Economic Feasibility of Electric Vehicle Adoption Among Urban Commuters: A Cost-Benefit Analysis

R. Uma Maheswari*
Assistant Professor
Department of Economics
Loyola College, Chennai - 600 034
*E mail: uma@loyolacollege.edu

Abstract

This study evaluates the economic feasibility of electric vehicle (EV) adoption among urban commuters using a cost-benefit framework with Net Present Value (NPV) analysis. Primary data were collected from EV owners and conventional vehicle users through structured surveys and interviews, while secondary data from market reports and government sources supported cost estimations. The analysis compared purchase costs, charging infrastructure, battery replacement, and maintenance expenses with potential benefits such as fuel savings, government incentives, and reduced operational costs over a 10-year period. Findings indicate that although EVs involve significantly higher upfront costs, their lower fuel and maintenance expenses and available subsidies yield long-term financial viability. NPV analysis confirmed EVs as cost-effective over a 10-year horizon, with break-even achieved within six years under favorable conditions. Sensitivity analysis revealed the importance of fuel price fluctuations, electricity costs, and government incentives in determining financial outcomes. The results highlight the crucial role of supportive policies, efficient charging networks, and technological progress in enhancing EV affordability. These insights are relevant for consumers, policymakers, and urban planners seeking to balance environmental sustainability with economic feasibility.

Keywords: Cost-Benefit Analysis, Electric Vehicles, Net Present Value, Charging Infrastructure, Financial Viability

Introduction

The global transition toward sustainable transportation has intensified in recent years, with electric vehicles (EVs) emerging as a viable alternative to conventional internal combustion engine (ICE) vehicles. Governments, environmental advocates, and industry leaders have promoted EV adoption as a strategy to reduce greenhouse gas emissions, decrease dependence on fossil fuels, and enhance urban air quality. However, while the environmental benefits of EVs are widely acknowledged, their economic feasibility for individual consumers remains a subject of debate. The high upfront costs, limited charging infrastructure, battery replacement concerns, and fluctuating energy prices contribute to uncertainty regarding their financial viability. This study seeks to analyze the cost-benefit aspects of EV adoption among urban commuters, using Net Present Value (NPV) as a primary evaluation method to determine the long-term financial sustainability of owning an EV compared to an ICE vehicle. EV adoption has increased significantly over the past decade, driven by technological advancements, government subsidies, and growing environmental consciousness. However, despite this growth, EV penetration in many urban markets remains lower than expected. One of the major barriers to widespread adoption is the higher initial purchase cost of EVs, which often exceeds that of comparable ICE vehicles. While EVs offer lower operating costs due to reduced fuel expenses, minimal maintenance needs, and tax incentives, potential buyers remain skeptical about whether these savings outweigh the initial investment over the vehicle's lifespan.

Another key factor influencing EV adoption is charging infrastructure availability. Unlike ICE vehicles, which can refuel quickly at readily available gas stations, EVs require dedicated charging infrastructure. Consumers who lack home charging facilities may face difficulties in accessing public charging stations, leading to range anxiety and additional operational costs. Furthermore, variations in electricity pricing, government incentives, and battery longevity further complicate the financial evaluation of EV ownership. Given these challenges, a cost-benefit analysis is essential to determine whether EV adoption provides tangible financial benefits for urban commuters. By considering both short-term and long-term economic factors, this study aims to provide data-driven insights into the financial viability of EVs, helping potential buyers make informed decisions and guiding policymakers in designing effective incentive programs.

Objectives

- To compare the total costs of EV ownership with ICE vehicles, including initial purchase price, fuel/charging expenses, maintenance costs, and battery replacement over a 10-year ownership period.
- To analyze potential financial benefits, such as fuel savings, government incentives, lower maintenance costs, and resale value of EVs.
- To conduct a sensitivity analysis on how fuel prices, electricity costs, and policy incentives influence the financial viability of EVs.

Significance

- For consumers, it provides a clear financial assessment of whether EV adoption is a cost-effective choice compared to ICE vehicles.
- For policymakers, it highlights the role of subsidies, charging infrastructure expansion, and taxation policies in promoting EV adoption.
- For urban planners, it underscores the importance of an efficient public charging network in enabling a smooth transition to sustainable transportation.
- For researchers and industry professionals, it contributes to the ongoing discourse on EV economics and policy planning.

Literature Review

EVs have a higher initial purchase cost than internal combustion engine (ICE) vehicles, primarily due to battery costs, which account for 30–50% of total vehicle price (Sperling & Gordon, 2019). However, several studies highlight that EVs offer lower long-term costs through reduced fuel and maintenance expenses. Hao et al. (2020) conducted a lifetime cost analysis comparing EVs and ICE vehicles, concluding that

EVs become cost-competitive after six to eight years of ownership due to lower energy and maintenance costs. Similarly, Breetz and Salon (2018) found that while upfront costs deter buyers, long-term savings often compensate. However, cost savings vary significantly based on regional electricity prices, fuel costs, and government incentives. For instance, in countries with high electricity prices (e.g., Germany), cost benefits are lower compared to regions with low electricity costs and strong subsidies (e.g., Norway) (Mock & Yang, 2018). Government policies play a crucial role in promoting EV adoption. Several studies emphasize that financial incentives, tax rebates, and infrastructure subsidies significantly impact purchasing decisions (Li et al., 2021). Gallagher and Muehlegger (2011) found that financial incentives increase EV adoption rates, with tax credits reducing consumer reluctance toward high upfront costs. Wang et al. (2020) reported that non-monetary incentives, such as toll exemptions, free parking, and carpool lane access, improve EV attractiveness. Jenn et al. (2020) found that when Norway reduced EV incentives, adoption rates declined, highlighting the importance of sustained policy support. The availability of charging stations is a critical determinant of EV adoption. Multiple studies show that range anxiety and inadequate charging networks hinder mass adoption (Neaimeh et al., 2017). Urban areas often have better charging infrastructure, while rural areas face limited access, discouraging adoption (Axsen & Kurani, 2012). According to Kontou et al. (2019), EVs have fewer moving parts, resulting in 40–60% lower maintenance costs than ICE vehicles. Several studies used NPV to assess lifetime costs vs. benefits. Wu et al. (2020) found that EVs had positive NPVs in regions with strong government incentives and low energy costs.

Methodology

This study employed a quantitative research approach to assess the economic feasibility of electric vehicle (EV) adoption among urban commuters using Cost-Benefit Analysis (CBA) and Net Present Value (NPV). Primary data were collected from a sample of 200 urban commuters, including 100 EV owners and 100 conventional vehicle users, selected through stratified random sampling to ensure diversity in income levels, commuting patterns, and vehicle ownership types. Data collection involved structured surveys and semi-structured interviews focusing on purchase costs, fuel/charging expenses, maintenance costs, government incentives, and long-term financial perceptions. Secondary data were obtained from market reports, government policies, and industry sources to supplement cost estimations.

The study used descriptive statistics to summarize the data, while NPV analysis was applied to assess the financial viability of EV adoption over a 10-year period. In addition to these techniques, basic hypothesis testing was considered to validate differences in cost patterns between EV and conventional vehicle users. Regression models were also reviewed to assess the influence of income levels, commuting distance, and access to charging infrastructure on the financial viability of EV ownership, though detailed econometric estimation was beyond the scope of this paper.

Results and Findings

Table 1

Descriptive Statistics of Respondents

Variable	EV Owners (N = 100)	Conventional vehicle owners (N = 100)
Average Age (Years)	35.40	36.20
Average Monthly Income (INR)	85,000	80,500
Average Daily Commute (Km)	32.10	30.70
Primary Vehicle Usage (%)	78 (Personal), 22 (Work)	75 (Personal) , 25 (Work)

Source: Primary Survey Data

The demographic analysis of respondents indicates that EV owners and conventional vehicle users share similar commuting patterns and income levels, suggesting that economic factors rather than personal characteristics influence vehicle choice. The slightly higher average income of EV owners may indicate that higher upfront costs act as a financial barrier for lower-income groups. The similarity in daily commute distances suggests that range limitations may not be a primary concern for urban commuters, reinforcing the importance of cost savings and policy incentives in driving EV adoption.

Table 2

Cost Comparison: Initial Purchase Cost

Vehicle Type	Average Purchase Cost (INR Lakhs)
Electric Vehicle	14.20
Conventional Vehicle	8.60

Source: Primary Survey Data and Secondary Data

EVs had a 65% higher upfront cost than conventional vehicles, primarily due to battery costs.

Table 3

Cost Comparison: Operational Costs

Cost Component	EVs (INR per month)	Conventional Vehicles (INR per month)	% Difference
Fuel / Electricity	2,100	7,400	-71.6%
Maintenance	900	2,800	-67.9%
Insurance	1,800	2,100	-14.3%
Total Monthly Cost	4,800	12,300	-61.0%

Source: Primary Survey Data and Secondary Data

EVs led to significantly lower fuel and maintenance costs, reducing total operational expenses by 61% per month compared to conventional vehicles.

NPV Analysis of Electric Vehicle Adoption

Formula for NPV Calculation:

NPV = ∑ Discounted Cash Inflow - Cash Outflow

Assumptions for NPV Calculation:

- Vehicle lifespan is assumed to be 10 years.
- A discount rate of 8% is applied.
- Fuel prices are projected to increase at 5% per annum.
- Electricity prices are projected to increase at 3% per annum.
- Government incentives are fixed for the first 3 years.

Table 4

NPV Analysis

Vehicle Type	Total Costs over 10 years (INR Lakhs)	Total Savings over 10 years (INR Lakhs)	NPV (INR Lakhs)
Electric Vehicles	20.40	30.50	10.10
Conventional Vehicles	32.10	19.30	-12.80

Source: Primary Survey Data

Inference

The NPV analysis shows that electric vehicles are economically more viable than conventional vehicles over a 10-year period. EVs record lower ownership costs (₹20.40 lakhs) and higher savings (₹30.50 lakhs), resulting in a positive NPV of ₹10.10 lakhs, indicating long-term financial benefits. In contrast, conventional vehicles incur higher costs (₹32.10 lakhs) with comparatively lower savings (₹19.30 lakhs), leading to a negative NPV of –₹12.80 lakhs, highlighting their financial disadvantage.

Hypothesis Testing:

H_0t: There is no significant difference in the mean NPV between EV and conventional vehicle users.

H_1t: The mean NPV of EV users is significantly higher than that of conventional vehicle users.

Table 5

Independent Samples t-test Results

Test Statistic	Value	df	p-value
t	5.12	198	< 0.001

Source: Primary Survey Data

Inference

Since $p < 0.001$, the null hypothesis is rejected. EV users report significantly higher NPVs than conventional vehicle users, validating the cost advantage of EV adoption.

A basic regression model was reviewed to examine whether socio-economic and usage factors affect NPV outcomes. The dependent variable was NPV, and predictors included income level, commuting distance, and access to charging infrastructure.

H_0r: Income level, commuting distance, and charging infrastructure do not significantly affect NPV.

H_1r: At least one of these factors significantly affects NPV.

Table 6

Regression Results

Predictor	β (Coefficient)	Std. Error	t-value	p-value	Significance
Income Level	0.08	0.07	1.14	0.26	Not Significant
Commuting Distance	0.34	0.10	3.40	0.001	Significant
Access to charging infrastructure	0.27	0.12	2.25	0.026	Significant

Source: Primary Data

Model Summary: $R^2 = 0.31$, $F(3,196) = 9.20$, $p < 0.001$

Inference

Commuting distance and charging infrastructure significantly enhance NPV, suggesting that high-usage patterns and availability of charging facilities make EV ownership more financially attractive. Income level was not a significant predictor, indicating that financial viability of EVs is not limited to higher-income groups.

Sensitivity analysis:

To test the robustness of NPV results, sensitivity analysis was conducted by varying fuel prices, electricity rates, and government incentives:

- Fuel Price Increase (+20%) → EV NPV increased to INR 12.4 lakh, confirming stronger financial benefits.
- Electricity Cost Increase (+15%) → EV NPV reduced to INR 8.9 lakh, showing moderate sensitivity.
- Removal of Government Incentives → Break-even extended to 7.2 years, highlighting policy importance.

Suggestions

- Policymakers should consider increasing subsidies, tax benefits, and low-interest EV financing to improve affordability and encourage adoption.
- Investments in widespread and fast-charging stations, especially in residential and commercial areas, can reduce range anxiety and operational barriers.
- Automakers should focus on lowering EV production costs through battery technology advancements and economies of scale to make EVs more competitive with conventional vehicles.
- Educational initiatives on the long-term cost benefits of EVs, environmental advantages, and available incentives can influence consumer decisions.
- Governments can regulate fuel pricing or introduce carbon taxes to make conventional vehicles less economically attractive, thereby promoting EV adoption.

Conclusion

This study assessed the economic feasibility of electric vehicle (EV) adoption among urban commuters using a cost-benefit analysis based on Net Present Value (NPV). Primary data collected from EV and conventional vehicle users provided insights into real-world costs and savings. The findings indicated that while EVs have higher upfront costs, their long-term financial benefits, including fuel savings, lower maintenance costs, and government incentives, make them a viable alternative to conventional vehicles over a 10-year period. The NPV analysis revealed that EVs generate a positive financial return compared to conventional vehicles, with fuel and maintenance savings playing a crucial role in offsetting initial expenses. Sensitivity analysis further highlighted the impact of fuel price fluctuations, electricity costs, and policy incentives on the overall economic viability of EVs. The study emphasized the importance of supportive government policies, charging infrastructure development, and consumer awareness in accelerating EV adoption.

Overall, the results suggest that transitioning to EVs is not only an environmentally sustainable choice but also a financially beneficial one in the long run. Future research could explore regional cost variations, emerging battery technologies, and consumer behavior factors that influence EV purchase decisions.

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