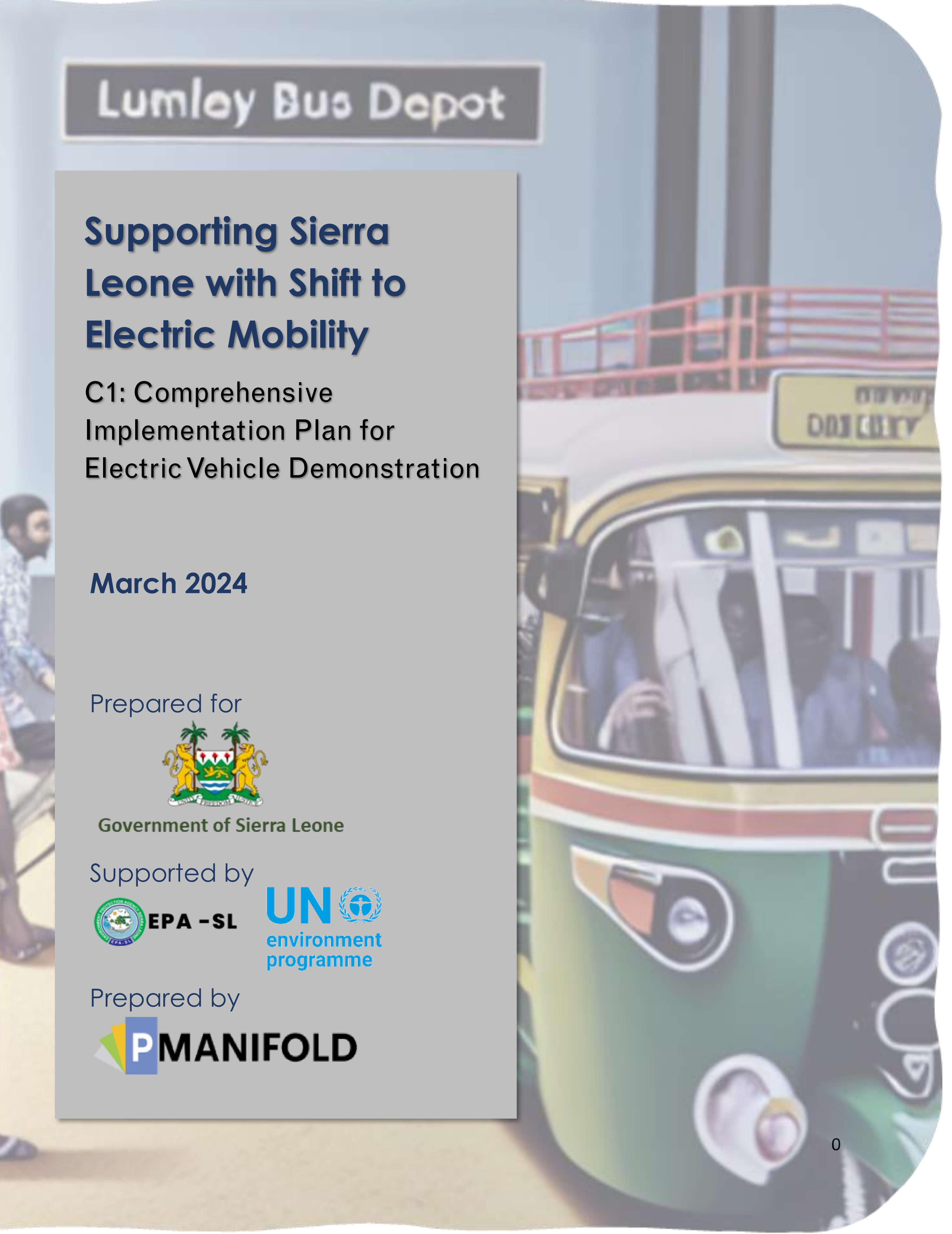

Supporting Sierra Leone with Shift to Electric Mobility

C1: Comprehensive Implementation Plan for Electric Vehicle Demonstration

March 2024

Prepared for

Government of Sierra Leone

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EPA -SL

UN environment programme

Prepared by

PMANIFOLD

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1. Introduction

In alignment with the Paris Climate Agreement's goals and the urgent need to address soaring air pollution, it is imperative to engage low and middle-income countries in the global push towards zero-emission electric mobility. Collaborations among leading international entities, private sector stakeholders, financial institutions, and academic institutions have given rise to a groundbreaking worldwide initiative focused on advancing the adoption of electric mobility in several nations.

Amongst those initiatives, there lies an emphasis on the significance of prioritizing electric two (e-2W) and three-wheelers (e-3W), which are the fastest growing modes of transport in many low and middle-income regions. These initiatives have attracted a formidable alliance of supporters, securing backing from prestigious institutions such as the Global Environmental Facility (GEF), the European Union, the German Climate Initiative, the Climate and Clean Air Coalition, and the FIA Foundation, along with a host of foundations and bilateral donors.

1.1. Objectives

Sierra Leone has been the beneficiary of funds from GEF for the implementation of a project titled **“Supporting Sierra Leone with Shift to Electric Mobility”.** This four-year endeavor, to be executed by the Environmental Protection Agency of Sierra Leone (EPA-SL), aims to reduce greenhouse gas (GHG) emissions within the country by expediting the adoption of electric mobility. The project's strategy encompasses establishing a comprehensive legal, regulatory, and institutional framework, enhancing local capacities, showcasing electric vehicle pilots, and formulating viable business models to engage the private sector, alongside financing mechanisms that enable broader application and scaling up. This project is organized around the following four components:

- Component 1: Institutionalization of low-carbon electric mobility
- **Component 2: Short-term barrier removal through low-carbon e-mobility demonstrations**
- Component 3: Preparation of scale-up and replication of electric mobility
- Component 4: Long-term environmental sustainability of low-carbon electric mobility

1.2. Scope

This report addresses a comprehensive implementation plan for electric vehicle (e-Keke) demonstration including a low-carbon charging scheme, and a data collection framework along with the reporting and analytical framework under the second component. It comprises the following elements:

- Assessment of potential locations, technologies, and capacities for e-Keke charging stations.
- A thorough feasibility study for the operation of e-Kekes.
- Articulation of business models and financial plans for vehicle and charging station operators.
- A comprehensive demonstration implementation plan that includes an intricate framework for data collection, reporting, and analysis.

The subsequent report under this component would discuss in detail the demonstration vehicles and charging equipment procured, staff training, implementation of demonstration project, data collection and analysis.

2. Country Profile

Sierra Leone, officially the Republic of Sierra Leone, is a country on Southwest Coast of Africa, endowed with distinct geographical regions is among the most vulnerable countries to the adverse impacts of climate change. The government acknowledges the impacts of climate change seen in the growing number of people at risk and significant effects on the economy and remains committed to addressing climate change based on science, equity, and sustainable development.

In the last decade, the total GHG emissions in Sierra Leone has increased considerably from ~15,000 GgCO2/year (15 MtCO2e) to more than 25,000 GgCO2/year (25 MtCO2e). Across various sectors, transport remains one of the key contributing sectors for high GHG emissions, with significant potential reduction. As per Intended Nationally Determined Contribution (INDC), the Government of Sierra Leone has set an achievable target to reduce its emission levels to 7.58 MtCO2e by 2035 and carbon-neutral by 2050. The government has published revised Nationally Determined Contributions (NDC) in 2021 to strengthens the objectives, plans, and approaches of INDC with improved data collection, in-depth technical analysis, and extensive stakeholder engagement.

2.1. Transport Landscape

As of 2019, the national on-road vehicle population was approximately 400,000, with numbers on the rise.[1] The combined total of 2- and 3Ws in 2020 stood at around 40,000, of which 9,000 were tricycles, commonly known as kekes.[1] Projections suggest that the taxi fleet of 2- and 3Ws might expand to roughly 80,000 by 2030 and could reach 140,000 by 2050. [1] In Freetown, the transport services are predominantly provided by the private sector, commanding close to an 85% share of the market.[1] Additionally, Freetown significantly impacts the national economy, generating over 30% of the country's GDP, with the transport sector being a substantial contributor.[2]

The country's 'Integrated Transport Policy, Strategy and Investment Plan' established in 2013 was primarily targeted at enhancing road infrastructure, international transport links, and urban mobility.[3] Yet, it falls short of addressing the crucial issues of energy efficiency, greenhouse gas (GHG) and pollutant emissions, as well as fuel costs in the transport sector. Moreover, there is a lack of national policy frameworks that advocate for or provide incentives for the adoption of low-emission and electric vehicles.

2.2. Importance of Kekes

There has been a marked decline in the modal share of conventional buses, concurrently with a notable surge in motorcycle-taxis, known as okadas, and 3Ws, referred to as kekes. Kekes play a vital role in first and last-mile connectivity, offering an accessible and convenient mode of commercial transportation alongside the okadas, serving the majority of the public in Freetown. The growing share is further linked to decrease in need for more costly taxi journeys, low upfront

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[1] Supporting Sierra Leone with the Shift to Electric Mobility, GEF CEO Endorsement, 2021

[2] Integrated Resilience Urban Mobility Project, World Bank, 2019

[3] Sierra Leone Integrated Transport Policy, Strategy and Investment Plan, 2013

cost of the vehicles, their ability to navigate congested and unpaved roads, and time-savings as the smaller vehicles are better able to navigate through the traffic in congested areas.

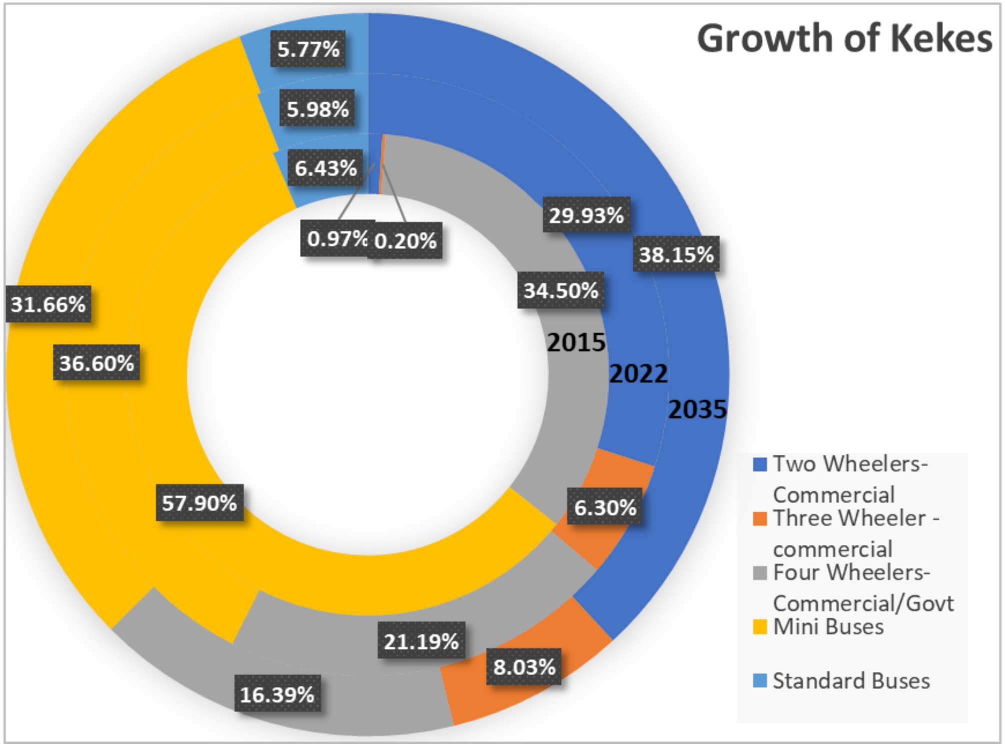

Figure 1: Growth of different public transport modes from 2015 to 2022, 2035

Despite these advantages, the keke segment faces several challenges:

- **Regulatory Gap:** There is no designated authority to implement and oversee standards of transportation quality control.
- **Fare Irregularities:** Fare structures are inconsistent, with prices ranging from 3 to 5 leones per kilometer at an average occupancy rate of 2.5 passengers.
- **Traffic Congestion:** Major roads and junctions are plagued by congestion, increasing the propensity for traffic accidents.
- **Safety Risks:** Kekes are involved in a significant share of traffic accidents, representing approximately 70% of emergency transportation cases.
- **Insufficient Infrastructure:** There is an evident lack of appropriate parking and docking facilities for kekes, affecting both operational and non-operational periods.
- **Poor Road Conditions:** Excluding highways and major arteries, the road quality in Freetown and the broader Sierra Leone region is below standards.
- **Maintenance Deficiencies:** Maintenance and repair services for kekes are scarce and often expensive without the support of authorized dealers.
- **Income Disparities:** Operators frequently encounter financial losses due to traffic violations, enforced penalties, unofficial payments to authorities, and costs associated with vehicle malfunctions or incidents.
- **Environmental Impact:** The utilization of suboptimal fuel combined with the lower quality of the kekes contributes to environmental degradation through air pollution.

- **Financial Hurdles:** Operators and potential owners face significant financial burdens due to the high cost of vehicle financing and exorbitant interest rates.

2.3. Need for electrification of Kekes

The imperative for e-Keke adoption is underpinned by the economic benefits that they offer over their life cycle. Firstly, the e-Kekes can play a significant role in reducing GHG emissions and local air pollution mitigation, thereby supporting Sierra Leone in meeting its NDC commitments. Secondly, despite their initial cost being approximately 1.2 to 1.5 times higher than traditional vehicles, e-Kekes feature operational costs that are significantly lower—thereby presenting attractive long-term savings.

In addition, e-Kekes are characterized by low maintenance needs, contributing to reduced overall maintenance expenses. They also demonstrate enhanced fuel efficiency on a tank-to-wheel basis as compared to the ICE counterparts, particularly when equipped with Lithium-Ion batteries. This equates to substantive fuel savings making them a cost-effective choice for operators (refer Table 1).

Table 1: EV Economics for different public transport modes in Sierra Leone

Modes	EVs	ICEs	EVs	ICEs	Fuel cost savings from EVs	
	kms/ kWh	kms/ liter	SLE/ 100km	SLE/100km	SLE/ 100km	%
2Ws	40	50	7.5	42	34.5	82%
3Ws	10	25	30	84	54	64%
Cars	5	7	60	210	150	71%
Buses	1	6	300	350	50	14%

Moreover, the environmental advantages are notable, with e-Kekes producing zero tailpipe emissions[4] and negligible noise pollution, thus contributing to cleaner and quieter urban environments. The e-Kekes have the capacity to store renewable energy, which can allow for an increase in the renewable energy mix within the grid. This integration can lead to reduced necessity for additional grid storage, lessen grid losses, and diminish the costs associated with grid upgrades.

Further, the e-Kekes afford operators with flexible options pertaining to battery charging and swapping. Such flexibility facilitates efficient management of charging and operating times, enabling better planning and utility of the vehicles in service. This overall transition not only aligns with sustainable practices but also amplifies operational efficiency and fosters economic growth.

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[4] overall environmental impact is contingent upon the cleanliness of the electricity source used to charge the vehicles

2.4. Landscape of Kekes in Freetown

The transportation landscape in Sierra Leone, as well as its capital Freetown, has been diversely impacted by the introduction of kekes, which are predominantly supplied by three manufacturers: Bajaj, TVS, and Piaggio. All equipped with gasoline engines, these vehicles register a fuel consumption rate between 4 to 5 liters per 100 km.[5] This level of gasoline usage significantly contributes to the degradation of air quality.

Figure 2: Kekes in Sierra Leone, Freetown

Despite being comparative newcomers in the transport sector, kekes are increasingly favored over motorcycle taxis due to their lower speed capabilities, enhanced comfort, and dimensions that encourage adherence to traffic regulations, such as refraining from sidewalk overtaking.

Table 2: Popular ICE keke models

Parameters	Unit	TVS King Deluxe	Bajaj Compact RE	Piaggio Ape City Plus	Bajaj RE 4S Petrol
Engine Type		4 Stroke, Air Cooled, Single Cylinder SI	6 Stroke, Air Cooled, Single Cylinder SI	Diesel, Water Cooled Engine	4 Stroke, Forced cooled SI
Engine Capacity	CC	199.26	236.2	597.7	198.88
Curb Weight	Kg	326	672	502	348
Fuel Tank Capacity	Liters	8	8	10	8

In assessing the operational model of the keke transport within Freetown, numerous key performance indicators offer insight into the system's efficacy. On average, these three-wheeled vehicles traverse approximately 80 kilometers daily, with the potential to cover up to 120 kilometers during peak operational periods.[5] The average distance per trip stands at a modest 4.35 kilometers, indicating a tendency towards short-range commutes.[5] When it comes to speed, kekes typically maintain an average cruising velocity of 19 kilometers per hour, with the capability of reaching speeds up to 45 kilometers per hour under certain conditions.[5] These vehicles are a staple in the local transport network, remaining operational for 300 days per year, which results in an average annual mileage accumulation of about 24,000 kilometers.[5]

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[5] Primary Survey and Stakeholder Consultation

Table 3: Operational characteristics of ICE kekes

Parameters	Unit	Typical Characteristics
Seating Capacity	#	3 + Driver
Avg. Distance travelled per day	km	80
Max Distance travelled per day	km	120
Avg. Distance per trip	km	4.35
Avg. Speed	kph	19
Max Speed	kph	45
Operational Days per year	days/yr	300
Avg. Mileage Accumulation	kms/yr	24,000

Further, the prevalent business models for "kekes” are primarily structured around two types of ownership patterns i.e., owner-operator model or rentals from KK aggregators (like the KK Union)/ private fleet provider/ other). In the case of the rental model, drivers are required to pay a daily rental fee for the use of these vehicles. The revenue they generate from passenger fares is used to cover both the cost of fuel and the rental charges. The residual amount after these expenses constitutes the driver’s earnings.

3. Global Best Practices

3.1. Electric Three-Wheelers in India - Market Size, Growth Trends, and Industry Dynamics

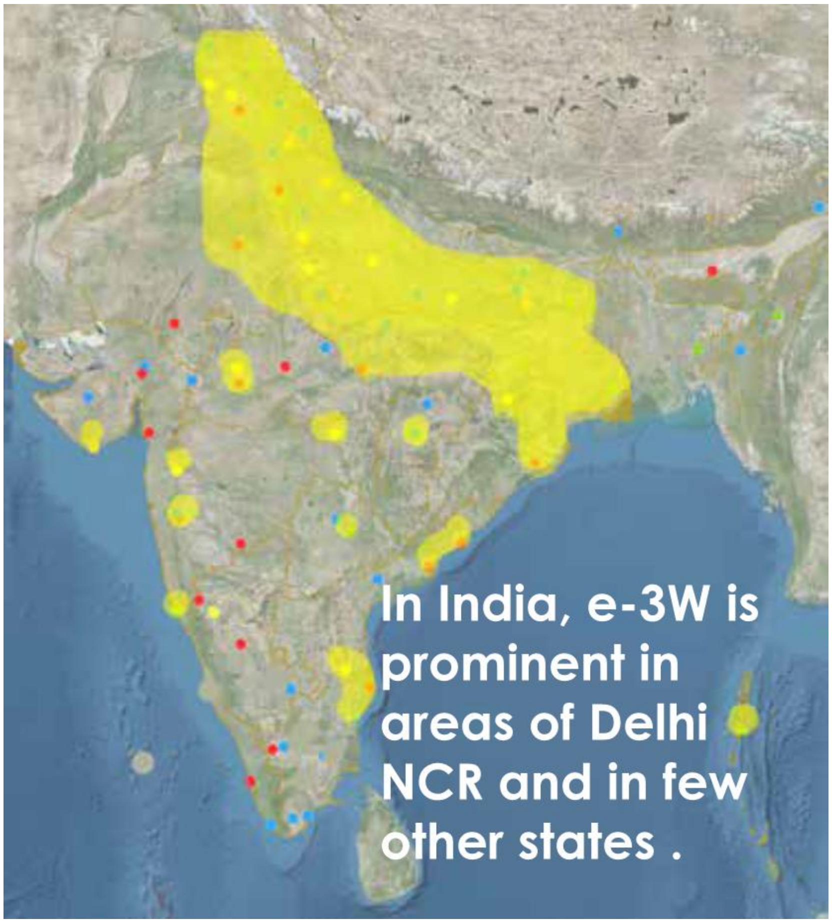

Figure 3: Prominence of e-3W in India

The Indian market for e-3W[6] has gained significant attention due to the increasing focus on sustainable and eco-friendly transportation solutions. This case study delves into the current market size and growth trends of e-3W in India, the challenges and growth factors for electric vehicle adoption in the industry.

Market Size and Growth Trends:

The current market size for e-3W in India is projected to reach 1.5 million (Mn) by the year 2023.[6] This indicates a substantial growth trajectory and underscores the increasing demand for e-3W, particularly in the Indian transportation sector.

The growth trends reveal that there has been a significant increase in the demand for 3W transport vehicles in India, especially before the COVID-19 pandemic. According to data from the Ministry of Road Transport and Highways (MoRTH), the number of registered e-3W in India nearly doubled from 2015 to 2018, growing from more than 350,000 to 690,000. More recently, registrations have surged.[7]

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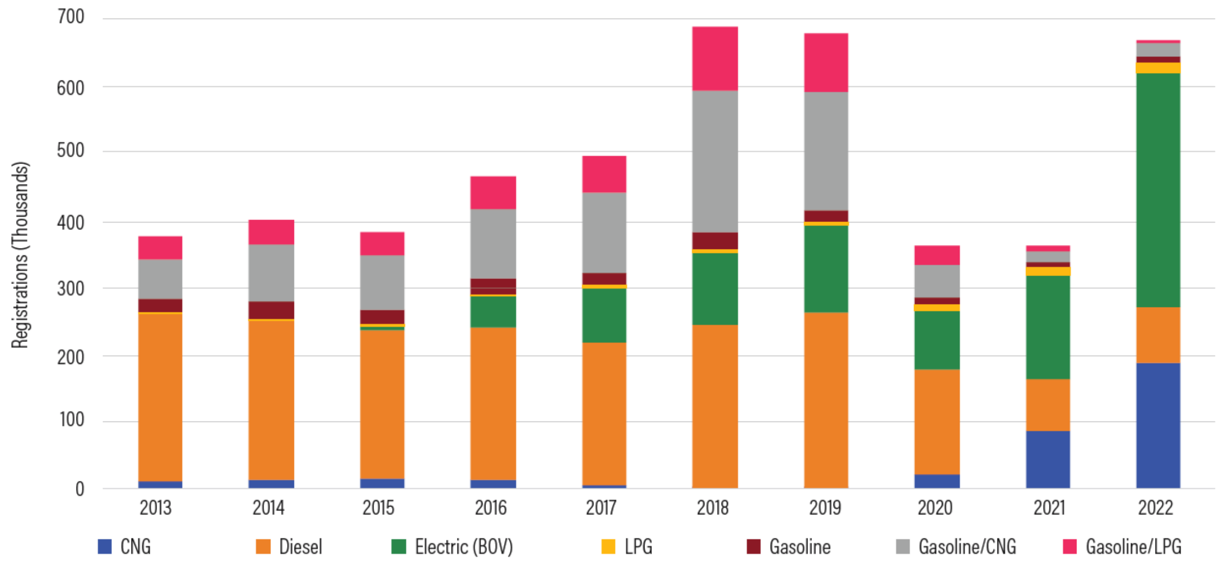
[6] India e-Rickshaw Market

[7] Assessing the Viability of Using Autorickshaws for Urban Freight Delivery in India, WRI, 2023



Notes: BOV = battery-operated vehicle; CNG = compressed natural gas; LPG = liquefied petroleum gas, Gasoline/CNG and Gasoline/LPG are hybrid vehicles.
Source: MoRTH (2023) (without AP, TL, and MP data).

Figure 4: Registered e-3W based on fuel types

Operational Model:

The e-3Ws are predominantly owned and operated either by individual drivers or by fleet aggregators. In recent years, there has been an uptick in the deployment of e-3Ws within ride-hailing services, particularly in Tier 1 cities. Additionally, local businesses markedly influence the utilization of these vehicles for branding and advertising purposes. A significant factor in the accelerated growth of the e-3W segment can be attributed to the established local ecosystem of chargers and after sales service in the cities. More recently, the battery swapping model has gained prominence in various cities enabling e-3Ws to stay operational for longer periods. Companies are able to reduce capital expenditures and boost sales through the development of comprehensive battery swapping networks.

Challenges and Growth Factors for e-3W Adoption:

The challenges for e-3W adoption in India encompass hurdles such as the lack of public charging infrastructure, high battery costs, weather-related breakdowns, and the presence of unregistered local e-3W solutions. These factors present significant obstacles to the widespread adoption and deployment of e-3W in the Indian market.

Conversely, the growth factors for EV adoption in India reflect positive influences on the market, including the increasing demand for first and last-mile connectivity, the implementation of pilot projects in various tier cities, tax incentives, policy mandates, capital subsidies, established local ecosystem, and heightened awareness among users and industry operators. These factors play a pivotal role in driving the growth and acceptance of e-3Ws in the Indian transportation landscape.

3.2. Introducing Electric Tuk-Tuks in Sri Lanka for Sustainable and Inclusive Transportation

This case study[8] focuses on the planned initiative to introduce electric tuk-tuks as a sustainable and inclusive mode of transportation in Sri Lanka. The project aims to support the revival of micro-level/informal economic activities by giving preference to specific operators, inject currency into the local economy, and address challenges related to fuel shortages and the need for more efficient transportation solutions.

The project aims to introduce electric tuk-tuks signifying their benefits for the local economy and transportation system through a pilot demonstration. The pilot stage, scheduled to begin in 2023, involves converting 200 petrol 3W tuk-tuks to electric tuk-tuks in two locations: Makumbura and Pettah.

Funding and Incentives

The involvement of various organizations and entities such as UNDP in collaboration with Ministry of Transport and the Ministry of Power & Energy in providing financial support and incentives for the project, highlights the collaborative effort to drive sustainable transportation solutions in Sri Lanka.

Challenges

The key challenges faced by Sri Lanka's transportation system are particularly fuel shortages, imports of petrol 4-stroke 3Ws beyond 10 years of age, and thus arises the need for smoother and more efficient transportation.

Solutions

The proposed approach, including the transition from petrol to electric tuk-tuks, with import restrictions on the age of petrol 3W tuk-tuks beyond 10 years from the date of manufacture.

The operating model emphasizes the inclusion of specific operators and the criteria for selecting applicants. Preference is given to women owners/operators, person with disabilities from Makumbara and Pettah, and applicants whose livelihood is dependent on a single 3W.

3.3. "Easy Bikes" Initiative in Bangladesh – Transforming Transportation and Livelihoods

In an era where urban mobility and sustainability are of prime concern, the "Easy Bikes" initiative presents a case worth evaluating. "Easy Bikes"[9] initiative in Bangladesh, a transformative project aimed at revamping the transportation system by introducing sustainable and comfortable electric rickshaws, known as "Easy Bikes". The project seeks to alleviate unemployment among the youth by enabling them to engage in the operation of these transport units. The project outlines the endeavor to improve the Bangladeshi transportation system while considering environmental impact and social upliftment.

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[8] e-Mobility Brochure, UNDP

[9] Electric Mobility Initiatives, ICLEI South Asia

Background Information

With over a decade of grappling with transportation inefficiencies and an uptick in unemployment rates, Bangladesh sought solutions that would deliver multifaceted benefits. The inception of "Easy Bikes" brought with it a promise of change, leveraging technological advancements in sustainable transit.

Project Overview

Initiated with 10 e-Rickshaws, the project has seen a staggering scale-up to over 4 million Easy Bikes. The initial pilot phase, spanning 2018-2019 and funded by the German development agency GIZ, set forth a target of 15,000 deployments with a strong leaning towards renewables, featuring a 10.8 kWh Lithium-ion battery with a range of 140-150 km.

Operating Model

The operating model pioneers a novel approach to employment by supporting moderately educated but unemployed youth. The scheme enables them to invest in and operate Easy Bikes or lease them out to drivers on a rental basis, thus sparking a self-employment wave that holds potential to boost the local economy.

Funding and Incentives

The German development agency GIZ plays a significant role in funding the project, thus underlining the importance of international collaboration in the facilitation of sustainable development goals.

Challenges

Despite notable growth, the initiative faces challenges of traffic congestion with an escalating number of Easy Bikes on the roads and an increased risk of accidents arising from the coexistence of high-speed and low-speed vehicles on the same thoroughfares.

Outcomes and Key Learnings

The primary takeaway is that economic growth can be stimulated via employment opportunities rooted in sustainable projects. "Easy Bikes" demonstrates that a focus on reducing carbon footprint, while promoting social entrepreneurship can marry the dual goals of economic development and environmental preservation. However, there needs to be a regulation in place for restricting the total no of the 3Ws in congested areas based on the daily demand as well as Designated halt points and route rationalization for preventing competition of e-rickshaws with other modes for space and commuters.

3.4. Conclusion

The conclusions drawn from the case studies on India, Sri Lanka, and Bangladesh collectively demonstrate the transformative potential of e-3Ws in the South Asian transportation sector. In India, the establishment of battery swapping network in the cities and establishment of local ecosystem contribute to the faster growth of e-3Ws. The Sri Lankan initiative showcases how electric tuk-tuks can relieve the operational strains on public transport services, contributing positively to the transportation economy, providing a source of income for women as well as other needy people. Similarly, Bangladesh's successful "Easy Bikes" project manifests the profound impact of sustainable vehicular integration on the fabric of transportation, providing a framework to bolster livelihoods through eco-friendly practices. However, it also highlights the need for regulating the market to alleviate urban congestion. Together, these studies reveal the critical importance and broader implications of e-3Ws for future-proof transport models in regions with analogous socio-economic contexts.

4. e-Keke Techno-Commercial Feasibility Assessment

4.1. Methodology

The depicted flowchart (Figure 5) provides a comprehensive process for evaluating the Total Cost of Ownership (TCO) of an e-Keke. This process is segmented into various sections that collectively depict a complete workflow from initial inputs to final results. A connecting arrow leads from each phase of the workstream to its succeeding step, showcasing the interconnected nature of the approach. This strategic method is designed to evaluate and organize the deployment of an e-Keke arrangement systematically. Finally, it illustrates the determination factors for pilot consideration as well as feasibility considerations.

Inputs:

- The specifications of e-Keke models commercially available in the market are referenced.
- A Duty cycle assessment is conducted on a pre-selected route, which includes an analysis of the ICE Keke's standard operational cycles on that particular route.

Workstream:

- The Route Energy Consumption Modelling phase is devoted to ascertaining the energy consumed across the route in totality and on a per-kilometer basis.
- During the Battery Sizing phase, specifications such as battery size, motor size, charger size, and power demand are established, guided by the route's energy consumption data and market availability of battery sizes.
- The Charging Strategy Formulation stage includes calculating the necessary battery size, evaluating various charging technology options, deciding on depots/terminals positioning, and considering the current state of keke operations. Options may cover opportunity charging, overnight charging, charger specifications, and grid requirement considerations.
- The Fleet Planning process relates to the scheduled operations of e-Kekes and their cost implications

Output:

- Catalogues under CAPEX are Vehicle Capitalization Cost and Infrastructure Capitalization Cost.
- Cataloged under OPEX are Energy Cost (Electricity), Annual Maintenance Cost, and Manpower and Other Cost.

The outputs itemized above fall into categories of either CAPEX, representing the primary outlay of capital, or OPEX, indicating sustained operational spending.

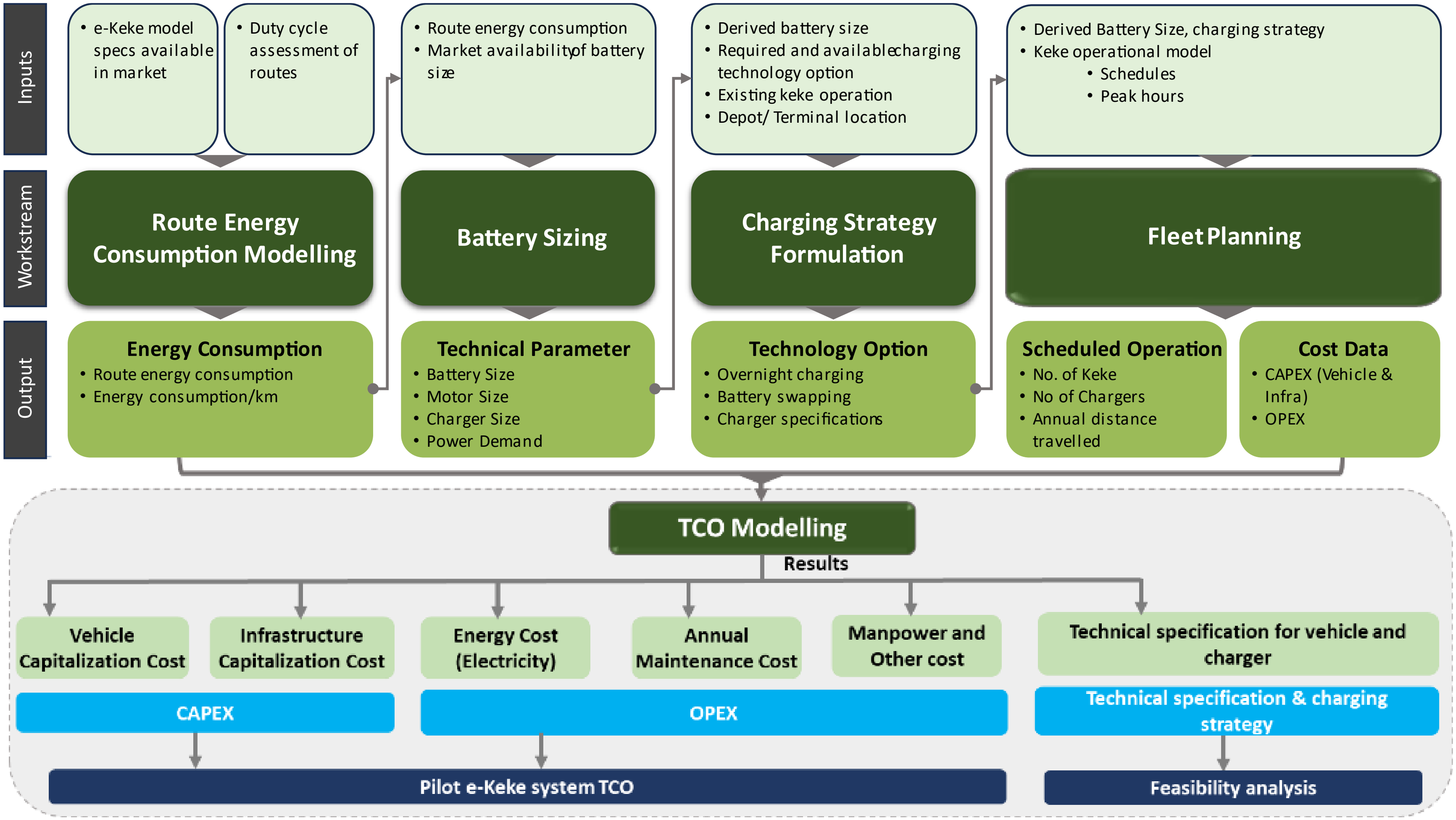

Figure 5: Methodology used for conducting techno-commercial feasibility of electric kekes

Results:

- The final result is the TCO Modelling Results, which offer a complete depiction of the expenses involved in the ownership and operation of an e-Keke infrastructure.
- The outcome of the TCO modelling includes delineating the technical specifications for the vehicle and charger.
- From the TCO findings, intricate technical blueprints and charging strategies are crafted.
- The ultimate stage is a Feasibility analysis, projected to assess the economic viability of the pilot e-Keke scheme.

The subsequent sections articulate the methodical process undertaken and delineate the correspondingly accrued results, presented in a sequential, stage-wise format.

4.2. Available Technology Options – Model Selection

The technological options considered for this study are based on new electric kekes[10] with seating capacity of 3 pax and max speed of 45kph. Following options are considered:

- electric-kekes with fixed battery
- electric-kekes with swappable battery system

A comparison was made between the two options to determine the optimal choice for Sierra Leone. The table below provides a comparison of specifications for three different vehicle models: the TVS King Deluxe (ICE), which uses an internal combustion engine; the Piaggio eCity Fixed (EV), which has a fixed battery electric system; and the Piaggio eCity Swap (EV), which employs a battery swap electric system. The table contrasts their market prices, vehicle categories, seating capacities, battery types, voltages, and capacities, as well as peak power and torque, dimensions, weight, speed, ranges, gradeability, and fueling/charging/swapping times.

Table 4: Technical specifications for different keke models

Specifications	Unit	TVS King Deluxe (ICE)	Piaggio eCity Fixed (EV)	Piaggio eCity Swap (EV)
Market Price[11]	USD[12]	2,865	3,590	2,475
Vehicle Category		L5M	L5M	L5M
Seating Capacity	#	D+3	D+3	D+3
Battery Type		Not required	Lithium Ion	Lithium Ion
Battery Voltage	V	-	51.2	48
Fuel Tank/ Battery Capacity	liter | kWh	8.5 ± 0.5 l	7.5 kWh	4.5 kWh
Peak Power	kW	7.8 @5500rpm	5.44 @3500rpm	5.4 @3500rpm
Peak Torque	Nm	15.5 @3750rpm	29	29

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[10] The analysis considered Piaggio Ape e-City since there is already supply of Piaggio ICE keke in the market. This is only for representational purpose to ensure that overall analysis remains valid for available industry models.

[11] The Market price of the vehicle is sensitive to several factors including the battery size selected, the total volume of vehicles ordered, applicable taxes, import duties, and any other levies. Furthermore, the price may also be influenced by whether the coach is constructed by the Original Equipment Manufacturer (OEM) or a third party.

[12] 1 USD ~ 20 SLE

Specifications	Unit	TVS King Deluxe (ICE)	Piaggio eCity Fixed (EV)	Piaggio eCity Swap (EV)
Dimensions (w*l*h)	mm	1329*2647*1740	1370*2700*1725	1370*2700*1725
Vehicle GVW (with battery)	kg	-	713	689
Kerb Weight (with 90% fuel| with battery | Battery dock+3batteries)	kg	356	413	389
Top Speed	kmph	63 ± 2	50	45
Typical Range	km/liter | km/Charge | km/Swap	**25 km/liter**	145 ± 5 kms/charge	68 km/swap
Gradeability	%	10	20	19
Fueling/Charging/ Swapping Time	Hr	0.16 – 0.2	3.75	0.08

The TVS King Deluxe appears to be a more traditional vehicle with a considerably lower price point but a significantly lower range in kilometers per liter compared to electric models. The Piaggio eCity Fixed has a higher purchase cost but offers a much longer range per charge, while the Piaggio eCity Swap has a lower initial price and faster swapping time but a reduced range per swap. The electric models boast identical peak torque, but the Piaggio eCity Fixed has a slightly lower peak power and top speed than the Piaggio eCity Swap and the TVS King Deluxe.

To summarize, the Fixed Battery System presents a lower initial Capital Expenditure, streamlined technology integration, and simplified accounting for Electric Vehicle incentives due to integrated batteries, which can significantly benefit businesses in terms of initial costs and operational complexity. However, its limitations include the requisite waiting time for vehicle charging that might hinder e-Keke drivers' efficiency and the need for larger charging areas. Conversely, the Battery Swap System can reduce Electric Vehicles' upfront costs and provide faster swapping times, enhancing operational availability and potentially extending battery life through controlled charging environments. The downside is higher Capital Expenditure due to reserve batteries and extensive infrastructure that necessitates a greater investment and systematic planning.

4.3. Route Data Collection

Subsequent to the identification of appropriate models, comprehensive data was methodically gathered along the actual routes currently in use by ICE kekes. The specific routes encompassed Aberdeen to Congo Cross, Aberdeen to Lumley, Lumley to Aberdeen, and Young Sports to EPA as shown in the image below. For precision, Global Positioning System (GPS) technology was employed to capture this data, as illustrated in the image below.

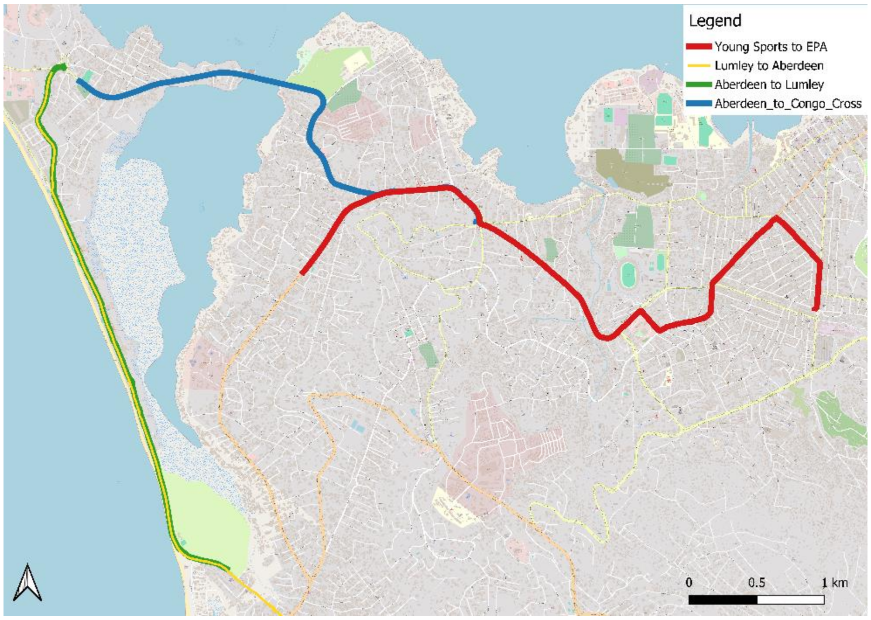

Figure 6: Route data collected based on ICE kekes

Each of the routes were then meticulously processed, adjusted, and calibrated to reflect real-life conditions and subsequently utilized in simulations for e-kekes. The images below highlight the altitude of the routes on which the ICE kekes are currently plying. It can be observed the majority of the routes are relatively flat and the available models also have a gradeability range of around 20%, thus, offering electrification favorability.

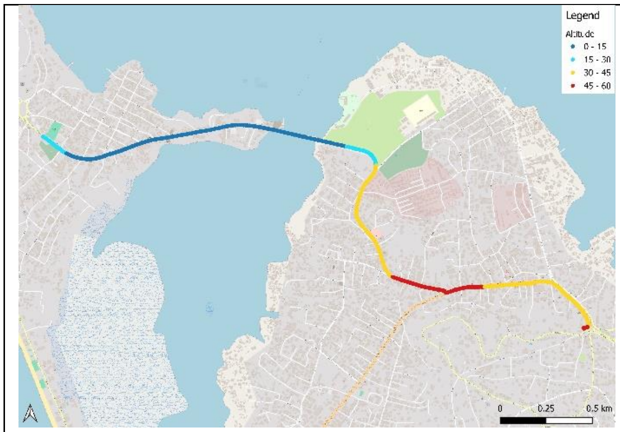

Figure 7: Aberdeen to Congo Cross (altitude in m)

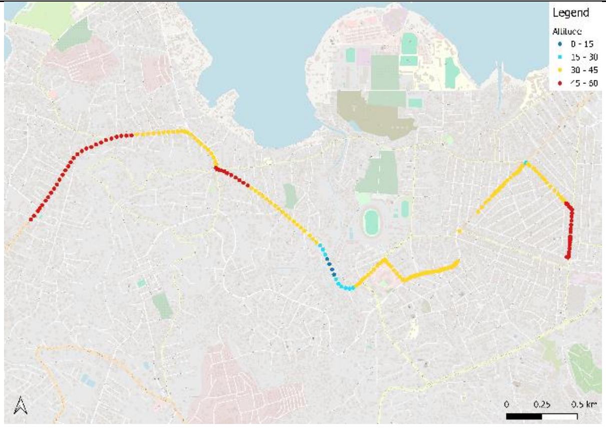

Figure 8: Young Sports to EPA (altitude in m)

Figure 9: Aberdeen to Lumley (altitude in m)

Upon further examination of the speed profiles for the route, it was observed that the prevailing speeds were primarily within the 20-30 kilometers per hour range, characterized by frequent stops and starts. These conditions underscore the suitability and potential benefits of transitioning to electrification for the vehicles in operation.

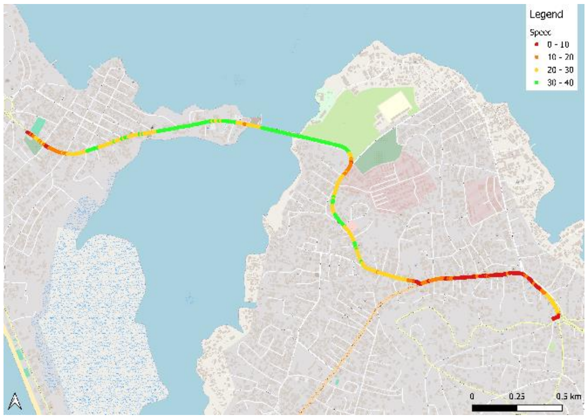

Figure 10: Aberdeen to Congo Cross (speed in kph)

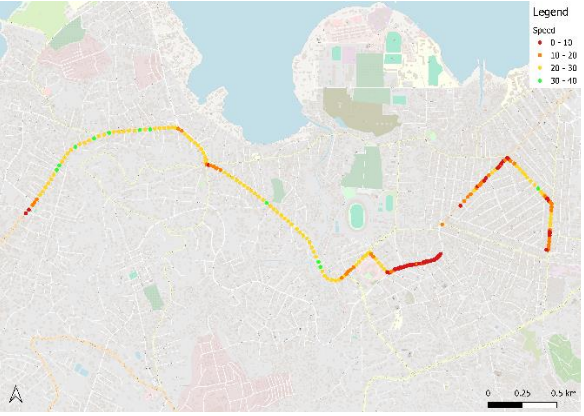

Figure 11: Young Sports to EPA (speed in kph)

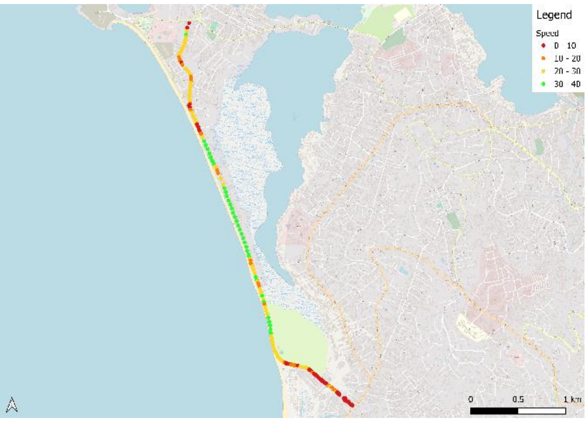

Figure 12: Aberdeen to Lumley (speed in kph)

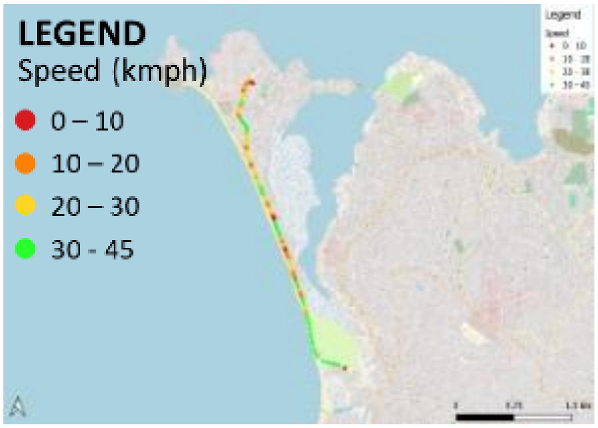

Figure 13: Lumley to Aberdeen (speed in kph)

4.4. Energy Consumption

Upon simulation of the designated routes using SciLab™ for the identified e-Keke models, specifically the Piaggio ape e-City Fixed and the Swap system, an evaluation of energy consumption per kilometer was calculated. The ICE vehicle exhibited a consumption rate of 0.04 liters per kilometer of petrol. In contrast, the electric fixed battery model demonstrated an energy consumption of 100 Wh/km, whereas the battery swap system model registered approximately 90 Wh/km, indicating a more energy-efficient performance of the swap system over the fixed system. This could be attributable to the fact that the swap system employs a smaller battery capacity (4.5 kWh) compared to the fixed system (7.5 kWh). This lower weight gives it the advantage of improved fuel economy over larger fixed battery systems when other factors are similar.

4.5. Charging Strategy

From the standpoint of energy utilization, it was deduced that the fixed battery system would necessitate one charging event daily to sustain daily operation, whereas the swap system would require two battery swaps per day to fulfill the same operational exigencies and uphold the economic efficiency of the models. This strategic approach to charging is predicated on the battery specifications adopted for simulation in both e-Keke models as per the market availability.

Table 5: Battery related parameters considered for the study

Parameters	Unit	TVS King Deluxe (ICE)	Piaggio eCity Fixed (EV)	Piaggio eCity Swap (EV)
		TVS King Deluxe	**Piaggio eCity FX**	**Piaggio eCity**
Battery Capacity	kWh	-	7.5	4.5
Battery DoD	%	-	80	80
Battery Capacity degradation at end of life	%	-	70	70
Useful Battery Capacity (at start life)	kWh	-	6	3.6
Useful Battery Capacity (at end life)	kWh	-	4.2	2.5
Range/charge (at start life)	Kms		60 kms per charge	40 kms per swap
Range/charge (at end life)	kms		42 kms per charge	28 kms per swap
Avg. battery life cycle used/day	#/day		1.57	2.35
Battery Life	years		1.91	2.83

For charging these vehicles, it is suggested to use 3.3 kW AC fixed chargers or Swap System with 1.5 kWh batteries (3 used at once in the keke).

4.6. TCO Analysis

The following graph shows the financial comparison of the three models. The financial comparison is based on real constant prices in USD, i.e., do not consider inflation or real price increases/decreases, e.g. of energy prices. Calculations are based on differential costs i.e., Capital Expenditures (CAPEX) and Operational Expenditures (OPEX) which differ between technologies. This includes the keke CAPEX plus infrastructure CAPEX and for OPEX energy and maintenance. Costs such as drivers, or administration which are independent of the technology chosen are not included.

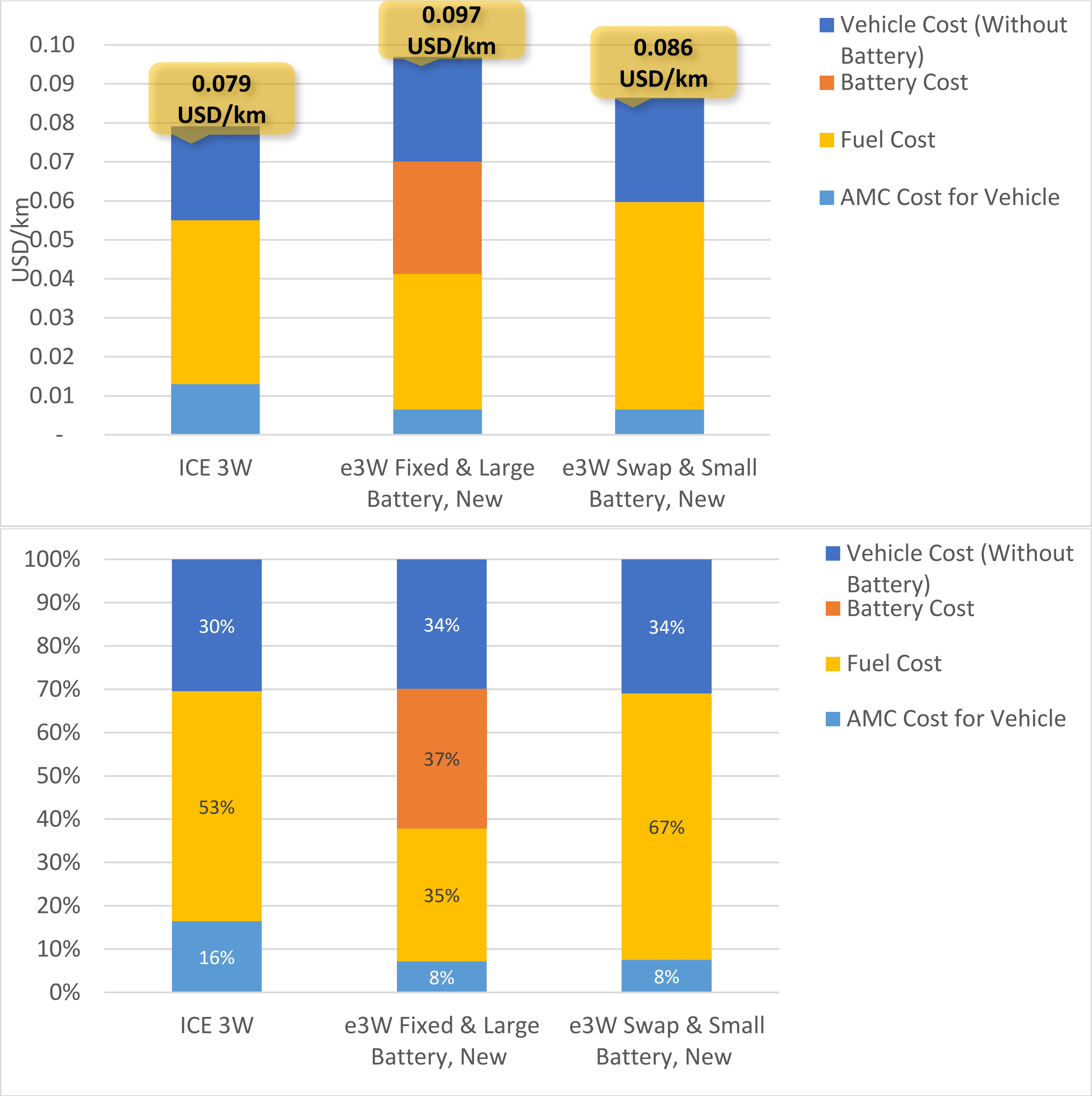

Figure 14: TCO for different keke models per km by absolute nos. and percentage of different components

This above image provides a multi-faceted comparative analysis for the ICE keke, e-keke with fixed battery and with swap battery, concerning their operational and cost parameters. The image contains two bar charts representing the cost per kilometer and breakdown of ownership costs for ICE 3Ws and e-3Ws with fixed and swap battery models. It illustrates that electricity costs for EVs are lower than fuel costs for ICE vehicles, but when battery costs are included, the total cost per kilometer for electric models increases.[13]

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[13] Refer Annexure for complete specifications and parameters used to calculate TCO

Utilizing a swap ratio of 1.8[14], the battery swap system exhibits marginally reduced cost per kilometer compared to the fixed battery system. This is chiefly due to the "Battery as a Service" business model, which effectively lowers the aggregate cost of the vehicle. **Achieving TCO parity may be realized through the meticulous optimization of the swap ratio, particularly when transitioning from traditional ICE models to a battery swapping framework.**

To optimize the swap ratio for e-3Ws using a battery swap system, several key strategies can be employed based on the comprehensive understanding of the operational and economic dynamics. The optimal swap ratio signifies the ideal balance between the number of batteries in circulation and the frequency at which they are swapped. This equilibrium directly influences the reliability and economic feasibility of the battery swapping framework. The following best practices and considerations can guide the optimization of the swap ratio:

- The capacity and range of batteries directly affect the frequency of swapping. Vehicles with lower ranges require more frequent swaps compared to those with higher ranges.
- Analyzing daily distances covered by vehicles, including fluctuations during peak and off-peak hours, provides insights into how often batteries need to be swapped to ensure consistent availability.
- The number and strategic placement of charging stations significantly influence the swap ratio. Limited infrastructure may require a higher swap ratio to maintain operational continuity.
- Faster charging times can reduce the required swap ratio as they minimize the downtime for vehicles awaiting a fully charged battery.
- Implementing a health management system for batteries can extend their life, reducing the immediate need for spare batteries and consequently impacting the swap ratio.
- Maintaining a buffer stock of batteries ensures additional batteries are available during emergencies or unexpected high demands, thus affecting the swap ratio.
- Understanding driver operational patterns and customer demand variability is instrumental in determining swap frequency, thereby influencing the swap ratio.
- Financial elements, including the initial investment in batteries and operational costs associated with swapping and charging, impact the determination of the optimal swap ratio from an economic perspective.

By balancing these factors with real-time operational data and constantly refining the swap ratio through data-driven insights, it is possible to optimize the e-3Ws battery swap system for reliability, efficiency, and economic viability. These practices aim to enhance asset utilization, reduce capital and operational costs, and ultimately lower the TCO for e-3Ws using a battery swap system.

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[14] During initial deployment typically, a higher swap ratio is considered allowing service providers to effectively manage and build reliability in their operations.

5. Deployment Plan

5.1. Pilot Concept

The pilot project intends to deploy a fleet of 15 e-Kekes, each designed with a 3-seater capacity (Driver +3). The vehicles will operate within the urban area of Freetown, enhancing first/mid/last mile connectivity and complementing the new proposed bus system under the RUIMP project.

Technology Specifications

- **Battery and Charger Technology:** The e-Kekes will be powered by lithium-ion battery technology, with the flexibility to implement either a fixed battery system or a battery swap system for the initial deployment phase. The fixed system will utilize a single 7.5 kWh battery, whereas the swap system will use a pack of three 2.5 kWh batteries. Charger technology will include a 3.3 kW AC charger for the fixed system, and a renewable energy-integrated battery swap charging system.
- **Motor Technology:** The e-Kekes will be equipped with Brushless DC electric motors (BLDC) with regeneration capabilities, enhancing energy efficiency and sustainability.

Figure 15: e-Keke pilot corridor proposed

Operational Model

- **Routes and Operational Structure:** The selected routes for the pilot project will serve as feeder routes for the newly proposed bus system under the RUIMP project, specifically focusing on the western corridor. The bus terminal/depot at Lumley can be used for e-Keke charging and parking along with two other locations placed equidistant on the route. Additionally, the operational model features the involvement of KK aggregator to manage the new bus western route, providing first/mid/last mile connectivity. The Keke Union will facilitate rider selection and training, with an emphasis on promoting gender inclusivity through the incorporation of 30% women drivers. Furthermore, the operational model includes considerations for digital payment systems by both riders and passengers, along with plans for collecting discounted rental fees from the Keke Riders.

Investment and Monitoring

- **Funding:** The funding for this pilot project, including the acquisition of the e-Kekes and related infrastructure, will be supported by the GEF (Global Environment Facility) funding, with potential engagement from other stakeholders.
- **Monitoring and Reporting:** To ensure operational transparency and efficiency, the KK aggregator will be responsible for monthly reporting of project operations, thereby establishing a robust monitoring framework.

5.2. Investment Sizing

The preliminary investment sizing was conducted with a focus on both the distinct battery systems: the fixed battery system and the battery swap system. The factors considered include the initial acquisition of 15 e-kekes complete with batteries, the procurement of requisite charging units, supplementary batteries for the implementation of a battery swap system, and the associated costs for charger installation, commissioning, and civil infrastructure works. Further, The model does not include the land charges as they are assumed to be provided by Freetown City Council.

It is important to note here that the Market price of the vehicle is sensitive to several factors including the battery size selected, the total volume of vehicles ordered, applicable taxes, import duties, and any other levies. Furthermore, the price may also be influenced by whether the coach is constructed by the Original Equipment Manufacturer (OEM) or a third party. Additionally, the analysis considered a specific e-3W model and charger/ swap station. This is only for representational purposes to ensure that overall analysis remains valid for available industry models.

Table 6: Investment sizing for fixed battery modelFixed Battery Model

Parameters	Unit	No. of Units	Cost/Unit	Total Cost
e-Keke (with battery)[15]	USD	15	3,645	54,675
3.3 kW AC Fixed Charger[16]	USD	5	1,049	5,247
Installation, Commissioning, Civil, & Electrical for Chargers	% | USD		25%	1,312
Total Investment Sizing	**USD**		**4,957**	**61,234**

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[15] *Includes freight, taxes, registration, and licensing fee*

[16] *Includes charger cost, grid infra cost, and customs duty*

Table 7: Investment sizing for swap battery model

Parameters	Unit	No. of Units	Cost/Unit	Total Cost
e-Keke (without battery)[17]	USD	15	2,475	37,125
Battery[18]	USD	81 *(15 x 3 x 1.8)*	281	22,785
Swapping Station[19]	USD	3	3,938	11,813
Installation, Commissioning, Civil, & Electrical for Chargers	% | USD		25%	2,953
Total Investment Sizing	**USD**		**7,678**	**74,676**

The capital outlay required for the implementation of the fixed battery model is projected to be $61,234 USD. Conversely, the swap battery model incurs a moderately higher expenditure of approximately $74,676 USD, surpassing the allocated $69,000 USD from the Global Environment Facility (GEF) Investment Budget.

As an alternative financial strategy to align with budgetary constraints, it is proposed that consideration be given to a revised scheme comprising of 12 electric tricycles (e-Kekes) supplemented with 65 batteries, based on a battery swap ratio of 1.8. This adjusted proposal is estimated to aggregate to a total investment of $62,694 USD.

5.3. Preferred Technology Option

In light of the initial pilot phase considerations, it is advised to prioritize the acquisition of swap battery e-Kekes due to their superior suitability for densely populated regions with a high influx of commercial fleet operations.

- The swap battery model demonstrates a closer alignment to the TCO of current ICE operations, with further reductions in TCO anticipated through the refined optimization of the battery swap ratio.
- Notably, the model significantly streamlines the refueling process, reducing it to a mere 2-5 minutes per swap, thereby enhancing operational efficiency.
- The swap model promises an extended battery lifecycle relative to fixed battery configurations, contributing to sustainable operational longevity.
- The existing network of household energy hubs can be seamlessly repurposed for e-Kekes stations, leveraging shared infrastructure. The adoption of a multi-purpose and brand-agnostic battery system augments operational flexibility, catering to a variety of transport prerequisites, and paves the way for off-grid energy solutions via Renewable Energy (RE) sources integration.

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[17] *Includes freight, taxes, registration, and licensing fee*

[18] *Includes freight and customs duty at 1.8 swap factor*

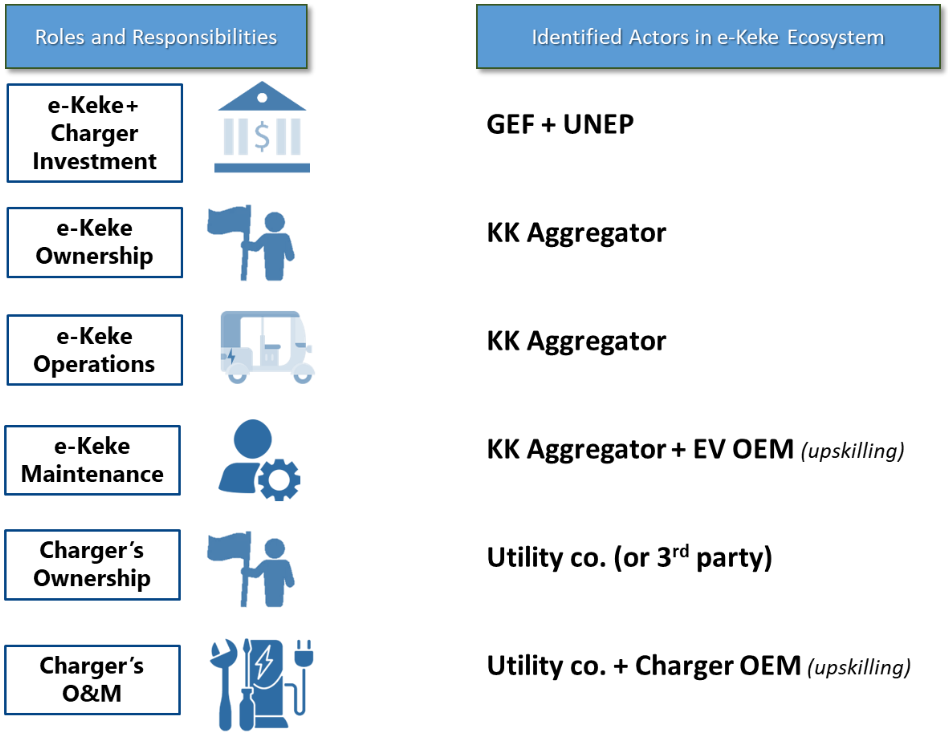
[19] *Includes charger cost and customs duty*

- In addition, the swap system's spatially economical design requires minimal area to service a larger fleet, significantly optimizing space utilization. Such a model is economically advantageous for both service providers and drivers, establishing an economically sound proposition for all parties involved in the e-Kekes ecosystem.

5.4. Proposed Business Model

To mobilize the deployment of e-Kekes it is crucial to identify and define elaborately the roles and responsibilities of all participating entities, delineate the service provision and financial transactions among stakeholders, and outlines the economic implications for each party involved in the project.

Roles and responsibilities of Actors involved:
In the structured layout of roles and responsibilities within the "e-Kekes Freetown Pilot Project," several organizations as shown in the Figure 16 are earmarked for key contributions to the successful implementation of the transport system:



Roles and Responsibilities	Identified Actors in e-Keke Ecosystem
e-Keke+ Charger Investment	**GEF + UNEP**
e-Keke Ownership	**KK Aggregator**
e-Keke Operations	**KK Aggregator**
e-Keke Maintenance	**KK Aggregator + EV OEM** *(upskilling)*
Charger's Ownership	**Utility co. (or 3rd party)**
Charger's O&M	**Utility co. + Charger OEM** *(upskilling)*

Figure 16: Roles and responsibilities

- The Global Environment Facility (GEF), in conjunction with the United Nations Environment Programme (UNEP), is poised to potentially undertake responsibilities related to the investment in e-Kekes charging infrastructure.
- The KK aggregator is envisaged to assume a multi-faceted role that encompasses the ownership of e-Kekes, the facilitation of e-Kekes' operational activities, and the upkeep and maintenance of the e-Kekes.

- A strategic partnership is being considered between the KK aggregator and Electric Vehicle Original Equipment Manufacturers (EV OEM), with the objective of enhancing operational capabilities through advanced training and upskilling measures.
- The involvement of utility companies, or alternatively third-party entities, is conceptualized for the ownership division of the chargers and the management of Operation & Maintenance (O&M) services.

This collaborative paradigm is aimed at leveraging the collective strengths of participating stakeholders to ensure enhanced operational efficiency, sustainable management, and the long-term viability of the e-Kekes urban transportation ecosystem.

Recommended Business Model

The Pilot Project introduces a meticulously crafted business model that compartmentalizes the roles, financial exchanges, and service provisions within the enterprise. This methodical approach streamlines the integration and cooperation among the key stakeholders involved in the project. Asset and service provisions are depicted by solid lines, indicating the transmission of e-Kekes, chargers, and associated services through the stakeholders, typifying a circulation essential for the sustenance of the project.

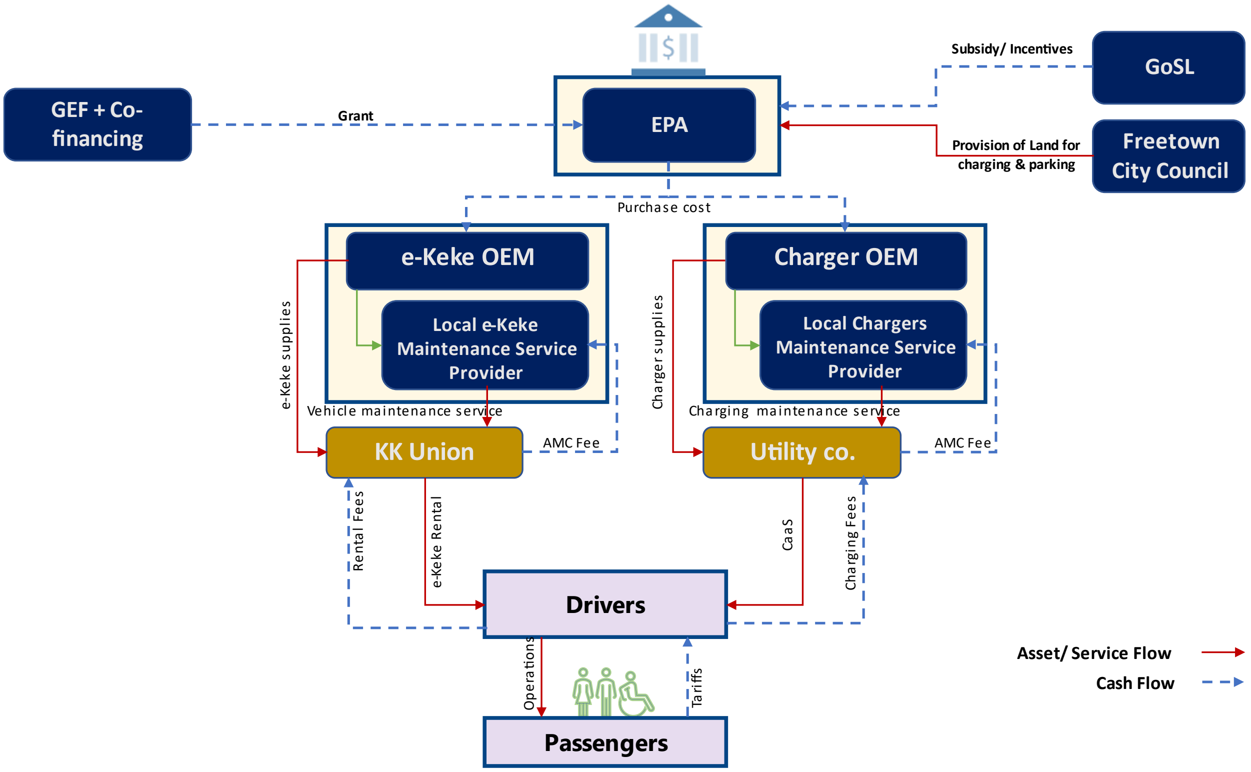


Figure 17: Business Model for e-keke pilot deployment

- **Funding and Subsidies:** At the genesis of the financial structure, the Global Environment Facility (GEF) along with some co-financing contributes a foundational grant, which is supplemented by subsidies, incentives, and the provisioning of essential infrastructure such as land for charging stations and parking, provided by the Government of Sierra

Leone (GoSL) and the Freetown City Council. This ensures the foundational support required for the implementation and operation of the pilot project.
- **Core Operational Stakeholders:** Central to the operations is the KK aggregator, which orchestrates the intricate aspects of e-Keke management spanning vehicle maintenance, driver rentals, and collection of Annual Maintenance Contract (AMC) fees. This body liaises with the e-Keke Original Equipment Manufacturer (OEM) to ensure supply and maintenance of the vehicles.
- **User Engagement and Operations:** Drivers form the link between the KK aggregator and passengers, facilitating the actual transport service. They rent e-Kekes from the union and, in turn, conduct fare transactions with the commuting passengers, effectively rendering the envisioned urban transport service.
- **Support Infrastructure:** The operations are complemented by the Charger OEM, which is charged with the supply and upkeep of charging infrastructure. Meanwhile, a Utility Company or a designated third party is accountable for the operational maintenance of these charging stations and the associated AMC fee collection.
- **Financial and Asset Flows:** The financial architecture is characterized by a delineated cash flow system transporting funds through the network, from grants to service payments, and rental to AMC fees. This framework transparently bifurcates the AMC fee for vehicle maintenance, flowing from KK aggregator to e-Keke OEM, and for charging station maintenance, from the Utility Company to the Charger OEM.
    - The conduct of operations reflects a cyclical economic interaction, wherein passengers pay fares to the drivers who, subsequent to their operations, remit rental fees (1.5 USD/ keke/ day) back to the KK aggregator, thereby perpetuating the continuous motion of the business model.

This comprehensive ecosystem underscores not only the symbiotic relations but also the financial intricacies that are pivotal for the seamless operation and sustainable growth of the e-Kekes urban transport system.

Estimated Economics for Actors

The financial model delineates the income, expenditures, and net profits for the key parties engaged in the "e-Kekes Freetown Pilot Project": the Keke Drivers, the Keke Union, and the Utility Company by considering certain assumptions as follows:

- The rental fees are reduced to 1.5 USD/keke/day (~30 SLE/keke/day) since the e-Kekes are not being purchased by the KK Aggregator as compared to ~5 USD/keke/day (~100 SLE/keke/day) in the existing landscape.[20]
- Electricity tariffs are assumed at 0.32 USD/kWh (~6.4 SLE/kWh) for the charging operator.[21]
- Electricity tariff for swapping is assumed at 0.59 USD/kWh (11.8 SLE/kWh) for drivers.[22]

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[20] PoliticoSL, 2020

[21] EDSA Revised Electricity Tariff, 2023

[22] pManifold analysis based on Indian market

- The transport fares are assumed at 0.20 USD (4 SLE) from 'Pole to Pole'.[23]

Keke Driver:

A breakdown of the financial outcomes for Keke Drivers is as follows:

- Income: Drivers receive 192 SLE (2.4 SLE/km) daily from fares paid by customers.
- Expenses: Total daily expenditures for drivers amount to ~136 SLE, consisting of ~30 SLE rental fee for the e-Keke and ~106 SLE charge for battery swapping services (~53 SLE/1 complete swap).
- Net Profit: Upon offsetting the costs against the income, drivers realize a profit of ~56 SLE per day.

Keke Aggregator:

The Keke aggregator's financial operations are detailed below:

- Income: The aggregator secures a daily income of ~450 SLE through the lease of 15 e-Kekes @~30 SLE per e-keke.
- Expenses: Daily outlays for the KK aggregator are limited to ~30 SLE associated with the Annual Maintenance Contract for electric vehicles (~720 SLE/year/keke).
- Net Profit: The Keke aggregator garners a net daily profit of ~420 SLE post-expenses.

Utility Company:

The Utility Company's finances are tabulated as follows:

- Income: The company accrues ~1,593 SLE each day from the provision of charging services (~106 SLE/day/keke).
- Expenses: Daily electrical tariffs cost the company ~950 SLE, a figure that considers a 90% efficiency rate for the swap station and an established EV tariff rate of ~6.4 leones/kWh.
- Net Profit: Subsequent to the reduction of costs, the Utility Company's net daily profit is ~643 SLE, which notably includes compensation for three station operators.

This fiscal representation offers insights into the economic feasibility and cash flow distribution within the framework of the e-Kekes project, encapsulating the interplay between income generation, operational costs, and profitability margins. However, it is important to note here that this is only for representational purposes to understand the economics for the involved actors and understand the profitability of the swap model. These nos. are sensitive to different factors and may vary during actual operations.

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[23] Ministry of Transport & Aviation, GoSL, 2022; City Profile-Freetown, T-SUM, 2021

6. Monitoring & Evaluation Framework

For the implementation of the e-Kekes Freetown Pilot Project, it is essential to develop a structured Monitoring and Evaluation (M&E) plan to assess the performance, effectiveness, and impact of the initiative. This chapter provides a comprehensive overview of the proposed M&E parameters that will be tracked to measure progress, outcomes, and ensure the project's objectives are met.

The cornerstone of the M&E plan is founded on quantifiable indicators and metrics that reflect the operational efficiency, customer satisfaction, financial sustainability, and environmental benefits of the e-Kekes transportation model. An intricate system of data collection, analysis, and reporting will be implemented, which will allow for informed decision-making and adaptive management throughout the project's life cycle.

Key components to be monitored include:

- **Operational Metrics:** This includes the number of e-Kekes in service, daily usage rates, service availability, and reliability of the transport system.
- **Financial Metrics:** Tracking income, costs, and profitability for each stakeholder in the ecosystem, including Keke drivers, the Keke aggregator, and the Utility Company, will be pivotal. Evaluating the financial aspects will also encompass assessing the impact of funding and subsidies from GEF, GoSL, and the Freetown City Council in sustaining the project.
- **Environmental Impact:** Assessing the reduction in carbon emissions and improvements in air quality due to the deployment of electric-powered e-Kekes compared to traditional fossil fuel-based transportation methods.
- **Customer Experience:** Customer feedback mechanisms will be established to measure satisfaction levels, safety perceptions, and the overall effectiveness of the e-Kekes system in meeting the transport needs of the community.
- **Stakeholder Engagement:** Evaluation of the collaboration efficacy among primary stakeholders such as the KK Aggregator, e-Keke OEM, Charger OEM, and Utility Companies.
- **Socio-Economic Benefits:** Analysis of the social and economic impacts, such as job creation, gender inclusivity by promoting female drivers, and increased accessibility to efficient urban transport services.
- **Training and Capacity Building:** Monitoring the effectiveness of upskilling initiatives for KK Aggregator personnel and drivers will also be integral to the project's success.

The M&E framework shall entail regular progress reports, which will provide transparency and accountability to all project stakeholders. These reports will include both quantitative data and qualitative insights, offering a holistic view of the project's progression. Additionally, the M&E framework will incorporate adaptive strategies to respond to any emerging challenges or opportunities, by revising protocols and approaches as necessary to optimize project outcomes.

Data Collection Methodology:

The M&E plan will utilize both primary and secondary data sources to gather comprehensive insights into the project's performance. Data will be collected through periodic surveys, feedback forms, operational records, financial transactions, and environmental impact measurements. Key data collection methods include:

- **Operational Data:** Real-time tracking systems may be installed in each e-Keke to collect data on usage patterns, distances traveled, and operational hours.
- **Financial Records:** Systematic recording of all financial transactions related to the e-Kekes operations may be carried out. This includes rental payments from drivers, maintenance costs, charging fees, and income from customer tariffs (digital payment if possible/ daily basis income log of drivers).
- **Customer Surveys:** Regular surveys may be conducted on passengers to gather data on customer satisfaction, service quality, and areas for improvement.
- **Environmental Metrics:** Derived from distance travelled in kms and mileage of ICE keke.
- **Socio-Economic Impact:** Socio-economic data may be gathered through community surveys to assess the broader impacts of the project, such as no. of female drivers driving the e-Keke and its impact on their social status, safety, and income, job creation, and improvement in urban mobility.

Data Analysis Protocol:

Collected data will be analyzed using quantitative and qualitative methods, depending on the nature of the data and the information needed. Data analysis will involve:

- **Performance Indicators:** Developing metrics to assess operational efficiency, financial viability, environmental sustainability, and customer engagement.
- **Financial Analysis:** Assessing profitability and cost-effectiveness through detailed financial models and accounting procedures to evaluate economic sustainability.
- **Comparative Analysis:** Comparing the e-Kekes project outcomes with traditional transport models to determine improvements and added value.
- **Thematic Analysis:** Qualitative data from surveys and interviews will be scrutinized using thematic analysis to extract prevalent themes and narratives.
- **Statistical Analysis:** Statistical methods, including regression analysis and variance analysis, will be utilized to interpret data, identify significant trends, and validate the reliability of findings.
- **Reporting:** Data and analysis outcomes will be compiled into comprehensive reports, which will be shared with stakeholders, including the GEF, GoSL, Freetown City Council, and the general public.

Reporting Framework:

Based on the above discussed key components, a data collection framework is prepared for the monitoring, evaluation, and validation purpose of the e-Keke Pilot as highlighted in the table below. Any significant deviations such as point of charging or battery specification need to be re-evaluated for operational feasibility and efficiencies.

Table 8: Monitoring and Evaluation Framework

Grouping	Parameters	Unit	Data Source[24]	Per e-Keke	Fleet Level
Vehicle Performance	Vehicle Speed	km/h	Digital		
	Distance Travelled per Trip	km	Digital		
	SOC at Trip Start and Trip End	%	Digital		
	Failure Type		Manual Log		
	Failure Duration	hour	Manual Log		
	Maintenance Time per Failure Event	hour	Manual Log		
	Vehicle Utilization	hours	Derived		
	Energy Consumption per km Travelled	kWh/km	Derived		
	Seasonal Variation Rate of Energy Consumption	%	Derived		
	Ratio of Actual Range to Nominal Range	%	Derived		
	Battery Degradation Rate per 10,000 km Travelled	%	Derived		
	Failure Rate per 10,000 km travelled	%	Derived		
	Average Maintenance Time	hour	Derived		
Operating Performance	Vehicle Attendance Rate (Days of Operation)	days	Digital		
	Daily Distance Travelled	km	Digital		
	No. of Trips per day	#	Digital		
	Charging or Swapping Duration and Time	hour	Digital		
	Charging or Swapping Events per Day	#/day	Digital		
	Charger or Swap Station Failure Type		Manual Log		
	Charger or Swap Station Failure Duration	hour	Manual Log		
	Maintenance Time per Failure Event	hour	Manual Log		
Financial Performance	Energy Cost/ Charging or Swapping Event	Le	Manual Log		
	Maintenance Cost per Failure Event	Le	Manual Log		
	Driver Income per Day	Le	Manual Log		
	Proportion of Peak-Hour Charging Duration	%	Derived		
	Charger Utilization	%	Derived		
	Maintenance Cost per km Travelled	USD	Derived		
	Energy Cost per km Travelled	USD	Derived		
	Operating Cost per km Travelled	USD	Derived		

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[24] **Manual log/ Digital/ Derived/ Survey**

Grouping	Parameters	Unit	Data Source[24]	Per e-Keke	Fleet Level
	TCO per km Travelled	USD	Derived		
	Stakeholder Income vs. Profit	%	Derived		
Environmental Impact	No. of Power Outage Events	#	Manual Log		
	Energy saved per e-Keke per Year	kWh	Derived		
	CO2 Emission Reduction per e-Keke per Year	%	Derived		
	Air Pollutants Emission Reduction per e-Keke per Year	%	Derived		
Social & Gender Impacts	No. of Female Drivers	#	Manual Log		
	Upliftment in Income and Social Status		Survey		
	Safety Perception of Female Drivers		Survey		
	Customer Satisfaction by Gender		Survey		
	Service Reliability		Survey		
	Travel Comfort		Survey		

The data collection and analysis protocols within the M&E framework are critical for evaluating the e-Kekes project's progress towards achieving enhanced urban mobility, economic empowerment, and environmental conservation goals. They will serve to ensure the project remains accountable, transparent, and capable of adapting to challenges while scaling successes.

In conclusion, the M&E framework will not only serve as a tool for continuous improvement of the e-Kekes Freetown Pilot Project but will also generate valuable lessons and practicable knowledge to inform future scalability and replication in other urban centers. It is through this meticulous and ongoing evaluative process that the project aims to achieve its ambitions of transforming the urban transport landscape in Freetown.

7. Way Forward

For any pilot deployment, there are three phases namely, Design of Pilot, Sourcing and Deployment, and Pilot Monitoring and Learning. This report addresses the first phase. The subsequent report will address the Sourcing and Deployment, and Pilot Monitoring and Learning Phases.

- **Sourcing and Deployment:** To move forward, the initial step is the Expression of Interest (EOI) for the supply of e-Kekes and their charging equipment, which has been announced. Based on the suppliers' interest, technical specifications will be refined and included in the subsequent Request for Proposals (RfP). This updated RfP will then be circulated among the shortlisted suppliers. Additionally, comprehensive training resources, including a drivers' manual as well as operational and safety protocols, will be prepared and provided to drivers before the pilot's inception.
- **Pilot Monitoring and Learning:** Alongside the operational commencement, a systematic data collection initiative will be set in motion. Upon completion of the pilot phase, the data amassed will undergo detailed analysis and culminate in a report. This report will articulate the practical feasibility of e-Kekes as evidenced by the on-ground pilot program and help in planning the next phase for scaling up the operations.

Annexure

Table 9: TCO assumptions and comparison for Kekes

Scenario No.		**Scenario-0A**	**Scenario-1A**	**Scenario-1B**
Scenario Name		**ICE 3W**	**e3W Fixed & Large Battery, new**	**e3W Swap & Small Battery**
Vehicle Model		TVS King Deluxe	Piaggio eCity Fixed	Piaggio eCity Swap
Vehicle Cost (without battery)	CUR	2,818	2,438	2,438
Fuel (or Electricity) tariff	CUR/litre (CUR/kWh)	1.05	0.32	0.59
Battery cost	CUR/kWh		231	-
Battery size	kWh		7.50	4.50
Battery subsidy available	#		-	-
Battery subsidy	CUR/kWh		-	-
Battery cost (after subsidy)	CUR		1,155	-
CIF & Other costs	CUR	47.00	52	37
Vehicle cost (with battery and subsidy)	CUR	2,865	3,645	2,475
Battery weight	kgs/kWh		13.00	13.00
	kgs		98	59
Battery DOD	%		80%	80%
Battery useful Life cycles	#		900	2,000
Battery capacity degradation at end of life	%		70%	70%
Useful Battery capacity (at start life)	kWh		6.00	3.60
Useful Battery capacity (at end of life)	kWh		4.20	2.52
Avg. Vehicle efficiency	litre/km (kWh/km)	0.04	0.10	0.090
	km/litre (km/kWh)	25.00	10.00	11.11
Avg. range in one charge (at start life)	kms/charge		60.00	40.00

Scenario No.		**Scenario-0A**	**Scenario-1A**	**Scenario-1B**
Avg. range in one charge (at end life)	kms/charge		42.00	28.00
Avg. kms run per day	kms/day	80	80	80
Days per year	days/year	300	300	300
Fleet utilization	%	100%	100%	100%
Avg. battery life cycle used per day	#/day		1.57	2.35
Battery life	years		1.91	2.83
Annual mileage accumulation	kms/year	24,000	24,000	24,000
Charger size	kW		3.30	28.00
1C Charging Current	A		125	75
Permitted Battery Charging rate	1/hour		0.25	1.00
Max Charger current	A		69	583
Max Charging speed	1/hour		0.25	1.00
Charging speed (0% to 100% SOC after DOD)	hour/full charge		4.00	1.00
Chargers cost	CUR/kW		-	-
	CUR		-	-
Charger utilization	%		45%	45%
Charging time required per vehicle per day	hours/day		6.90	2.59
No. of vehicles shared per charger	#		3	5
Charger Grid Infra cost	CUR/kW-peak		-	-
	CUR		-	-
Charger Installation & Commission	%		15%	15%
Charger cost per vehicle	CUR/Vehicle		-	-
Vehicle life	years	7	5	5
Charger Life	years		10	10
Interest rate	%	10%	10%	10%

Scenario No.		**Scenario-0A**	**Scenario-1A**	**Scenario-1B**
Vehicle salvage value	%	10%	10%	10%
Battery salvage value	%		20%	20%
Charger salvage value	%		3%	3%
Charger Efficiency	%		95%	90%
Switchyard/ Transformer Loss	%		3%	3%
Fuel (Electricity) consumption	litre/day (kWh/day)	3	9	8
	litre/year (kWh/year)	960	2,604	2,474
		-	-	-
Vehicle man-power cost	CUR/km	-	-	-
Vehicle Annual Maintenance cost	CUR/km	0.01	0.01	0.01
Vehicle Insurance cost	%	2%	2%	2%
Capital Cost Annualised				
Vehicle Cost (without battery)	CUR/year	579	643	643
Battery Cost	CUR/year		693	-
Charging Infra Cost	CUR/year		-	-
Opex Cost Annualised	CUR/year			
Fuel Cost	CUR/year	1,008	659	1,461
AMC Cost for Vehicle	CUR/year	312	156	156
Battery Leasing Cost (if swap)	CUR/year		-	-
Manpower (Charging Station)	CUR/year	-	-	-
Total Cost	CUR/year	**1,899**	**2,151**	**2,260**
Salvage Recovery				
Vehicle salvage value	CUR	(281.80)	(243.75)	(243.75)
Battery salvage value	CUR	-	(346.50)	-
Charger salvage value	CUR	-	-	-
Capital Cost	**CUR/km**	**0.02**	**0.06**	**0.03**
Vehicle Capitalization Cost	CUR/km	0.02	0.03	0.03
Battery Capitalization Cost	CUR/km	-	0.03	-

Scenario No.		**Scenario-0A**	**Scenario-1A**	**Scenario-1B**
Charging Infra Capitalization Cost	CUR/km	-	-	-
Opex Cost	**CUR/km**	**0.06**	**0.03**	**0.06**
Fuel Cost	CUR/km	0.04	0.03	0.05
AMC Cost for Vehicle	CUR/km	0.01	0.01	0.01
Battery Leasing Cost (if swap)	CUR/km	-	-	-
Manpower (Charging Station)	CUR/km	-	-	-
Total Cost of Ownership (TCO without salvage)	CUR/km	**0.079**	**0.097**	**0.086**