Journal of Development and Social Engineering
Volume 9 | Number 1 | December 2023, 63-77
ISSN 2383-5332 © School of Development and Social Engineering, Pokhara University


# Assessing the Dynamics of the Financial Viability of Eleven-Seater Public Battery Electric Vehicles in Nepal

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**Abstract**: Public electric vehicles have been identified to make notable contributions to sustainable development and climate change mitigation among other goals. In Nepal, public battery electric vehicles (BEV) are becoming mainstream in certain segments of the market. With that, there are also several systemic challenges that could halt this momentum. This calls for understanding their viability and how they are impacted by interactions and interdependencies between various components of the public BEV ecosystem and the environment around it. The purpose of this study is to conduct a total cost of ownership (TCO) analysis of public BEVs in Nepal and assess sensitivities resulting from the interlinkages and changes in key factors.

The study prepared a financial model for a TCO estimation of an intercity public electric microbus (EMB) model in Nepal and compared it with a diesel microbus (DMB). Guided by a systems thinking framework, sensitivity analyses were done to provide broad insights into financial viability.

The TCO of the EMB was found to be lower than that of its diesel counterparts. That said, the sensitivity analyses show that there are several factors that could affect the financial viability of public EMBs. Overall, it was seen that the EMBs are more resilient to change than the diesel variants.

Financial viability is one of the key factors for vehicle adoption by businesses. Policymakers and practitioners can use systemic perspectives to have a well-rounded approach to supporting BEVs' growth. The proposed framework aims to help gather such perspectives.

**Keywords:** Public battery electric vehicles, Total cost of ownership, Sensitivity analysis, Assessment framework

## Introduction

The transport sector is the largest source of CO2 emissions in the energy sector of Nepal (Government of Nepal [GoN], 2021). As a part of its commitment to mitigating Green House Gases (GHG) emissions, Nepal has set targets and prepared policies around electric vehicle adoption. One of the key documents is GoN (2020) which has set a target to have 90% of the total sales of private passenger vehicles and 60% of the total sales of public passenger vehicles to be covered by electric vehicles in 2030. As a member country of the UN, Nepal is also committed to achieving the Sustainable Development Goals (SDGs) (National Planning Commission, 2017). The SDGs include a dedicated target, Target 11.2 of Goal 11, which focuses on public vehicles. Besides that, there are five targets directly related to and seven targets indirectly related to sustainable transport (SLOCAT Partnership, n.d.).

According to the Central Department of Environmental Science (2017), public vehicles are among the largest emitters in Nepal's transport sector. Electrifying buses has been a major concern because they are the main mode of public transportation in the country (Department of Transport Management [DoTM], 2020; MoFE, 2021). However, it is difficult to assess progress because accurate figures on the state of electric buses in Nepal are not publicly available. Newspaper articles (Onlinekhabar, 2023; Onlinekhabar, 2022) and field interactions indicate that the adoption of electric buses has increased over the years. Especially, the operation of EMBs is thriving in certain intercity routes (The Rising Nepal, 2022). Sustaining and scaling such growth could take the country closer to its decarbonization targets.

Currently, there is a lack of literature on the performance and challenges of intercity buses in Nepal due to which it is unclear how these electric buses compare economically to internal combustion engine (ICE) buses. The TCO analysis is an emerging tool to compare the economic performance of different vehicles where it provides a basis to estimate the cost of owning a vehicle over a certain period (IEA, n.d.). It comprises the expenses incurred directly from the operation of a vehicle. This tool has been used in a wide range of research. In a study conducted by Nurhadi et al. (2014), the TCO of two distinct electric buses was compared. The authors emphasized sensitivity analysis to minimize uncertainty by identifying the key factors that are likely to have the most influence on the estimated cost values for the electric bus. Kumar and Chakrabarty (2020) present a financial model to compare the TCO per km of different modes of transport in India's context (Kumar & Chakrabarty, 2020). A TCO model is used for freight vehicles in Vijayagopal and Rousseau (2021) where sensitivities related to battery and energy cost, and vehicle range and distance traveled are studied.

**Problem Statement**

Several grey literature sources (Global Green Growth Institute, 2018; MoFE, 2021) have identified barriers to the adoption of public electric vehicles in Nepal. In addition to these papers, others (Maharjan & Susskind, 2011; Smith, 2019) have also discussed past failures in electric public transport operations. These technologies initially showed promise but ultimately failed. Various factors hindered the expansion, management, or financial health of the operation. Economic viability is a key factor in sustaining public transport operations, as indicated in the literature. If electric vehicles are not cost-competitive with Internal Combustion Engine (ICE) vehicles, adoption becomes challenging (franzo et al., 2022).

Various research papers (Pathak & Subedi, 2021; Sah & Paudel, 2023; Maharjan & Shakya, 2020) have analyzed the Total Cost of Ownership (TCO) of electric vehicles in Nepal's context. Maharjan & Shakya (2020) compared an electric bus with a diesel bus operating inside the Kathmandu Valley. Pathak & Subedi (2021) performed a sensitivity analysis for two-wheelers and cars. However, an assessment of intercity EMBs has not yet been done. Microbuses have become the most popular category of electric buses in Nepal, so understanding their operation details could provide useful insights. Additionally, because the public electric vehicle market is nascent and there are many uncertainties and dynamics at play, a holistic understanding of the ecosystem and how the viability of the transportation system is interconnected with other factors could provide a better approach to understanding sensitivity. Simply using out-of-the-box parameters to check sensitivities may not be sufficient.

The novelty of this study is the use of a framework to assess the interaction of public electric vehicle operation with various components of the public transport ecosystem and the external environment. It uses the TCO as the focal point and analyzes how various factors impact the TCO. A framework is proposed to holistically understand the dynamics of financial viability. Such an approach can also highlight externalities that indirectly impact viability but cannot be quantifiable with the currently available data.

The following objectives aim to provide a comprehensive understanding of the economic feasibility of EMB operations in Nepal. This information can be used for further research, and for informed planning and decision-making.

a. Perform an economic viability analysis through a Total Cost of Ownership (TCO) comparison of an electric and a DMB operating on an intercity route in Nepal.

b. Propose a framework to assess the sensitivities dynamics of the economic viability of EMB operation in the selected route due.

## Data and Methods

The TCO can drastically change depending on the type of vehicle and operating conditions. Vehicles can differ in terms of energy consumption, quality of the product, and government regulations among other features. Similarly operating conditions such as the Vehicle Kilometers Travelled (VKT), driving behavior, atmospheric condition, and road conditions (gradient, smoothness, windings) can also vary. These factors make generalization of TCO difficult. The purpose of this study, however, is to assess the sensitivities that impact the TCO of any inter-city public vehicles and routes rather than for specific cases, therefore, a sample route and vehicles are considered for simplicity.

The study uses quantitative and qualitative methods to analyze the viability of intercity public electric micros in Nepal. The study did a literature review and stakeholders' interactions to source the data for the analysis and to develop the framework. A review of grey and white literature was done to gather the global scenario, formulas for calculation, and other available information. To understand the public electric vehicle operation situation, especially that of the inter-city routes, the study depended on interactions with stakeholders: vehicle operators, vehicle owners, passengers, vehicle importers, and dealers, representatives from the development sector, government staff, and policymakers. To address the data gaps, assumptions related to the operation were made based on information provided by the limited available sources.

The study first developed a model to calculate the TCO.

The TCO fundamentally comprises the capital cost and operation cost of the vehicles. This study calculates the TCO in terms of NPR/km. The formula for the TCO calculation is adopted from Wu et al. (2015) which is as follows:

$$\text{TCO/km} = \frac{(C_v + C_b - RV * PVF) * CRF + \frac{1}{N}\sum_{n=1}^{N}\frac{C_o}{(1+d)^n}}{VKT}$$

Where is the purchase cost of the vehicle, is the purchase cost of the battery replacement. is the residual value of the vehicle and the battery. is the average operating cost, is the discount rate, and N is the operating years of the vehicle. PVF is the present value factor calculated as 1/(1+ )N and CRF is the Capital Recovery Factor calculated as ( (1+ )N/((1+ )N-1). VKT is the annual average vehicle kilometers traveled.

The first part of the equation is the capital cost component. The and are taken from the market while the residual value is calculated based on Liu et al. (2023). Because the vehicle and the battery depreciate at different rates and the cost of the battery is significant as a proportion of the whole vehicle, the residual value is segregated.

$$RV = \begin{cases} \frac{(1-DR_v)^N * C_v}{(1+d)^{N-1}} + \frac{(1-DR_b)^N * C_b}{(1+d)^N} & (N < N_b) \\ \frac{(1-DR_v)^N * (C_v - C_b)}{(1+d)^{N-1}} + \frac{(1-DR_b)^{N-N_b+1} * C_b}{(1+d)^{N-N_b}} & (N \geq N_b) \end{cases}$$

Where and are the depreciation rates of the vehicle and the battery which are calculated based on the current estimated resale rate and operation life. is the year when the battery is replaced. If the year for which the TCO is being calculated exceeds the battery life, then will have to be reset to calculate the residual value of the replaced battery. To address this, the second equation is formulated. It is to be noted that the oldest EMBs have operated for only three years, therefore the study makes an estimate with the limited data received from stakeholders. The resale rate of diesel vehicles also varies largely, and documented past resale rates were not available during the study; therefore, the resale rate is also an interaction-based estimate.

The second part is the total average operating cost per year. The study assumes that the purchase will be done through a loan. Therefore, the operating cost also incorporates the interest paid against the loan. The equation for the operating cost is as follows.

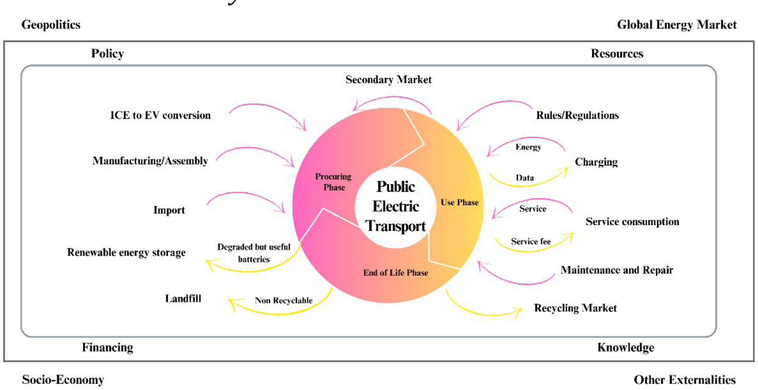
$$C_o = C_e + C_f + C_m + C_{ad} + I_v + I_b$$

Where $DR_v$ and $DR_b$ is the cost of employees' salary and allowances and is the fuel cost which is the charging cost for the EMB and diesel cost for the DMB. is the servicing and maintenance cost and is the administrative costs.

To understand the sensitivities, the study proposes an electric public transport framework that looks at the subcomponents of the EMB ecosystem, the environment around it, and how there is interaction between these different layers. Figure 1 illustrates the proposed framework which has been used once previously in the draft of a grey literature to understand the opportunities and challenges of public electric transport in Nepal (UN ESCAP, 2023). This framework and its analysis approach are based on the circular economy framework of Esteva et al. (2020) and the systems thinking approach, particularly the hard systems approach. Hard systems thinking is one of the approaches that incorporate systemic thinking into research instead of using a reductionist approach to problems (Bawden, 1984). This implies looking at a problem more holistically (Monat & Gnnon, 2015). This type of approach aims to identify important environmental factors and interactions that affect the system's behavior.

**Figure 1**

*Public Electric Vehicle Ecosystem Framework*



In Figure 1, the core system comprises the life cycle of the electric vehicle which starts from procurement, then operation, and then it is sold in the market if there is remaining life or reaches the end-of-life phase. Within the system, there are sub-systems, for instance, charging and repairing in the use/operations phase. Furthermore, the public electric transport ecosystem is largely influenced by four key factors: policy, financing, resources, and knowledge. National and global needs shape the policy landscape for public electric transport. Financing enables the development of businesses and initiatives. Resources provide the foundation for the effective operation of public electric transport. Data plays a crucial role in facilitating informed planning and decision-making. Beyond these governing factors are the elements such as socio-economy, global market, geopolitics, and other externalities that influence the public electric transport landscape.

## Results and Discussion

This section summarizes the outcome of the data collection and analyses. Table 1 shows the capital cost-related data. All the data except the ones cited were collected from stakeholder interactions. The battery cost is based on the current international costs of li-ion batteries (International Energy Agency [IEA], 2023) and incorporates the government taxes (Department of Customs [DoC], 2020). The discount rate is taken as a three-year average recurring deposit interest rate published by the Nepal Rastra Bank (NRB, n.d.a.).

**Table 1**

*Capital Cost Components of the TCO*

| Parameters | EMB | DMB |
|---|---|---|
| Maximum passenger occupancy | 11 | 13 |
| Battery capacity (kWh) | 42 | NA |
| Vehicle cost (NPR) | 4,500,000 | 4,700,000 |
| Battery cost (NPR) | 1,351,186 | NA |
| Discount rate (%) | 8.48% | 8.48% |
| Expected vehicle life (years) | 15 | 15 |
| Vehicle depreciation rate (%) | 6% | 6% |
| Battery depreciation rate (%) | 11.7 | NA |
| Vehicle resale rate (%) | 10% | 10% |
| Battery resale rate (%) | 30% | 30% |

Similarly, the details of the operational costs are shown in Table 2. The annual driven distance or the VKT for the vehicles is 77,500 km calculated from the assumption that they drive 310 km (all buses do two-way trips every day, covering 155 km one-way) for 250 days a year. An extra 5 km for the 150km route is taken because it is a practice to drop the passengers beyond the destination and cover their last miles and based on drivers' experience that is roughly the average daily distance they travel for their passengers. For the fuel cost, a mileage of 5.5 km/kWh for the EMB and 9 km/l for the diesel micro bus is taken. The charging cost is taken as NPR 10.44, a 20% markup (Gnawali, 2022) on NEA's tariff rate (Nepal Electricity Authority [NEA],

2022) meanwhile the diesel cost is taken as NPR 130 per liter based on three years average diesel price in Nepal (MoF, 2022; MoF, 2023). To estimate the interest on the vehicle, a loan term of five years, down payment of 30%, average interest rate of 14.5% (NRB, n.d.a.), and loan processing fee of 0.75% (NRB, 2022) is considered. Yearly inflation of 5.7% is assumed based on the past three-years average rate (NRB, n.d.b)

**Table 2**

*Operational Cost Component of the TCO*

| Parameters | EMB | DMB |
|---|---|---|
| Annual driven distance (km) | 77,500 | 77,500 |
| Yearly fuel cost (NPR) | 147,109 | 1,119,444 |
| Yearly staff cost (NPR) | 495,000 | 495,000 |
| Annual maintenance cost (NPR) | 106,500 | 163,333 |
| Annual administrative cost (NPR) | 208,942 | 218,131 |
| Annual interest on the vehicle (NPR) | 259,909 | 271,460 |

**Figure 2**

*Total Cost of Ownership of the Electric Microbus and Diesel Microbus*

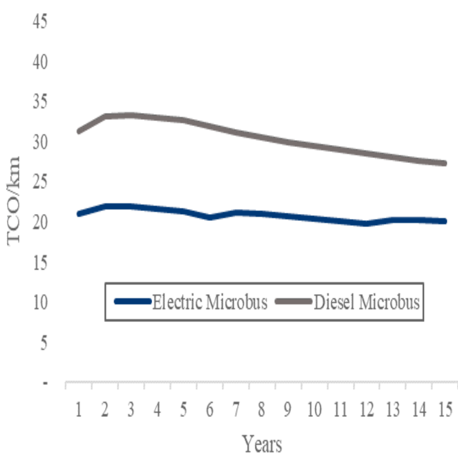



Figure 2 highlights the total cost of ownership per km of the EMB and the DMB based on the years of ownership. Overall, the TCO of the EMB is nearly 1.5 times cheaper than the DMB. If operated for 15 years, the TCO per km of the EMB is NPR 20/km while that of the diesel counterpart is NPR 27.2/km. If the owner chooses to operate for 10 years only, then the TCO is again similar at 20.3/km and 29.4/km respectively. The significant difference between these two vehicles is the fuel cost where diesel refueling cost is over seven times higher than charging costs.

There are no existing TCO analysis papers/reports of EMBs in the public domain, however, GGGI (2020) presents the TCO for a mid-size bus of seating + standing capacity of 50-person was calculated to be NPR 13.98. Analysis of private four-wheelers by Pathak and Subedi (2021) shows the TCO for private vehicles to be in the range of NPR 40 to 150 and as the assumed VKT increases, the TCO can go as low as 20.96 for VKT 20,000. As mentioned in the Data and Methods section, TCO widely varies based on the vehicles and operating conditions, these results cannot be compared directly for insights.

***Understanding the Sensitivities***

Using the framework, the study has gathered the following insights on the public electric transport ecosystem and the sensitivities to the economic viability of EMBs. The change in TCO values is shown for sensitivities that can be quantifiable based on reasonable assumptions. For the ones with high uncertainty, qualitative observations are made. This section also examines the versatility of the TCO approach to holistically assess economic viability.

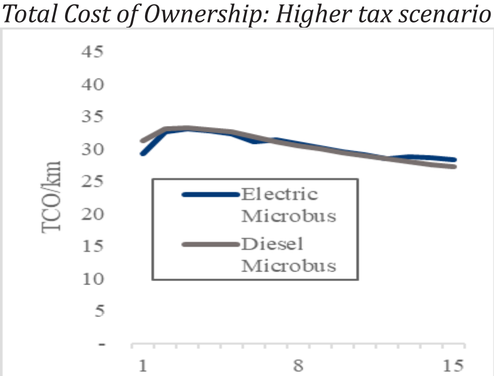
***Procurement Phase***

Ownership of the vehicle begins from the procuring phase. Vehicles could be imported, sourced from local manufacturers/ assemblers, or bought from the secondary market. Currently, all the electric buses are imported in Nepal. The government of Nepal has subsidized the import taxes for electric buses (DoC, 2020) which has highly reduced their capital cost in the Nepali market. The EMB under study would have costed nearly 9,400,000 instead of NPR 4,500,000 had there been same tax as that of the DMB. The purchase cost competitiveness of the EMB with its diesel counterparts has been one of the key factors for the rapid adoption.

Tax subsidies seem to support electric vehicles adoption overall, however, there also needs to be an assessment of the cost benefits of such provisions for the government. If these subsidies are removed from the EMB, then the TCO increases from NPR 20 per km to NPR 28.26 per km as shown in Figure 3. The TCO is nearly the same as that of the DMB, however, because the purchase cost is now over two times higher, the down payment and EMI will also double.

**Figure 3**

*Total Cost of Ownership: Higher tax scenario*




Quality assurance of the vehicles and battery was seen as another key factor in the procuring phase. As current regulations are not strong enough, poor-quality products could penetrate the market and create problems in operations. Manufacturing/ assembling within the country could contribute to the economy, however, there are no frameworks to bind the produced vehicles by standards and regulations to prevent compromise in safety and other qualities. Quality uncertainties could mean risks of reaching end-of-life early, increased maintenance costs, increased fuel costs, and frequent breakdowns all of which will impact the TCO.

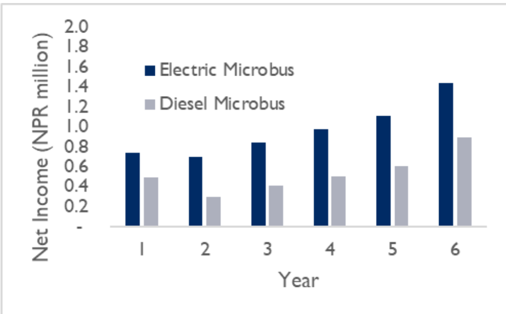
Stakeholders' remarks and the sensitivity analyses from the model signified that markets for batteries and used vehicles are other important factors when evaluating the economic feasibility of EMBs. Currently, there is uncertainty about the future costs of batteries as none of the existing EMBs have had to replace or pay for the replaced batteries yet. The global battery market will also have an impact on these costs. Additionally, the market for second-hand EMBs is not well established due to the limited number of vehicles that have entered the secondary market. As a result, it is difficult to predict resale rates. Another emerging topic of interest among stakeholders is the potential for ICE to EV conversion for public vehicle fleets (TechLekh, 2022; Sajha Yatayat, n.d) which is also not explored enough in terms of technical and financial feasibility. How the TCO will be impacted if the businesses own the converted vehicles needs more insights.

***Operation Phase***

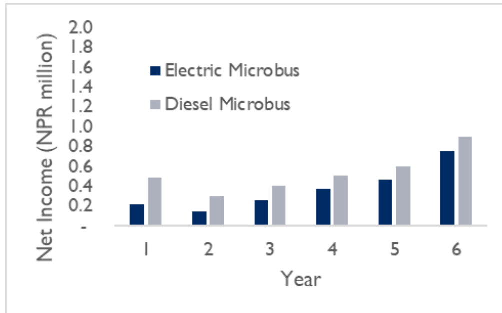
During the operation phase, the focus is on delivering service to passengers and generating income from their fares. Sufficient passenger demand is crucial for the viability of public transport. However, if service delivery is inadequate, passenger demand is negatively impacted. For instance, on one route where an EMB operates, there are no fast-charging stations beyond a certain point, causing the vehicle to spend an extra hour reaching an adequate State of Charge (SOC). This extra waiting time is inconvenient for the passengers, and they shared that they preferred the diesel buses instead. Other factors such as increased private vehicle ownership and migration can also affect demand. While a decrease in passenger occupancy does not impact the TCO, it does reduce the revenue generated by the vehicle.

**Figure 4**

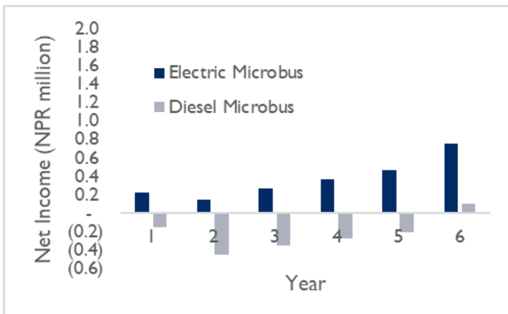
*Net Profit under different scenarios*




(a) Base case




(b) 25% reduction in passenger occupancy of




(c) 25% reduction in passenger occupancy of both

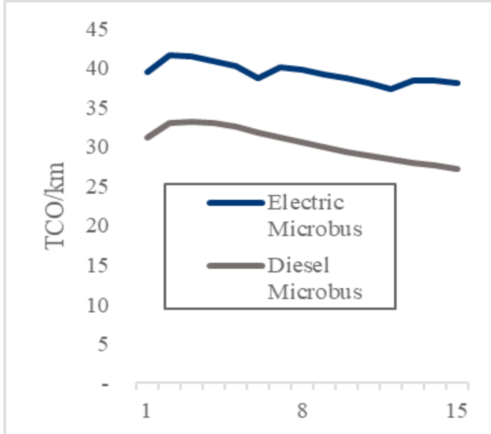
Figure 4 shows the net profit/loss analysis for the first six years of operation of the two vehicles. In practice, the fare for both vehicles are NPR 800 per person and the operator's experience shows an average passenger occupancy over a year is 64% and 62%. The net profit of the EMB is currently higher than that of the DMB as shown in Figure 4 (a), however, if there is an arbitrary 25% decrease in average passenger occupancy, the profit is lower (Figure 4(b)). Loss of revenue is one of the biggest concerns and can deter a business/entrepreneur from opting for the vehicle despite the lower TCO. On the other hand, because the TCO is lower for the EMB, a similar rate of decrease in occupancy in both types of vehicles will have comparatively less impact on the EMB than the DMB as seen in Figure 4(c).

For electric vehicles, charging infrastructure is the backbone of operation. Operators charge at their overnight dwelling location and in the charging stations along the route. Fast chargers were seen to be crucial for intercity vehicle operation when public vehicles had to traverse distances beyond the battery range. For the route under study, the vehicles were able to reach the destination (one-way) on a single charge but had to plug in for the return trip on the same day. During the initial year of operation of the first EMBs, there was no DC fast charger available, and the operators had to use slow chargers. They could do only a one-way trip per day. As seen in Figure 5, if the vehicle operates only a one-way trip due to the lack of charging infrastructure, the TCO per km becomes higher than that of the DMB which would operate without refueling hurdles. Availability of financing, proper placement and sizing of chargers, and reliable electricity infrastructure are some of the key requirements for seamless charging services. These factors should be well understood and improved to support electric public vehicle operations.

Some of the regulation related costs for public transport operations are registration and regular fees for operation in a route, and tax payments. The vehicle owners are also part of associations which are companies that encompass multiple vehicle owners. Because most public vehicle owners in Nepal have one or a few vehicles in their fleet, they enroll in the associations for administrative support. They usually pay a fee for enrollment, a monthly levy, and a fee for a central collection called Bhalai Kosh. The Bhalai Kosh is used when a large sum of money needs to be mobilized and the insurance would not cover all the costs such as when an operator gets severely injured in an accident. Operators have mentioned that if the associations are dependable, the Bhalai Kosh provides a massive support in emergencies. Accounting expenses for this fund collection can therefore provide a more reliable TCO result because some unforeseen and large expenses are transferred to the association. All these costs are covered in the administrative costs in the TCO analysis of this study.

Figure 5

*Total Cost of Ownership: Reduced number of trips*




Maintenance and repair are other key factors for operation. Currently, maintenance and repair facilities are lacking for public electric vehicles. Especially for the batteries and the battery management system (BMS), different sets of skills are required from that of maintaining ICE vehicles for which resources are limited. This has resulted in situations such as long waiting periods for repair, high cost of maintenance, and recurring maintenance issues. These factors would increase the cost of operation.

***End-of-life Phase***

As mentioned in the procurement phase section, there is high uncertainty about the life of the electric micros and the batteries. There is no evidence on how the vehicle and the battery perform in Nepal's condition. The current assumption is that the vehicle life is 15 years and the battery life is 6 years. How the TCO would change if the lifespan changes were unclear. Furthermore, the recycling market of lithium-ion batteries is also not mature in Nepal, therefore, the resale value after the end-of-life was difficult to quantify. As the existing electric EMBs start to age, some supporting data could be generated.

## Conclusion

The study conducted an illustrative TCO per km analysis comparison of an EMB and a DMB model operating in an intercity route in Nepal. The results show that the TCO per km of the EMB is lower than that of the DMB primarily due to a large difference in the fuel cost. Furthermore, the proposed framework for assessment of the public EMB ecosystem highlighted the sensitivities through quantitative and qualitative observations. There are several factors in play that can impact the financial viability of the EMB. Most of those factors pose uncertainties due to the nascency of the BEVs' operation and lack of information. It was, however, observed that when there are sensitivities that impact both the electric and the diesel vehicles, the EMB were more resilient to those changes. It was also clear that some factors of financial viability cannot be captured through the TCO analysis alone and other tools such as the traditional net profit analysis should also be employed to get a well-rounded picture.

The findings of this study can be used for further research on financial viability, challenges, and opportunities for electric public vehicles, and understanding other dynamics of public electric vehicle operations.

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