Cureus Journal of Business and Economics

Open Access Original Article

Shaping the Path to Electric Vehicle (EV) Transition in India: An Assessment of Demographic Factors and Charging Behaviour of EV Users in Indian Metropolitan City

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Received 01/08/2025
Review began 01/08/2025
Review ended 02/28/2025
Published 03/23/2025

DOI:
https://doi.org/10.7759/s44404-024-02882-y

Abstract

The rapid industrialisation and urbanisation in India have led to a significant increase in greenhouse gas emissions, with the transport sector being one of the major contributors. To address this issue, the adoption of electric vehicles (EVs) has gained momentum as a promising solution to curb pollution and reduce energy demand from the transport sector. It is crucial to understand the factors that influence the adoption of EVs in India and evaluate the effectiveness of the existing policy measures to promote their integration. Within this context, the present study is focused to examine the various factors that influence the adoption of EVs in Bengaluru urban area. The study examines the socio-technical factors, availability of charging infrastructure, and user experience as key determinants of EV adoption within the city. The critical demographic characteristics have also been identified as influential factor in the adoption of EVs. The target population for the study was individuals with either a two-wheeler or four-wheeler EVs. The responses were collected from 432 participants through non-probability purposive sampling. The findings from this study are expected to assist policymakers, government entities, and industry stakeholders in developing more effective policies and marketing approaches to enhance consumer uptake of EVs in India.

Categories: Consumer Behavior, Transportation, Sustainable Economic Development
Keywords: green infrastructure, government policies, electric vehicles, geo-demographic analysis, sustainable transportation

Introduction

A pivotal and an essential element of economic and industrial growth is transportation sector. With its enormous growth over a period of time, this sector is posing a severe threat to the environmental health, becoming a significant source of greenhouse gas emission. The nuisance created by automobiles is worsening the air quality day by day [1]. In order to achieve the Net Zero Emission scenario, transport-related emissions need to fall by about 25% by 2030. Enabling electrification of road transportation, and policies encouraging transition to less carbon-intensive travel will help in accomplishing this target [2].

India's growing fleet of passenger vehicles is responsible for decline in country's air quality [3]. Internal combustion engine vehicles (ICEVs) used in the transportation sector are the major contributors of PM2.5 pollutants in Indian metropolitan city, Bengaluru [4]. There is a need for expeditious corrective measures to reduce transport-related air pollution from diverse stakeholders including government, research institutions, and international organisation.

Electrifying road transportation offers considerable reductions in carbon emissions and other pollutants into the environment leading to better air quality, especially in metropolitan cities. Further, consumers benefit from lower operational cost [5-7]. Electric vehicles (EVs) provide both environmental and economic benefits by reducing air pollution, and increased energy security through reduced oil imports [8]. The widespread adoption and diffusion of EVs can facilitate the decarbonisation of the transportation sector, thereby contributing to climate change mitigation efforts, and supporting the achievement of key United Nations Sustainable Development Goals.

How to cite this article
Sunanda B, Parchure R (March 23, 2025) Shaping the Path to Electric Vehicle (EV) Transition in India: An Assessment of Demographic Factors and Charging Behaviour of EV Users in Indian Metropolitan City. Cureus J Bus Econ 2 : es44404-024-02882-y. DOI https://doi.org/10.7759/s44404-024-02882-y

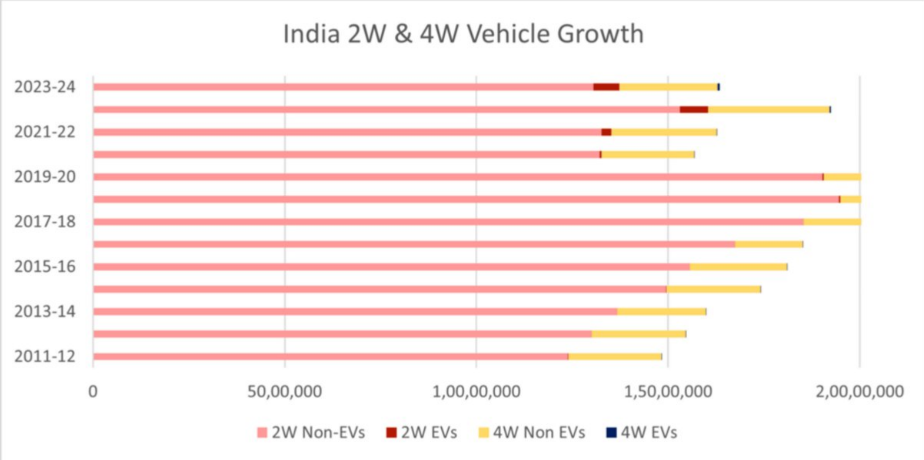

FIGURE 1: Growth of 2W and 4W vehicles from 2011-12 through 2023-24 in India

Source: VAHAN Dashboard, The Ministry of Road Transport and Highways (MoRTH), GoI. EV, electric vehicle; 2W, two-wheeler; 4W, four-wheeler

The data presented in Figure *1* show the growth trajectory of two-wheeler and four-wheeler vehicles in India. In 2011-12, the number of non-electric two-wheeler and four-wheeler vehicles stood at 1,23,89,258 and 24,26,633 units, respectively. By 2023-24, these figures had increased to 1,30,52,251 and 25,60,740 units, respectively. During this period, the total number of registered EVs has also increased; in 2011-12, the number of registered electric two-wheelers and four-wheelers were 6,646 and 693, respectively. However, by 2023-24, the number of registered electric two-wheelers had increased to 6,76,605, while electric four-wheelers had reached 61,966 units.

The governments around the world have employed a variety of policy tools to incentivise the adoption of EVs and support the transition to sustainable mobility. The initial push towards the EV adoption in India started with the National Electric Mobility Mission Plan (2013). Thereafter, the government launched the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME-India) Scheme (2015, 2019). Further, the Ministry of Heavy Industry of the Indian Government introduced the Electric Mobility Promotion Scheme (2024), and PM E-drive (2024) initiatives to promote the adoption of EVs across the country. The government efforts to promote electric mobility have resulted in remarkable growth of EVs in a short span. However, their market share can be further strengthened by comprehending the demographic characteristics and charging behaviour of current EV users. The better understanding of charging behaviour of existing EV users and their demographic characteristics will enable formulation of targeted EV promotion policies.

The current study aims to evaluate the interconnection between demographic factors and EV ownership in Indian metropolitan city, Benglauru. The author examines the influence of age, gender, occupation, income level, and educational attainment on the EV adoption in both of 2W and 4W category. The travel pattern and charging behaviour of E2W and E4W owners in the city is being evaluated. Further, the influence of demographic variables on the travel pattern is analysed. Finally, the study identifies the preferred location of EV battery recharge.

Theoretical background

Consumer Demographic Theory emphasises that consumption patterns and preferences of individuals are largely determined by their demographic characteristics and socioeconomic status. Demography examines key population features like gender, marital status, language use, ethnicity, health, education, employment, and income [9, 10]. Household demographics, such as employment status, income, and household size, have been found to influence the timing of consumers' purchase decisions [11].

Review of literature

Multiple studies conducted in the past have identified that the demographic variables influence the acceptance of innovative technology. A study carried out in Germany states that EVs are purchased mostly by the male population who are highly educated and earn high income [12]. Similar studies in India have explored that the demographic factors like gender, age, education, occupation significantly affect consumer intentions towards EV adoption [13, 14]. The widespread adoption of EVs necessitates market segmentation based on age, gender, and income, and design marketing strategies to suffice the prospective consumers [15].

Age, gender, and political orientation are the three primary demographic variables used to understand how it affects their inclination towards EVs. Online social network platforms, namely, Twitter and Reddit, are used to identify the influence of demographic factors on EVs [16]. The study found that share of male user opinion is more compared to female user opinion on EV-related discussions and they are mostly middle-age population.

The importance of demographic characteristics in shaping EV adoption decisions is assessed by employing stated preference data from the Nordic region, namely, Denmark, Finland, Iceland, Norway, and Sweden [17]. The study examine the influence of gender, experience, education, occupation, ageing, and household size on EV purchase intention. The study highlights the orientation towards EV are seen among men, educated, securely employed and younger middle-aged population. Further, study indicates that larger families prefer to own EVs, which correlates with household size and car ownership.

A cluster analysis was conducted by segmenting and profiling young and educated population studying at a technological university in Indian metropolitan city [18]. The study classifies this student population into three different clusters based on their knowledge, attitude, and perception towards EVs with an assumption that young population are more open to early adoption of innovations and sustainable technologies like EVs. They found that technological and environmental enthusiasm of innovation among young and educated population drives the EV adoption in the country.

There is a strong relationship between gender and vehicle ownership. The male population is more inclined towards EV purchase compared to female population [19-22]. The difficulties in mobility and family obligation make women opt for home-based work and they tend to make more frequent and shorter trips. Women modify and interrupt their journeys to pick up children, to run errands, and to meet other family responsibilities [23].

A notable association exists between income, housing, and access to charging facility. Electric mobility is opted as a supplementary fleet by those who already own ICEVs [24]. However, parking facility at household prove to be vital parameter influencing EV purchase [25]. EV owners prefer to charge their vehicles at their residence, followed by workplace, and then public locations [22]. The convenience of charging EV batteries at household is associated with housing type, and tenure. Lower-income households and individual are less likely to have charging facilities at both their homes and workplace. Public charging infrastructure become crucial to nudge them to adopt EVs [26]. Therefore, it is necessary to incorporate diverse demographic features and preferences into designing and optimising charging infrastructure facilities [27].

Range anxiety, are some of the widely discussed technological barrier of EVs [28]. However, an extensive investment made into the research and development, display a considerable improvement in battery capacity of EVs [29]. Another obstacle in the process of EV adoption is the number of hours taken for battery recharge. The non-availability of fast recharging set-up also act as an obstacle [30].

The existing literature has clearly established a strong linkage between demographic factors and EV ownership. While most of the past studies have primarily focused on developed countries, fewer have examined EV adoption in emerging countries like India. Therefore, there is a need to further investigate consumer EV adoption pattern in the Indian context to enhance acceptance among consumers. Past literature has explored the relationship between demographic factors on the buying intentions of potential EV users, but limited study examines the influence of demographic factors on EV adoption patterns and charging behaviour of the existing EV users.

Research Method

The study employed a self-administered survey questionnaire in order to carry out quantitative research. The target population for the study was individuals who own either two-wheeler and four-wheeler EVs. This was essential as the study focused exclusively to examine the influence of demographic factors and charging behaviour of current EV users. Hence, non-probability purposive sampling technique was used. Confidentiality of the data was promised to participants in order to reduce variance issues [31].

The questionnaire distributed to the participants consisted of two categories. Section A composed of questions regarding the demographic information of the respondents, such as age, gender, and monthly income. Section B targeted understanding the travel and charging behaviour of the participants. It included the questions on the preferred location of battery recharge, number of hours required for full recharge, distance travelled per day, number of vehicles in the household, and other related factors. Primary data were collected through in-person meetings and face-to-face interviews with respondents, conducted between April and July 2024. With an objective to arrive at the desired level of statistical power, the present study utilises Slovin's formula.

The Slovin's Formula (1) is represented below:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

where; n = Number of samples N = Total population and e = Error tolerance.

According to VAHAN Dashboard, Ministry of Road Transport & Highways (2024), the total number of high-speed E2W (electric two-wheeler) and E4W (electric four-wheeler) are 19,06,442 (January 2024) in India. Using Slovin's formula (1) with e = 0.05, the sample size should be 399.99. The total sample size in our study is 432, which is validated by the technique mentioned above.

Karnataka, being the first one to issue a state-level EV policy in India, aims to make Bengaluru the EV capital of the country. To address many issues related to road transportation, the city is gearing up to transition towards electric mobility. In alignment with the research objectives, primary data collection was carried out in the capital city of Karnataka. After administering the questionnaire for a period of four months in Bengaluru, a total of 432 valid samples were collected, of which 269 participants owned E2W and 163 of them owned E4W.

For the statistical analysis, IBM SPSS Software 24.0 was used. The nature of the data does not require advanced statistical tools such as validity test, reliability test, and factor analysis. The percentage analysis and chi-squared technique were adopted in the current study. This type of analytical approach is well-suited to the research objectives.

Results

Demographic profile and electric vehicle category

In this section, an analysis is made to understand the influence of demographic factors like gender, age, occupation, education, and income level on the purchase of 2W and 4W EVs in Bengaluru city.

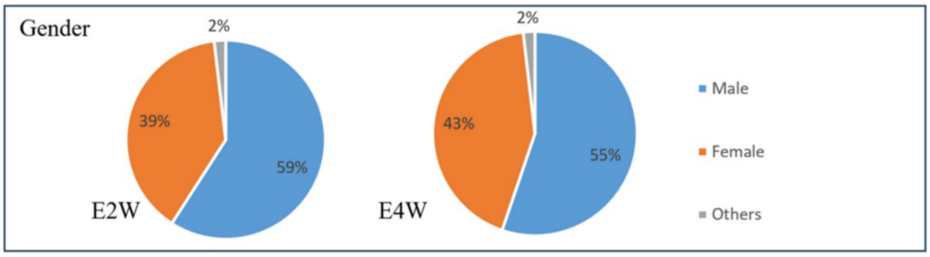

FIGURE 2: Gender differences between E2W and E4W

Findings from primary data collection. E2W, electric two-wheeler; E4W, electric four-wheeler

Figure 2 shows the EV ownership based on gender. The majority of ownership in both the E2W and E4W categories is held by the male population, at 59% and 55%, respectively. In contrast, the female population owns 39% of E2Ws and 43% of E4Ws. The remaining 2% of the population did not wish to reveal their gender identity.

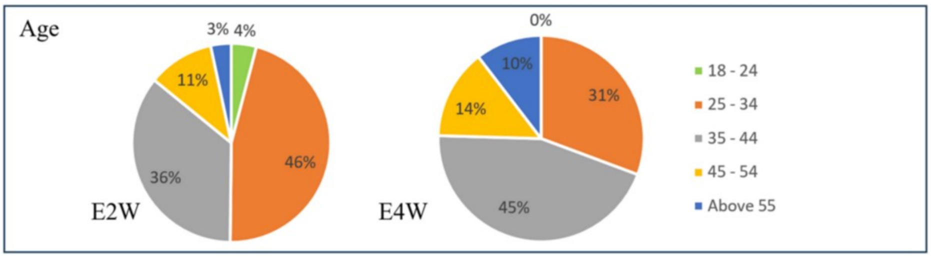

FIGURE 3: Age differences between E2W and E4W

Findings from primary data collection. E2W, electric two-wheeler; E4W, electric four-wheeler

Figure 3 presents the age characteristics of EV ownership. Four percent of the student population aged 18-24 own only E2W, and this group does not own E4W. In contrast, the age group 25-34 owns 46% of E2W and 31% of E4W. The age group 35-44 owns 36% of E2W and 45% of E4W. The age group 45-54 owns 11% of E2W and 14% of E4W. The population aged above 55 owns 3% of E2W and 10% of E4W. From the figure, it becomes evident that EV ownership is more prevalent among the mid-age groups. The data indicate that the older population is less likely to purchase EVs in both the 2W and 4W categories.

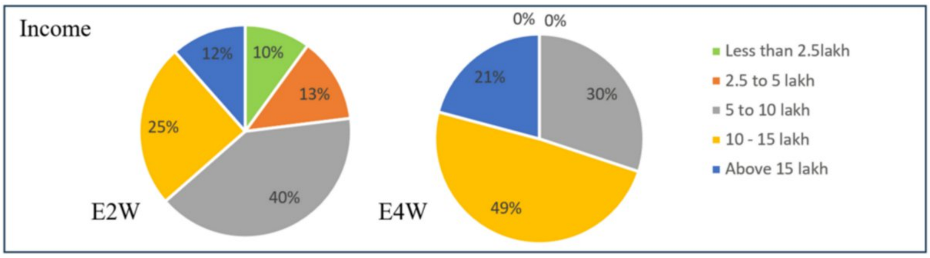

FIGURE 4: Income differences between E2W and E4W

Findings from primary data collection. E2W, electric two-wheeler; E4W, electric four-wheeler

The relationship between annual income and EV ownership is presented in Figure 4. Respondents earning up to Rs. 2,50,000 annually own 10% of E2W but do not own E4W. Those with an income range of Rs. 2,50,001 to Rs. 5,00,000 own 13% of E2W, with no representation in the E4W category. Further, respondents with an income range of Rs. 5,00,001 to Rs. 100,000 own 40% of E2W and 30% of E4W. Respondents with an income range of Rs.10,00,001 to Rs.15,00,000 own 25% of E2W and 49% of E4W. Individuals earning above Rs. 15,00,000 own 12% of E2W and 21% of E4W. This highlights the direct relationship between income and EV ownership. The data reveal a significant disparity in E2W and E4W ownership based on income background. Higher-income individuals tend to purchase E4W, while lower-income individuals predominantly opt for E2W. The results underscore the high upfront cost associated with EV ownership.

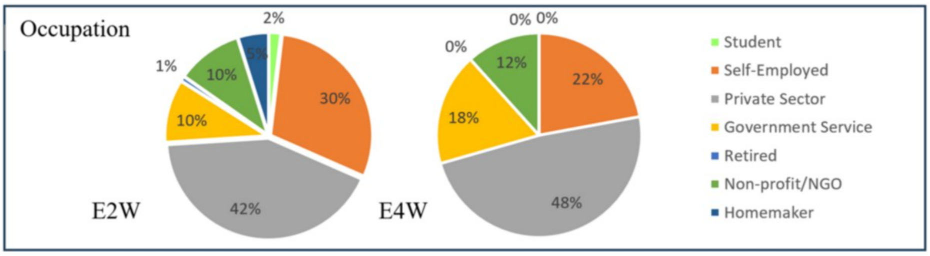

FIGURE 5: Occupational differences between E2W and E4W

Findings from primary data collection. E2W, electric two-wheeler; E4W, electric four-wheeler; NGO, non-governmental organisation

The data in Figure 5 reveal that EV ownership is dominated by private sector employees, who account for 42% of E2W and 48% of E4W ownership. Self-employed individuals also have a significant presence, owning 30% of E2W and 22% of E4W. In contrast, students make up only 2% of E2W ownership, with none owning E4W. Government sector workers own 10% of E2W and 18% of E4W. Retired individuals and homemakers have relatively low EV ownership, with just 1% of E2W and no E4W for retirees, and 5% of E2W but no E4W for homemakers. Non-profit/non-governmental organisation (NGO) employees account for 10% of E2W and 12% of E4W.

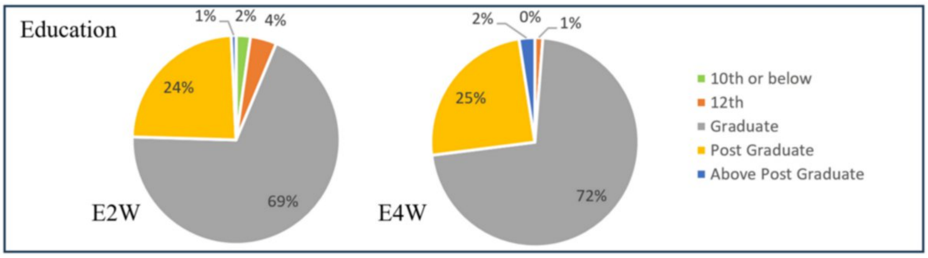

FIGURE 6: Educational differences between E2W and E4W

Findings from primary data collection. E2W, electric two-wheeler; E4W, electric four-wheeler

The data presented in Figure 6 demonstrate a strong link between education level and EV ownership. The majority of EV owners are graduates, holding 69% of E2Ws and 72% of E4Ws. Post-graduates closely follow, comprising 24% of E2W and 25% of E4W owners. In contrast, respondents with 10th-grade or lower qualifications own only 2% of E2Ws and none of E4Ws. Those with 12th-grade qualifications account for 4% of E2Ws and 1% of E4Ws. The remaining respondents, holding doctoral degrees or higher, own a mere 1% of E2Ws and 2% of E4Ws.

Demographic Variables	Value	df	Asymptotic Significance (2-sided)
Gender	0.650[a]	2	0.722
Age	24.203[a]	4	0.000
Occupation	20.028[a]	6	0.003
Income	63.912[a]	4	0.000
Education	8.661[a]	4	0.070

TABLE 1: Pearson chi-squared test on the demographic factors and EV category

Author's calculation. EV, electric vehicle

The results of chi-squared test for independence conducted to evaluate the association between different demographic variables and type of EVs are shown in Table 1. The analysis revealed that there is no significant relationship between gender and type of EVs, $\chi^2(2) = .650a$, $p > 0.05$. The primary data show that male population dominates ownership with 59% and 55% in both E2W and E4W categories, respectively.

There is a significant association between age and type of EVs, $\chi^2(4) = 24.203a$, $p < 0.05$. The data reveal that the age group 18-24 own 4% of E2W and none in E4W segment. The age group 25-34 own 46% of E2W and 31% of E4W. Further, the age group 35-44 own 36% of E2W and 45% of E4W. The older age group category consisting of individuals aged between 45 and 54 and above 55, own 11% and 3% of E2W, respectively, whereas it is 14% and 10% in E4W category.

The analysis reveals a significant relationship between occupation and type of EVs, $\chi^2(6) = 20.028a$, $p < 0.05$. Only 2% of student, retired population, and 5% of homemakers own E2W, whereas individuals in these categories do not own E4W in the present study. Self-employed individuals and those who are working in private sector exhibit greater share of E2W ownership with 30% and 40%, respectively. The individuals in the same category own 22% and 48% in E4W. Respondents working in government sector and NGO exhibit relatively smaller share of EV ownership.

There is a significant relationship between income level and type of EVs, $\chi^2(4) = 63.912a$, $p < 0.05$. The data related to income variable reflect that respondents with low-income with annual earnings of 2.5 and 5 lakh own 10% and 13% of E2W, respectively, whereas respondents in this income category do not own E4W. Respondents with income level 5-10 lakh, 10-15 lakh and above 15 lakh per annum own 41%, 25%, and 12% of E2W, respectively, whereas it is 30%, 49%, and 21% in E4W category.

The primary data show that there is an association between educational attainment and type of EVs, $\chi^2(4) = 8.661a$, $p < 0.10$. This demographic factor shows that people with educational qualification up to 12th standard do not own E4W, whereas they own 6% of E2W. Respondents with graduate degree own 69% of E2W and 72% of E4W. Post-graduate degree holders own 24% and 25% of E2W and E4W, respectively.

Travel patterns and charging behaviour of EV owners

This section examines the travel patterns and charging behaviours of EV users in an Indian metropolitan city. The motivation behind the purchase of EVs helps in comprehending the travel behaviour. Further, the understanding of daily commute distance, charging frequency, duration of battery recharge, and charging location preference of EV users provides insightful knowledge to build a cohesive EV ecosystem. In order to plan infrastructure expenditure and to improve research and development in the field of battery development, it is important to gather information and understand the travel and charging behaviour of EV owners.

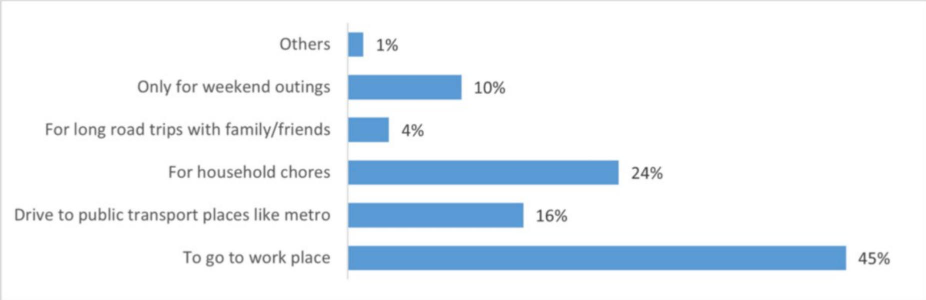

FIGURE 7: Purpose of buying electric vehicle

Findings from primary data collection

Purpose of purchasing EV: The respondents during the survey were asked to choose the most important reason for the purchase of their EV. As shown in Figure 7, majority of the respondents (45%) purchased EV for regular commuting to their workplaces. The second popular reason was to meet the needs of household activities like buying groceries, picking up children from school, and others. In all, 16% of the respondents have purchased EV to commute to public transportation places, whereas only a small number of respondents have purchased it for weekend outings and long road trips.

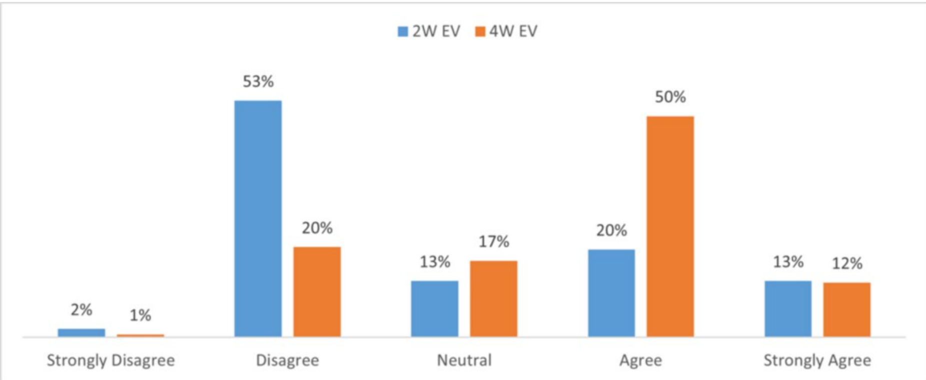

FIGURE 8: Environmental concern as the purpose of EV purchase

Findings from primary data collection. EV, electric vehicle

Since EVs are popular mode of sustainable transportation, respondents were asked if the motivation behind EV purchase was environmental health. Interestingly, the result shows that 50% of 4W owners purchased EV because of the environmental benefits, whereas 53% of the 2W owners disagree on this statement as shown in Figure *8*.

Analysis of Travel and Charging Behaviour of Passenger EV segment: Due to the differences in vehicle range and battery capacity, the study examines the differences in travel pattern and charging behaviour in both E2W and E4W category. The need for the purchase of new vehicle is significantly influenced by the number of vehicles in household and type of housing [24, 25, 32]. The household size, income level, and number of vehicles have direct influence on opting more fuel-efficient vehicle [33, 34]. The household with a greater number of vehicles and children are more likely to purchase EVs [35]. However, the range anxiety issues associated with EVs will offset the option of completely switching to electric mobility [36, 37]. Number of vehicles owned in a household plays a crucial factor to understand EV purchase behaviour.

An average distance travelled by any passenger vehicles in the country is around 8,000km [38]. If the total distance travelled by EV user is more than 10,000km, it is assumed that he has been using it since more than a year. This information is helpful in validating the travel and charging behaviour of respondents. In India, an average daily distance travelled for office is 17km [39, 40]. In Indian city, distance travelled by commuters is 11km and 32% of the population commute more than the average distance [41]. An association between daily distance travelled in EVs highlights the purpose of usage in two different EV segments.

The battery is a crucial element of electric mobility. The battery capacity, duration of recharging, and the frequency of recharging determines the choice of EVs. The longer duration taken for recharging the battery can be an obstacle in EV adoption, whereas the short recharging period is positively correlated with EV adoption [42]. The frequency and time taken for battery recharge is directly associated with range anxiety and choice of electric mobility [43]. Table *2* presents the information related to the number of ICEVs, distance travelled, and charging behaviour with respect to passenger EV category.

Variables	E2W Users	E4W Users	Chi-square
Number of total ICEV in your household			$\chi^2(3) = 11.38, p < 0.05$
1–2	67%	55%	
3–4	29%	44%	
5–6	3%	1%	
More than 7	1%	0%	
The total distance travelled in EV			$\chi^2(3) = 50.79, p < 0.001$
Less than 1 year or 10,000km	50%	23%	
10,000km–30,000km	49%	65%	
30,000km–60,000km	0%	7%	
More than 60,000km	0%	4%	
Average daily distance travelled			$\chi^2(4) = 132.22, p < 0.001$
Less than 10km	21%	1%	
10km–20km	38%	15%	
20km–30km	39%	46%	
30km–50km	2%	28%	
More than 50km	0%	10%	
Frequency of battery recharge			$\chi^2(3) = 39.82, p < 0.001$
Everyday	6%	3%	
2 times a week	74%	66%	
Once a week	14%	5%	
2–3 times a month	6%	26%	
Number of hours taken for full battery recharge			$\chi^2(4) = 383.28, p < 0.001$
Less than 30 minutes	3%	0%	
1–3 hours	45%	4%	
4–5 hours	50%	0%	
6–8 hours	2%	87%	
More than 8 hours	0%	9%	
Number of km travelled per full battery recharge			$\chi^2(4) = 374.30, p < 0.001$
Less than 50km	5%	0%	
50km–100km	40%	0%	
100km–200km	54%	7%	
200km–400km	1%	92%	
More than 400km	0%	1%	

TABLE 2: Differences in travel and charging behaviour between E2W and E4W users

Findings from primary data collection. E2W, electric two-wheeler; E4W, electric four-wheeler

There is an association between the number of total ICEVs owned in a household and the type of EV purchased at the 5% significance level. In all, 67% of E2W owners had 1-2 other fuel vehicle at household, whereas it is 55% for E4W owners.

There is an association between total distance travelled and type of EV purchased at a significance level of 1%. In all, 76% of E4W owners have travelled more than 10,000km since its purchase, whereas E2W owners have travelled shorter distance.

There is an association between the average kilometres travelled per day and the type of EVs at a significance level of 1%. The data reveal that 21% of E2W owners travel less than 10km and 38% of them travel between 10km and 20km per day. Whereas, the majority of E4W owners use their EV for longer distances for travelling more than 20km per day.

There is an association between the frequency of battery recharge and the type of EV owners at a significance level of 1%. A large number of E2W owners, 74% and 14% recharge their vehicles twice or once per week. In contrast, 63% of E4W owners recharge their vehicles twice a week and 26% of them recharge 2-3 times a month.

There is an association between the duration of battery recharge and the type of EV users at a significance level of 1%. In all, 45% of E2W users recharge their vehicle battery between 1 and 3 hours and 50% between 4 and 5 hours. However, 87% of E4W users take 6-8 hours to recharge their vehicle battery.

There is an association between the number of km travelled per full charge and the category of EV users at a significance level of 1%. Due to the lower battery capacity, E2W users can travel only under 200km per full battery recharge, whereas E4W users can travel beyond 200km per full battery recharge.

Analysis of demographic variables on the EV usage

Gender: The previous literature presents that women exhibit high orientation towards sustainable mode of transportation, and can lead transition towards greener mobility options [44]. Electric mobility is one of the most advocated sustainable transportation alternatives. Contradictory to the popular opinion of women as the champions of sustainability, existing literature shows that men are leading EV transition globally [17, 34]. The active participation of women in the EV adoption is slowed down by their economic dependency and high upfront cost of EVs [20]. If men travel to work at longer distance, women make frequent and shorter trips to meet household chores [45]. Another dimension of gendered difference in EV adoption appears in the labour force participation of women. Women who are restricted to the home-based work or informal sector lack the EV charging facility at workplace [23]. Primary data presented in Table *3* reiterates the previous literature where men dominate the EV adoption, travel longer distance, and have covered maximum number of distances compared to women.

Age: The travel pattern and the distance travelled in EV are influenced by the age factor. Earlier studies have exhibited that younger and mid-age population are more susceptible towards EV adoption [22, 25, 27]. The younger age group is environmentally conscious and technologically enthusiastic [18]. Since the mobility needs of the older population are limited, they prefer conventional transportation and are reluctant to adapt to the new technology. Interest in EVs is definitely higher for the younger age group but elderly may also represent attractive electric mobility market [17]. The results from the primary data align with the previous literature. The younger and mid-age group have travelled more distance in EV, signalling as the early adopters. The average daily distance travelled by this age group is higher than the older population as presented in Table *3*.

Income level: Urban mobility needs to gear up for the transition towards sustainable transportation [46]. Urban dwellers with higher income levels are the torchbearers of EV adoption as they have accessibility for home-charging, and strongly support renewable energy charging infrastructure [47]. Middle-income working-class population prefer EVs as they are concerned about environment and want to switch to fuel-saving mobility options [48]. However, Mingjun and Eugene [21] highlight that even low-income populations are interested in the purchase of EVs, but they prefer EV models with lower price and shorter driving ranges, whereas middle-income and higher-income populations choose EVs with longer driving range despite high initial cost of purchase. Therefore, income level is positively associated with EV adoption. Table *3* exhibits that mid-range and high-range income population are the early adopters of electric mobility, as the total distance travelled by this group is comparatively higher. This category of respondents further display that they travel longer distance compared to low-income respondents.

Demographic Variables		The Total Distance Travelled in EV				Average Daily Distance Travelled				
		Less than 10,000 km	10,000–30,000 km	30,000–60,000 km	More than 60,000 km	Less than 10km	10–20 km	20–30 km	30–50 km	More than 50km
Gender	Male	55%	61%	46%	43%	47%	60%	61%	54%	56%
	Female	44%	37%	54%	57%	52%	38%	38%	44%	44%
	Others	1%	3%	0%	0%	2%	2%	2%	2%	0%
Age group in no. of years	18–24	6%	0%	0%	0%	2%	6%	1%	2%	0%
	25–34	44%	39%	23%	14%	41%	52%	39%	26%	6%
	35–44	35%	41%	46%	57%	34%	30%	44%	48%	44%
	45–54	10%	13%	15%	14%	17%	8%	12%	14%	19%
	Above 55	5%	6%	15%	14%	5%	4%	4%	10%	31%
Annual income (Rs. in lakhs)	<2.5	11%	3%	0%	0%	12%	10%	4%	0%	0%
	2.5–5	10%	7%	0%	0%	16%	15%	4%	0%	0%
	5–10	43%	34%	8%	29%	40%	37%	44%	59%	0%
	10–15	25%	38%	69%	57%	19%	27%	35%	31%	50%
	15<	10%	18%	23%	14%	14%	11%	14%	10%	50%

TABLE 3: Demographic variables on the EV usage

Findings from the primary data. EV, electric vehicle

Location of EV battery recharge

The accessibility to convenient charging infrastructure is crucial in accelerating the EV adoption. EV users do not have access to regular parking spaces and charging facilities and feel anxious about declining battery capacity [49]. The charging behaviour is influenced by different demographic factors and preferences [27]. The most preferred location for charging is at home, followed by workplace, and public charging facilities [22].

The following Figure 9 indicates the most likely destination of respondents for recharging EV batteries. The result shows that 51% of them prefer to recharge at their respective residence followed by 26% of them choosing to recharge at the workplace, and 15% of them preferring public charging station. Only a small number of 5% and 3% of respondents would like to charge at other public places and showrooms, respectively.

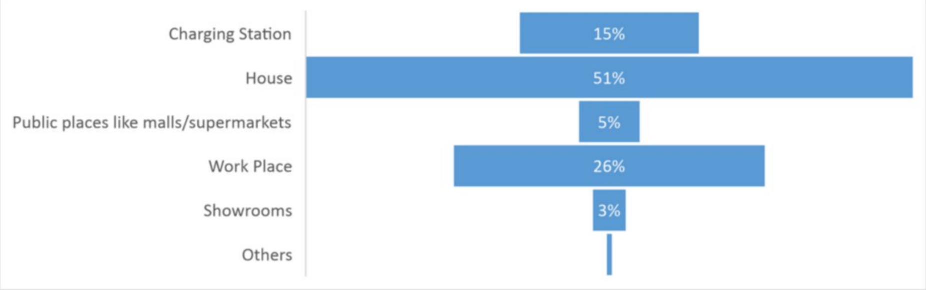

FIGURE 9: Preferred place for EV battery recharge

Findings from primary data collection. EV, electric vehicle

Charging facility at workplace

As presented in Figure 9, the second most popular location of EV recharging is at workplace. The emphasis on providing charging facility at the workplace is gaining momentum. The range anxiety commonly witnessed in the EV users [42, 50] can be mitigated by introducing charging facility at workplace. The convenience of accessibility to the charging infrastructure will effectively reduce the range anxiety [51]. Additionally, the provision of charging facility at the workplace will enable improvement of efficiency and productivity of employees [52].

The working population who uses EV for commuting to their places were asked if they have a facility to recharge batteries at their respective workplaces. Respondents working in the government sector positively responded with 44% of them agreeing on availability of charging infrastructure at the workplace. Respondents working in other sectors have lesser provisions of charging facility at their workplace as shown in Table 4.

Occupation	Self-Employed	Private Sector	Government Service	Non-profit/NGO
Yes	17%	33%	44%	7%
No	32%	49%	3%	16%

TABLE 4: Charging facility at workplace

Findings from primary data collection. NGO, non-governmental organisation

Discussion

A sample of 432 EV users were segmented into two-wheeler and four-wheeler category. The influence of demographic variables such as gender, age, income level, occupation, and education on the purchase of EVs was evaluated using frequency distribution. Further, the effect of demographic variables on the purchase of E2W and E4W was examined. The chi-squared test was used as a statistical tool to comprehend an association between demographic variables on the type of EVs purchase.

Demographic variables influencing EV ownership

The results reveal that the percentage of male EV owners is significantly higher than female EV owners in both categories, E2W and E4W. The proportion of male ownership in E2W category is higher than the E4W category. The other gender in the sample represent those who did not wish to reveal their gender identity. This category owns 2% in both EV segments.

With respect to the variable age, the study found that the E2W is majorly owned by younger population (25-34) followed by the mid-age group (35-44). However, it is opposite in the case of E4W, where the mid-age group represents majority of the share followed by the younger population. The share of older population aged above 55 is negligible in both EV categories.

The upfront costs of EVs are high, and they are one of the major obstacles to their adoption [53, 54]. The findings in the present study validate this relationship, as EVs are purchased and used by the middle-income and higher-income categories than the lower-income group. Respondents with income less than 5 lakh per annum have purchased and use E2W, whereas this category does not own E4W at all. Overall, the majority of the EVs are owned by the middle- and high-income categories in both EV segments.

The current research reiterates that self-employed and those who are working in the private sector own the majority of the EVs. Respondents working in the private enterprises use more E4W than E2W. Self-employed respondents use more E2W than E4W. However, it is these two categories that represent the maximum EV ownership. Respondents working in the government sector represent greater share in E4W than E2W. Retired population and homemakers only use E2W and their share in E4W category is negligible.

Past literature identifies a positive relationship between educational attainment and EV ownership [55, 56]. The results from the primary data uphold this association. The share of ownership in both EV segments is owned by respondents who have completed graduation and post-graduation degrees. The respondents with less educational qualification owned only E2W in our study.

From the primary data analysis, it is evident that there is a significant difference among the demographic variables and the type of EV ownership. When EVs are classified into two segments, E2W are owned by low-income, less qualified, and younger population, whereas E4W are owned by relatively highly qualified, better earning mid-age population. EVs that are promoted as an innovative solution for transport-related pollution have proven to be popular among the educated and young populations who are more adaptable to new technology.

Travel pattern and charging behaviour influencing EV ownership

The relationship between EVs and number of ICEVs owned in the household highlights that both E2W and E4W users own an alternative fuel-based vehicle. An EV is not being used as the sole vehicle in household. This emphasises the EV adoption barrier regarding range anxiety and battery recharging duration. Further, it highlights the hesitancy of respondents to purchase EVs as their only choice of transportation.

An association between total distance travelled in EV and type of EV highlights the experience of EV users and validate their statement towards charging behaviour (Table *5*). Average daily distance travelled in EV, and its association with type of EVs presents an interesting information regarding usage and purpose of electric mobility. E4W are used for longer distance commuting, whereas E2W is used for daily trips within 30km. The data regarding frequency of battery recharge further validate the average daily distance travelled by E2W and E4W owners. The study reveals that EV owners in both the vehicle category recharge battery twice a week. This can provide an inference that EVs are used for daily travelling within the city.

An association between number of hours taken for full battery recharge and the number of km travelled per full battery recharge highlights the battery capacity used in E2W and E4W vehicles. The E2W owners need about 4-5 hours, whereas E4W owners require 6-8 hours for full battery recharge. With a lower battery capacity, E2W can cover a distance of 100km, whereas E4W can cover a distance of 200-400km.

Demographic variables influencing EV usage

The study identifies gender, age, and income level as the three major demographic variables affecting the travel pattern of electric mobility. As illustrated in the previous literature, male population dominates the EV transition in the country. The social and economic framework of women limit them to make frequent and shorter non-motorised trips [44]. The share of women in the total distance travelled and average daily distance travelled is less compared to men. Another demographic variable age shows that younger and mid-age group are faster adopters of electric mobility, and travel more using the EV. The mid-age population are the primary group of people attracted to the electric mobility who are economically independent and adaptable to the new technology [18]. Lastly, income level also plays an important role in EV adoption. Low-income category of respondents has fewer share in the EV adoption and travel lesser distance. This could also highlight their preference towards low-battery-capacity vehicles. Middle and high-income respondents are leading the EV adoption in the city.

Preferred recharging location

The respondents in the study display their preference for charging EVs at home. The limited public infrastructure, longer duration taken for the recharging of batteries, and other safety concerns limit them from opting for public charging stations. Further, the research identifies the limited charging facilities provided at workplaces. The working population employed in private sector and informal sector exhibit the lack of charging facilities at workplaces.

Conclusions

In summary, there is a strong relationship between demographic attributes and travel behaviour of individuals towards the uptake of EVs. The purchase pattern of EVs is not only decided by the purchase price and government incentives but is equally influenced by demographic characteristics and the existing EV environment. The results of the study shed light on preferences and limitations of existing EV users, highlighting the need for constant investment in research and development and facilitating necessary infrastructure support from the government.

Based on the results and analysis, the study makes the following policy recommendations:

The disparity in the demographic distribution between E2W and E4W arises from the initial high purchase price and lack of robust infrastructure facilities. Therefore, the financial support extended towards the purchase of EVs needs to be gender-based. Women are dependent on men for their economic and physical mobility. The provision of an additional subsidy offered to the women will enable equitable EV transition in the country. Further, in order to avoid the perception of electric mobility as a luxurious commodity, which is limited to the consumption of only higher-income population, immediate action must be taken to reduce the upfront cost. The uptake of EVs will be increased and will become accessible to the lower-income category only if the purchase price of EVs is reduced. Hence, the study demands extensive investment in the field of research and development in order to reduce the recharging duration of EVs, to enhance the battery capacity, and to witness decline in the overall cost of EVs.

Creating awareness of the environmental benefits of EVs will result in its faster adoption among the less educated and older population. The provision of training and employment generation in the EV sector and associated ancillary firms will reduce the anxiety issues and accelerate the EV uptake. Availability and deployment of public charging stations with Fast-EV charging setups will quicken the EV transition by reducing range-anxiety and stress associated with longer durations. Additionally, facilitating wider charging infrastructure at workplace will quicken the EV transition. These suggestions are made to enhance the user experience, and especially to ensure socio-economic equitability in the EV transition.

Limitation and scope for future work

The study does not include the parking facility and, charging conditions available at the household. The study was carried out in only one of the metropolitan Indian cities and focused only on the demographic characteristics influencing the EV adoption. The subsequent study can be undertaken in other locations while considering other socio-economic, environmental, technological and governmental factors influencing the EV adoption in the country. Further, the study may be subject to bias due to its use of a non-probability purposive sampling approach.

Appendices

Q. No.	Demographic and Charging Behaviour of EV Users in Bengaluru City	
1	Gender	Male
		Female
		Others
2	Age (in years)	18–24
		25–34
		35–44
		45–54
		Above 55
3	Occupation	Student
		Self-employed
		Private sector
		Government service
		Retired
		Non-profit/NGO
		Homemaker
		Others
4	Your annual income (in INR)	Less than 2,50,000
		2,50,000–5,00,000
		5,00,001–10,00,000
		10,00,001–15,00,000
		Above 15,00,000
5	Educational attainment	10^{th} or below
		12^{th}
		Graduate
		Post-graduate
		Above post-graduate
6	Type of EV owned/currently using	Only E2W

		Only E4W
7	Number of total vehicles in your household including EV	1–2
		3–4
		5–6
		More than seven
8	The total distance travelled so far in my EV is	Less than 1 year or 10,000km
		10,000km–30,000km
		30,000km–60,000km
		More than 60,000km
9	Average kilometres that you ride/drive on EV per day	Less than 10km
		10km–20km
		20km–30km
		30km–50km
		More than 50km
10	What is the main use of your EV?	To go to workplace everyday
		Drive to public transport places like metro
		For household chores
		For long road trips with friends/family
		Only for weekend outings
		Others
11	How often do you recharge your EV battery?	Everyday
		2 times a week
		Once a week
		2–3 times a month
12	Where would you prefer to recharge your EV's battery?	Charging station
		House
		Public places like malls/supermarkets
		Workplace
		Showrooms
		Others
13	How long does it take to fully recharge your EV's battery?	Less than 30 minutes
		1–3 hours
		4–5 hours
		6–8 hours
		More than 8 hours
14	How many kilometres distance does your EV travel after a full charge	Less than 50km
		50km–100km
		100km–200km
		200km–400km
		More than 400km

15	Indicate your agreement on the following statement:	
	(a) I have a EV charging facility at workplace	Yes
		No
	(b) I purchased EV because of environmental concerns	Strongly disagree
		Disagree
		Neutral
		Agree
		Strongly agree

TABLE 5: Questionnaire used for the primary data collection

Demographic and charging behaviour variables. EV, electric vehicle; NGO, non-governmental organisation

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: BV Sunanda, Rajas Parchure

Acquisition, analysis, or interpretation of data: BV Sunanda

Drafting of the manuscript: BV Sunanda

Critical review of the manuscript for important intellectual content: BV Sunanda, Rajas Parchure

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Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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