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

Project Summary Report

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).

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1. PROJECT CONTEXT & OBJECTIVES

The Bangalore Metropolitan Transport Corporation (BMTC) envisions to upgrade its bus fleet (mostly BS IV diesel buses) to electric buses (e-buses). The transition will happen in phases, starting with an initial deployment of 300 + 90 e-buses, which will be gradually introduced while the different challenges regarding e-bus infrastructure, technology, and business models are evaluated and addressed. BMTC estimates that the transition to an all-e-bus fleet could reduce greenhouse gas (GHG) emissions by up to 51,460 tons of CO2 per year.

Bengaluru was identified as one of CFF's partner cities for adoption of Zero Emission Public Transport in 2019 and a Memorandum of Understanding for implementing the Technical Assistance (TA) Project was signed between CFF Implementation partners and BMTC. The main objective of this TA project was to plan and realise the transition to an all EV / Clean fuel PT fleet until 2030 as indicated in present BMTC's Vision-2030 Document.

In order to fulfil the TA commitments, CFF engaged Deloitte Touche Tohmatsu India LLP for gap assessment across the value chain of e-bus lifecycle in relation to the project proposed by the city of Bengaluru. The Deloitte Report assessed the preparedness of BMTC for e-bus transition and identified gaps in strategic planning, technical competence, infrastructure and bus operations. A detailed work plan was developed to identify intervention areas and fixing roles and responsibilities of different stakeholders in addressing them.

Subsequently, GFA Heat International GmbH was engaged by CFF from March – October 2020. GFA HEAT GmbH was assigned to structure a long-term e-bus transition strategy for BMTC through a complete and comprehensive procurement package comprising of a strategic Business Case and Project implementation and procurement strategy. Additionally, TA provided support for draft contract and RfP finalisation with detailed procurement process, for the ongoing e-bus procurement under FAME-II. In doing so, the project scope has included the preparation of additional supportive project documents (such as e- bus Technology and Infrastructure Planning, Market Consultations and Gender & "Leave no One Behind" Analysis) that complement the e-bus procurement process.

2. PROJECT OUTPUTS

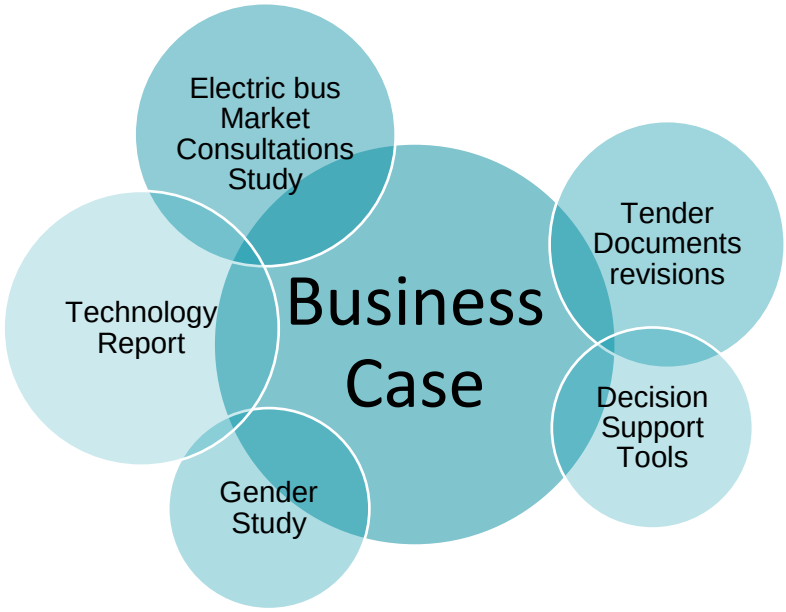
Under the TA, 6 project outputs were developed by experts of GFA Heat International Gmbh through primary surveys, consultations, studies and related activities. The results of each of these documents were separately presented to BMTC and with their inputs incorporated before finalising these outputs. These outputs comprising of Reports and Studies are to support BMTC while making critical decisions during the transition to an e-bus fleet-based operation, as outlined in BMTC's Vision 2030.

The project outputs are shown in Figure 1. The assumptions on the e-bus transition phases steered the assumptions made in the other studies and reports. Conversely,

the findings of these Reports and Studies guided the preparation of Business Case (BC) for e-bus transition within BMTC.

In addition to studies and reports, the TA has provided two excel based technical tools to assist BMTC with (1) **B**attery **E**lectric-bus **A**doption **S**upport **T**ool (***BEAST***) and (2) financial analysis (***ZEBRA tool***) for comparing e-bus procurements through outright purchase, outsourcing or leasing models. Additionally, a draft financial model, prepared under this TA for the strategic Business case of full transition, is provided for further assistance of BMTC.

Figure 1: Project Outputs and their integration



A brief detail of each of the project reports (viz. objectives, approach and main findings) is available in following sections while details can be found in respective reports.

2.1. Gender Equality and Social Inclusion in Electrification of BMTC Fleet

From an overview of gender and socially inclusive policies adopted by BMTC and findings of a user perception survey of BMTC services and infrastructure, this report develops a Gender Equality and Social Inclusion Action Plan (GESI/AP) to make a transition to gender and socially inclusive Public Transport (PT) service by BMTC. The methodology included a secondary literature review, creating a problem tree, conducting primary PT user perception surveys and preparing GESI/AP.

The literature review revealed that BMTC already offers a spectrum of PT services catering to the mobility needs of a cross section of society including economically weaker and marginal sections. BMTC is also sensitive to working women commuters

and therefore many initiatives to improve the safety and comfort of women in buses, like reserved seats in ordinary buses, CCTV cameras inside buses, 22 ladies special bus services have been operationalized.

User perception surveys revealed that 83% of female respondents were satisfied with BMTC services during day but this dropped to 68% for night services. Major user concerns seemed to be high travel costs, high travel time, low level of safety, security and comfort. The findings of the user survey were used to create the GESI/AP to identify indicators, responsibilities and timelines (See Table 1 below) for BMTC to consider a phased implementation.

Table 1: Gender Equality and Social Inclusion Action Plan

OUTCOMES	1. By 2032, women's ridership in BMTC services in the peak hours increases to 40%. (Baseline 2011: 32%[1]) 2. Women's satisfaction of BMTC services improves. (Baseline: 2.96/4.0, 2020)		
OUTPUT 1: BMTC BUS SERVICES AND ACCESS ARE GENDER AND SOCIALLY INCLUSIVE			
Activity	**Indicators/Targets**	**Responsibility**	**Years of Implementation**
1.1 Access to BMTC bus stops, bus shelter design and vehicles are gender and socially inclusive.	1. At least 20% of the standard e-bus fleet has low-floor buses. (Baseline 2018: 20%)	BMTC Gender Nodal Officer (GNO), GESI Expert	1-12
	2. All buses are equipped with emergency buttons and CCTV cameras.		
	3. All buses have (i) reserved seats for care givers, women, elderly and PWD; and (ii) all standard buses have space for a wheelchair/ stroller.		
	4. All bus stops [2,122] have well-lit, universally accessible shelters. (Baseline 2020:0)	Bruhat Bengaluru Mahanagar Palike	1-5
	5. Well-lit, universally accessible footpaths are constructed within 400m of 2,212 bus stops, as per IRC:103-2012.		
	6. Sarathi vehicles, deployed in the day and night, address incidents related to women's safety within 10 minutes of reporting.	BMTC GNO, GESI Expert,	

1 Women's work trips.

		Bangalore Police	
	7. A study is conducted to assess the feasibility of fare concessions for lower-income groups, and trans persons.	BMTC GNO, GESI Expert	1-2
OUTPUT 2: BMTC BUS STATIONS AND TTMCs ARE IMPROVED.			
2.1 BMTC bus stations and TTMCs are safe and accessible.	8. 3 major bus stations, 27 bus stations and 10 TTMCs have (i) well-lit separate, free, clean public toilets for men, women and a universally accessible gender-neutral toilet, accessible by a step-free route with tactile pavers; (ii) breast feeding rooms; (iii) 1 helpdesk with at least 2 trained staff; and (iv) 2 accessibility officers	BMTC GNO, GESI Expert	1-12
	9. 3 major bus stations have separate waiting rooms for men, women, families and trans persons with clean public toilets and showers.		
	10. Consider leasing at least 33% of commercial spaces at bus stations and TTMCs to women owned MSEs or SHGs.		
OUTPUT 3: INFORMATION AND COMMUNICATION SYSTEMS ARE ESTABLISHED.			
3.1 BMTC communicates with users regularly and effectively.	11. The BMTC website and mobile phone application is universally accessible and updated regularly. The website has (ii) a dedicated section on all initiatives for EWCDT; (iii) map and information on amenities available in each bus station and TTMC.	BMTC GNO, GESI Expert	1-2
	12. An integrated, accessible PIS is developed across multiple media channels.		
	13. Information on gender and socially inclusive features in buses, travel etiquettes, helpline, zero tolerance to sexual harassment, and gender-specific audio/video/visual bilingual messages disseminated in all buses, 2,212 bus stops, 29 bus stations and 10 TTMCs.		1-5
	14. Sexual harassment complaints reporting, redressal system and SOPs is developed and adopted by BMTC.	BMTC GNO, GESI Expert, Women's	1

		Safety Committee	
OUTPUT 4: INCLUSIVE STRENGTHENING OF BMTC			
3.1 BMTC is a gender and socially inclusive agency.	15. A senior advisor/staff appointed as Gender Nodal Officer (GNO) and a full-time GESI Expert is recruited.	MD, BMTC	1
	16. BMTC HQ has (i) 1 creche; and (ii) separate, free, clean public toilets for men, women and a universally accessible gender-neutral toilet, accessible by a step-free route with tactile pavers.	BMTC GNO, GESI Expert	
	17. Women's Safety and Access Committee is constituted and meets quarterly.		
	18. At least 33% of BMTC personnel are women and trans persons. (Baseline 2020: 8.8%)		1-12
	19. At least 33% of selection grade and senior staff of Class-1 employees are women. (Baseline 2020: 3 out of 31, 2020)		
	20. (i) At least 10% of all drivers are women and trans persons; (ii) At least 50% of conductors are women. (Baseline 2020: 0.03%; 29.8%,)		
	21. At least 4% of personnel are differently abled, as per Rights of Persons with Disabilities Act, 2016. (Baseline 2020: 0.17%)		
	22. Annual sex-disaggregated user satisfaction surveys are conducted.		
3.2 Develop and implement GESI training modules	23. All BMTC staff receive annual training on the anti-sexual harassment policy and creating a gender equitable environment.	BMTC GNO, GESI Expert	1-12
	24. All BMTC bus drivers/driver-cum-conductors, conductors and depot managers receive GESI training, during induction and bi-annually.		
	25. 95% of staff responsible for BMTC traffic, operations, planning and infrastructure, receive annual technical GESI capacity development training.		

The Report concludes with an Implementation Note that provides specific guidance to achieve selected targets mentioned in the GESI/AP.

2.2. Electric Bus Market Consultation Study

This report provides a complete and up-to-date overview of the e-bus market players, with specific focus on providers interested or currently operating in India. The study objective was to collect information about e-bus market and its future scenario in India, present experiences of e-bus adoption across Indian cities, identify key challenges and potential mitigation measures that will aid BMTC to achieve the long-term e-bus transition plan.

Desk research work identified 20 key stakeholders in Indian e-bus eco-system representing Research Organizations, DISCOMs, Financial Institutions, EVSEs, Bus Operators, OEMs and Regulators. It was followed up with consultations through virtual meetings between July to August 2020. Main findings from these consultations are tabulated in Table 2 below:

Table 2: Main findings from consultations with electric bus market players

Thematic Areas	Main Findings
Policy & Strategy	A long-term plan for phased deployment around bus route operations is required. Initially large scale EV adoption is not required. A mix of diesel and e-buses and a gradual shift to full e-bus fleet is recommended
	From manufacturers perspective, a large-scale e-bus transition over a reasonable duration will facilitate faster technology stabilization and economically feasible.
	Govt. of India should incentivize EV value chain stakeholders to: • expand technology access to more operators, • install charging infrastructure, • build power distribution network, • promote renewable sources of power, as much as possible. • *Subsidies are necessary for next 5 years until Total Cost of Ownership (TCO) parity with diesel buses is reached.*
Technology Adoption	Initially, deploying a mix of e-bus technologies will enhance learning for BMTC as their performance in city conditions will be known.
	To reduce e-bus costs, standard floor heights for all types of e-buses is recommended. Allied infrastructure will require necessary upgradation for comfortable and convenient boarding and alighting of all passengers, ensuring universal accessibility.

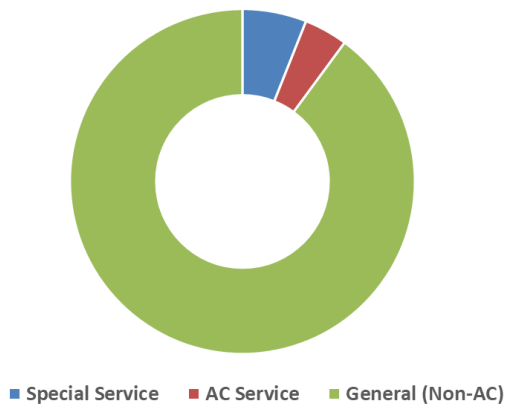
	System wide standardization, inter-operability and scalability across different e-bus technology platforms should be ensured during the e-bus procurement process
Financial Planning and Funding Support	Attractive PPP terms are available to bridge high CapEx and address the dynamic needs of BMTC's city bus operations. Instead of a single-party PPP model, multi-player models for specialized services make better business sense to sustain complex and large e-bus networks and services.
	For financing support from global funds/ private banks/ institutions, project-based proposals rather than vehicle-based proposals are recommended.
	Cost rationalization through appropriate project sizing and technology selection will present better funding opportunities and lesser financial cost to the operator.
Procurement Strategy	Appropriate project sizing, sub-project formations coupled with scale and duration of contracts/ concessions will be important part of procurement strategy for e-bus adoption.

2.3. Electric Bus Technology and Infrastructure Planning Report

The adoption of e-bus technology is critical to the long-term success of BMTC's e-bus transition process. This report aims at providing recommendations about the most appropriate e-bus technologies to be deployed for the next ten years. This is an important aspect of this project since the decision about technology selection will impact BMTC's decisions and policies in sustaining the transition to e-buses.

The e-bus technology system has three key elements - Powertrain Technology, Charging Stations & Infrastructure and Power supply. Technology selection and its mix, for BMTC's full transition over the next decade, will be guided by its services and operational requirements (both present and future), technology availability and applicability (both in present and in future) alongside the financial implications and expected economic and social impacts of transition. Based on the BMTC route and schedule operations characteristics an e-bus technology transition plan is developed.

Figure 2: BMTC Services' Distribution



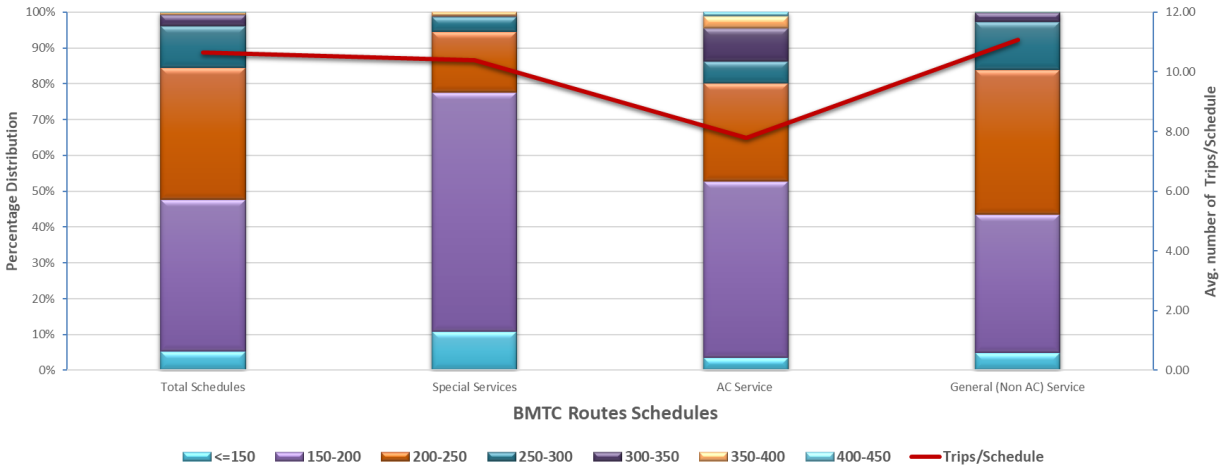
BMTC has 2200 routes served by 6700 buses. The buses are primarily standard size non-airconditioned (non AC) buses alongside almost 800 Volvo AC buses and rest as Midi non-airconditioned buses. The route operations are categorised as General non-AC services, AC service and Special services (Figure 2) that cover Big 10, Atal Sarige,

Trunk, Metro Feeder, Chakra, City bus terminal services. The total daily bus trips are of the order of 65,800 carrying 3.5-4 million passengers, before COVID lockdowns.

2.3.1. Operations Categorization by Daily Kms/Bus

The route length distribution of different BMTC services is analysed for an overview of daily range and bus fleet deployed. BMTC operations have larger share of daily bus kms of the order of 150-200 and 200-250 (Figure 3). An analysis of BMTC's daily bus schedules average more than 10 round trips.

Figure 3: Daily Km coverage by different types of BMTC schedules



The average kilometre run for the e-buses in Bengaluru would range between 60,000 kms to 80,000 kms annually along different routes. Since the cost parameters of an e-bus primarily depend upon the distance covered per day and charging time availability, a schedule is considered to be the primary unit of analysis. Understanding route length along with daily total km and peak and off-peak headway for each route would help determine the battery size and required number of chargers at depots and terminals. Accordingly, various battery sizes are recommended for BMTC in Table 3. However, these need to be verified based on actual daily utilization kms.

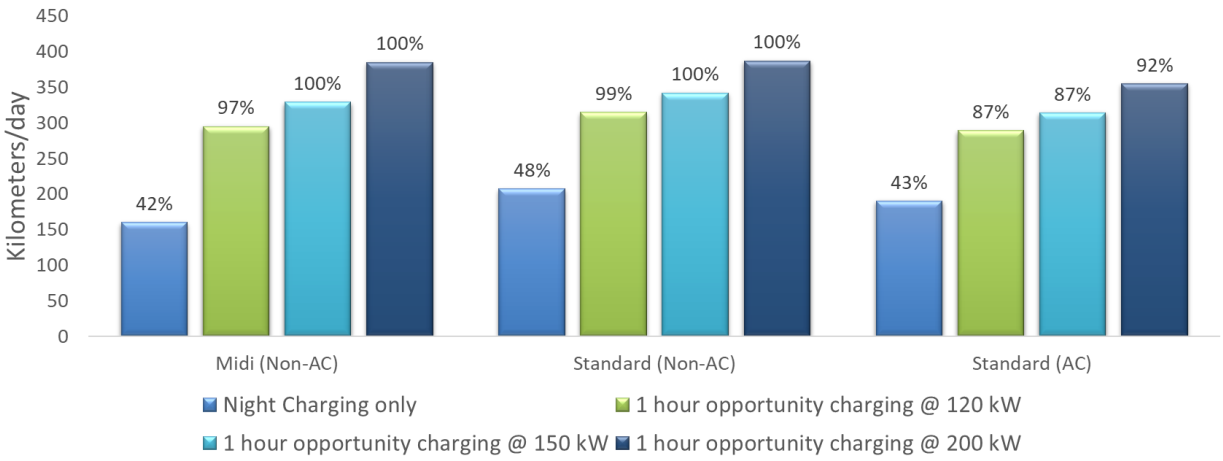
Table 3: Battery size choice for BMTC based upon route lengths

Route Length	Battery Size	Remark
Upto 10 kms	Small Battery Size (<150 kWh)	Smaller battery size with opportunity charging is also an option. TCO should be calculated for both cases i.e. Large battery with Slow charging Vs Smaller Battery with Slow/ Opportunity Charging
10-20 kms	Medium Battery Size (150-250 kWh)	
More than 20 kms	Big Battery Size (>250 kWh)	

2.3.2. Battery and Charging Combination for BMTC Operations

For an analysis of suitability of available e-bus battery sizes, their operating ranges and charging strategies, the ranges of different BMTC bus types are analysed. For an electric midi-buses, with only overnight charging option, the achievable range is only 160 kms (covering ~42% of BMTC's scheduled trips). However, the range can be increased to 295 kms with 1-hour fast charging @120 KW, resulting in 97% coverage of the schedules. With one hour of fast charging @150 KW, midi-electric bus can cover 329 kms covering 100% of the existing BMTC midi bus schedules. Figure 4 shows percentage of midi bus, standard non-AC and standard AC bus schedules for combination of battery size and charging solutions.

Figure 4: Battery size and charging solution combinations for BMTC bus schedules



By adjusting the battery size for achieving the desired range, it is estimated that for midi buses, a battery of 125 kWh with one-hour of fast charging will result in range of up to 300 kms per day. For standard non-AC and standard AC buses, battery size of 150 kWh with one hour of fast charging will result in a range of about 280 kms per day.

2.3.3. Roadmap of Technology Adoption by BMTC

Based on availability and expectations of technology upgrades over the short to medium term, an overall summary on e-bus technology adoption is summarised in Table 4 below for a three-phase transition over 2021-25, 2026-29 and 2030-32, based on slow and gradual transition approach.

Table 4: Roadmap of the e-bus technology adoption

E-bus Technology Element	2021-2025	2026-2029	2030-2032
Battery Technology	LFP and NMC	LFP and NMC, testing with LTO and NMCA	LFP, NMC, NMCA & LTO and other technologies evolving in the market for urban buses to be tested.
Battery Size	Bigger Battery: Daily utilization kms >200kms	Bigger Battery: Daily utilization kms >200kms	Bigger Battery: Daily utilization kms >200kms
	Medium size battery: Daily utilization kms 125kms-200kms	Medium size battery: Daily utilization kms 125kms-200kms	Medium size battery: Daily utilization kms 125kms-200kms
	Small size battery: Daily utilization kms 75kms-125 kms (Feeder services)	Small size battery: Daily utilization kms 75kms-125 kms (Feeder services)	Small size battery: Daily utilization kms 75kms-125 kms (Feeder services)
Electric Motor Ratings	120 kW (minibus) / 160 kW (midi-bus) / 200 kW (standard bus)	120 kW (minibus) / 160 kW (midi-bus) / 200 kW (standard bus)	120 kW (minibus) / 160 kW (midi-bus) / 200 kW (standard bus)
Charging Options	Combination of Depot Charging and Opportunity Charging: Based on range extension needed, headway and dead kms	Combination of Depot Charging and Opportunity Charging: Based on range extension needed, headway and dead kms	Combination of Depot Charging and Opportunity Charging: Based on range extension needed, headway and dead kms
	Thumb rule: One slow charger for three buses (1:3)	Thumb rule: One charger for three buses (Slow chargers)	Thumb rule: One charger for three buses (Slow chargers)
	One fast charger for five buses (1:5) (When the deployment is spread and there is not enough scale). However, needs to be determined based on actual operations.	One fast charger for ten buses (1:10) (As the e-buses scale-up across the city). However, needs to be determined based on actual operations.	One fast charger for ten buses (1:10) (As the e-buses scale-up across the city). However, needs to be determined based on actual operations.

On the basis of fleet replacement policy, being followed by BMTC, and fleet age profile of different bus types, a phased e-bus deployment plan is prepared for working out of the strategic business case of full transition (refer Table 5).

Table 5: Phased deployment of electric buses by type

	Midi (Non-AC)	Standard (Non-AC)	Standard (AC)	Total	
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%

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 project details and implementation plan from 2021 onwards. The project implementation is divided into three phases 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***.

2.4. Business Case for Full Electrification of BMTC Fleet – Part 1 Financial Analysis and Funding

2.4.1. Business case basis

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;
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 fewer moving parts and hence **maintenance cost is lower** and expected to last longer.
5) Electricity is not prone to pilferage unlike diesel.

The business case study investigates the desirability, viability and achievability of all stakeholders to invest the needed amounts. It also offers a communication strategy for BMTC to showcase this project convincingly to the public. The BC report has been prepared in two parts: Part 1 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.

2.4.2. Business case scenarios

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

1. **Business As Usual (BAU)**: This scenario assumes all future fleet replacement will be using diesel buses of BS VI standard.
2. **Base Case Scenario**: Electrification of present fleet of 6,697 buses.
3. **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 Base case and Augmented fleet scenarios, where only e-buses are used for replacing existing diesel fleet from FY 2022 onwards. The entire electrification project is divided into three phases over 12 years implementation period.

2.4.3. Implementation Options

The e-bus implementation options arise from the wide range of kilometres covered by the BMTC buses daily. Three options were developed which determine the cost of owning and operating e-buses for BMTC as follows:

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 summary of evaluation of the options is presented below. *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 e-bus makes for better business sense than the status quo.*

A financial summary and evaluation of identified options is shown in Table 6.

Table 6: Financial evaluation of electric bus transition options for base case scenario

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%

In addition to the financial benefits to BMTC, the electrification project will also benefit the environment by reducing the emission of particulate matter (by 7335 tonnes p.a.) and noise pollution (by 23 dB), Forex outgo (by USD 175 p.a.) and GHG (by 0.45 MTPA).

2.4.4. Funding Options

This financial analysis shows that the electrification project will be highly beneficial for BMTC as well as the Bengaluru city. The investment requirement to implement the project 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 in Table 7 below:

Table 7: Year wise e-bus financing requirements for BMTC (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		24,464		39,815

In view of the sizeable requirement of funds, the following funding scenarios are evaluated with different levels of public private participation (PPP):

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

The proposed funding structure (Table 8) looks at three different funding structures for BMTC to finance e-bus fleet deployment. The private funding options include gross cost contracting, wet leasing, leasing of batteries, PPP for charging infrastructure etc. The public funding options include loan/equity/grant assistance from Government of Karnataka/ Urban Transport Fund, grant from Govt. of India, concessional loans from state financing institutions like KUIDFC, bilateral and multilateral organisations.

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

Table 8: Proposed funding structures for BMTC (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**

From the phase-wise financial analysis, it is seen that except Phase 1, the e-buses are financially better than diesel buses on life cycle cost basis and hence no grant/subsidy is envisaged in Phases 2 and 3. Therefore, the project deserves to be financially supported by the Govt. of Karnataka.

2.4.5. Risk Assessment and Mitigation

Following four sources of risks to BMTC are envisaged during e-bus transition project implementation:

Product risks on account of tech reliability, price and levels of energy consumption.

Financing risks from BMTC's fragile financial condition alongside expected OpEx escalations, decline in ridership levels and inability to increase fares.

Operational risks arise from city's unfavourable driving conditions causing service delays, trip cancellations resulting in low bus ridership levels.

Traffic revenue risks as a consequence of operational risks resulting in lower farebox collections, fare evasion/pilferage and inability to exploit non-traffic revenues.

A detailed list of risks and mitigation measures, corresponding to above primary risks, is prepared for BMTC to study and utilise for transition to e-buses.

In conclusion, bus fleet electrification will help BMTC to reduce the operating costs significantly. But the high initial cost of e-buses, limited operating range, constraints of creating charging infrastructure etc. constitute stumbling blocks to smooth e-bus transition for BMTC. Despite the high initial capital requirement, it is financially

beneficial to BMTC in addition to the equally significant environment benefits resulting from this transition.

2.5. Business Case for Full Electrification of BMTC Fleet – Part 2 Implementation and Procurement Strategy for Transition to Electric Bus

2.5.1. Need and Suggested Approach

The e-bus technology adoption is very closely linked to route operational characteristics such as duration of operations, daily distance coverage by e-bus, availability of gaps in operations for possible recharging, service level requirements and passenger load levels. The business case analysis for full transition of BMTC fleet operations to e-bus technology, as carried out under this technical assistance, has indicated that such a transition is expected to be financially viable over medium to long term than diesel-based operations of buses.

Adoption of e-bus technology, combined with a review of operational planning and service delivery, would not only bring medium to long term operational improvements but also prospective cost reductions, service level improvements and user satisfaction. The implementation strategy coupled with the procurement strategy, for transitioning to e-bus technology, will provide a structured approach and guided timelines of scale and nature of transition. This would simultaneously project BMTC and government's commitment to this transition that in turn further benefit BMTC through strong tie ups with industry, technology and academia.

Suggested approach for transition to new technology vehicles is a multi-faceted outlook covering necessary aspects as listed and shown in Figure 5 below.

Figure 5: Suggested approach for implementation and procurement strategy

1. Long term commitment and strategy, depicting clarity and flexibility
2. Start E-bus adoption early and gradually
3. For E-bus technology - one size fits all approach is costly and inefficient. Multiple technology choice suiting broad route/schedule operational categories
4. Market study and consultations with vendors to understand cost implications for available and expected advancements
5. Develop partnerships with city agencies, vendors, industry and R&D institutions
6. Adoption of PPP for technical backup and transfer of risks
7. Adopt a Project based approach for timely and definitive path to transition as planned
8. Training and Capacity building of staff
9. Combine technology transition with ongoing/prospective service delivery improvements

2.5.2. Implementation Strategy

Transitioning or shifting to a new technology is imminent but at the same time not an easy proposition for BMTC, given its financial condition and social obligations. BMTC may consider adopting a two-pronged strategy for induction of e-bus fleet – one through small pilot projects for immediate induction and second through an adoption plan over short, medium to long term. The organisation is already on its way to start pilot projects of e-bus induction into its fleet through two tenders. Additionally, preparation of detailed plan of gradual e-bus induction, either as replacement or augmentation or both, over coming years needs to be initiated. Primary component of implementation strategy comprises (1) defining the project, strategy of adoption and timelines, (2) constitution of Pilot E-Bus Project Implementation Unit (PPMU), (3) constitution of an E-Bus Project Implementation Unit, (4) Constitution of Special Purpose Vehicle(s), and (5) external e-bus project advisory and support.

A schematic view of suggested implementation strategy for long terms and gradual transition to e-buses is shown in Figure 6.

2.5.3. Procurement Strategy

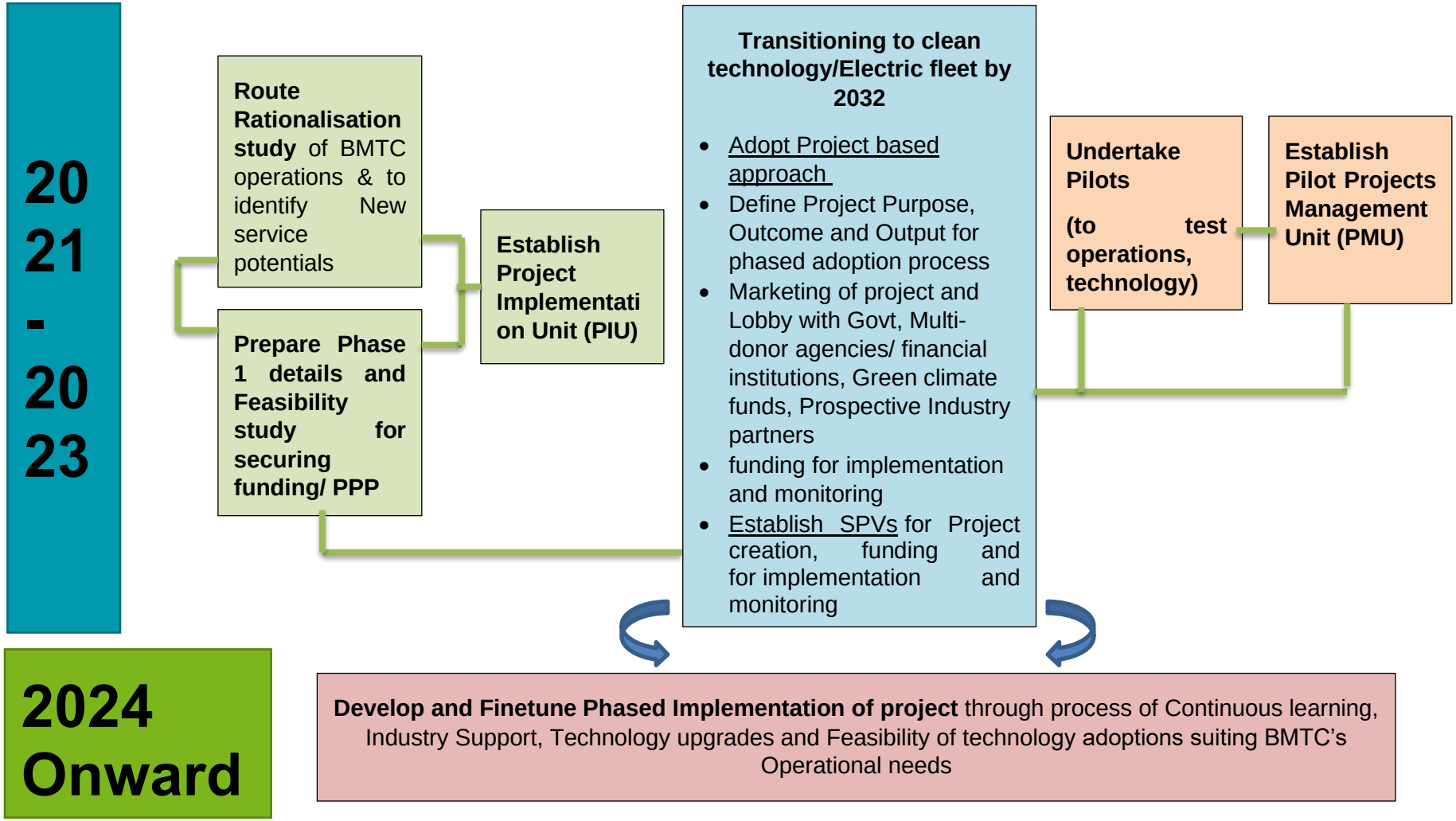
With implementation strategy providing an overall structure, direction and push to the e-bus induction and transition within BMTC, adoption of a procurement strategy will provide a functional platform and engine of transition, in line with the identified scale, pace and outcomes.

BMTC has been operating Diesel and CNG buses, procured through outright purchase model and has been carrying out all operational and maintenance activities mostly in-house. With this practice, outright purchase model may seem attractive for induction of new technology e-buses. However, BMTC's technical and funding limitations, for transitioning from diesel to electric/clean fuel-based bus operations, requires shaping up of a procurement strategy to assist and guide for cost efficient and qualitative transition to a technology that is costly to acquire and is still undergoing maturity and cost corrections.

The purpose of procurement is primarily to **raise capital, acquire assets and garner skill-based support in a timely and cost-effective manner ensuring minimum requisite quality**. Accordingly, basis of procurement strategy for e-bus technology induction will be guided by envisaged scale of operations and timelines, availability of budgets and funds as well as organisational capacity and capability profiling. BMTC may like to enhance the e-bus project support by partnering with government and private sector entities. A schematic presentation of procurement strategy is shown in Figure 7.

Further for large transitions, expected in each phase of the order of 2,000 buses or more, it will be advisable to break the total e-bus project into smaller, more manageable sub projects. The project breaks up could be across functionality or service packages as conceptually shown in Figure 8 and Figure 9. The breakup into smaller sub-projects will add to the complexity of implementation while facilitating cost effective and qualitative procurement. BMTC staff will require training and BMTC will need organisational strengthening to handle multiple projects, tenders and contracts.

Figure 6: Electric bus transition project implementation framework



Funding partners:

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

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Figure 7: Large scale electric bus procurement strategy framework

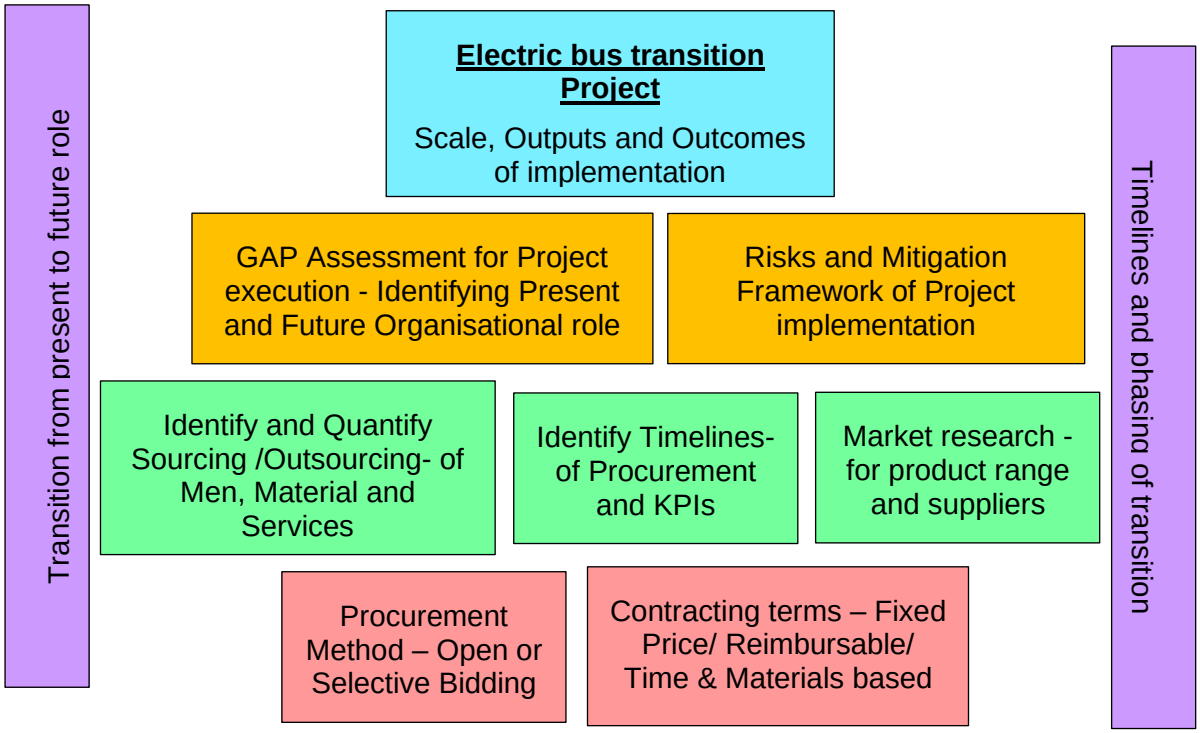


Figure 9: Conceptual Electric bus sub-projects breakup across functionalities

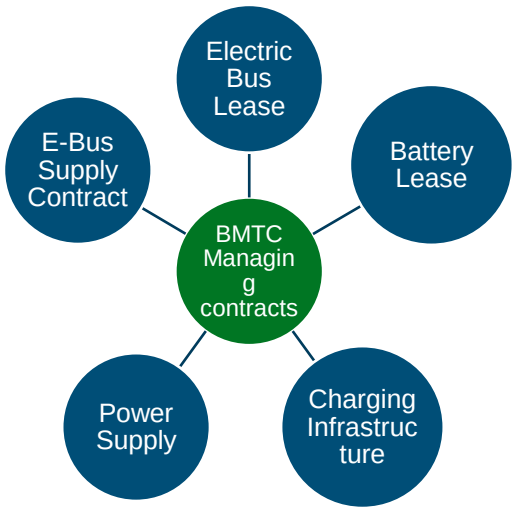
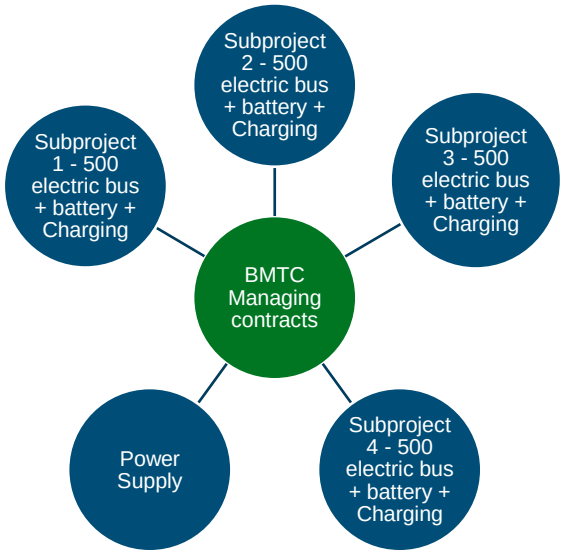


Figure 9: Conceptual sub-projects breakup across fleet size and functionality



BMTC may adopt a **combination of outright purchase and PPP models** for e-bus transition depending upon capacity and capability built within and outside of BMTC.

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2.6. IT Decision Support Tool

Making the right decision and choosing the proper course of action in the three phases of e-bus deployment can be challenging, especially when all the possible data required for decision-making is not available at their disposal. This issue can still be complex when decision makers have some insights but without a software tool, the connection between the available data/ information and rational decision making gets difficult.

Decision support tool is a software developed to support decision makers in taking better and faster decisions. DSTs merge deep analytical frameworks, helping users to improve the way they approach the available information and provide valuable insights in the contexts that surround them. This aid decision makers in taking better informed decisions from the outputs of the DSTs.

On request of BMTC, the following two Microsoft Excel based DSTs have been developed and customised for BMTC.

2.6.1. ZEBRA financial modelling tool

The Zero Emission Bus Rapid Deployment Accelerator (ZEBRA) Financial Modelling Tool was developed for accelerating the transition to zero emission buses across Latin American cities by C40, as one of the partners. This dynamic tool can estimate the financials for transitioning to e-buses under various scenarios of project funding and structuring (Figure 10). The purpose of this Tool is to support stakeholders (Bus Operators, Financial Institution/s and Third Parties) understand the financial implications of transitioning to e-buses in different e-bus procurement and financing scenarios.

Figure 10: Components of ZEBRA tool inputs, outputs and analysis platform

Tab	Description
OUTPUTS	**These are calculations pages, the user should reference but NOT change**
Output graphs	Provides a summary that compares the four scenarios. This includes a comparison of their expected IRR, NPV, and projected cash flows.
Diesel - Financials	Projects cash flows of buying a determined amount of diesel buses, defined by the user of the model in scenario inputs, financed at commercial rates.
EBUS 1 - Financials	Projects cash flows of buying a determined amount of e-buses in a commercial arrangement, defined by the user of the model in scenario inputs
EBUS 2 - Financials	Projects cash flows of buying a determined amount of e-buses in a commercial arrangement, defined by the user of the model in scenario inputs
EBUS 3 - Financials	Projects cash flows of buying a determined amount of e-buses in a commercial arrangement, defined by the user of the model in scenario inputs
INPUTS	**These are pages for the user to input raw data and assumptions for the current operator business model and the e-bus commercial arrangements they wish to model, in order to estimate financials**
Scenario inputs	Allows user to define three scenarios of commercial arrangements to model. The user can select e-bus assets to purchase, specify the number of each, and adjust ownership
Bus system - rev & costs	Allows user to input information about the revenues of the system and costs all types of buses will have (e.g., driver salaries, admin). This includes the remuneration scheme for each bus.
Diesel buses - costs	Allows the user to input cost information about diesel buses, including CAPEX, OPEX, etc.
E-buses - costs	Allows the user to input cost information about e-buses, including CAPEX, OPEX, etc.
INTERM CALCULATIONS	**These pages have all intermediate calculations. Users should not edit these pages, but they may reference them.**
SOURCES	These pages have all data sources, for users to see where data is being sourced.

Through a set of five output graphs the ZEBRA model summarizes the financials in four scenarios - Diesel, e-bus Type I, e-bus Type 2 and e-bus Type 3 – Financials. The financials include IRR, NPV calculations, Income Statement, Cash Flows, Balance Sheet and TCO. This tool focuses on a specific investment in an individual procurement. Therefore, it cannot be used for fleet transition through a series of procurements over time.

Based on the available data gathered from BMTC and during stakeholder interactions, the model inputs were systematically revised. This Tool has been demonstrated and has been made available to BMTC.

2.6.2. Tool for e-bus technology choice (BEAST)

2.6.3. Features

A Battery Electric-bus Adoption Support tool **(BEAST)** is prepared for BMTC, to guide selection of battery size and charging solution for a given route or schedule operation (Figure 11). Corresponding inputs of CapEx and OpEx elements of diesel and e-buses are provided by the user. Additionally, the e-bus technology features and other general inputs are used in the tool functionality, and are open for user to change. Accordingly, the tool inputs are divided into three parts:

1. Selected Route/Schedule information considered for e-bus operation,
2. Capex and Opex based inputs, and
3. Electric and diesel bus technology inputs.

The tool computes most cost-efficient combination of battery size and charging solution (Only Depot based slow charging Or Depot Charging supported with Opportunity charging). The CapEx and OpEx per kilometre are displayed for the recommended e-bus technology solution alongside the diesel BS-VI bus cost parameters. The tool additionally displays the reduction in annual CO_2 emissions by shifting from diesel to e-bus.

2.6.4. Outputs

The graphics interface of the tool displays four graphics to showcase the variation analysis for average cost per km of diesel and e-bus corresponding to battery size and daily km range variations. The tool outputs the battery size and replacement ratio variations and recommend the combinations corresponding to the minimum cost per km.

The tool allows to save the outputs of each run as a PDF document (refer Figure 12) that can be saved with desired file name to reflect the scenario run. Once all desired runs of the tool are made, the collective pdfs (for each run) can be studied to analyse and decide on next steps of e-bus transition for a route.

2.6.5. Applications

1. Select battery size, charging strategy and replacement ratio for given avg. pax load, type of bus, km range required,

2. Estimated environmental benefits of e-bus-based operation,
3. Support BMTC in operational planning and performance monitoring of schedules to be transitioned/transitioned to e-bus,
4. Have a per km rate assessment for inviting tenders of e-bus operations or lease out of buses + operations. Accordingly decide for outright purchase or outsourcing,
5. suitable procurement rates for bulk purchase of e-bus components (e-bus body + chassis and Battery), and
6. Test at what rates and levels of base inputs, e-buses draw cost parity or perform better than diesel bus.

Figure 11: Primary BEAST instructions for usage

Funding Partners:

Implementing Agencies:

Winner of the 2020 United Nations Global Climate Action Award in the category "Financing for Climate Friendly Investment"

User Guide and Instructions

OBJECTIVE OF THE TOOL: To determine the optimum charging strategy and battery size for a schedule

This tool provides TCO based on the assumption that the buses are owned and operated by the Authority. It does not give expected GCC rates.

Capital Subsidy is considered independent of battery size.

Inputs: The insputs related to operating costs, propcurement costs etc should be regularly reviewed and updated for more accurate results.

Schedule Inputs are to be provided in the "Tool" as follows:

- Bus Type: Choose from drop down list (Midi-9m Non Airconditioned, Std NonAc- 12m non airconditions and Std Ac - 12 m Airconditioned
- Operating Hours : Number of hours of operation excluding empty runs (from/to Depot)
- Maximum charging at terminal - In case opportunity charging is possible, how many hours of charging possible during off-peak hours, else enter 0
- Usage per day - Number of kilometres the bus will cover per day excluding dead kms
- Avg. Pax Loading: Number of passengers present in the bus on an average (including crew)
- Dead km/bus/day: Distance between depot to start point and end point to Depot
- Midday charging at depot is not considered i.e. bus only comes to depot at the end of day.

Press "Calculate" button in Tool sheet after changing any inputs .

Tool provides total cost of ownership using the discount rate specified in inputs over the life of the bus at constant prices i.e. without use of inflation for projecting future costs.

The energy consumption depends on many factors, but this tool only consider factors like bus type, battery weight and number of passengers.

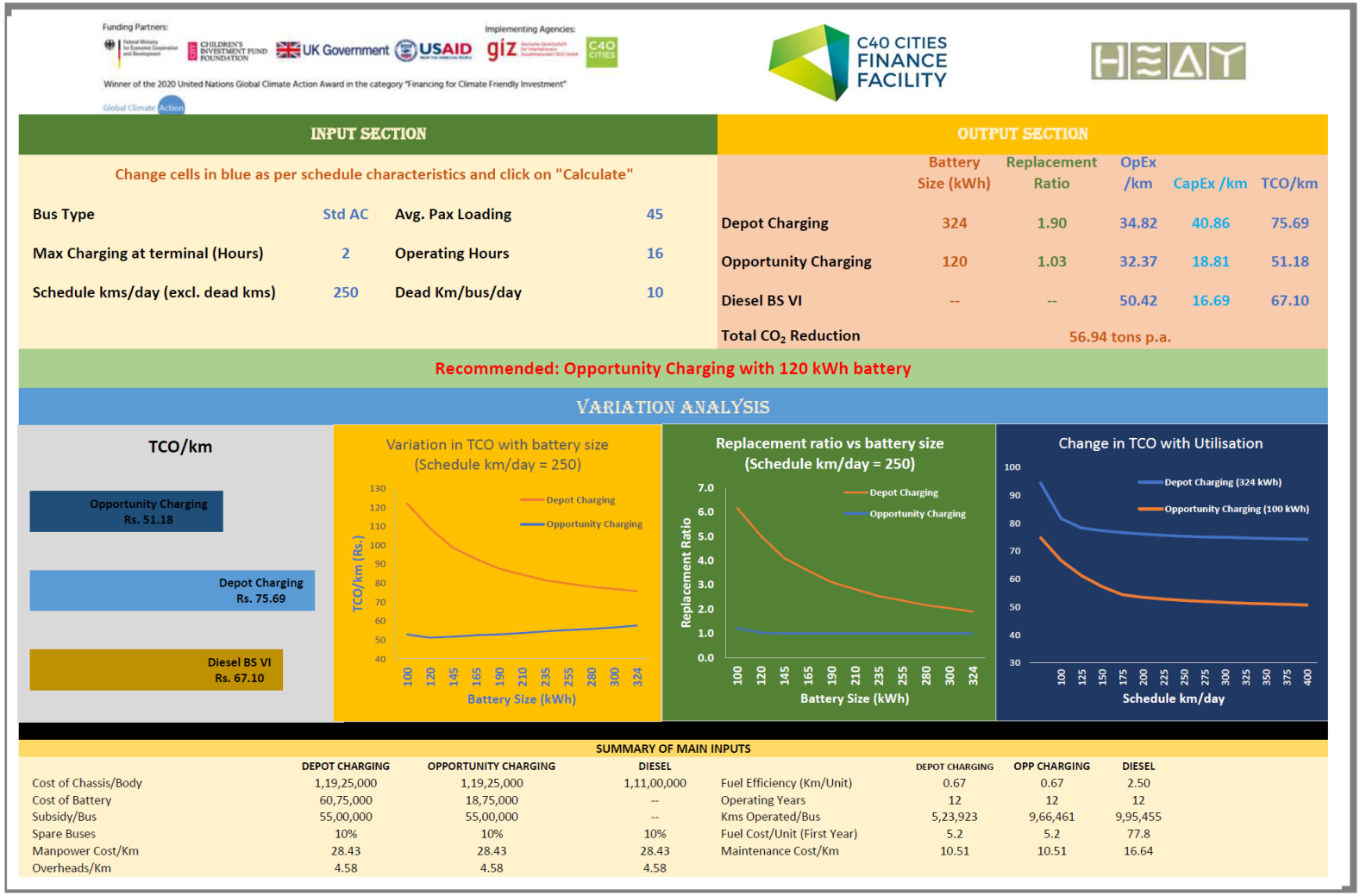
Other factors e.g. traffic conditions, temperature, quality of roads, model specs would need to be adjusted in the avg consumption rates in "Inputs" sheet.

User Guide | Inputs | Tool | Sources

Funding partners:

Implementing agencies:

Figure 12: Structured BEAST outputs for a scenario run or set of operational inputs



Funding partners:

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2.7. Revisions to Tender Documents for 300 Electric Bus Procurement under Fame-II Subsidy

From Niti-Aayog's MCA, Market Study and Business Case study, BMTC was supported in critically reviewing BMTC's draft Tender documents (RfP and MCA) for 300 e-buses. The review was guided by the following objectives:

- Minimize difference between CPKM of Diesel bus and e-bus
- Minimize per Km (Per Km) rate for e-bus in initial years of contract period
- Maximise learnings for large scale implementation

Following were the key recommendations:

1. Eliminate the need for Operator to deposit Bank Guarantee to reduce his liability. An option is to deposit the available subsidy amount in an escrow account and release the amount with accrued interest to the operator in 60 equal monthly instalments. This could reduce the PKM rate quoted by Rs. 6/km (See Table 9).

Table 9: Subsidy Payment (in Rs. Crores)

Particulars	With Subsidy Bank Guarantee (SBG)	Without SBG
Cost of Project	515	515
Less Subsidy	165	0
Net Cost	350	515
Debt	245	360.5
Margin Money for BG	165	0
Total Equity required	270	154.5
D/E Ratio	1.1	2.3
Cost of Capital for 1st year	78.5	62.00
Impact on PKM Rate (Rs./km)	29	23
* Excluding working capital requirements ** 10% debt, 20% equity (pre-tax)		

2. To minimize PKM extract higher assured km/day at the beginning and gradually reduce it, as battery wears out over the contract period, instead of a fixed daily rate throughout. Assuming that the e-bus batteries will be replaced after 7 years, the km/day rates will be reset accordingly as indicated in Table 10.

Table 10: Yearly reduction of assured km/day in MCA

GCC Contract Year	Max Operating Range		Minimum Guaranteed (in Km/day)
	In Km/day	**7th Year Range**	**95% of Maximum**
Year 1	240	180	228
Year 2	222	180	211
Year 3	205	180	195
Year 4	201	180	191
Year 5	197	180	187
Year 6	193	180	184
Year 7	189	180	180
Year 8	240	180	228
Year 12	197	180	187
Total kms	8,71,835	7,48,980	8,28,039
Total Payment		74,898,000	76,083,885
-Fixed		85	77
-Variable		15	15
PKM Rate		100	92

3. Since the impact of any change in GST rates, Laws and Scope (Art. 36), during the contract period, cannot be ascertained at the time of contract signing, appropriate clauses in MCA should allow both parties to amicably adjust rates on actuals. It is recommended that BMTC bear applicable GST liabilities for e-bus operations instead of the GCC operator. BMTC will be better equipped to seek reimbursement / subsidy from the Government than a private operator.

4. PKM Rate Escalation Formula to be reworked considering the cost components and frequency of revisions for procuring and operating e-buses. The cost escalation for a GCC operator varies depending on the cost component (Fixed or Variable). While Interest and Depreciation constitute fixed costs, cost heads in Table 11 vary according to the bus operations and therefore the escalation index and revision frequency should be re-worked by BMTC as indicated below. Otherwise, it will get included onto the PKM rate quoted by GCC Operator.

Secondly, BMTC should assess service performance and reimburse the operator every month to reduce working capital requirement of operator. For underutilized km, it is proposed that 80 – 90% of PKM rate should be reimbursed. This rate can be reduced to 20-25% of PKM rate for excess kms since all fixed costs are already recovered.

Table 11: Proposed PKM rate escalation formula

Cost Components for Operator	% of PKM rate	Escalation Index	Revision Frequency
Capital costs of e-bus	50%	N/A	N/A
Manpower Costs	35%	Minimum wages	w.e.f. revision in wages
Maintenance	7.5%	WPI	Annual
Energy	7.5%	Electricity tariff	w.e.f. date of revision

5. On operator's liability for defects after termination (Art. 34.1), an option is for BMTC to inspect all e-buses, prior to handover by the operator, and any defects identified and repaired before accepting them by BMTC.

6. For the following clauses, Niti Aayog's MCA clauses are recommended as they provide a balanced and fair perspective for all stakeholders without additional costs or risks to BMTC.

   Art. 23.6 Deputation

   Art. 29.9 Termination Payment for Force Majeure Event

   Art. 32.3 Termination Payment

   Art. 32.4 Certain limitations on Termination Payment

   Art. 42 Miscellaneous

The above-mentioned recommendations and appropriate justifications to the 300 e-bus tender documents are available in a presentation. Also, appropriate revisions to the contents of the RfP Vol. I, II and MCA for 300 e-buses are made available to BMTC.

3. CONCLUSIONS

According to BMTC's Vision Document 2030, Bengaluru's state-run PT Undertaking (BMTC) envisions to upgrade its full fleet of buses (mostly comprising of Euro 4 diesel buses) to e-buses in next 10 years. In 2019, Bengaluru was identified as one of C40 CFF's partner cities for adoption of Zero Emission Public Transport in 2019 and a TA Project was conceived. The main objective of this TA project was to plan and realise the transition to an all EV / Clean fuel PT fleet until 2030 as was indicated in BMTC's Vision Document. GFA Heat GmbH was assigned to structure a long-term e-bus transition strategy for BMTC through a complete and comprehensive procurement package comprising of a Business Case for the project, draft contract and RfP with detailed procurement process. In doing so, the project scope also prepared e-bus Technology and Infrastructure Report, Market Study, Gender and "Leave No One Behind" Analysis that complemented the final e-bus procurement process.

At the time of closing the C40 CFF TA Project, BMTC did not have any operational e-buses, while procurement under FAME-II and SMART CITY projects were under various stages of tendering processes. With present challenges of low ridership as a fallout of COVID pandemic, BMTC is advised to develop a long-term e-bus Adoption Action Plan based on the outputs from C40 CFF Project. One clear picture that emerges from this project is that it is opportune time for rapid e-bus adoption for BMTC. However, a long-term commitment and planning is necessary for exploiting the potential of adopting clean technologies in PT operations for BMTC. Pune city (PMPML), which has the maximum operational fleet of e-buses deployed presently in spite of lower lesser central subsidies available under FAME II scheme of DHI, has shown the way forward.

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