimum State of Charge at EoD	20%			
Contingent Fast charging capacity	30%			
Cost Escalation	p.a.		p.a.	
Diesel/Lub/Consumables	5%	Staffing	5.50%	
Spares	1.50%	Bus	1.80%	
Reconditioning	1.30%	WPI	1.90%	
Electricity	1.50%			

Revenue Assumptions

Increase in Earning per km	6.6%		
Non-Fare revenue	9.0%	of fare revenue	
Government reimbursement	9.5%	of fare revenue	
Fare Revenue (EPKM)	Rs./km		
Midi	46.11	FY: 2021	
Standard	37.57	FY: 2021	
Standard-AC	66.63	FY: 2021	
Growth Rate in Ridership	2.0%	p.a.	
	INT/US$	**INR/Euro**	
Exchange Rate	75	85.00	
Rupee Depreciation	5%	3.00%	
Unit	1,000,000	Rs million	
Years are financial years ending on	31st March		

Funding partners:

Federal Ministry for Economic Cooperation and Development
CHILDREN'S INVESTMENT FUND FOUNDATION
UK Government
USAID FROM THE AMERICAN PEOPLE

Implementing agencies:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
C40 CITIES

Annexure 3. Risk Assessment and Mitigation

RISK FACTOR	PARTY	DESCRIPTION	MITIGATION
1. Technology Related Risk			
1.1. Early adoption anxiety	TA	As for every case for early adoption, for e-buses also suffer from limited operating experience and data and the chances of failure or adverse outcome is high. The e-buses also cost much more than the diesel/CNG buses. Deploying scarce public resources in newer and unproven systems causes discomfort and anxiety amongst decision makers. This tends to result in deferment and delays or smaller scale of deployment. Also operating conditions, extent of deployment and deployment strategy differs from city to city, so is the perception towards risk as also capability and capacity for change. Continuous development in e-bus, battery chemistry and charging technology makes it a moving target.	Although tramways and railways have been operating on electricity for over a century, electric buses operating on batteries and deployed for intra-city operations is not even a decade old. Except Shenzhen, China, very few other cities have any significant e-bus operations experience. Nonetheless, a considerable body of experience has been collected over the last decade and in combination with consultations with manufacturers, experts and trial runs, much of the uncertainty can be reduced. Further since public bus operations will continue for a long time, a long-term informed view on shifting to new technology-based operations can take away a large part of the anxiety.
1.2. High Initial Cost of the Bus	Operator/ Investor	The initial cost of the e-bus is 2-4 times of the standard diesel/CNG buses.	The effect of high upfront cost can be reduced by • Leasing of buses, battery or both and pay lease rentals from savings • Building charging infrastructure on Opex model • Up-front subsidy from Government • Joint purchase for bulk discounts • Tax/duty concessions

1.3. Uncertainty with respect to residual value/ alternate deployment	Operator/ Investor/Lender	Diesel/CNG buses are versatile and can be practically run in any situation whereas an Electric Bus is designed specifically for a route particular application and in case the contract is terminated prematurely, the owner/lenders will find a significant gap between book value and realisable value of the buses/equipment.	The risk can be reduced by following ways: • Up-front subsidy • Interest free/low interest sub-ordinated loans from the TA • Compulsory buy-back clause in concession agreement upon termination (BOT contract)
1.4. Spare parts availability 1.5. Technological obsolescence	Operator	Electric Bus technology is continuously evolving and most countries do not manufacture e-buses and hence the spare parts are not readily available in local market. Although the Operator is mostly concerned with performance of the E bus procured, technological obsolescence may have impact in terms of spare parts availability and resale value of the e-bus. In case the OEMs close down production of the model procured, the Operator will be left stranded.	e-buses have 80% less moving parts and about 55% less wearing parts as compared equivalent Diesel/CNG Buses (Sunny Sen & Anand Murali, 2018). Hence the requirement for maintenance and replacement of spare parts will be considerably lower. Nevertheless, the Operators can mitigate this risk by: • Long term spare parts contract /AMC with OEM. • Clause in procurement agreement that requires OEM to give advance notice to the Operator in case production of any of the spare parts are discontinued so that the Operator can order and stock the parts for future use. • Clause for extension of concession period for exploitation of the residual life of the e-bus.
1.6. Replacement of battery 1.7. Battery Disposal Risk	Operator	The life of battery depends on the number of charging cycles, rate of charging, ambient temperature etc. The battery needs to be replaced when the maximum charge retention is about 80% of the original capacity. Depending on the usage, battery chemistry and charging strategy, this may vary from 5-8 years. The price of battery is continuously reducing. The operators need to estimate the expected cost and periodicity of battery replacement during the life of the concession. It is subjected to risk of actual cost/replacement cycle being different from what is factored in the business case.	Adequate attention given while designing of the e-bus system based on data from trial runs and deployment in other cities in similar situations will be helpful in mitigating this risk. Safe battery disposal at the end of life also constitutes another risk. Although the batteries are stated to have a second life use for energy storage, telecom towers etc., such usage has a repurposing cost estimated at around $ 49/kWh (Bloomberg New Energy Finance, 2018). The falling prices for batteries may reduce the realisable value (in terms of %age of original cost) as the repurposing cost may not reduce but rather increase with time. However, this would be more than offset by the reduction in battery purchase cost.

			One way of avoiding these risks is to obtain the battery on lease e.g. Proterra's Park City project. This has the added benefit of reducing the Capex and the battery expert managing the battery life cycle costs optimally.
1.8. Gap between advertised product specifications and actual performance:	TA/ Operator	Unexpected and significant deviation from expected values can be for the operator/TA. A flawed system design in terms of effective range, charging frequency and traffic congestion levels etc. may impact the availability of the e-buses and therefore their reliability and usage. Some of the related operating risks are: - Excess use of energy - Reduced effective Range - Reliability/ availability of e-bus - More frequent charging leading to earlier replacement of battery	Mitigation measures: • Rigorous trial runs in actual deployment scenario • Detailed route planning, charging strategy and design of suitable charging infrastructure with flexibility to adapt as per emergent situation. Provision should be left for supplementing the charging infrastructure to some extent including mobile chargers. • Stipulation of maximum energy usage under prescribed operating conditions or making cost of energy part of operator remuneration would protect the TA from excessive energy costs • Instead of specifying e-bus technical requirements, the TA should specify the routes and operational conditions and services to be rendered and leave the Operators/OEM to design the system for an economical and technology feasible solution. • Performance warranty/guarantee from manufacturer for extended period e.g. in Shenzhen city, the e-buses came with life time warranty for the batteries. • Adequate driver training is essential as driving e-buses is different than driving Diesel/CNG Buses and the learning curve should be shortened. e.g. difference in minimum and maximum energy usage amongst 49 drivers in Milton Keynes, UK was found to be as high a 1 kWh/km in the initial 5 months of e-bus operations (Kontou & Miles, 2015).
1.9. Flawed system design		Lack of operational data may result in flawed system design including - Inadequate charging infrastructure - Inadequate sizing of batteries	
1.10. User response	Operator/ TA	Depending on user comfort, awareness and implementation scenario, the user response to any new system will vary. In the context of e-buses, passenger comfort improves and this may result in preference for e-buses. However, initial response may be tepid due to safety concerns. Preference for	All buses in a given route should be electrified in order to reduce the impact of preference for e-buses. Prior to launch of e-bus services, awareness campaign regarding their safety and environment friendliness should be carried out.

		e-buses may result in more than average ridership at the cost of other buses plying on the same route. This will reduce viability of existing buses and increase energy costs for e-buses. E.g. In Pune, India, the (airconditioned) e-buses are much preferred to the (non-airconditioned) CNG buses as the fare is the same and as a result the energy consumption of e-buses is beyond the prescribed limit and the operator is paying for excess energy as per contract conditions.	The conventional buses should be spruced up to reduce the difference in comfort levels/preference as compared to new e-buses.
1.11. Safety Concerns	TA/ Operator/ commuters	The e-buses store large amount of energy on-board in the form of battery which are also charged at very high voltage levels while the bus is in use (wireless/flash charging). Further, locating batteries in the roof of the bus in hot conditions or in the undercarriage in flood prone areas is also a concern. The other concern is due to the rather silent operation of the e-buses. The introduction of electric buses may cause significant issues for pedestrians who are blind or vision/ hearing -impaired or are inattentive because electric buses make much less noise (Busenews.com.au, 2020).	Prior to introduction of e-buses, awareness of the safety aspects and benefits of e-buses need to be created. The drivers also need to be made aware of the adverse effects of the silent buses. Many models of e-buses now come with audio warning systems which get activated when any road users is likely to collide with it should they continue on their path (Road Safety, GB, 2018).
1.12. Increase in GHG emissions	TA	One of the arguments against e-buses is that they don't really reduce GHG and other emissions but only shift their location out of the cities. Many countries are using bio-fuels such as ethanol and bio diesel and consequently the GHG emission in transportation is lower than or equivalent to that in power generation. Hence the e-buses may actually result in higher overall emissions.	• Renewable power has become very affordable and countries like India are scaling up their renewable generation capacities at a rapid pace. By 2030, more than 50% of India's power capacity could be from non-fossil fuel sources (Michael Safi, 2016). • On account of reduction in renewable power costs and storage costs, soon renewable power would become dispatchable (i.e. available on demand) /round the clock (RTC). In a recent tender in India, the cost of renewable RTC power was quoted at less than 4 US cents (Business Standard, 2020).

		Further, renewable power generation for e-bus charging cannot be relied upon as it's uncertain and may not match with charging pattern.	• Hence TAs can consider procurement of renewable power for charging if not all but at least a substantial part of their energy requirements thereby achieving both a cleaner city and GHG emission reduction. • Further, the combined space in the depots, maintenance yards, bus stations/terminals/stops etc can be considerable and can be used to generate power through rooftop solar and meet at least some part of the e-bus requirements.
2. Procurement/Financing Risks			
2.1. Transparency in procurement		Discretionary factors in procurement contracts create uncertainty in the procurement outcome for the participants and increases the risk factor. E.g. if the routes and service frequency is not specified in the tender and TA proposes to inform the same upon finalisation of the contract, the Operator is uncertain on utilisation of the services and any over/under-utilization may be financially adverse for the operator.	The TA should specify the operating conditions in finest detail possible to remove uncertainty. Also, clauses regarding changes due to emergent situation not in control of the operator, TA convenience or even on operator request should be provided and formula for compensation/sharing of benefits for the same should be specified based on actual economic effect. This brings fairness, clarity, commitment and flexibility into the contract.

2.2. Higher Total Cost of Operations /per kilometres rates	Transport Authority/ Operator	Operating electric buses is a paradigm shift as compared to running the Diesel/CNG Buses. It involves higher capital cost, detailed planning, customised design to route characteristics. This is duly rewarded in terms of lower operating costs in the long run. However, often lack of understanding of stakeholders and or inefficient use of the resources may increase the total cost of operations.	Due to higher Capex and lower operating cost, e-buses should be deployed on routes where the daily usage is maximum but within the operating range of the e-buses. e-buses have even been run for 17 hours a day by using wireless charging at terminals (Kontou & Miles, 2015).
			In addition to annual assured kilometres, the TA needs to specify the following for better design and pricing of the services:
			• Operational Details such as:
			  ○ Route names and characteristics (length, average speed, congestion, number of stops, passenger loads etc)
			  ○ Schedule of operation (start times, layover time etc)
			• Depot facilities to be provided by TA and facilities that need to be created by the operator. It is better for TA to create the depot facilities so that the operator can focus on bus procurement,

			training of personnel and planning of operations. Typically, the TA has more expertise in dealing with utility companies for permissions, power connections, civil works etc. • Details of power supply to be made available • Cap on overall penalty per month/year will reduce the risk of the Operator. Further, since the capital expenditure is incurred by the Operator, it stands to bear significant loss due to early termination of the concession. Hence, the PBG requirements should be kept at minimum reasonable level and should be tapered off with years of successful operations. This will reduce prices.
2.3. Limited OEMs/ Product Types 2.4. Limited number of bidders	Transport Authority/ Operator	As compared to Diesel/CNG Buses, the range of models available in a specific geographic location for electric mobility is very limited while at the same time the possible range of applications is very varied in terms of bus sizes, charging mechanisms and charging strategy, single charge range etc. Further, once a particular charging system gets implemented, it may become difficult for the operator/authority to adopt another system which may be more beneficial on a standalone basis due to technological advancement or specific application.	• Prior to launch of procurement process, a detailed survey of suitable products of all manufacturers active in the given geographical area needs to be conducted and based on the same the OEMs should be shortlisted. • Roadshows should be held with the selected OEMs to understand their concerns and suggestions which can be incorporated in the system design. • Cumbersome tender conditions such as drawing power lines, constructing depot facilities etc should not be included in the bidders' scope and clear demarcation of roles and responsibilities should be communicated. • Discretionary clauses making the contract one-sided in favour of the TA should also be avoided to reduce risk perception of the bidders which may chose not to participate in such tenders. Many tenders in India have received very low response owing to onerous tender conditions. Approvals/permissions should be provided on objective basis as documented in the contract. • History of fair dealings of the TA also provides comfort to the bidders. • The TA should endeavour to provide a fair concession contract which balances the risks and rewards for the operators and assures them of efficient management of contractual issues that may arise during the concession period on a fair and equitable

			basis. Focus should be on higher performance which is a win-win for both rather than fines and penalties.
2.5. Payment Security: - Counterparty risk - Timely Payment risk - Termination Payment Risk	TA/ Operator/ Lenders	Bus Operators and investors/lenders are very sensitive to the payment security mechanism offered under the concession contracts. Due to uncertainty of timely payment, bidders may provide for higher working capital mainly from expensive equity capital and also increase risk premiums increasing the bid price.	• Adequate and well-structured payment mechanisms have been found to receive favourable bids and participation than others. • In case the TA's financial credentials are not strong enough, the TA should procure liquidity backstop/payment security/letter of comfort from the municipality/government to provide surety to the bidders towards monthly payments as well as termination payment if such an eventuality does arise.
2.6. Policy Risk	TA	Frequent change in policy may create uncertainties in the minds of the bidders who may view the current procurement as a onetime activity and may load all overheads in the pricing instead of averaging out on possible future procurements.	Firm long-term policy of the TA to adopt e-buses backed up by regulatory/government promulgations will create more interest from manufacturers and operators who may participate in a competitive manner with a view to scale up the operations over time.
2.7. Force Majeure Risks	TA/ Operator	Force Majeure situations like pandemic, strikes, natural disasters which effect the operations of the project for a long duration and has significant effect on both the parties. However, the Operator has limited ability to bear the risk of disruption (except those which can be insured).	• Making part payment to operator to cover at least the fixed costs such as payroll, interest etc. • Extension of the Concession term can be for the investors/lenders to recover their investments. • In case of long-term force majeure, the CA should provide for the TA buying out the assets of the operators at pre-determined price so as to cover the unrecovered capital invested by the operator. Such provisions in the concessions will greatly boost the investor/lender confidence and will ultimately result in finer pricing of the services.
2.8. Availability of funds 2.9. High cost of funds	Operator	Considering higher CapEx, lack of experience in local conditions and asset specificity of e-buses (resulting in value diminution on redeployment), the lenders are likely to limit the amount debt operators would get and accordingly much higher amount of equity would be required to be brought in by operators.	The Concession agreement (CA) need to be drafted keeping in mind the characteristics of the e-bus systems and would require a completely different approach as compared to buying Diesel/CNG Bus services. Considering the higher equity requirements (due to both lower debt availability and higher CapEx), operators would have to seek

		Further, risky concessions are likely to be funded by more equity and less debt. Cost of equity as well as debt in such cases will be higher. This will ultimately result in higher prices for TA.	investments from green funds and other pedigreed investors who would look for a well-balanced CA which protects their interests. The CA need to have following clauses to provide comfort to lenders/investors: • Compensation on termination due to TA default/ convenience/force majeure of any kind, change of law and change in input prices • Compensation for underutilisation of buses • Lender's step-in rights/operator substitution rights • Asset transfer to TA at the end of concession etc. at pre-determined price • Robust payment security mechanism Such provisions will ensure bankability of the concessions and availability of adequate debt and equity funds at reasonable cost.
2.10. Working capital risks	Operator	In general, it is seen that CAs provide for monthly payment and hence the operator would need to arrange minimum two month's working capital. However, in case there are possibilities of payments from the TA may be delayed, the operator may need to arrange for working capital for longer periods.	• A fare and well-defined payment mechanism and payment security will reduce working capital requirements and cost of services. • Since TA gets paid from users on advance basis, they should remit payments to the operators as frequently as possible. A part of the payment may be retained to be paid after verification of the monthly bill. This would reduce the working capital requirements.
2.11. Foreign Exchange	TA/Operator	Since all components of e-buses are not produced domestically and some Operators may be relying on imported e-buses altogether, a variation in foreign currency rates between budgeting date and procurement date may result in increase in costs. The operator is also exposed to higher prices of imported spares and battery replacement cost during the operating period.	• Procurement in bulk or through long term supply contracts will encourage OEMs to indigenise to a larger extent to reduce dependence on imports. • Countries through national policies on grants/subsidies can set targets for indigenisation.

2.12. Operator under-performance	TA/ Operator/ Lenders	An experienced operator is well conversant with operations of Diesel/CNG Buses whereas e-buses bring in new dimensions including effective range, matching of operations and charging scheduling, reliability of power infrastructure, availability of spare parts, balancing between fast charging (higher vehicle availability, lower efficiency and battery life) and slow charging etc.	Typically, concession agreements provide for SLAs and penalty rate in case SLAs are not met. However, levy of excessive penalty on the operator should be avoided. Penalties should be set at a level where it hurts the operators if it underperforms but does not break its back and result in further disruption of the services. Higher penalty levels increase the risk of the concession resulting in higher buffers/margins and risk premium resulting in overall inefficient design/pricing. During initial deployment, handholding, support, understanding and lee-way will be required on the part of TA. The SLAs may be tightened as the operator gains experience and confidence with the e-buses. The Concessions need to be flexible to accommodate genuine concerns of the Operators which emerge during operations and provide fair resolution of the same. Further, the TA would need to have back-up plans in place to deal with situations in which the e-bus are not available as envisaged originally (e.g. actual range during operations being much less than initial estimates due to congestion, driver familiarisation etc.)
2.13. Delayed start of operations	TA/ Operator	The start of e-bus services may be delayed due to • political factors, unavailability of financing, among others. • delays in supply of e-buses as currently production capacity is low and many manufacturers set up production lines for e-buses on receipt of firm orders • Misalignment or lack of coordination among local entities and other stakeholders.	The e-bus services are deployed as a replacement of existing diesel/CNG services and hence the incumbent operators may delay the induction of electric buses. The e-buses would also need to use the same depots as the existing diesel/CNG buses and there could be a period of overlap. In addition, a part of the depot needs to be vacated much earlier for installation of charging equipment. These issues should be discussed and addressed before hand to avoid crisis during implementation.
1. Operating Risks			

2.14. Unexpected increase in electricity tariffs/ change in tariff structure		In case the rates per kilometre are inclusive of electricity prices, the operator is subjected to risk of tariff increases which are dependent on external factors. Often Governments provide attractive tariff for EV charging which may be withdrawn afterwards. If the operator builds the risk of such changes, the per km rate will be higher from the outset.	The ability of TA to negotiate suitable tariffs favourable for e-bus is much greater than the operators. Hence the electricity costs should be borne by the TA. The concession agreement should incentivise the operator to be more energy efficient and cooperate with TA.
2.15. Reliability of power supply	TA/Operator	In case of power supply disruption, the operator won't be able to charge it's e-buses and the operations will get disrupted. Robust distribution network and Transmission line reliability/redundancy a must for e-bus operations similar to metro rail.	Initially, when e-bus are only a small part of the overall fleet, this risk is not great. However, in the long run the TA must discuss with the DISCOM to arrange back up sources of supply /transmission /distribution facilities to cater to such contingencies. Arrangements similar to uninterrupted power supply available to railways and metro rail operations would need to be made.
2.16. Underutilisation of E- Bus due to range anxiety	Operator	Range anxiety amongst the drivers causes them to return to the depot at undesirably high level of battery state of charge resulting in underutilisation of equipment and higher proportion of dead-kilometrage.	Battery charging cycles should be determined by the system using operating data and algorithms to optimise the costs rather than by the humans/drivers. This will take-away the pressure of decision-making regarding charging from the driver who can focus on efficient and safe driving of the e-bus.
2.17. Increase in interest costs	Operator	The Concession period will be for a period of 10-12 years and during such time the interest rates may vary significantly.	Operator would need to enter into contracts with fixed rate of interest or utilise credit derivative products, if available to insulate itself from the risk of rising interest rates.
2.18. Resistance to change	TA/ Operator	Resistance to change to an electric fleet may come from • Treasury – The TAs that are not financially strong, depend on capital support from the municipal/ provincial/ national governments. Each e-bus requiring 2-3 times the capital as compared to a diesel/CNG bus puts the financial	Suggested Mitigation measures are as follows: • Opex models like GCC/NCC/Licensing may shift the onus of capital investment from the TA to the private operators. At best, the TA may have to provide some up-front/running subsidy to make up from the difference in TCO. • The maintenance crew needs to be retrained/reskilled in maintenance of e-buses. Overall, the staff to bus ratio for e-bus and Diesel/CNG Bus is more or less same although there will be some

		planners in a dilemma in rationing the limited capital resources. • Maintenance Crew - Lot of maintenance activities get curtailed due to reduction in moving parts and total number of parts. The nature of maintenance activity changes towards electrical from mechanical. The maintenance staff worried about job loss may create hindrances in faster adoption of e-bus fleet. • Drivers may have 3-5 min recovery time between trips during peak hours and may be unwilling to utilise part of their recovery time in connecting/disconnecting charging equipment.	difference in the qualifications/ skills / training of the maintenance staff15. • Fuelling of Diesel/CNG Buses is less frequent as compared to Electric buses and done mostly en-route. The e-buses may have to return to depots for recharging (unless opportunity charging is used). The drivers will have additional responsibility to connect/disconnect the charging equipment. This additional responsibility mill be mitigated to some extent by the less fatigue from driving an e-bus.
2.19. Lack of flexibility/ Interlining	Operator	Diesel/CNG Buses are standard and versatile. They may be deployed in any route and under any condition. In comparison the e-buses systems are application specific e.g. an e-bus having a range of 150 km/day cannot be deployed on a schedule having 200 km/day. Hence sparer e-buses will have to be maintained as compared to Diesel/CNG Buses.	Initially, some of the existing diesel buses would need to retained to provided operational flexibility and these can be gradually curtained as the operator gains experience and confidence on the e-buses increase. However, additional parking/maintenance facilities may be needed.
2.20. Unavailability of depot space	TA/ Operator	e-bus parking/charging requires additional space as compared to diesel/CNG variants. Further, the Diesel/CNG Buses may be parked on the road side but e-buses would have to be parked in depots to receive slow charging at night which is more efficient and also for availability of full charge at the start of operations next day.	Using suitable design methodology, multi-level parking etc., the space requirement can be optimised e.g. use of fast chargers, converting AC to DC at a single location and distribute system in DC mode eliminating the placement of charging boxes next to bus bays etc.

15 Source: Consultant Team- discussions with operators/OEMs

2.21. Availability of technical manpower for maintenance	Operator	The maintenance staff of Diesel/CNG Buses are more conversant with the mechanical systems. Maintenance of e-buses will require more understanding of the electrical systems. The nature and qualification of manpower requirement will undergo a change and availability of trained manpower to maintain e-buses will be an issue in initial adoption.	The Operator would need to enter into a medium to long term maintenance contract with the OEMs to ensure transfer of knowledge/skills for maintenance of e-buses. Initially running maintenance may be done by Operators personnel and the scope can be increased gradually to take over from the OEM eventually.
2.22. Other factors	Operator	Other risk factors affecting operation of e-buses include: • Poor infrastructure/ Congestion • Unexpected acclimatization processes • Additional maintenance procedures due to mechanical failures found at overhauling • Damages caused by third parties (e.g. by protests or vandalism)	These factors would need to be considered at design stage in detail to avoid unanticipated situation during operation.
2.23. Change of law	TA/ Operator	Some of the main regulatory changes that increase risk to TA/operators include • Misalignment among authorities and the reality of the system. • Tax reforms not considering transit system needs. • Changes in labour regulations.	The Change of law provision in concession agreement is beneficial for both TA and Operator. If this is absent, the operator will provide for more contingency margin and cost of capital and price will increase.
3. Revenue Risk			
3.1. Ridership	TA/ Operator	The TA is affected by ridership risk in case of Gross Cost Contracts (GCC) and departmental operations. Further even in case of net cost contracts (NCC)/PPP, although the Operator bears the immediate revenue risk, in the long run the TA	The TA is in the best position to drive the ridership through influencing suitable transportation policies, route rationalisation, frequency of operation, fare policies, curbing unauthorised operations etc. and hence this risk should be in the scope of the TA. TA shall also have the ability to direct subsidies at particular user groups e.g. the provincial

		ultimately affected which may manifest in the form of early termination of the concession and future concessions being more expensive for the TA. Ridership risk may arise due to: • variations in economic and demographic variables • Policies favouring use of private modes such as new roads, low taxes, lack of parking control • User preference to informal modes (bike taxis, shared taxis, etc.), unauthorised services • Introduction of other mass transit systems	Government of Delhi, India has decided to make public transport free for women users and compensate the Operators for the loss of fare (The Economic Times, 2019).
3.2. Fare Escalation	TA/ Operator	The TA and/or Operator as the case may be, face the risk of delayed or non-revision of the fares owing to public/political pressure. e.g. Delhi Metro suffered for years from delays in revision of fares by the Government (The Business Line, 2013).	As mentioned above, ridership and fare policies are closely related and hence the TA should bear both the risks. E.g. BEST, the Mumbai bus transport authority, reduced fares for lower slabs to attract more riders (DNA India, 2019)
3.3. Fare evasion	TA/ Operator	In the event that buses do not have on-board ticketing system (and to a lesser extent if they do), there arises a risk of riders not buying any ticket or buying short tickets and thus not paying or under paying fares. In the bus component of Santiago de Chile's transit system the average evasion rate is over 20% (Guarda et al., 2014). Factors contributing to fare evasion risk: • fare prices not in line with user's purchasing power	The operator lacks punitive powers. Hence, it's best that the TA controls the risk of fare evasion by suitable regulatory, inspection and control mechanism.

		• Lack of awareness of payment methods • Insufficient or difficult-to-reach payment locations • Lack of sense of belonging among users. • Wrongly oriented subsidies • Vulnerability of the smart card system. Complicity of drivers/conductors	
3.4. Advertising	TA/ Operator	Advertisement forms a small but important source of income for the public transport. There may be conflict of interest issues in utilisation of advertisement income on assets owned by another party.	While the TA owns the permit/service concession, the Operator may own the asset on which advertising is displayed. The TA has more influence in getting requisite permissions than individual operators. Thus, cooperation of both are required to achieve optimum revenue potential. It is better to allow the TA to coordinate and control the advertisement efforts due to economy of scale and consolidation of the media and the operator may be given a share of the net advertising income.
3.5. Carbon Credits	Ta/ Operator	e-bus Projects can claim GHG emission reduction credits subject to prevailing framework for earning and selling the credits.	The Carbon credit market is very uncertain and volatile. It is better to share the income between the TA and the Operator as it requires substantial effort to register CDM projects, earn and sell the credits.

C40 Cities Climate Leadership Group
3 Queen Victoria Street,
London EC4N 4TQ
United Kingdom

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Potsdamer Platz 10
10785 Berlin
Germany

E contact@c40cff.org
W c40cff.org

Funding partners:

Federal Ministry for Economic Cooperation and Development

CIFF CHILDREN'S INVESTMENT FUND FOUNDATION

UK Government

USAID FROM THE AMERICAN PEOPLE

Implementing agencies:

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