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PUBLIC READINESS AND FEASIBILITY OF BATTERY SWAPPING FACILITY FOR ELECTRIC VEHICLES IN MUMBAI

[1]Ms. Urvi Samant and [2]Prof. Dr. Ravikiran Garje

[1]PhD scholar K.C. College, HSNC University, Mumbai, Department of Economics, [2]PhD Guide K.C. College, HSNC University, Mumbai, Department of Economics

ABSTRACT

The idea of battery swapping has surfaced as a viable remedy to solve issues like time-consuming charging periods and range anxiety as a result of the quick uptake of electric vehicles (EVs) in major cities like Mumbai. In order to learn more about the viability and public opinion of swappable battery infrastructure, this study polled 251 people in Mumbai. The answers showed that although the concept has a lot of support, there are still major issues with accessibility, affordability, environmental sustainability, and safety. In order to deter various issues, respondents underlined the necessity of standardized, long-lasting, lightweight battery designs with robust security features. Many argued that battery swapping stations should be placed every one to three kilometers, especially along roads and in places with significant population densities. Some embraced the time-saving advantage of battery switching, particularly if done with environmentally appropriate disposal methods, while others favored home charging due to its economic effectiveness and less environmental waste. Although swappable battery facilities are seen as beneficial and essential, the government, EV manufacturers, and service providers must work together to ensure standardization, affordability, and environmental responsibility if they are to be successfully implemented in Mumbai, the study concludes.

Keywords: Accessibility, Affordability, Battery Swapping, Environmental Sustainability, Range Anxiety, Standardization

1. Introduction

Global adoption of electric vehicles (EVs) has increased because to the rising need to tackle climate change and reduce reliance on fossil fuels (Udendhran et al., 2025). EV usage is steadily expanding in India, especially in major cities like Mumbai, as a result of growing environmental consciousness, government incentives, and the need for sustainable urban transportation (*15% Rise in Electric Vehicles in Mumbai in 8 Months: Transport Dept | Mumbai News - Times of India*, n.d.). However, issues like range anxiety, lengthy charging times, and a lack of public charging infrastructure still prevent EV adoption from being widely adopted (Sankaran et al., 2020) (LaMonaca & Ryan, 2022).

In order to overcome these drawbacks, battery swapping has become a viable substitute for traditional plug-in charging. Battery switching reduces downtime and does away with the need for extended charging by swapping out a drained EV battery with a fully charged one at a designated station. Additionally, it detaches the battery's cost from the vehicle's, which might reduce EVs' initial purchase price and increase accessibility (Simwaba & Qutieshat, 2025)

Notwithstanding these possible benefits, infrastructure accessibility, public acceptance, battery model standardization, and environmental concerns are all critical to the success of battery swapping in India. Mumbai, a crowded and bustling metropolis, offers a special setting for assessing public opinion and the viability of putting in place a battery-swapping network. In order to gauge public awareness, interest, preferences, and concerns regarding battery swapping for electric vehicles, this study polls respondents throughout Mumbai. The results are intended to educate stakeholders—such as legislators, EV producers, and energy suppliers—about the potential and difficulties of creating a sustainable ecosystem for swappable batteries in urban India.

2. Scope of Study

• To ascertain how the general public feels about Mumbai's implementation of infrastructure for electric car battery swapping.
• To identify major problems and expectations of consumers related to battery changing, such as time restrictions and convenience (location and accessibility).
• To evaluate how battery swapping compares to conventional EV charging in terms of perceived environmental effects.
• To find out what people think about the best places and densities for battery swapping stations in cities.
• To offer suggestions for effective adoption to legislators and EV service providers based on user input.

3. Review of Literature

Dash (2025) showcases intentions of Indian government in assisting citizens in charging their electric vehicles, such as buses and trucks, for long-distance travel, by providing subsidies for battery swapping stations. By paying a fee, people can exchange their discharged batteries for charged ones at these facilities. While guidelines for automobile battery switching are being created, the incentive will first target electric vehicles and two- and three-wheelers. The project is in line with the growing popularity of electric cars and the construction of infrastructure for charging them beside national routes. Delhi-Chandigarh, Delhi-Jaipur, Bangalore-Mumbai,

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Coimbatore-Bangalore, Goa-Pune, Chennai-Bangalore, Kochi-Kanyakumari, Prayagraj-Patna, Guwahati-Jorhat, and Kharagpur-Visakhapatnam are priority highway segments for the construction of battery charging facilities.

Azeem et al. (2023) highlights that adoption of electric vehicles (EVs) is increasing due to environmental concerns, but charging takes time and can cause unpredictable peak time arrivals. Battery-swappable charging stations are a quick solution, but they face challenges such as grid load, battery management, and peak time charging tariffs. This research study aims to estimate peak time events using a novel integrated techno-economic assessment framework. A fuzzy-based parametric assessment tool is developed to identify factors influencing higher congestion events. Grid and solar PV-based generation is optimized using mixed integer linear programming. The study compares battery-swappable charging stations (BSCSs) with fast-charging (FC) stations. FC can perform well if integrated with solar PV systems, but the capital cost is 80% higher. BSCSs have a 39% higher operational cost due to night operations under congestion.

Vishnu & Ajaykrishna (2011) study suggests a creative way to address the growing issues of traffic congestion and environmental pollution with the help of an excellent public transportation system. The suggested architecture optimizes the use of energy sources based on the riding circumstances of the vehicle by combining two battery-powered plug-in hybrid electric vehicles (PHEVs). A PHEV bus's installation and operating costs can be greatly decreased by using a deep cycle NiMH battery for steady speed driving conditions and a starter lead acid battery for vehicle starting. By reducing reliance on gasoline, series hybrid powertrains will significantly lower pollution levels. Compared to a traditional PHEV that requires lengthy charging times, the battery pack module may be easily replaced under the hood, saving time while refueling the car. A cost-effective substitute for the contemporary hybrid buses, swappable batteries with designated swapping stations allow for proper battery maintenance, improving the battery parameters needed to run a public transportation system.

Tahara & et al's, (2020) paper discusses the challenges of electric vehicle deployment, including high battery costs and time-consuming energy refueling. It presents a battery as a service (BaaS) concept, which shares a part of the battery and offers two different battery modes for short-range driving and long-range operation. This shareability increases battery utilization and reduces costs. The BaaS infrastructure provides users with recharged batteries on demand. A cost-efficient operation requires optimizing battery number, charging techniques, and transportation costs. The model is based on the minimum cost flow problem, and numerical simulations and case studies show potential cost-benefits for battery, user opportunity, charging, and transportation costs.

Rag & Rajan, (2024) highlights how businesses are constructing charging infrastructure and offering battery swapping services as a result of the rapid commerce industry's growing usage of electric cars for last-mile deliveries. While spending heavily on marketing, discounts, and dark store expansion, platforms like Blinkit, Zepto, Swiggy, Instamart, and Flipkart's Minutes, which are vying for market share in the rapidly expanding but fiercely competitive quick commerce space, are embracing EVs as a way to reduce delivery-related operating costs.This is generating a lot of business for startups like EMO Energy, BatterySmart, Kazam, and others that offer energy management and charging solutions to these platforms' delivery partners. Quick commerce platforms account for up to 90% of EMO Energy's business, which offers hardware and software battery solutions, according to cofounder Sheetanshu Tyagi.

Rushadiawan & et al (2022) notes that evolution of batteries has changed. The existence of thermal runaway in the cell battery is one of the possible issues that could arise. The adjacent battery will be affected when thermal runaway happens. One of the most frequent causes of thermal runaway is a temperature increase that beyond the ideal permissible limit. Vehicles that are powered by batteries will need more cooling. Maintaining battery performance requires a conditioned temperature; temperature adjustments will help extend battery pack life. The implementation of the swap technique on the battery and the electric motorcycle's restricted area provide a challenge when it comes to regulating the battery pack temperature. One way to maintain the battery temperature at its ideal operating temperature (less than 35C) is to utilize a container with a cooler. Up to 12% more battery performance may be maintained with air cooling in the swap-type battery compartment than without coolers.

Subirana & et al (2018) showcases an alternative to the EV industry's bet on "large battery packs" (i.e., tens of kwh), which still suffer from two fatal flaws that keep them from becoming widely used in comparison to gasoline-powered vehicles: range anxiety and unused battery life sunk costs, this paper presents a traffic simulation model. In order to examine the performance of an alternative system approach that might result in EVs being substantially less expensive than ICE (internal combustion engine) vehicles by utilizing what we refer to as "smart small swappable batteries (SSSB)," the model incorporates driver roaming decisions, infrastructure layout, and battery pack characteristics. Our conjecture's basic idea is to use inexpensive, small packs (about 10 kwh or less) and swap them out as frequently as possible to keep the per-mile cost below the current levels of gasoline prices while avoiding the two aforementioned problems.

Choi & et al (2014) notes that battery-swappable smart electric bus system has been created and is presently in experimental operation as part of the electrification of public transportation systems in an attempt to conserve fossil fuels and reduce greenhouse gas emissions. A smart bus information service, a battery swapping station, and a battery-swappable smart electric bus make up the system. The effective and cost-effective operation of the public transportation system may be tested and its utility assessed with this battery switching method and solution technique. Additionally, a new business model for the battery swapping and charging station may be created separately from the ownership of the bus because it is easy to exercise autonomous ownership of the battery. The current article provides a detailed overview of the system's general design.

Liang & et al (2022) states that in major cities, battery swapping-charging systems (BSCSs) provide better battery swapping services for electric vehicles (EVs). Truck routing, battery charging, and swapping are among the difficult real-time optimization scheduling issues in BSCS. A novel approach, the Value Decomposition Network (VDN)-BLP, is put forth to address these limitations. This approach improves computational efficiency with no loss of performance by combining MADRL with local search, actor-critic architecture, and binary integer programming (BLP). The efficacy of this approach is confirmed by simulation results from historical battery swapping data in Sanya City.

Nayak & Misra (2024) states to reduce operating costs, the study offers a mathematical optimization model for electric vehicle battery swapping stations (BSS) that includes demand response techniques. The model considers factors like charging modes, battery capacities, charger availability, and battery states of charge. For sustainable operation, it also takes into account how quicker charging modes affect battery health. In order to account for shifting demand uncertainty in BSS operational decision-making, the model is expanded. The model, which has been tested using case studies, calculates battery requirements and finds the best demand satisfaction patterns while offering a risk-neutral solution. By increasing customer happiness and BSS operational efficiency, the model hopes to hasten the adoption of EVs.

Helander & Ljunggren (2023) highlights today's trend of flexible battery leasing has been implemented by electric car company NIO as a component of their Battery as a Service (BaaS) business model. Customers can now temporarily upgrade their primary leased batteries in accordance with their range requirements. The feasibility of this innovation is examined in the study by contrasting it with straightforward battery leasing. The findings indicate that flexible battery leasing can raise battery capacity, lower customer costs, and boost manufacturer profit. This is especially true for moderately priced high-capacity batteries and wide high-capacity battery ranges. According to the study, a manufacturer may satisfy all battery up/downgrade demand without purchasing extra batteries if it selects a high-capacity battery range for flexible leasing. This could influence operational guidelines for the EV industry's adoption of flexible battery leasing.

Gode et al. (2022) research looks into battery switching for electric two-wheelers (E2Ws) in India and emphasizes the advantages of doing so, such as lower purchasing prices and speedy battery installation. The study discovered that commercial operations with high daily usage, like ride-hailing and e-commerce deliveries, have the lowest total cost of ownership (TCO) per kilometer for both conventional and E2Ws. According to the report, in order to preserve best practices, governments should assist battery swapping operators and pay attention to things like charging time savings. This can entail establishing operational and safety requirements as well as extending FAME II subsidies to battery-free E2Ws.

Dai & et al. (2014) emphasized electric-vehicle (EV) battery-swap stations (BSSs) are crucial infrastructures for EV development, but their load demand is stochastic due to battery swapping and charging patterns. To mitigate disorderly charging behaviors, researchers investigate the charging load characteristics of BSSs. Four variables are essential: hourly number of EVs for battery swapping, charging start time, travel distance, and charging duration. A Monte Carlo simulation model is presented to estimate uncontrolled energy consumption and introduce a generic nonparametric method for estimating prediction uncertainty. Simulation results show the proposed prediction methods are suitable for forecasting the horizon 24 hours ahead.

Yang et al.'s (2023) study explores battery swapping in countries promoting EV diffusion, focusing on policy-making. It uses a Hotelling model to analyze three scenarios: no subsidization, consumer subsidization, and provider subsidization. The findings reveal that incentive programs are effective for battery swapping development and social welfare improvement, but subsidized service providers are more effective. Controlling incentive amounts and making continuous adjustments is necessary to promote battery swapping services without harming charging services.

Islam et al.'s (2022) study explores consumer attitudes towards waste battery collection and recycling in Australia, revealing that awareness about the negative impacts of improper disposal is not universally shared. Most consumers were unaware of waste battery collection points and convenience, with over 50% unaware of them. The most preferred collection systems were deposit return systems or supermarkets/retailers. Incentives for recycling batteries were "old-for-new" swaps, vouchers for other items, and cash payments. The study highlights policy implications for the future development of sustainable waste battery management systems in Australia, emphasizing the need for better awareness and awareness among consumers.

4. Research Gap

Limited empirical study has concentrated on public perception, awareness, and behavioral preparedness, especially in Indian metropolitan places like Mumbai, despite the fact that there is a wealth of literature on the technological viability, economic modeling, and legislative frameworks for battery swapping. Most Indian studies are either policy-driven or economic models, and do not reflect the voice of end-users — the very population who will interact with this infrastructure daily.

Furthermore, from a user-centric perspective, issues like battery standardization, environmental sustainability, safety during exchanges, and the long-term consequences of shared battery use (including deterioration and responsibility) have not been sufficiently addressed.

The theoretical and structural potential of battery swapping is well-established in the paper. By gathering firsthand information from 251 respondents in Mumbai, this study aims to close the gap and provide insightful information on the viability, apprehensions, and preferences of the general people. This is a crucial step in creating a battery-swapping ecosystem that is both inclusive and useful.

5. Objectives of Study

1. To determine if current and prospective electric vehicle (EV) owners are prepared to switch to swappable battery technology from conventional charging techniques.
2. To assess user attitudes and perceptions regarding important components of the ecosystem for swappable bat teries, such as:
• Using mobile applications to find or reserve battery swap stations;
• Battery swapping's time efficiency;
• General interest in swappable battery services; and
• Comparison with at-home charging preferences.
3. Based on user responses and behavior patterns, identify the best places to install swappable battery stations (e.g., near highways, commercial zones, residential areas).

6. Hypothesis Statement

The aim of the test is to determine whether there is a significant association between user preferences regarding battery swapping facilities and their adoption intentions or behavioral responses.

Null Hypothesis (H_0):

There is no significant association in user opinions with regards to interest in battery swapping facility, preference over home charging, time convenience, and use of mobile apps and their likelihood of using battery swapping services.

That is, the variables are independent.

Alternative Hypothesis (H_1):

There is a significant association in user opinions with regards to interest in battery swapping facility, preference over home charging, time convenience, and use of mobile apps and their likelihood of using battery swapping services.

That is, the variables are not independent.

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7. Research Methodology

Survey methodology is adopted which is backed with analytical, descriptive and mixed research methodology i.e. quantitative and qualitative research. The study was conducted through google form.

7.1 Rationale for research problem

Mumbai provides a unique setting for researching the viability of battery switching because it is a fast-paced metropolis with rising environmental concerns. Even while EVs are becoming more and more popular, the city still has logistical and infrastructure issues that might make it more difficult to deploy electric mobility options effectively. Battery switching is showing promise as a way to get beyond these obstacles, but its success mostly rests on uniformity, cost, environmental sustainability, and public acceptability. This study attempts to close the gap in the literature on user readiness and real-world concerns regarding battery-swapping systems in Mumbai by documenting the opinions of 251 respondents. To create a strong, user-friendly, and sustainable EV ecosystem, legislators, EV manufacturers, and urban planners must have a thorough understanding of these viewpoints.

7.2 Research design

Investigating problems that are not well defined or understood is the goal of exploratory research, a qualitative research methodology. It aids in finding trends, coming up with concepts, and formulating theories for more study. For examining complicated subjects like the viability of swappable battery services in Mumbai, this research approach is very appropriate. In order to gather information, the researcher used both quantitative and qualitative methods, as well as both closed-ended and open-ended questions, in their adaptation of the exploratory study design. To find out how prepared they were for this facility and what they thought about related issues, 251 respondents were surveyed.

8. Methods of Data Collection

8.1. Data Sources

This study used a structured questionnaire survey to gather primary data as part of an exploratory research design. Between August 2024 and June 2025, 251 respondents from different neighborhoods in Mumbai were given the survey. The survey, which was intended for both current and prospective electric vehicle (EV) users, included both closed-ended and Likert-scale questions. Concerns about technology, environmental issues, convenience preferences, readiness to switch batteries, and awareness were all evaluated through questions.

8.1.1. Primary Sources Tools of Data Collection

Google form was circulated to random people to get their insights, while few had less or no idea about the same, but on solving their queries their responses were collected.

8.1.2. Secondary Data

Reading newspaper articles, journals articles helped the researcher to gain insights on the trend.

8.1.3. Place and Duration of the Study

The study was carried out in Mumbai, an Indian metropolis renowned for its increasing use of electric cars (EVs) and fast urbanization. The eleven-month period from August 2024 to June 2025 was used for the data collecting and analysis. 251 individuals were polled over this period to learn more about their opinions on EV battery swapping facilities.

8.1.4. Sample Design

Simple random sampling was undertaken for the survey to ensure that every individual within the target population had an equal and independent chance of being selected. This approach minimized selection bias and allowed for generalizability of findings to the larger population of Mumbai's current and prospective electric vehicle (EV) users.

8.1.5. Sample Survey

Total of 384 respondents should have been be surveyed viz users/aspiring users of green vehicles. With a confidence level of 95%.

The no. of e-vehicles is in increasing in Mumbai daily, but we have only Honda providing the swappable battery services. Thus, By applying sampling formula, we get the sample size of 384.

With Cochran's Formula with Finite Population Correction (Cochran, 1977)

$$n' = \frac{n}{1+[\frac{n-1}{N}]}$$


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Where:
n: Sample size for an infinite population (calculated using Cochran's original formula):
n=$\frac{z^2.\hat{p}(1-\hat{p})}{E^2}$
N: Total finite population size
n' Adjusted sample size for the finite population

Z-score (e.g., 1.96 for 95% confidence level)

$\hat{p}$ Estimated population proportion

E Desired margin of error

This serves as the foundation for choosing the sample size.
But the survey could only get responses from 251 users/aspiring users of EVs in Mumbai. It has been observed that around 200 respondents are statistically acceptable in social science research studies (Bartlett et al., 2001; Fowler, 2013; Krejcie & Morgan, 1970). Thus, the survey can be used for generalizing the results.

9. Statistical Techniques for Data Analysis

Following the exploratory research design, various statistical techniques were employed to analyze the primary data collected from 251 respondents in Mumbai. Microsoft Excel was used for data entry, cleaning, tabulation, and graphical representations. The analysis included both descriptive and inferential statistical tools to interpret patterns and test hypotheses.
Descriptive Statistics and Visual Representations
Basic descriptive statistics such as frequencies and percentages were used to understand demographic profiles and general opinion trends. Two key visual tools were applied:

- A pie chart was created to depict respondents' preferences between charging at home versus using swappable battery facilities.
- A bar chart illustrated the range of public opinions on swappable battery facility location.
  These visuals offered a clear and concise understanding of public sentiment toward battery swapping solutions.
- **Chi-Square (Test for Goodness of Fit and test for independence)**
  To examine whether observed responses were significantly different from expected frequencies across key categorical variables, a Chi-Square Test for Goodness of Fit was conducted. For example, responses to questions such as:
- "Would you use a mobile app to locate and reserve batteries?"
- "Would you be interested in using battery swapping services for your EV?"
- "Would you prefer swapping that takes less than 10 minutes?"
- "Do you find swappable facility better than home charging?"
- **Jarque-Bera**
  To verify the assumption of normality in the dataset, particularly before applying the **non-parametric test like chi-square test**, a **normality test** was conducted using **EViews software**. The **Jarque-Bera test** was employed to assess the skewness and kurtosis of the data distribution.
  The **Jarque-Bera (JB) statistic** is a common method used to determine whether sample data has the skewness and kurtosis matching a normal distribution (Bera & Jarque, 1981).

10. Discussion

Mumbai residents showed a modest level of support for swappable battery capabilities, highlighting the necessity of a system that is widely available, economical, eco-friendly, fast, and dependable. In order to improve convenience, it was suggested that stations be placed every 1-3 km, particularly in important metro regions like Kandivali, Malad, and Borivali, as well as close to highways. Nonetheless, several emphasized that for seamless operation and interoperability, batteries for e-2Ws and e-3Ws must be standardized. Strong locking mechanisms and long-lasting, lightweight designs were demanded in response to concerns over battery weight, security, and theft prevention. Some people favored home charging to cut down on waste and extra expenses, while others said swappable batteries were a simple way to save time and lessen range anxiety. A recurrent topic was the impact on the environment; consumers called for government-supported programs to guarantee low pollution levels and sustainable battery disposal methods. The idea is generally seen by the public as novel and greatly

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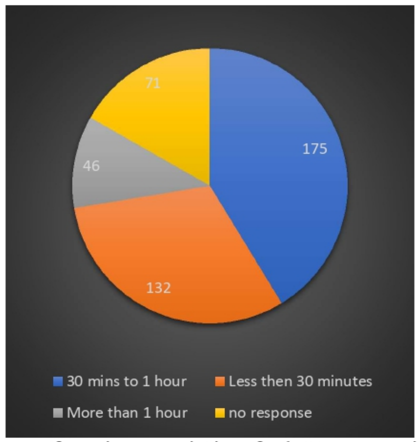
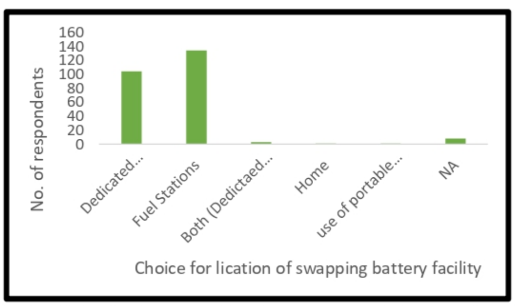
needed, but its success hinges on factors including pricing, infrastructure, environmental responsibility, and usability.

Chart 1 : People interested in adopting swappable battery facility whether owning or aspiring to own EV (i.e. Yes Percentage from each category of waiting period)



The respondents' showed their issue of maximum wait time for battery swapping, which is displayed in the pie chart "people interested in adopting swappable battery facility whether owning or aspiring to own EV (i.e. Yes Percentage from each category of waiting period)".
Below given distribution highlights an important finding for policymakers and service providers. To guarantee customer happiness and optimize uptake, these preferences must to be taken into account while designing and running battery swapping infrastructure.

Chart 2: Locational Preference of Swappable Battery Facility



The preferred locations for battery swapping infrastructure, as indicated by the 251 respondents polled in Mumbai, are depicted in the bar chart, options were dedicated charging station, fuel station, both or any other location.

Fuel stations were preferred by the majority of responders (53.4%, n = 134) as the best location for battery switching facilities. This indicates a need for ease of use and compatibility with the current infrastructure for car refuelling.

A sizable majority (41.4%, n = 104) supported dedicated swapping centers, highlighting the necessity of specialized, well-organized infrastructure that might guarantee improved system efficiency, battery management, and service quality.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A very small percentage of respondents opted for a combination of both fuel stations and dedicated centers (1.2%, n = 3), suggesting limited but notable openness to hybrid models.

There was relatively little interest in personal or decentralized swapping options, since just one responder chose home-based switching and the usage of portable batteries.

n = 8 (about 3.2%) were non-respondents, maybe as a result of their ignorance or confusion about the selections.

These findings imply that the intentional placement of swappable battery infrastructure at well-known and convenient locations, including gas stations and designated centers, may be essential to its success in cities like Mumbai. This preference emphasizes how crucial location-based planning is when building infrastructure to support EV adoption.

10.1. Hypothesis Testing

Chart 3: Jarque Bera for Interest in swappable service

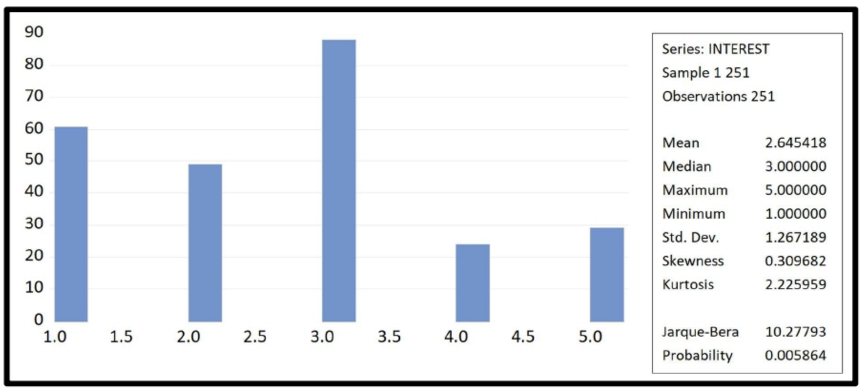

Chart 4: Jarque Bera for Opinion on whether swappable service is better than charging at home

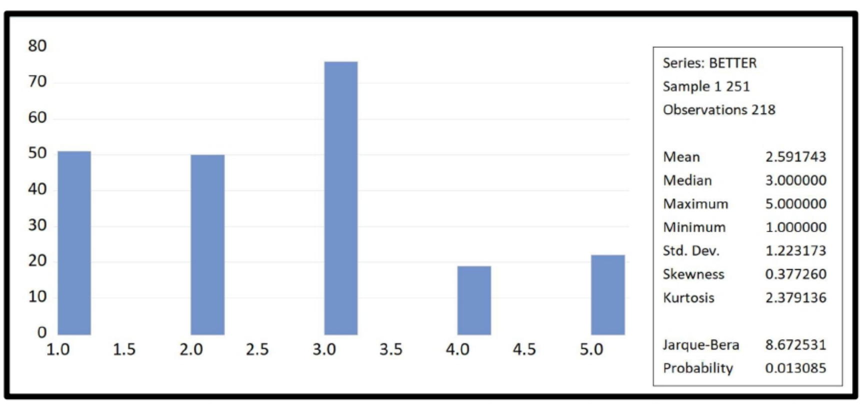

Chart 5: Jarque Bera for Opinion towards interest in Swappable facility due to less time taken

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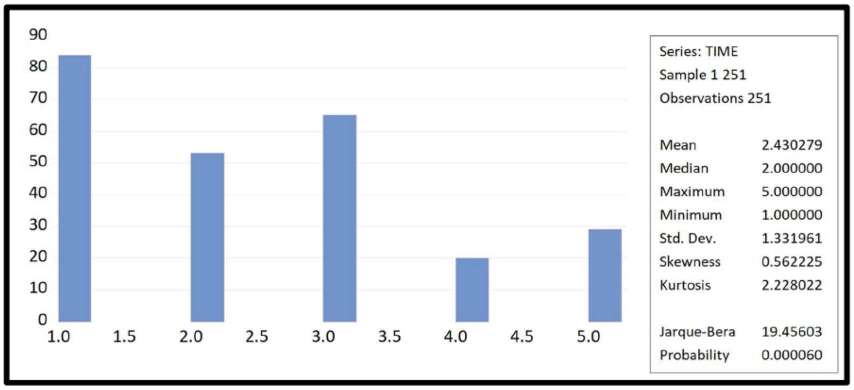
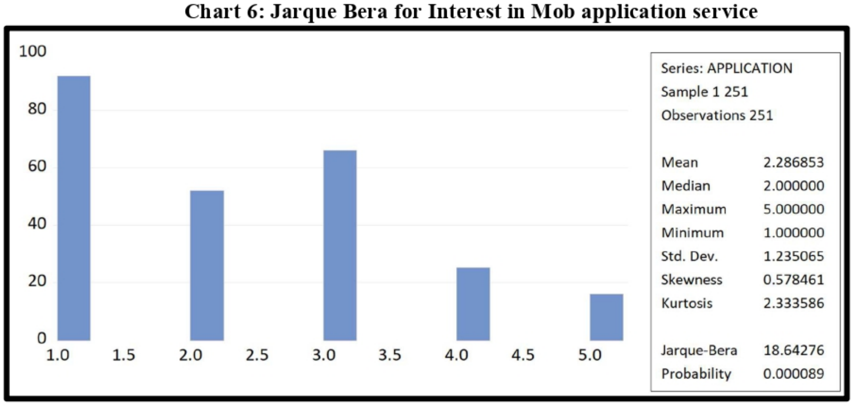


Chart 6: Jarque Bera for Interest in Mob application service



Since all the observed data's Jarque Bera p-values were less then 0.05, so we reject the null hypothesis of normality for each variable.

This means that the Likert-scale response distributions do not follow a normal distribution.

Implications:

- Use non-parametric tests (like Chi-Square, Kruskal-Wallis) instead of parametric tests (like ANOVA or t-tests).

Table 1: Chi Square Analysis

Observed Frequencies					
	Interest in swappable service	Interest in Mob application service	Opinion towards interest in Swappable facility due to less time taken	Opinion: whether swappable service is better than charging at home	
Agree	49	52	53	50	204
Disagree	24	25	20	19	88
Neutral	88	66	65	76	295
Strongly Agree	61	92	84	51	288
Strongly Disagree	29	16	29	22	96
	251	251	251	218	971
Expected Frequencies (Uniform Distribution):					
	Interest in swappable service	Interest in Mob	Opinion towards interest in Swappable	Opinion: whether swappable service	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		application service	facility due to less time taken	is better than charging at home	
Agree	53	53	53	46	
Disagree	23	23	23	20	
Neutral	76	76	76	66	
Strongly Agree	74	74	74	65	
Strongly Disagree	25	25	25	22	
Chi-Square Goodness-of-Fit Test					
	Interest in swappable service	Interest in Mob application service	Opinion towards interest in Swappable facility due to less time taken	Opinion: whether swappable service is better than charging at home	
Agree	0.26429741	0.010196165	0.0013492	0.385113331	
Disagree	0.06894321	0.22300877	0.331891421	0.029001221	
Neutral	1.80851986	1.379483459	1.661595688	1.441014999	
Strongly Agree	2.42885377	4.138639628	1.225846357	2.885461792	
Strongly Disagree	0.7055527	3.131723022	0.705552703	0.009268992	
			CHI SQUARE (sum of all these observations)	22.8353137	
			DF (5-1)*(4-1)	12	
			p-value	0.02915706	

• Thus, Chi-Square Statistic (χ^2) = 22 was computed.
• With Degree of Freedom = 12, the critical (tabled) value of Chi-Square at the 5% significance level is 21.026. Therefore, we reject the null hypothesis (H_0) since 22 > 21.026.

The desire of users to employ battery swapping services for EVs in Mumbai is therefore statistically correlated with their preferences (such as time efficiency, app-based access, and home charging options).
This suggests that customer judgments about the adoption of battery switching are significantly influenced by characteristics like speed of service, app integration, and ease.

A Chi-Square Test of Independence was used to determine if participant answers to several survey questions on electric car battery swapping services were statistically linked. Four categorical variables' observed and expected frequencies were compared in the analysis:

1. Interest in swappable service
2. Interest in mobile application for swapping
3. Opinion on swappable facility being better due to less time taken
4. Opinion on whether swappable service is better than charging at home

- Summary of Statistical Output:
- Degrees of Freedom (df): 12;
- Chi-Square Statistic (χ^2): 234.49;
- Critical/Table Value (χ^2 at $\alpha = 0.05$): 21.03
- The p-value is 2.33×10^{-43}, which is extremely near zero.

Hence, we reject the null hypothesis of independence because the computed Chi-Square statistic (234.49) is significantly higher than the critical value (21.03) in the table and the p-value is significantly less than 0.05.

Contextual Interpretation:

The findings unequivocally show that the factors under investigation have a statistically significant correlation. To put it another way, participants' views on time efficiency, app usage, swappability, and comparisons to home

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charging are not separate from one another. People's answers to one question have a big impact on how they answer others.
This implies a relationship between user preferences and perceptions of electric vehicle battery swapping services. For example, people are more likely to support mobile applications and favor swapping over home charging if they think that swappable batteries save time.

Research and Practice Implications:

• There is compelling evidence of respondents' consistent behavioral patterns.
• Stakeholders, such as EV manufacturers or service providers, should take into account the possibility that interest in one element—such as mobile apps—will affect other elements, including perceived convenience or preference for charging.
• It is possible to connect marketing, design, and policy initiatives by emphasizing feature packages that are preferred collectively.

10.2. Limitations of Study

Due to lack of awareness about swappable battery services the no. of responses are less than required.

11. Challenges

Although 251 replies from all around Mumbai were successfully collected for the study, there were some difficulties in gathering the data. Potential responders' ignorance of the idea of battery switching in electric vehicles was one of the main obstacles. Before distributing the survey, the researcher had to spend more time elucidating the notion because many people were not aware with the language or the workings of such infrastructure.
The unwillingness of some people to complete the survey was another important drawback. Respondents frequently exhibited hesitancy or declined to participate, claiming time restrictions or indifference, particularly in public settings. This led to a delayed data gathering procedure that necessitated repeated outreach efforts.

12. Recommendations for Additional Research

Although the public's perception of Mumbai's battery swapping facilities has been better understood, there are still a number of significant issues that need exploration.

1. Environmental Effects of Infrastructure for Battery Swapping

Future research should assess how widespread battery swapping systems affect the environment over the long run. This entails looking at the disposal procedures, the life cycle of swappable batteries, and the carbon impact related to the regular manufacture and replacement of batteries. Despite the existence of the Extended Producers Responsibility (EPR) law, nothing is known about how it works and how effective it is. To gauge area issue at Fuel Stations in Mumbai, understand the impact of swappable battery facility on employment.

2. Issues with Standardization and Compatibility

Lack of uniformity of battery brands, connections, and vehicle designs is a major problem in the present battery switching environment. Future studies should examine whether universal battery standards are technically feasible and how cooperation among EV manufacturers might ease implementation challenges related to battery switching.

3. Battery Degradation and Depreciation

Battery swapping is the practice of using shared battery units by several people, which can hasten wear and tear, hasten depreciation, and lower battery performance. The effects of frequent exchanges on battery longevity, safety, and charging efficiency—as well as the financial ramifications for both customers and service providers—need more research.

4. Issues with Ownership and Liability

Research may examine operational and legal issues such consumer protection, accountability for battery failure, and confidence in battery health tracking systems because users do not own the batteries they use in switching systems.

5. User Acceptance and Behavior over Time

A longitudinal research can evaluate how battery-swapping is seen, accepted, and used over time, particularly as legislative frameworks and infrastructure expand.
Future research can help create a battery-swapping ecosystem that is more sustainable, effective, and user-friendly in India and around the world by addressing these technical, environmental, and behavioral aspects.

6. Reasons of not adopting the Swappable Battery Facility

There were 127 respondents from 251 who opted out of from such facility, this brings in curiosity to know the reasons for same.

13. Conclusion

The adoption of swappable battery technology for electric vehicles (EVs) in Mumbai was investigated in this study along with public opinion and interest. Approximately 49% of the 251 respondents said that they would be prepared to use swappable battery options. This suggests that although the idea is becoming more visible, it has not yet gained the trust of the general people, indicating a moderate level of acceptability.

The results show that even while EV adoption is on the rise in Mumbai, the battery swapping concept is still viewed with skepticism. The absence of uniformity in swapping infrastructure, the possibility of battery deterioration from shared usage, worries about battery compatibility among EV models, and low awareness are some of the main obstacles. More than half of the respondents showed reluctance, which was probably caused by these causes.

The survey also shows that most respondents thought that gas stations and exchanging centers were the best places to exchange batteries, which emphasizes the necessity of easily accessible and organized infrastructure. However, throughout the poll, questions were also expressed about the technical viability of frequent exchanges and environmental issues associated with managing many batteries.

Respondents interest in implementing swapping facilities was validated by statistical method like Chi-square analysis. The findings of the Jarque-Bera normality test showed a non-normal distribution, indicating that public opinion is still split and emphasizing how young this technological revolution is.

In summary, although battery swapping shows potential as a quick and easy substitute for conventional EV charging, more has to be done to increase infrastructure accessibility, consumer confidence, and technology compatibility. Adoption will be greatly aided by pilot projects, public awareness initiatives, and policy interventions. Future research should examine user happiness, economic feasibility, and long-term environmental effects in actual battery swapping model implementations.

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