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Multivariate Analysis of the Factors Influencing Consumer's Purchase Decision towards Electric Vehicles (EVs) in Maharashtra, India

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ABSTRACT

The evolution of electric vehicles (EVs) has accelerated and attracted attention in recent years due to significant developments in EV technology. Electric Vehicles (EVs) are an effective technology for creating a sustainable transport sector in the future, due to low carbon emissions, high efficiency, low noise, and flexibility in grid operation and integration. The shift in EV adoption results in an increase in the number of electric vehicles (EVs) in the coming years. However, it is not clear what factors drive this widespread acceptance of electric vehicles, particularly, battery electric (BEV) vehicles in a developing country like India. This study was conducted through structured interviews amongst 150 individuals (two wheeler and four wheeler passenger car owners) to explore the various factors that influence consumer's purchase decision towards electrical vehicles (EVs) in Maharashtra, India. The factors are identified astechnological, environmental, economic, and infrastructural.Multivariate analysis is used to identify the importance of each factor in purchase decision. Furthermore, secondary data has been collected to understand the policy initiatives taken by the central as well as Maharashtra government to promote EVs. The findings of the study indicate that, economic aspect is the most important factor in the adoption of EV, followed by environmental, technological and infrastructural factor.

KEYWORDS: Electric Vehicles (EVs), Battery Electric Vehicles (BEVs), EV Adoption

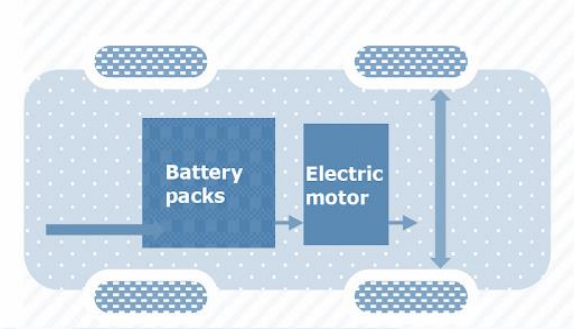
INTRODUCTION

According to the World Health Organization, 9 out of 10 people worldwide breathe polluted air, resulting in an estimated 7 million deaths worldwide each year. It is a matter of great concern that, India is ranked in the top five most polluted countries in the world (Climate Risk Index, 2020). Emissions of toxic gases in cars are one of the major contributors to environmental pollution (World Health Organization, 2019). Large numbers of standard vehicles do not conform to Indian emissions standards, emitting toxic gases into the atmosphere (Dey and Mehta, 2020). There is a common perception that mineral fuel vehicles are gradually being replaced by battery-powered vehicles (BEVs), as they are environmentally friendly, energy efficient, and produce less noise pollution.

What is Battery Electric Vehicle (BEV)?

BEVs are also called as All Electric Vehicles (AEVs). Electric vehicles using BEV technology run fully on a batterypowered electric drivetrain as shown in Figure-1. The electricity used to drive a vehicle is stored in a large battery pack that can be charged by connecting to the power grid. The rechargeable battery pack then supplies power to one or more electric motors to drive the electric vehicles.

Figure 1: Battery Electric Vehicle (BEV)



Source: Niti Aayog

The energy of an electric motor is converted to alternating current by a DC battery. When you step on the accelerator pedal, a signal is sent to the controller. The controller adjusts the vehicle speed by changing the frequency of the AC power supply from the inverter to the motor. The motor then connects and operates through gears to rotate the wheels. When the brakes are applied or the electric vehicle slows down, the motor becomes an alternator, producing electricity and sending it back to the battery.

Central Government Policy Initiatives for Promotion of EVs

The Government of India introduced a policy of 'only electric vehicles' on the road by 2030 to mitigate the environmental issues andoffered perks such as an additional income tax exemption on the interest paid on loans taken for the purchase of BEVs. The government of India planned to set up incubation centers for start-ups dealing in the BEV space. Moreover, under the FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) scheme, eleven Indian cities have been shortlisted for introducing BEVs within their public transport fleet (India Brand Equity Foundation, 2021). Despite positive initiatives by Indian government to promote various utility prospects that BEVs would serve, statistics show that the BEV adoption percentage in India stood at 1% in 2020 (Society of Manufacturers of Electric Vehicles India, 2020).There are multiple reasons for the resistance shown by different stakeholders. For instance, due to the high infrastructure cost, several Indian automakers resist in migrating their manufacturing setups to BEVs. Prospective customers tend to exhibit inhibitions in adoption due to price, range anxiety, or resale (Soni, 2019). Suppliers have shown resistance due to dependency on import of the raw materials for batteries, especially lithium and nickel, which cause undue delays within the supply chain (Paymen Taheri, 2011).

Maharashtra Government Policy Initiatives for Promotion of EVs

The Maharashtra government has announced revised policy (2021) for electric vehicles, which were introduced by the state environment minister Aditya Thackrey. The highlights of the policy are:

- Accelerate adoption of battery electric vehicles in order to contribute 10% of the registration of the new vehicle by 2025.
- Achieve 25% electrification of public transport and last-mile delivery in 6 targeted urban areas by 2025.
- Convert 25% of Maharashtra State Road Transport Corporation's (MSRTC) existing bus fleet to electric.
- Make Maharashtra the country's top producer of BEVs in Indian in terms of annual production capacity.
- Development of 2375 Public& Semi-public charging stations in 7 major urban areas and founder national highways.
- From April 2022, all new government vehicles are going to be electric vehicles.
- At least 25% of the urban fleet operated by the fleet aggregators (Ecommerce companies, delivery/ logistics players) within the state to transition to EVs by 2025.
- Formulation of varied incentive plans for electric vehicles and associated infrastructure.
- Property tax rebates for installing private charging infrastructure within the society premises.

- The policy will encourage fleet aggregators to operate electric vehicles.
- All the EVs sold within the state shall be exempted from the road tax.
- All EVs eligible under the policy shall be exempted from the registration charges.

Key Challenges

The challenges in India's demand for electric vehicles include the high initial purchase cost of vehicles, lack of charging stations and maintenance infrastructure, and consumer perceptions towards battery performance. Limited batterymanufacturing capabilities and a non-existent supply chain will be a hurdle to EV adoption in India.There is no national target, but at least fifteen states across the country have published policies to promote electric vehicles (EVs). Several state governments, including Karnataka, Telangana, Kerala,Maharashtra, Uttar Pradesh, Uttarakhand and Delhi, have already taken initiativesfor further developments of EV. These declared initiatives include funding to setupan outstanding center of excellence for research and development, incubation centers for clean energy start-ups, tax exemptions for electric vehicles, promotion of skill development activities, adoption of electric buses for public transportation, and building charging infrastructure. It further emphasized that these initiatives are atvarious stages of the plan, some of them have already begun, but the situation varies from state to state.

Impact of ElectricVehicles (EVs) on Economic Growth and Employment

1. India's battery manufacturing industry can grow larger than the total amount spent on crude oil imports. This will give a big boost to the Indian economy.
2. There must be a careful plan to tackle the light vehicle and auto parts industry, which employs many people. Many of these companies will not survive as electric vehicles replace gasoline / diesel vehicles. Therefore, it is essential to support them during the transition phase for manufacturing EV components.
3. The European Climate Foundation estimates that by 2030, employment will increase by 500,000 to 850,000 as a result of more efficient reductions in oil demand from electric vehicles.
4. According to one study, net private and social benefits are estimated at US$ 300-400 per electric vehicle.
5. Government lost revenues from oil sector taxes are expected to be replaced by higher tax revenues from other sectors of the economy.
6. EVscreate opportunities for durable and lightweight thermoplastics, higher power requirements, storage and more.

OBJECTIVES OF THE STUDY

The primary objective of this study is to investigate the various factors that influence the purchase decision of consumers towards Electric vehicles (EVs) in Maharashtra, India. The secondary objectives of the study is to gain better insights into the phenomenon of adoption of Electric Vehicles (EVs) and to understand the present challenges and future prospects of Electric Vehicles (EVs) in India.

METHODOLOGY

Research Gap: Past studies emphasis more on financial, technical and social factors for the adoption of EVs. In Indian context, there are other factors too which needs to be considered as drivers for the adoption of EVs.

Research Type: Exploratory research is conducted to explore the factors using the statistical test exploratory factor analysis (EFA).

Data Collection & Sample Size: Data is collected from both secondary sources and primary sources. Secondary sources include journal articles, newspaper articles, government websites, magazines, and other authentic literature available in published form. Primary data is collected through survey of 150 consumers (owners of two-wheeler and four-wheeler passenger cars) spread across Maharashtra through structured interview using closed-ended questions having responses on five point likert scale (1-Strongly Disagree to 5-Strongly Agree). SPSS is used as statistical software to process the primary data.

Limitations: The study emphasizeson limited identified factors influencing EV adoption. Therefore, the scope of this research is limited to specific set of variables that were uncovered by previous studies and geographical location Maharashtra.

SIGNIFICANCE OF THE STUDY

The widespread adoption of electric vehicles (EVs) could help to alleviate issues including pollution, global warming, and oil dependency. Despite the fact that many governments have implemented aggressive promotion strategies; the present market penetration of electric vehicles is still very low. This study gives a comprehensive analysis of factors that influence consumer purchase decision for electric vehicles, with the goal of better informing policymakers and directing future research.

LITERATURE REVIEW

With the rapid development of BEV technology, many studies have attempted to understand the factors affecting the adoption of BEVs by the consumers.

(Fanchao Liao, 2017), found that economic, technical and infrastructure characteristics have a significant impact on the choice of electric vehicles. This is supported by the vast majority of studies that consider such factors. Tax cut strategies also seem to be effective in adopting EVs.

(Zeinab Rezvani, 2015), found that the adoption of BEVs is affected by several factors, including vehicle costs, hands-on experience with technology, emotional response to BEV driving, and environmental issues.

(Makena Coffman, 2017), categorized the driving factors for BEV adoption internally or externally in relation to vehicle characteristics and factors beyond the direct control of the BEV vehicle manufacturer. Battery, purchase price, range and charging time were considered as internal factors. However, fuel prices, policy incentives, consumer characteristics, charging stations, mileage, public visibility, and vehicle diversity were considered external factors.

(Joram H.M. Langbroek, 2016), analyzed the impact of policy incentives on BEV adoption and concluded that they would have a positive impact on adoption. Many pioneering studies have also used the CGE model to assess the environmental impact of EV adoption.

(Meghna Verma, 2020), concludes that both environmental and economic incentives serve as important motivators for EV adoption. The results of this survey will help us understand consumer preferences. This helps policy makers design policies to promote and deploy EVs in India.

(Ritu Chhikara, 2021), concluded that the government's tendency to invest in research and development and provide financial and non-financial benefits was identified as the main driving force. Inadequate infrastructure and general product-related technical issues, high manufacturing costs due to domestic imports of raw materials, and inadequate legal support for customer incentives have proved to be major obstacles. Effective government and industry awareness and promotion campaigns, strengthened industry-academia collaboration, continuous testing and improvisation of vehicle performance can serve as support mechanisms.

(Yang, 2019), states that, according to the results of structural equation modeling (SEM) analysis, (1) With respect to behavioral intention:Consumer control over the resources required, consultation opinions from their surroundings, environmental awareness and acceptance of technology products significantly influence their behavioral intent. (2) With respect to behavioral attitudes: If consumers believe that electric vehicles are more beneficial at the individual, environment or national level, or if they believe that using EV is easier and more convenient, they will show positive attitude towards the purchase of EV. Consumers seeEVs as next-generation technology products with similar driving operation and usage cost compared to traditional vehicles. (3) With respect to regulations: The opinions of consumers' families, friends, colleagues and supervisors do not have a significantimpact on consumer attitude and behavior regarding the purchase of electric vehicles. An important factor influencing the purchase of electric vehicles by consumers is not only applied to the design and development of electric vehicles, but also serves as a theoretical basis for the spread of EVs. Therefore, the government and manufacturers need to introduce more attractive battery and charging systems to spread awareness of electric vehiclesamongst consumers and promote the sustainable future of the automobile industry.

(Jonathan Wellings, 2021)**,** identified several key issues that affect the electric vehicle market.Analysis and investigation of ethical issues reveals wide range of problems in the industry. However, he emphasizedon various groups to reduce the impact of these issues. This analysis reveals that many of the other

factors investigated in this paper are directly or indirectly influenced by political and economic factors. It emphasizes the impact of governing bodies and businesses on the various problems that exist in the market and how to resolve the harmful factors under investigation.

(Som Sekhar Bhattacharyya, 2020), identified eleven key factors influencing EV adoption in this study. Key considerations regarding the availability of charging technology, relevant choice dilemmas, new business models, and support from public policy were presented and discussed. It turns out that the market penetration of electric vehicles is mainly influenced by the choice of charging technology. In addition, consumer switching intent was considered to emphasize the particular technical and psychological preferences of the consumer. Charging station accessibility has emerged as the most influential factor. The findings show a lack of harmony among stakeholders in India's EV ecosystem. Instead, careful efforts have been made by the organization. The EV ecosystem needed collaboration to improve EV adoption. In addition, the need to fix the country's chaotic charging infrastructure is highlighted as a major customer issue in EV adoption.

(Taeseok Yong T. Y., 2017), concluded that, fuzzy-set qualitative comparative analysis(fsQCA)shows that policy support such as tax incentives and subsidy payments will affect the adoption of electric vehicles. Environmental factors such as the economic level and status of EV charging stations were also affected. On the other hand, the quantitative number of fiscal policy toolsand whether the charging is free or not are not strongly influential factors for the adoption of electric vehicles. It is clear that there needs to have powerful policy tools to drive the spread of electric vehicles.

(Haiming Fu, 2018), reveal that, large number of Plug in Electric Vehicles connected to the power grid might intensify power fluctuations. They studied optimizing PEV charging and discharging operations to balance the interests of the power grid and PEV owners. They proposed a novel two-phase optimization method for charging and discharging PEVs. The first phase is the optimization of electricity prices.The status of electricity price is defined on the basis of principle of high load and high price. This phase ensures the maximum benefit of both the power grid and PEV owners. The second phase is the optimization of charging and discharging power. This phase ensures the reduction in fluctuations and power transmission safety of the distribution network. Compared to the non-coordinated and non-PEV power curves, the simulation results show that the optimization strategy proposed in this paper reduces the high and low voltage difference of distribution network.

RESULT AND DISCUSSION

To explore the factors that influence the purchase decision of consumers towards electric vehicles, 16 variables are identified. The responses are collected from the respondents on these variables based on their importance in the purchase decision process. Five point likert scale is used where 1- Not at all Important to 5- Very important. Exploratory factor analysis (EFA) is applied on these variables to reduce the dimensions into few factors.

Following are the variables attributing to purchase decision of EV:

Purchase Cost of EV
Battery Cost
Maintenance Cost of EV
Government Incentives
Road Tax Exceptions
Battery Range
EV Speed
Battery Life of EV
Low Traffic Noise Pollution
Reduction in Greenhouse Gases
Swappable Battery
Resale Value of EV
Insurance Policy Cost
Charging Time of Battery
Charging Stations
Road Conditions

Factor Analysis:

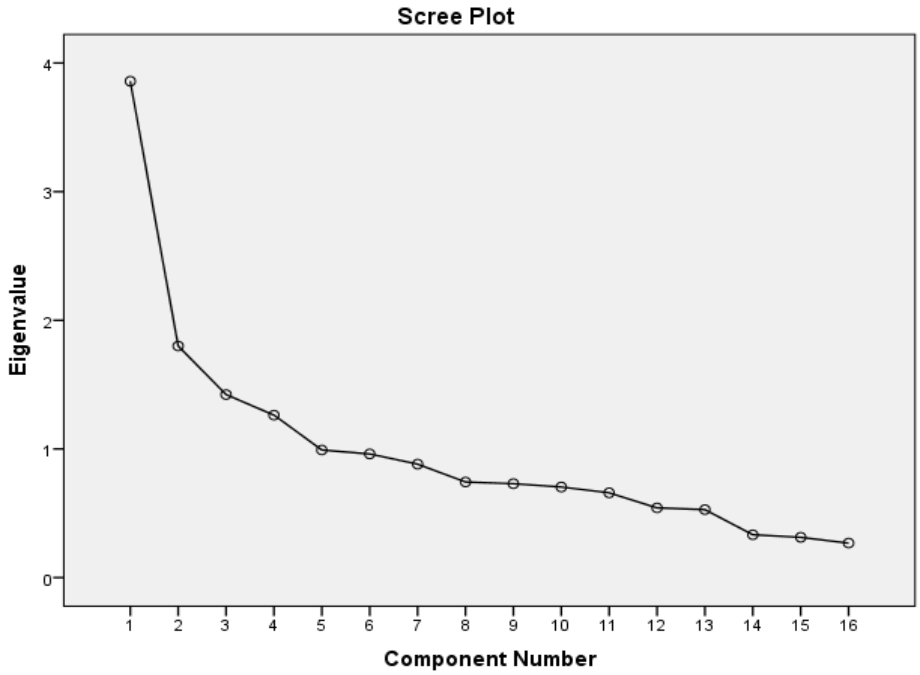
Table-1: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.711
Bartlett's Test of Sphericity	Approx. Chi-Square	550.853
	df	120
	Sig.	.000

Source: Primary data analysis on SPSS

Table -1indicate the measure of sampling adequacy (MSA), which as far as this analysis is concerned falls in the acceptable range (above 0.45) with a value of 0.711. Examination of the values of each variable identifies that all variables have the values above 0.50. Therefore, all 16 variables are statistically significant and collectively meet the necessary threshold of sampling adequacy with an MSA value of 0.711.Each of the variables meets the fundamental requirement for factor analysis.

Figure-2: Scree Plot



Source: Primary data analysis on SPSS

Figure-2 exhibit the scree plot which explains the 16 factors extracted in this study. Starting with the first factor, the plot slops steeply downward initially and then slowly becomes an approximately horizontal line. The point at which the curve first begins to straighten out is considered to indicate the maximum number of factors to extract. As seen in figure-3, we consider four factors and would qualify. The four factors retained represents 52 percent of the variance of the sixteen variables.

Table-2: Total Variance Explained

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.858	24.115	24.115	3.858	24.115	24.115	3.096	19.352	19.352
2	1.800	11.251	35.366	1.800	11.251	35.366	1.870	11.688	31.040
3	1.423	8.892	44.259	1.423	8.892	44.259	1.835	11.467	42.507
4	1.263	7.894	52.153	1.263	7.894	52.153	1.543	9.645	52.153
5	.992	6.198	58.351						
6	.961	6.009	64.359						
7	.882	5.512	69.872						
8	.743	4.644	74.516						
9	.730	4.563	79.079						
10	.704	4.402	83.481						
11	.659	4.118	87.599						
12	.542	3.386	90.985						
13	.528	3.300	94.286						
14	.333	2.080	96.366						
15	.313	1.957	98.323						
16	.268	1.677	100.000						
Extraction Method: Principal Component Analysis.									

Source: Primary data analysis on SPSS

Table-2 contains the information regarding the sixteen possible factors and their relative explanatory power as expressed by their Eigen values. In addition to assessing the importance of each component, we can also use the Eigen values to assist in selecting the number of factors. If we apply the latent root criterion, four components will be retained. The total sum of squared factor (3.858+1.800+1.423+1.263) represents the total amount of variance extracted by factor solution. The percentage of trace explained by each of the four factors (24.11%, 11.25%, 8.89%, and 7.89%)respectively.

The index for this solution shows that 52.15 percent of the total variance is represented by the information contained in the factor matrix of the four factor solution. Therefore, the index for this solution is more than 50 percent and is sufficient to say that variables are somehow related to each other,

Table-3:Component Matrix

Component Matrix[a]					
	Component				Communalities
	1	2	3	4	
Purchase Cost of EV	.725	-.052	-.028	.020	.529
Battery Cost	.719	-.138	-.115	.021	.549
Maintenance Cost of EV	.656	-.484	.029	-.056	.668
Government Incentives	.601	-.164	-.138	.116	.420
Road Tax Exceptions	.637	.069	-.178	-.164	.469
Battery Range	.433	.363	.076	.514	.589
EV Speed	.452	.201	.342	.439	.554
Battery Life of EV	.566	.208	.261	.097	.441
Low Traffic Noise Pollution	.524	.574	-.012	-.339	.719

Reduction in Greenhouse Gases	.388	.553	.089	-.481	.696
Swappable Battery	.390	-.561	.280	.052	.548
Resale Value of EV	.320	-.366	-.467	-.097	.464
Insurance Policy Cost	.423	-.020	-.455	.058	.390
Charging Time of Battery	.138	.107	.482	.163	.290
Charging Stations	-.169	.139	-.355	.581	.512
Road Conditions	.043	-.425	.544	-.164	.506

Sum of Squares (Eigen Values)	3.858	1.800	1.423	1.263	**8.344**
Percentage of Trace	24.115	11.251	8.892	7.894	**52.153**
Extraction Method: Principal Component Analysis.					
a. 4 components extracted.					

Source: Primary data analysis on SPSS

The row sum of squared factor loadings is shown at the far right side of table-3. These figures referred to in the table as communalities; show the amount of variance in a variable that is accounted for by the four factors taken together. According to Hair et al. (1998), the size of the communality is a useful index for assessing how much variance in a particular variable is accounted for by factor solution. Large communalities indicate that a large amount of the variance in a variable has been extracted by the factor solution. Small communalities show that a substantial portion of the variance in a variable is unaccounted for the factors. For instance, the communality of 0.290 for variable 14 indicates that it has less in common with the other variables included in the analysis.

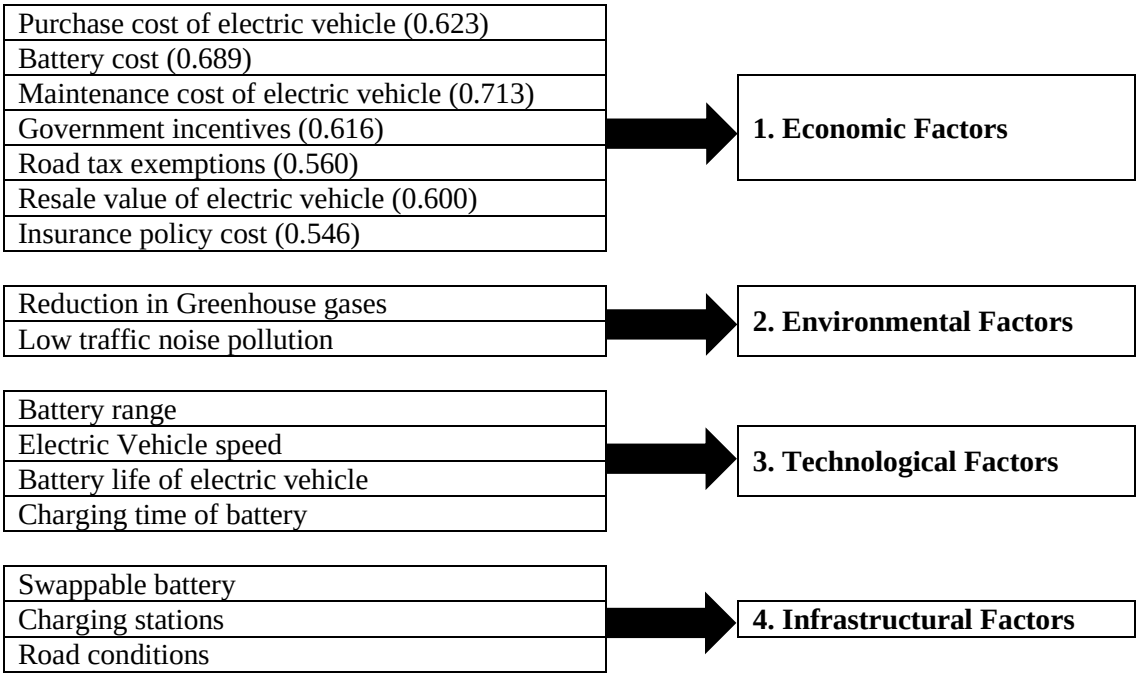
Table-4: Rotated Component Matrix

Rotated Component Matrix[a]					
	Component				Communalities
	1	2	3	4	
Purchase Cost of EV	**.623**	.227	.285	.088	
Battery Cost	**.689**	.163	.207	.071	
Maintenance Cost of EV	**.713**	-.031	.094	.387	
Government Incentives	**.616**	.037	.196	.016	
Road Tax Exemptions	**.560**	.383	.090	-.021	
Battery Range	.193	.074	**.674**	-.303	
EV Speed	.159	.039	**.726**	.010	
Battery Life of EV	.271	.304	**.514**	.104	
Low Traffic Noise Pollution	.190	**.795**	.191	-.117	
Reduction in Greenhouse Gases	.041	**.828**	.092	.008	
Swappable Battery	.426	-.237	.163	**.533**	
Resale Value of EV	**.600**	-.083	-.307	-.058	
Insurance Policy Cost	**.546**	.083	-.041	-.289	
Charging Time of Battery	-.128	.046	**.463**	.239	
Charging Stations	-.024	-.372	.151	**-.592**	
Road Conditions	-.029	-.124	.069	**.696**	
Sum of Squares (Eigen Values)	3.096	1.870	1.835	1.543	**8.344**
Percentage of Trace	19.352	11.688	11.467	9.645	**52.153**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.					
a. Rotation converged in 7 iterations.					

Source: Primary data analysis on SPSS

Based on the factor loading pattern, interpretation would be difficult and theoretically less meaning full. There, the only way is to rotate the factor matrix to redistribute variance from the earlier factors to the later factors. The VARIMAX rotated component matrix is shown in the table-4. Thus the explanatory power has shifted slightly to a more even distribution because of rotation. From table-4, in the rotated factor solution, variables 1,2,3,4, 5, 12 and 13 loads significantly on factor 1; variables 9 and 10 load significantly on factor 2; variables 6,7, 8 and 14 load significantly on factor 3; and variables 11, 15 and 16 load significantly on factor 4.

Figure-3Factors facilitating Purchase Decision factors for EV



From figure-3, factor 1 has seven significant loadings; factor 2 has two significant loadings; factor 3 has four significant loadings; and factor 4 has three significant loadings.

CONCLUSIONS

This study reveals that, economic factor is the most important factor that influences consumer's purchase decision towards EVs, followed by environmental, technological and infrastructural in Maharashtra, India. Vehicle manufacturers should focus their efforts on developing batteries at least with a range similar to Internal Combustion Engine (ICE). Since battery price and rangeplays an important role in purchase decision, it is crucial for EV manufacturers to balance these factors. In order to mitigate the large initial investment in EV, governments should provide financial stimuli in terms of tax incentiveswhich in turn substantially lower the price of EVs. Moreover, grid operators, battery manufacturers and governments should mainly focus on developing the charging infrastructure by increasing the number of charging points along major highways.

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