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Modelling Route Cost and Performance Evaluation of Public Buses in Kathmandu: A Case Study of Sajha Yatayat Electric Buses

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Abstract

This study assesses the operational and financial performance of Sajha Yatayat's electric buses in Kathmandu, highlighting route cost estimation, revenue generation and service productivity. A mixed method approach was applied including field surveys, key informant interviews (KIIs), operational data analysis and statistical evaluation through SPSS. Signal to Noise (SNR) analysis was used to identify and rank the key factors affecting route cost which emphasizes vehicle and battery depreciation, route distance, energy price fluctuation, labor costs and fare structures. A cost allocation model was developed based on vehicle hours (VH), vehicle kilometers (VK) and peak vehicles (PV) to estimate route wise operational expenses for fiscal year 2023/24. The model projects a total operational cost of NRs. 139.4 million with higher costs related with longer routes requiring peak vehicles. The performance evaluation such as revenue/cost ratio, operating cost per vehicle kilometer, operating cost per passenger and revenue per vehicle kilometer show overall profitability and financial sustainability with revenue/cost ratio between 1.2 to 1.3. Annual revenue reached NRs. 50.97 million supported by 3.45 million passengers, showing increasing ridership and growing public acceptance.

Keywords: Electric Buses; Route Cost; Cost Allocation Model; Operational Performance; Revenue Efficiency

1. Introduction

Globally, electric bus sales exceeded 70,000 units in 2024 with the increase significantly attributed to market expansion in China while sales in outside China increased discreetly by 5% in 2024, they have nearly tripled compared to 2020 (IEA, 2025). In Nepal, Sajha Yatayat operates a fleet of 40 electric and 71 diesel buses with the larger diesel fleet considering a higher proportion of indirect operational expenses.

The Government of Nepal initiated electric mobility objectives through National Action plan for Electric Mobility (2020-2030) which aims to replace 60% of fossil fuel based public transport vehicles with electric alternatives by 2030 (MoPIT, 2020). Nepal's second and third Nationally Determined Contributions (NDCs) commit to achieving 20% electric public transport vehicles by 2030 (MoFE, 2025). In 1961, Sajha Yatayat has become a public transport operator in Nepal and has recently advanced the national electrification plan by introducing electric buses on different intracity routes in Kathmandu manufactured by China Hi- Tech Group Corporation (CHTC) and assembled locally are equipped with fast charging lithium iron phosphate ($LiFePO_4$) batteries representing a major technological improvement relative to growing public transport fleet.

Kathmandu and Lalitpur districts are facing increasing stress on their transportation networks as a result of explosive urbanization, high population density, unplanned urban growth and rising private vehicle ownership influenced by fossil fuel vehicles. By fiscal year 2023/24, Nepal reached 5.85 million registered vehicles with a significant portion concentrated within the Kathmandu valley (DoTM, 2025). Although electric buses have comparatively lower lifecycle operating cost, long term financial viability remains uncertain due to high capital requirements, fluctuate electricity tariffs and battery degradation. Further literatures indicates that route cost characteristics including traffic congestion and stop frequency play a major role in determining the route cost of electric bus operations (Basuki, 2025; Dirks et al., 2022). The general objective of the study was to develop route cost model and performance evaluation of public electric buses of Sajha Yatayat in Kathmandu.

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2. Literature Review

2.1 Factor Affecting Route Cost for Electric Public Transport

Table 1 represents the key factors affecting route cost for electric public transport considering both operational and policy dimensions that give electric bus systems across diverse urban settings. Additionally, the table 1 shows overview of cost factors identified in international and national studies.

Table 1 Route Cost Factors affecting an electric public transport

Factors	(Tong, Hendrickson, Biehler, Jaramillo, & Seki, 2017)	(Charwand & Gitizadeh, 2018)	(Zhao, Zhang, & Xu, 2020)	(Li, Zhang, & Wang, 2022)	(IEA, 2022)	(Ji, Bie, Zeng, & Wang, 2022)	(Pei, Hu, Han, Qu, & Zou, 2024)	(Gharehghani, et al., 2024)	(MoFE, 2025)	(MoPIT, 2020)	(EVAN, 2022)
Depreciation Cost (Vehicle/Batteries)	×	×	×	×	×	×	✓	×	×	×	×
Route Distance	✓	×	×	×	×	✓	×	×	×	×	×
Traffic Congestion & Travel Delays	✓	×	×	×	×	✓	×	×	×	×	×
Ticket Fare Pricing and Revenue Generation	✓	✓	×	×	×	×	×	×	×	×	×
Trip Time	×	×	×	✓	✓	×	×	×	×	×	×
Staff Salaries & Labor Costs (Drivers, Technicians, Conductors)	×	×	×	×	×	×	×	×	✓	✓	✓
Battery Degradation/Replacement	✓	×	×	×	×	×	×	✓	×	×	×
Energy Price Fluctuation (Electricity Tariff Changes)	×	✓	×	×	×	×	×	×	×	×	×
Route Planning Efficiency (Passenger Load per Trip)	×	×	×	✓	✓	×	×	×	×	×	×
Charging Duration and Time Lost in Recharging	✓	×	✓	×	×	×	×	×	×	×	×
Downtime Due to Charging or Technical Issues	×	×	✓	×	×	×	×	×	×	×	×
Bus Maintenance and Repair Cost	✓	×	×	×	×	×	×	✓	×	×	×
Bus Procurement Cost and Financing	×	×	×	×	×	×	×	×	✓	✓	✓
Battery Charging Cost (Electricity Used per Day)	✓	✓	×	×	×	×	×	×	×	×	×
Government Subsidies for Electric Vehicle Operation	✓	×	×	×	×	×	×	×	✓	✓	✓
Availability of Spare Parts for Electric Buses	✓	×	×	×	×	×	×	✓	×	×	×
Fringe Benefits Cost (Operator Bonuses/Incentives)	✓	×	×	×	×	×	×	×	×	×	×
Public Acceptance and Ridership Levels	×	×	×	✓	✓	✓	×	×	×	×	×
Advertising Media & Meetings	×	×	×	×	×	×	×	×	×	✓	×
Availability and Accessibility of charging Stations	✓	×	✓	×	×	×	×	×	×	×	×
Policy and Regulation Support (Tax Exemption, Import Duties)	✓	×	×	×	×	×	×	×	✓	×	✓
Cost of Training Staff to Operate/Maintain Electric Buses	✓	×	×	×	×	×	×	✓	×	×	×

2.2 Signal to Noise Ratio in Performance Evaluation

The Signal to Noise Ratio (SNR) is a statistical indicator shown as the ratio of the mean to the standard deviation which is commonly used to determine stability of a variable (Thangjai & Niwitpong, 2019). A higher SNR value indicates lower variability. In electric vehicle study, SNR has been employed to rank cost related factors. In this research, it is utilized to determine the consistency and stability of route cost factors for Sajha Yatayat's electric bus operations.

2.3 Cost Estimation and Modelling

Analytical cost estimation including Total Cost of Ownership (TCO), cost per kilometer (CPK) and levelized cost of transport (LCOT) are commonly used to assess the financial viability of public transport systems (Rogge et al., 2018). For electric bus operations, administrative labor costs, material and supplies cost, electricity expenses substitute traditional fuel costs while battery depreciation, replacement and charging infrastructure are treated as capital and maintenance costs.

In mixed fleet environments, system expenses must be proportionately distributed across vehicle types to derive route cost estimates (Simpson & Curtin, 1981). Sajha Yatayat's fleet mixed of 40 electric and 71 diesel buses, the Fully Allocated Cost Model (FACM) is an appropriate model as it assigns indirect costs into fleet structure (Cervero et al., 1980; Rogge et al., 2018).

2.4 Route Operational Performance

Route operational performance was evaluated through quantitative indicators that evaluate service efficiency, cost effectiveness and system utilization (Fielding et al., 1978). The key performance determines include operating cost per kilometer, operating cost per passenger, revenue to cost ratio, revenue per kilometer and passengers per vehicle per day (Ahasan & Kabir, 2019; Singh, 2023). Financial evaluation incorporates fixed and variable costs, depreciation, interest rates and residual value (Mishra et al., 2020) while overall benefits depend on service utilization, responsiveness to passenger demand and reductions in private vehicle use contributing to broader economic and social gains (Litman, 2025; Wright, 1987).

2.5 Operational Variables Influencing Electric Bus Costs

Studies by Zhao et al. (2020), Li et al. (2022) and Shen et al. (2019) report that electric buses achieve 33-38% lower operating costs than diesel buses though their cost performance is more sensitive to energy prices and operational efficiency as presented in figure 1.

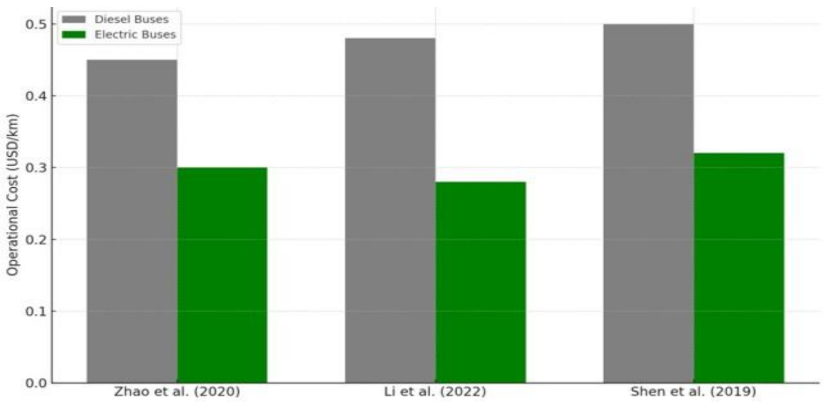


Figure 1 Operational costs of electric versus diesel buses as per different studies

(Source: Zhao, Zhang, & Xu, 2020; Li, Zhang, & Wang, 2022; Shen, Zhang, & Liu, 2019)

Electric bus costs are influenced by route gradients, charging availability, power reliability and downtime (Liu et al., 2017; Tong & Ng, 2023; IEA, 2022; Tong et al., 2017). While these factors affect operational costs, their impacts on revenue are often not quantified.

Sajha Yatayat operates a heterogeneous fleet, so indirect costs are proportionally allocated according to vehicle share, consistent with fully allocated cost models used internationally (Cervero et al., 1980; Rogge et al., 2018). Government initiatives ranging from tax incentives to incorporation within national climate strategies have facilitated the transition toward electric mobility (MoPIT, 2020; EVAN, 2022). The placement of electric buses along major corridors such as Airport-Lagankhel and Kalanki-Ratnapark during 2022-2023 mark an important role in Nepal's public transport electrification (Sajha Yatayat, 2024).

Despite these policy and operational developments, Nepal still lacks of research on route cost estimation and performance evaluation for electric public transport. Existing studies have mainly focused on electric vehicles from a consumer perspective and have not provide comprehensive route cost model suitable for public transit operations (Ghimire et al., 2023).

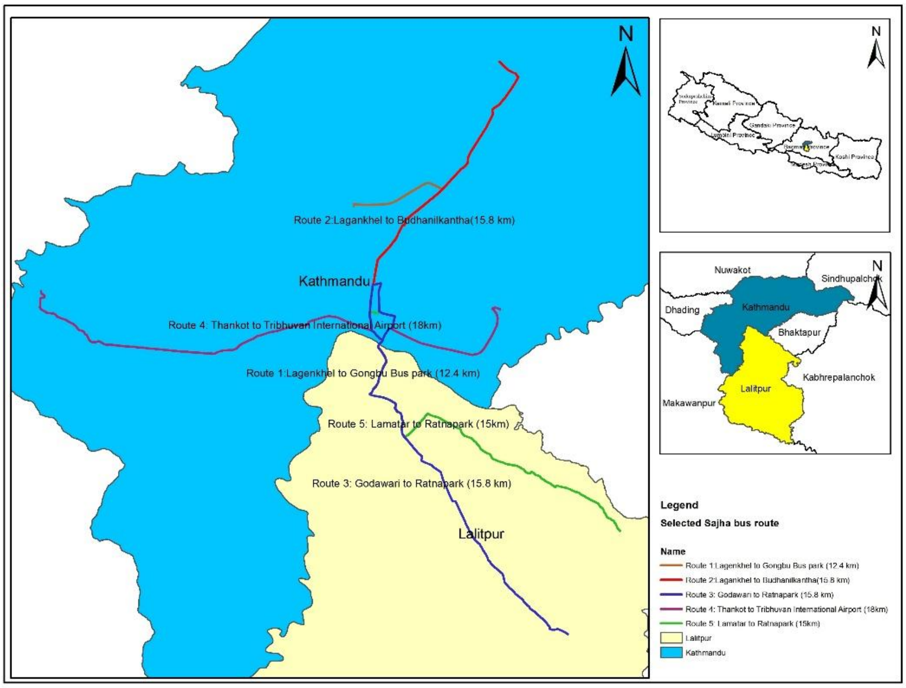
3. Methodology

3.1 Research Approach

The research utilized a mixed method approach, incorporating qualitative and quantitative data collection for analytical validation and model development.

3.2 Study Area Selection

The study focused on Kathmandu and Lalitpur districts where high traffic density and route variability significantly impact electric bus performance and operating costs as presented in figure 2.



(Survey, 2026)

Figure 2 Study Area Map

3.3 Data Collection

Data were collected in September 2025. Primary data included key informant interviews (KII) and field measurements while secondary data were obtained from Sajha Yatayat officials. KIIs evaluated the importance of factors affecting route costs identified in the literature. Travel time, route length and frequency data from vehicle logs were cross checked through field enumeration.

KIIs were conducted with purposively selected experts including 7 from the Department of Transport Management (DoTM), 3 engineers each from Kathmandu Metropolitan City (KMC) and Lalitpur Sub-Metropolitan City (LMC) and 4 from Sajha Yatayat management and operators. The sample size followed semi-structured interview guidelines (12-30 participants) (Saunders et al., 2012). Non-probability sampling was used with interviews guided by pre-defined questions to encourage discussion (Longhurst, 2009).

FACM data were collected during peak (9:00-11:00 AM, 4:00-6:00 PM) and off-peak (12:00-4:00 PM) hours on a regular operating day (Kandel et al., 2023) for calculating travel time measurement which is used to evaluate performance parameters. Operational data were verified using GPS loggers and digitized vehicle logs, capturing vehicle hours (VH), vehicle kilometers (VK) and peak vehicles (PV). Secondary data included fleet numbers, route information, vehicle logs and audit reports with cost and revenue details from Sajha Yatayat.

3.4 Conceptual Framework

The conceptual framework as presented in Figure 3 focuses on intracity electric bus routes operated by Sajha Yatayat in the Kathmandu Valley and provides the analytical foundation for achieving the stated research objectives.

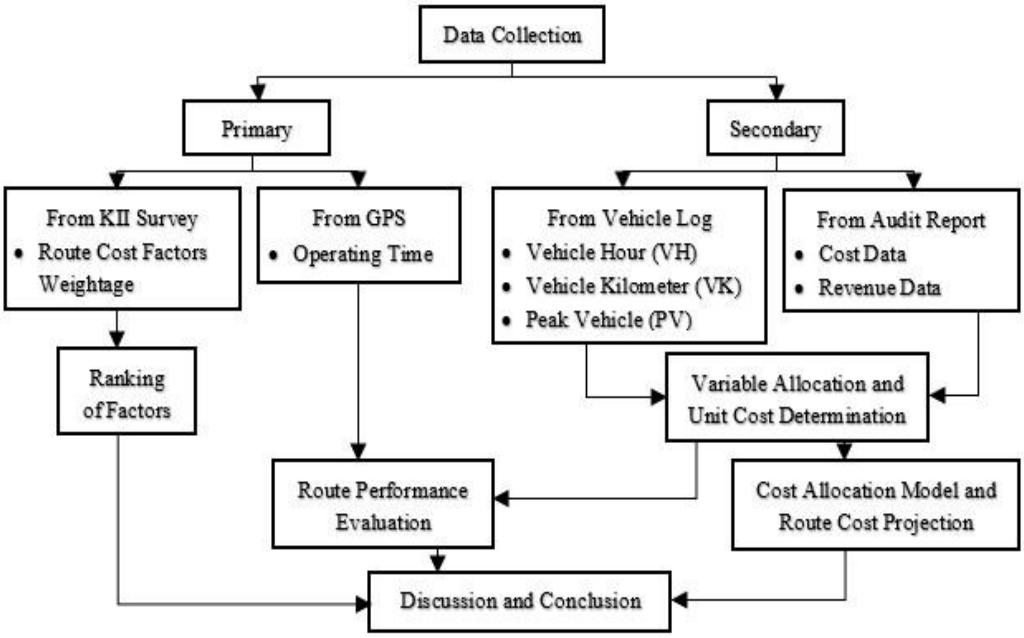


Figure 3 Conceptual Framework

3.5 Factors Affecting Route Cost

Factor affecting route costs were identified and ranked through Signal to Noise Ratio (SNR) is a statistical indicator shown as the ratio of the mean to the standard deviation analysis in SPSS with finally organized in Excel. A Fully Allocated Cost Model (FACM) integrating both conventional and electric bus elements was employed to compute cost elements. Qualitative findings obtained from key informant interviews (KIIs) informed the selection of related cost variables while quantitative processing in SPSS enabled statistical measure. Mean and standard deviation values obtained from KII responses were used to calculate SRN values which were then used to rank the most significant cost factors (Thangjai & Niwitpong, 2019).

3.6 Cost Allocation Model

Cost allocation model distribute total system expenses across operational indicators such as vehicle kilometers (VK), vehicle hours (VH) and peak vehicles (PV) and these data taken from vehicle log report of Sajha Yatayat for fiscal year 2024/25 (Hamilton et al., 1984). The cost of TK, OH and OV are presented in equation 1,2 and 3.

$$Cost\ (\mathrm{TK}) = UTCK * TK \tag{1}$$
$$Cost\ (OH) = UCOH * OH \tag{2}$$
$$Cost\ (OV) = UCOV * OV \tag{3}$$

Where,

UTCK= Unit Cost per Travelled Kilometer, TK= Total Travelled Kilometer, UCOH= Unit Cost per Operable Hour, OH= Total Operable Hour, UCOV= Unit Cost per Operable Vehicle, OV= Number of Operable Vehicle

Within this cost estimation methodologies, Fully Allocated Cost Model (FACM) represents average level of analytical complexity. A widely used application of this approach is the Birmingham Model (Simpson & Curtin, 1981).

The cost allocation model applied in the study by (Lai & Miller, 2020) is presented in equation 4:

$$Total\ Operating\ Cost = C_H * H + C_K * K + C_V * V \quad (4)$$

Where,

C_H = Cost per Revenue Hours, C_K = Cost per Revenue Kilometer, C_V = Cost per Operating Vehicle, H= Vehicle Hours, K= Vehicle Kilometer, V= Number of Operating Vehicle

A practical implementation of the fully allocated cost approach and establishes that total operating cost is the sum of allocated costs with VH, VK and PV is provided by the Birmingham Model expressed in equation 5:

$$C = UH\,(VH) + UK\,(VK) + UV\,(PV) \quad (5)$$

Where,

UH = Unit Hour, UK = Unit Kilometer, UV = Unit Vehicle

3.7 Application to Sajha Yatayat Mixed Fleet

As Sajha Yatayat operates a mixed fleet of electric and diesel buses, a hybrid cost allocation approach was adopted to incorporate route cost parameters for both vehicle types. Two separate cost pools were established: one for the electric bus fleet and another for the diesel bus fleet accounting for differences in fuel, operation and maintenance costs.

Costs associated with the electric bus fleet were analyzed and allocated using the Birmingham fully allocated cost model which systematically assigns all relevant expenses to operational units (Simpson & Curtin, 1981). Cost components were classified as follows:

- Vehicle Hours (VH): driver wages, supervision
- Vehicle Kilometers (VK): electricity, maintenance, tyres
- Peak Vehicles (PV): depreciation, insurance

The total allocated costs were aggregated to determine:

- S_{VH}: Total costs associated with Vehicle Hours
- S_{VK}: Total costs associated with Vehicle Kilometers
- S_{PV}: Total costs associated with Peak vehicles

3.*8 Unit Cost Parameter Estimation*

The Unit Cost Parameters (UCPs) were calculated using the following relationship expressed in equation 6.

$$C_X = \frac{S_X}{X} \quad (6)$$

Hence, the relations for calculating C_{VH}, C_{Vk} and C_{PV} are as presented in equation 7,8 and 9.

$$C_{VH} = \frac{S_{VH}}{VH} \quad (7)$$

$$C_{VK} = \frac{S_{VK}}{VK} \quad (8)$$

$$C_{PV} = \frac{S_{PV}}{PV} \quad (9)$$

Where,

C_{VH} = Cost of vehicle hour, C_{VK} = Cost of vehicle kilometer and C_{PV} = Cost of peak vehicles

(Simpson & Curtin, 1981).

This three variable unit cost model is widely applied in the transit sector to determine fully allocated costs for selected routes and vehicles by identifying key cost drivers associated with public transport operations and oversight. Equations 6,7,8 and 9 are sequentially connected to develop the cost model and it define how these unit cost parameters are calculated by dividing total allocated costs of each variable (VH, VK and PV) by their respective total service statistics.

3.9 Projection of Route Costs

Let ${VK_{R1}}^{n=1}$, ${VH_{R1}}^{n=1}$, and ${PV_{R1}}^{n=1}$ stand for period wise vehicle-kilometers, period wise vehicle-hours and period wise number of peak vehicles required respectively for route R1 in period 1 which were determined from trip logs, then the route cost for route R1; ${C_{R1}}^{n=1}$ was calculated using the Birmingham formula (Simpson & Curtin, 1981) as expressed in equation 10.

$$ {C_{R1}}^{n=1} = C_{VH} * {VH_{R1}}^{n=1} + C_{VK} * {VK_{R1}}^{n=1} + C_{PV} * {PV_{R1}}^{n=1} \quad (10) $$

Similar calculations were performed for different periods of time of operation on the different routes as well. Here C_{VH} , C_{VK} and C_{PV} are all UCPs derived from the equations 7,8 and 9.

3.10 Calculation of Route Performance Metrics

Similar to the approach adopted by Ahasan and Kabir (2019) in evaluating the performance of Dhaka's public transportation system across service efficiency, system efficiency, cost efficiency, utilization efficiency and network efficiency, this study evaluates route level public transport efficiency using a set of financial and operational performance indicators. Peak vehicles, total passengers and passengers count data taken from vehicle log report and tickets of Sajha Yatayat. The cost parameter in equation 11, 12, 13, 14, 15, 16, 17, 18 and 19 were indicates the annual average cost of buses.

This evaluated the following route performance metrics:

a) Revenue to Cost Ratio: $(R/C)_{R1} = \frac{Total\ Revenue_{R1}}{C_{R1}}$ (11)

b) Operating Cost per VK: $(Op.Cost/km)_{R1} = \frac{C_{R1}}{VK_{R1}}$ (12)

c) Operating Cost per Passenger: $(Op.Cost/passenger)_{R1} = \frac{C_{R1}}{Total\ passenger\ count_{R1}}$ (13)

d) Revenue per VK: $(Revenue/km)_{R1} = \frac{Total\ revenue_{R1}}{VK_{R1}}$ (14)

e) Revenue per Passenger: $(Revenue/passenger)_{R1} = \frac{Total\ revenue_{R1}}{Total\ Passengers_{R1}}$ (15)

f) Revenue Vehicle Hours: $(VH\ per\ PV)_{R1} = \frac{VH_{R1}}{PV_{R1}}$ (16)

g) Passengers per PV per day: $(Passengers\ per\ PV) = \frac{Total\ passengers_{R1}}{PV_{R1} * 365}$ (17)

h) Revenue Passengers per Revenue Vehicle Hour = $\frac{Revenue}{VH * (\frac{Revenue}{Passenger})}$ (18)

i) Operating expenses per Revenue Vehicle Hour = $\frac{Operating\ Cost}{VH}$ (19)

(Ahasan & Kabir, 2019)

4. Result and Discussion

4.1 Factors Affecting Route Cost

Based on literature, real world examples and expert input via Key Informant Interviews (KII), key factors influencing electric bus route costs in Kathmandu were identified. Factors were ranked using the Signal to Noise Ratio (SNR) test highlighting the most impactful drivers of cost as presented in Table 2.

Table 2 Rank Wise Overall Cost Factors

Factor	N	Mean	Std. Deviation	SNR	Rank
Depreciation Cost (Vehicle/Batteries)	17	4.471	0.514	8.689	1
Route Distance	17	4.353	0.606	7.179	2
Traffic Congestion & Travel Delays	17	4.412	0.618	7.135	3
Ticket Fare Pricing and Revenue Generation	17	3.412	0.507	6.725	4
Trip Time	17	4.235	0.664	6.376	5
Staff Salaries & Labor Costs (Drivers, Technicians, Conductors)	17	4.235	0.664	6.376	6
Battery Degradation/Replacement	17	4.353	0.702	6.202	7
Energy Price Fluctuation (Electricity Tariff Changes)	17	3.529	0.624	5.654	8
Route Planning Efficiency (Passenger Load per Trip)	17	4.294	0.772	5.564	9

Factor	N	Mean	Std. Deviation	SNR	Rank
Charging Duration and Time Lost in Recharging	17	3.471	0.624	5.559	10
Downtime Due to Charging or Technical Issues	17	3.412	0.618	5.518	11
Bus Maintenance and Repair Cost	17	4.059	0.748	5.430	12
Bus Procurement Cost and Financing	17	3.941	0.748	5.272	13
Battery Charging Cost (Electricity Used per Day)	17	4.000	0.791	5.060	14
Government Subsidies for Electric Vehicle Operation	17	3.235	0.664	4.871	15
Availability of Spare Parts for Electric Buses	17	4.118	0.857	4.802	16
Fringe Benefits Cost (Operator Bonuses/Incentives)	17	3.353	0.702	4.777	17
Public Acceptance and Ridership Levels	17	3.941	0.827	4.766	18
Advertising Media & Meetings	17	2.529	0.624	4.052	19
Availability and Accessibility of charging Stations	17	3.000	0.791	3.795	20
Policy and Regulation Support (Tax Exemption, Import Duties)	17	3.353	0.931	3.600	21
Cost of Training Staff to Operate/Maintain Electric Buses	17	3.235	0.903	3.581	22

Depreciation of buses and batteries (SNR: 8.689) ranks highest representing the largest cost contributor. Staff training (SNR: 3.581) is least impactful. Maintenance, charging and operational efficiency factors also contribute. Smart planning, stable pricing and supportive policies can mitigate these costs as presented in table 3.

Table 3 Section Wise Key Factors

Section	**Key Factors**	**N**	**Average Mean**	**Average Std. Deviation**	**SNR**	**Rank**
04 (Operational Efficiency)	Route Distance	17	4.141	0.656	6.313	1
02 (Vehicle Related Costs)	Depreciation Cost (Vehicle/Batteries)	17	4.188	0.714	5.866	2
01 (Energy and Infrastructure Costs)	Energy Price Fluctuation (Electricity Tariff Changes)	17	3.500	0.707	4.950	3
03 (Labor and Training Costs)	Staff Salaries & Labor Costs (Drivers, Technicians, Conductors)	17	3.608	0.757	4.766	4
05 (Financial and Policy Factors)	Ticket Fare Pricing and Revenue Generation	17	3.294	0.711	4.633	5

In table 3, the Section 04 (Operational Efficiency) is most influential (Route Distance, SNR: 6.313) while Section 05 (Financial and Policy Factors) is least influential (Ticket Fare Pricing, SNR: 4.633). Optimizing routes, managing vehicle costs and setting smart fares can enhance cost effectiveness.

4.2 Analysis of Total Annual Cost

Audit data for FY 2023/24 show Sajha Yatayat allocates ~36% of total expenses to electric buses and 64% to diesel, reflecting fleet proportions.

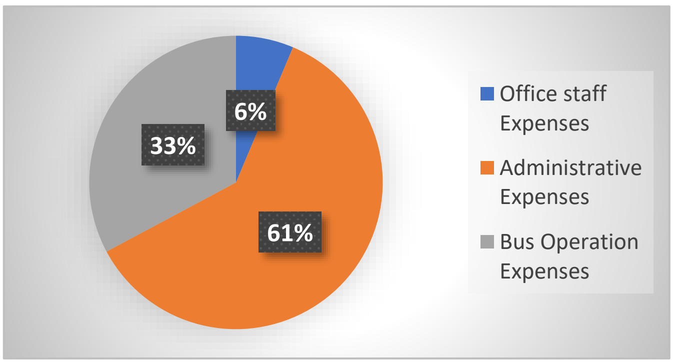


Figure 4 Analysis of Total Annual Cost

Electric bus costs:

- Vehicle Hours (VH): NRs. 37.20 million
- Vehicle Kilometers (VK): NRs. 36.26 million
- Peak Vehicles (PV): NRs. 34.69 million
- Total: NRs. 108.16 million

This fully allocated cost model confirms variable totals adjusts with system wide operational costs using VH, VK and PV as cost variables as expressed in figure 4.

4.3 Bus Operational Statistics

Table 4 Sajha Yatayat Electric Bus Operational Statistics for Fiscal Year 2023/24

S.N.	Routes	Route Distance (Km)	Vehicle Operation Time (Hr.)	Stops (No.)	Vehicle Hour (VH)	Vehicle Kilometer (VK)	Peak Vehicles (PV)	Operating Cost (NRs.)
1	Lagankhel to Gongabu Buspark	12.4	2.54	23	8,251	1,66,740	Avg.3	95,46,139
2	Langankhel to Budhanilkantha	15.8	2.52	25	10,876	2,16,188	Avg.4	11,805,782
3	Godawari to Ratnapark	15.8	2.6	20	25,230	3,52,688	Avg.7	90,52,557
4	Thankot to Tribhuvan International Airport	18	2.54	36	29,716	4,55,644	Avg.9	78,37,865
5	Lamatar to Ratnapark	15	2.62	31	16,420	2,07,088	Avg.5	20,53,861

Source: Sajha Yatayat 2023/24 Vehicle Log

Table 4 presents the electric bus operational statistics for the fiscal year 2023/24. It is detailing route wise operations.

4.4 Development of Cost Allocation Model

The allocated costs have been computed by separating expense object class into category variables (VH, VK, PV) and summing them accordingly. Monthly service statistics have been calculated by compiling and summing data from vehicle log details. The unit costs were determined for each distributed by dividing allocated costs to its monthly service statistics (Simpson & Curtin, 1981). These calculations are detailed in table 5 and cost model expressed in equation 20.

Table 5 Costs Allocation Model Calibration

Allocation variable	Allocated Costs (NRs.)	Monthly Service Statistics	Unit Costs (NRs.)
Vehicle Hours (VH)	37,205,749	90,458	411.30
Vehicle Kilometer (VK)	36,259,977.4	12,77,830.00	28.38
Peak Vehicles (PV)	34,696,892.52	27	12,85,070.09

Total Cost (NRs.) = (411.30 * VH) + (28.38 * VK) + (1285070.097 * PV) (20)

Based on Sajha Yatayat's fiscal year 2023/24 monthly service statistics and financial records, these three variable cost estimation models were formulated. It follows established frameworks from previous studies such as those by (Stopher, Brandrup, Lee, & Parry, 1987); (Lai & Miller, 2020); (Abbas & Abd-Allah, 1999) and additional references.

Where, VH= Vehicle Hours (Hr.), VK= Vehicle Kilometer (Km.), PV = Peak Vehicle (No.) Total Cost = Total cost of the transport agency, NRs. = Nepalese Rupees.

The unit cost 411.30 NRs/hour means every hour a bus operates adds about Rs. 411.30 to total operating expenses, the unit cost 28.38 NRs/km means each kilometer a bus travels contributes Rs. 28.38 to total cost and the unit cost 12,85,070.09 NRs/vehicle represents fixed costs such as depreciation, insurance and administrative expenses tied to maintaining each bus in the fleet. The model combines time based, distance based and fixed costs into a single equation to estimate route wise or total system operating costs efficiently.

4.5 Use of Cost Allocation Model

The cost allocation model estimates route wise operating costs for Sajha Yatayat's electric buses. Projected costs for fiscal year 2024/25 were calculated by multiplying unit costs (VH, VK, PV) with projected service statistics, forming the basis for annual route expenses. This systematic approach enables transparent expense distribution, supports route comparison and aids financial planning (Simpson & Curtin, 1981). The fully allocated costs for each route were determined by multiplying the values of the distributed variables by their respective unit costs as shown in Table 6.

Table 6 Calculation Projected Costs for Fiscal Year 2024/25

Allocation Variable	Total Values for Routes	Unit costs	Total costs (NRs.)
Vehicle Hours (VH)	1,12,991.24	411.30	46,473,749
Vehicle Kilometer (VK)	1,745,424	28.38	49,528,524
Peak Vehicles (PV)	34	12,85,070	43,692,383
Total Costs (NRs.)			**139,400,758**

The projected costs for each individual route during the upcoming planning year 2024/25 were calculated for Sajha Yatayat's bus operations based on the scheduled time table and assigned vehicles as details presented in table 7.

Table 7 Determination of Route Wise Projected Distribution Costs for Fiscal Year 2024/25

S.N.	Routes	Vehicles Hours (Hr.)	Vehicle Kilometer (Km)	Peak Vehicles (No.)	Projected Costs (NRs.)
1	Lagankhel to Gongabu Buspark	8,872	1,80,079	4	13,874,881
2	Langankhel to Budhanilkantha	11,203	2,22,674	5	17,320,688
3	Godawari to Ratnapark	35,405	4,93,540	9	28,469,149
4	Thankot to Tribhuvan International Airport	41,602	6,37,902	11	49,233,012
5	Lamatar to Ratnapark	16,749	2,11,230	5	19,261,796

Longer routes with extended travel times and additional vehicles such as Thankot-Airport and Godawari-Ratnapark, incur higher costs. Shorter routes, like Lagankhel-Gongabu, have lower costs due to fewer vehicles and lower VH and VK. Peak vehicle numbers are generally uniform, making VH and VK the primary cost drivers.

4.6 Sajha Yatayat Electric Buses Revenue and Ridership

In fiscal year 2023/24, Sajha Yatayat's electric buses generated NRs. 50,966,732 in revenue, with monthly earnings ranging from NRs. 2,531,210 to NRs. 4,908,967. Total ridership was 3,453,586 passengers, peaking at 383,110 and dipping to 239,156 monthly. Revenue and ridership have been calculated based only on ticketed passengers and were influenced by route distance, passenger demand, service frequency and operational efficiency while the gradual increase in peak vehicles reflected growing capacity to meet demand.

4.7 Route Performance Evaluation

Route performance was assessed using key metrics for fiscal year 2023/24 to evaluate efficiency, cost and revenue potential. The revenue to cost ratio indicates financial performance while operating cost per vehicle-kilometer and per passenger reflect cost efficiency. Revenue per vehicle-kilometer and per passenger measure earnings and passengers per vehicle per day and revenue passengers per revenue vehicle hour show utilization of vehicles and service time. The Lagankhel- Gongabu route reported the highest number of daily passengers (438) indicating ridership demand. In compare, longer route such as Thankot-Tribhuvan International Airport exhibited higher operating costs primarily due to expanded distances and the requirements for additional vehicles. Metrics such as revenue vehicle hours per vehicle and operating expenses per revenue vehicle hour further elaborate of route performance supporting informed decisions related to scheduling resource allocation and service improvement. Gradients and other relevant factors are also indirectly involved but have not separately justified in the study. These factors can also contribute to variations in operational costs. The study analyzed based on overall aggregated operational costs as presented in table 8.

Table 8 Route Performance Evaluation

S.N.	Routes	Revenue/Operating Cost Ratio	Operating Cost/Vehicle-Km (NRs. /Km)	Operating Cost/Passenger (NRs. /Passenger)	Revenue/Vehicle-Km (NRs. /Km)	Revenue/Passenger (NRs. /Passenger)	Passengers per Vehicle (Passenger/Vehicle per day)	Revenue Passengers per Revenue Vehicle Hour	Revenue Vehicle Hours per Vehicle (Hr./Vehicle per day)	Operating expenses per Revenue Vehicle Hour
1	Lagankhel to Gongabu Buspark	1.25	61	21	76	27	438	58	8	1,235
2	Langankhel to Budhanilkantha	1.24	55	19	67	24	423	56	8	1,085
3	Godawari to Ratnapark	1.25	26	10	32	12	377	38	10	359
4	Thankot to Tribhuvan International Airport	1.24	17	8	21	10	297	32	9	264
5	Lamatar to Ratnapark	1.30	10	5	13	6	249	27	9	125
Avg. Total		1.26	34	13	42	16	357	42	9	614

5 Conclusion and Recommendation

The study finds that Sajha Yatayat's electric bus operations elaborates strong potential for growing both operational and financial performance. Through qualitative and quantitative approach, key cost factors including route length, vehicle and battery depreciation, electricity tariff fluctuations, labor costs and fare structures were identified and ranked into a cost estimation model that supports reliable project of expenses and revenues. Based on fiscal year 2023/24 data, total operating costs calculated to NRs. 108.16 million with projected costs increasing to NRs. 139.4 million for 2024/25. Route cost evaluations yielded revenue to cost ratios between 1.2 to 1.3 indicating financial sustainable service. Despite high capital investments and battery related costs, electric buses achieved comparatively lower operating costs per kilometer and per passenger while revenue ridership trends continued to rise reflecting efficiency improvements and increasing public acceptance.

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