



MODELING THE FACTORS AFFECTING THE ADOPTION OF ELECTRIC VEHICLES TECHNOLOGY WITH A MACHINE LEARNING APPROACH

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Abstract

Electric and hybrid vehicles prove to be a good solution to reduce the use of fossil fuels and environmental and air pollution. The purpose of the study was to model the factors that affect the adoption of EVs (electric vehicles) technology using a machine learning approach. To this end, the study data were collected using the library method and examining the sources and internet studies. A questionnaire was prepared to measure the effective variables and distributed among 688 people in the virtual space to ensure the validity and reliability of the measurement tool (All collected data is available and will be provided via email upon request). The obtained data were analyzed using the machine learning tool and the hierarchical clustering algorithm, and the potential buyers of electric vehicles in Iran were divided into five clusters based on the hierarchical clustering. Each cluster has its behavioral traits, making it distinct from other clusters. The people in cluster three characterized the group of society, among whom hybrid vehicle technology is more accepted than the others, and this cluster must be targeted, and policies must be adopted to expand this cluster to expand the adoption of hybrid vehicle technology in Iran. Technology being updated is critical for the people of this cluster - the vehicle design and the reliable brand are effective factors in their choice while buying a vehicle. The variety of hybrid vehicle branded in Iran is considered an effective factor in the wider acceptance of this technology in Iran. The limited selection of these vehicles and the poor after-sale service of their batteries are obstacles to the development of these vehicles in Iran.

Keywords: Electric vehicles, machine learning, consumer-buyer behavior, clustering

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Introduction

The high consumption of fuel by motor vehicles like vehicles, motorcycles, and so on in the world, alongside the reduction of fossil fuel resources and the high pollution of the environment by these consumers, has caused increasing attention to the use of equipment that uses other energy sources (Khazaei, 2019). Among the many approaches towards fuel economy, the adoption of electric vehicles (EV) may have the greatest impact. However, existing studies on EV adoption predict very different market evolutions, which causes a lack of solid ground for strategic decision making. New methodological tools, based on Artificial Intelligence, might offer a different perspective (Bas, 2021). Experts argue that until the possibility of using fuel cell technology at a commercial level is provided, electric vehicles can be an intermediate solution to the problem of air pollution and optimal fuel consumption. Likewise, the pollution problem in big cities in our country, especially Tehran, restrictions on fuel production, and the liberalization of fuel prices have encouraged some automotive industries to conduct studies on the design and construction of hybrid vehicles (Anjanapriya, et al., 2021). Moreover, the responsible institutions have encouraged academic centers to conduct research and technology to conduct more studies and accelerate this (Fatima, et al., 2022).

In a paper entitled comparing the sales of hybrid vehicles in Iran compared to the global share, Amini et al. (2015) state that the industrialization of society, the excessive use of fossil fuels, and the increase in the number of existing vehicles have turned air pollution into having become a daily problem for big cities. The increase in concern of the communities has made governments resolve these problems by passing laws and amending policies. In their paper, they try to provide logical and possible solutions to this problem through theoretical foundations by examining the green marketing literature and factors affecting green purchasing. In a paper entitled "Who are the buyers of electric vehicles?" Rubens (2019) stated that the current markets of electric vehicles are usually in the emerging stage, and their buyers are among the early adopters or pioneers; as these buyers have had a significant contribution to the devehiclesbonization of public vehicles, they must be part of the development group and be known as the main consumers of the market.

In a paper entitled "Market review after the adoption of hybrid vehicles," De Luca - Di Pace (2018) examined the potential market and environmental benefits of hybrid vehicles. In a paper, Rubens et al. (2019) examined the identification of the main market of electric vehicles using machine learning. The findings indicated that most of the current electric vehicles markets are in the emerging stage and are classified as early adopters or pioneers of electric vehicle buyers. However, as they have significantly contributed to the devehiclesbonization of public vehicles, they must reach the main consumer segments.

In a paper entitled "Who are the buyers of electric vehicles in California?" In describing their heterogeneous early adopters and predicting the release of the electric vehicle market, Lee et al. (2019) examined and analyzed the early adopters of electric vehicles, findings indicated that households with high incomes would not necessarily remain the largest group of electric vehicle users; thus, for the market to grow, people need with average income must buy these vehicles, and the policymakers in this field must consider the different needs of the consumers of these vehicles and provide suitable infrastructure and incentives to buy these vehicles.

In a paper entitled "Classification of potential electric vehicle purchasers: A machine learning approach" Bas et al. (2021) examined the identification of key elements in EV adoption, proposing supervised Machine Learning (ML) techniques for compare different ML methods for the classification of potential EV purchasers. Finally, their finding reveals two well-differentiated groups, unveiling the importance that the profiling of a potential purchasers may have for marketing campaigns as well as for public agencies that seek to promote EV adoption.

In a paper entitled "Electric vehicles' consumer behavior: Mapping the field and providing a research agenda" Silvana Secinaro et al. (2022) analyzed 254 studies related to consumer behavior in the electric car market by conducting a bibliometric and thematic, the finding reveals the primary co-citation network between international journals and authors, a map of the leading research centres on the topic, and the dimensions covered by scholars. Additionally, the analysis extends the theory of planned behavior, offering a valuable consumer identikit for practitioners. Based on the results, the study provides multiple research questions helpful to feed the academic debate.

In a paper entitled "Usage of hybrid vehicles, advantages and challenges ahead,"

Samadyar (2007) analyzed the advantages and problems of using this technology. The findings indicate that hybrid vehicles are economical and can be considered a good alternative to normal vehicles because of less fuel consumption, longer lifespan of engines and equipment, and less air pollutants than the vehicles currently used. In a study entitled "The new technologies in new vehicles to adapt to environmental conditions," Marzbanrad et al. (2014) examined the role of vehicles in environmental pollution and energy consumption. The findings indicated that improving the level of social requirements to reduce noise and environmental pollution and the general tendency towards using safe vehicles with low fuel consumption has encouraged vehicle manufacturers to study and develop new technologies to meet these needs. They have less air pollution and noise pollution and the ability to recycle; these technologies include environmentally friendly fuels and materials (Oran, et al., 2021). In a paper titled "factors influencing the adoption of hybrid vehicles," Vothouq and Dawoudi (2014) studied replacing conventional vehicles with hybrid vehicles to reduce energy consumption in transportation. The findings indicate that the value of a warranty given to people in exchange for hybrid vehicle is one of the most important factors in buying hybrid vehicle. Thus, it is possible to make targeted policies and reduce fuel consumption.

As already stated, past studies in Iran on electric vehicles have less discussed technology acceptance, and it is rare to find a study using machine learning. Few foreign studies have dealt with the clustering of electric vehicle

customers and its impact on technology acceptance, and they have been limited to a machine learning technique, namely K-Means. Rubens clusters the buyers of electric vehicles with the machine learning approach and through the method, K-Means clustering, and Lee et al. examined the buyers of electric vehicles through K-Means clustering in another paper. Thus, some studies were conducted to fill this gap in the research background and advance knowledge in the acceptance of technology and the use of electric vehicles. According to the literature review and studies, this research aims to estimate the behavior of electric vehicles buyers and potential customers in the society using other clustering methods with a machine learning approach.

Considering the behavior of electric vehicles consumers and the use of past studies, the factors affecting the adoption of electric vehicles in Iran were divided into five categories, including 1-demographics, 2-background of vehicles use, 3-preferences of electric vehicles buyers, 4-incentives effective in selecting an electric vehicles and 5-obstacles to the spread of electric vehicles. The expert panel method is used to measure the validity of these variables. These experts are technology management experts who have experience in examining the behavior of electric vehicle consumers. The number of these experts is about 6 people, and we try to use their opinions and hold a model panel. and finalize its indicators. By examining and measuring the variables and giving weight to each factor, the factors affecting the development of these vehicles in Iran are identified. Figure (1) shows the conceptual model of factors affecting the adoption of electric vehicles.

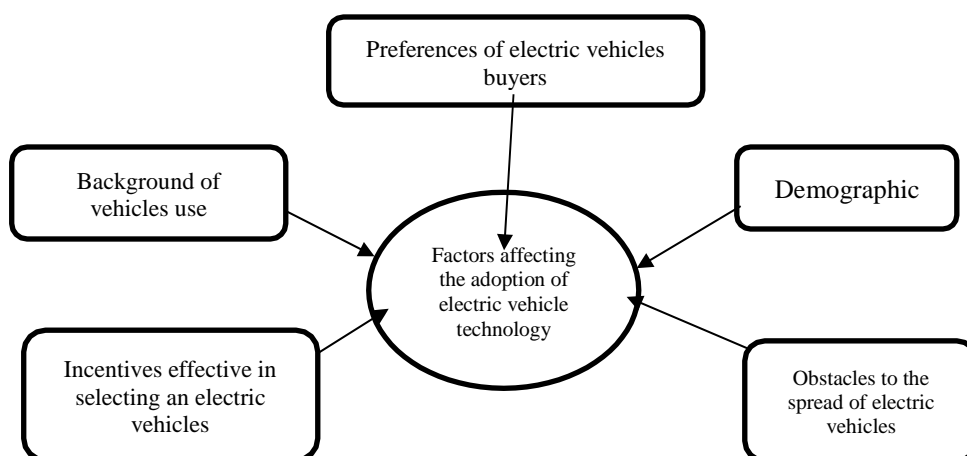


Figure 1. Conceptual model of factors affecting the adoption of electric vehicles

Methods

The study was practical in terms of its purpose and mixed (quantitative and qualitative) in terms of the type of information used. The study of sources was used in the qualitative section and the machine learning method in the quantitative part. The population was all potential vehicle consumers in districts 2, 1, and 3 of Tehran, where District One has a population of 487,508 people, District two, 701,303 people, and District Three 330,649, a total of 1,525,460 people. The random cluster sampling method was used due to the high population size. The questionnaire was distributed widely using email, websites, social networks, etc. According to Cochran's formula,

the sample size was determined to be 688 people.

Given the five key factors affecting the acceptance of hybrid vehicle technology, the questionnaire had 26 questions. Five hundred sixty random samples answered this survey, and 240 non-random samples –688 samples were thoroughly answered in districts 1, 2, and 3. The opinions of the respected instructor were used in examining the face validity of the questionnaire. Thirty questionnaires were distributed using Cronbach's alpha to examine the reliability. The results of Cronbach's alpha showed that the values of these indices for all variables were greater than 0.7, and thus the reliability of the measurement tool was also confirmed. The validity of the questionnaire was 1.18 and thus confirmed.

Table (1), Validity index of the measurement variables is given below.

Variables	CVR	Minimum validity values
Demographics	1	0.99
Background of vehicles use	1	0.99
Preferences of electric vehicles buyers	1	0.99
Incentives effective in selecting an electric vehicles	1	0.99
Obstacles to the spread of electric vehicles	1	0.99

Table 1. Validity index of the measurement variables

Python programming software was used to analyze the data, which was used to cluster potential buyers of electric vehicles using machine learning algorithms.

Results

Hierarchical clustering algorithm

The dendrogram from the questionnaire data was obtained in Python software, as shown in Figure (2).

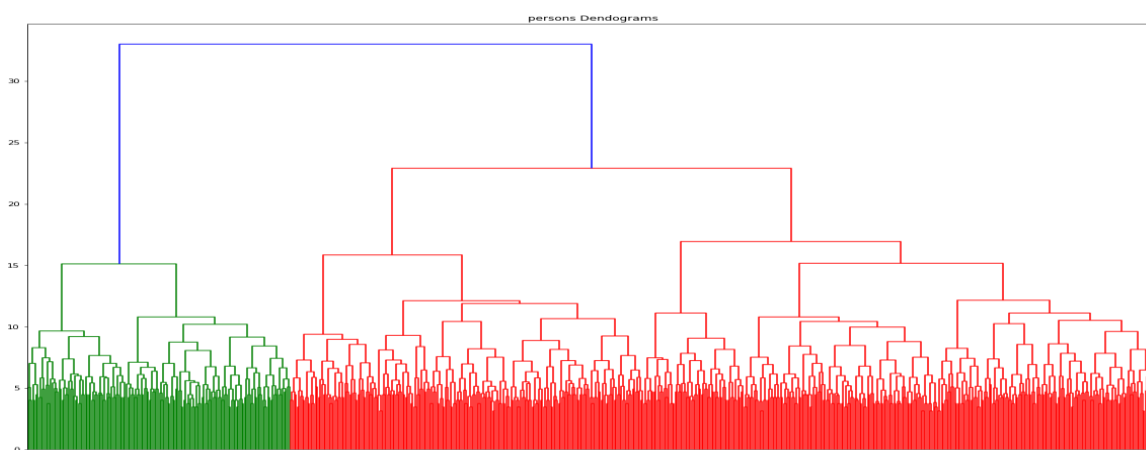


Figure 2. Dendrogram diagram of research data

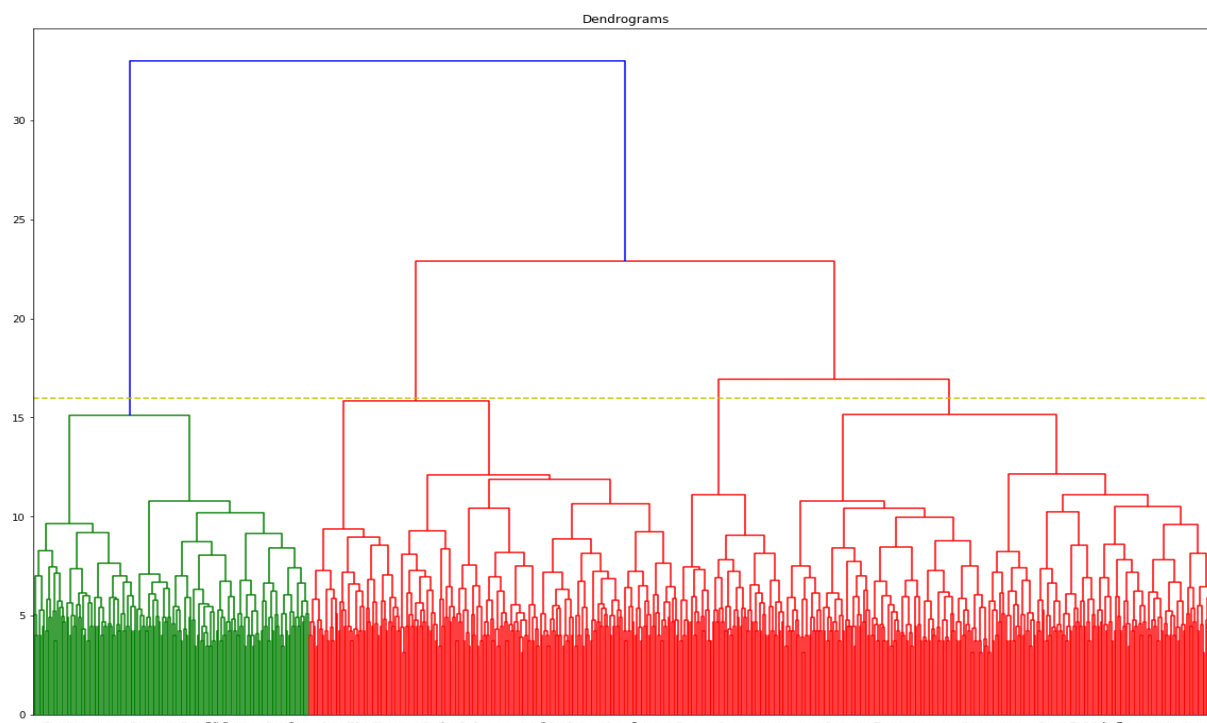


Figure 3. Plotted line D of the research dendrogram diagram

Each respondent to the questionnaire had a unique ID in this study. After clustering, each respondent was placed in only one of these five clusters. With the Excel output obtained from the Python software, each characteristic was placed in a cluster, and the clusters were named from 0 to 4.

Introducing the clusters obtained

Hierarchical clustering was vehicles ried out, and five clusters were obtained, respectively,

cluster 0, Cluster One, Cluster Two, Cluster Three and Cluster Four. The answers given to each option of the questions were specified in percentage in each cluster, and the option that a higher percentage of people answered was colored, as shown in Table (2). Table (3) is in percentage terms and shows the total number of people in each cluster as 100%, supplementary Table (3) is given below, and the number of subjects in each cluster is given in terms of people for better analysis.

Table 2. Clustering

Subjects	Cluster Zero	Cluster One	Cluster Two	Cluster Three	Cluster Four
Males	195	89	128	56	4
Females	57	71	34	5	49
Total	252	160	162	61	53

Table 3. Continued clustering of questionnaire questions

Questionnaire questions	Options	Cluster Zero	Cluster One	Cluster Two	Cluster Three	Cluster Four
Gender	Males	77.38	55.63	79.01	91.80	7.55
	Females	22.62	44.38	20.99	8.20	92.45
Marital status	Married	80.95	29.38	8.64	77.05	16.98
	Single	19.05	70.63	91.36	22.95	83.02

Job	University student	4.37	33.75	50.62	6.56	11.32
	Public sector employee	27.38	7.50	8.64	9.84	9.43
	Private sector employee	36.90	21.25	14.81	27.87	50.94
	Self-employed	25.40	16.88	11.11	54.10	16.98
	Unemployed	5.95	20.63	14.81	1.64	11.32
Age	18-30	9.92	66.88	79.01	29.51	41.51
	30-40	53.17	22.50	17.28	26.23	37.74
	40-50	26.59	3.75	3.09	32.79	9.43
	50-65	10.32	6.88	0.62	11.48	11.32
Education	Sub-diploma	1.59	3.13	0.62	1.64	0.00
	High school diploma	13.10	23.13	16.05	6.56	9.43
	Associate Degree	6.35	13.75	8.64	8.20	1.89
	Bachelor's degree	37.70	33.75	45.06	34.43	30.19
	Master's degree	34.52	23.13	20.99	34.43	50.94
	Ph.D. and above	6.75	3.13	8.64	14.75	7.55
Certificate	Have	98.41	80.00	95.06	98.36	100.00
	Do not have	1.59	20.00	4.94	1.64	0.00
Private vehicles	Have	98.41	3.13	93.83	100.00	98.11
	Do not have	1.59	96.88	6.17	0.00	1.89
The number of private vehicles	0	14.29	35.63	2.47	3.28	11.32
	1	61.90	48.13	38.27	18.03	35.85
	2	20.24	11.88	38.27	55.74	30.19
	3	1.98	1.88	16.05	16.39	15.09
	4 and more	1.59	2.50	4.94	6.56	7.55
Hybrid vehicles	Have	3.97	1.88	1.85	24.59	5.66
	Do not have	93.65	25.00	91.98	75.41	92.45
	Less than 3,000,000 Tomans	21.83	61.88	58.64	4.92	26.42
	From 3,000,000	35.32	30.63	23.46	9.84	43.40

Income	to 5,000,000 tomans					
	From 5,000,000 to 8,000,000 tomans	25.00	6.25	10.49	19.67	20.75
	From 8,000,000 to 15,000,000 Tomans	10.71	0.63	6.17	34.43	5.66
	Above 15,000,000 Tomans	7.14	0.63	1.23	31.15	3.77
Property condition	Personal	67.46	58.75	76.54	83.61	79.25
	Rental	32.54	41.25	23.46	16.39	20.75
The use of public transport	At least once a day	18.25	34.38	14.20	9.84	15.09
	Less than once a day but at least 3 times a week	10.71	15.63	8.64	4.92	7.55
	Once or twice a week	8.33	14.38	17.28	6.56	13.21
	Less than once a week but more than twice a month	5.95	8.13	8.02	0.00	7.55
	Once or twice a month	14.29	8.13	15.43	16.39	13.21
	Less than once a month but more than twice a year	15.08	5.00	12.96	9.84	20.75
	Once or twice a year	13.10	8.13	13.58	8.20	16.98
	Less than once a year or never	14.29	6.25	9.88	44.26	5.66
The private vehicles use (outside the city)	At least once a day	11.90	11.88	11.11	16.39	18.87
	Less than once a day but at least 3 times a week	6.75	7.50	9.88	8.20	7.55
	Once or twice a week	9.52	11.88	12.96	14.75	3.77
	Less than once a week but more than 2 times a month	7.14	6.88	10.49	9.84	11.32
	Once or twice a	18.25	15.00	17.28	14.75	5.66

	month					
	Less than once a month but more than twice a year	18.65	15.63	12.35	13.11	16.98
	Once or twice a year	21.83	24.38	15.43	18.03	24.53
	Less than once a year or never	5.95	6.88	10.49	4.92	11.32
The highest priority in buying a vehicles	It is a reliable commercial brand produced in the industrialized countries of the world	16.67	16.25	24.69	49.18	30.19
	Model and style of vehicles design	7.94	12.50	8.64	22.95	18.87
	Technical specifications of the vehicles	30.95	32.50	29.63	21.31	32.08
	The total value of the vehicles	44.44	38.75	37.04	6.56	18.87
The most effective factor in deciding while buying a vehicles	Environmental compatibility / low CO ₂ emissions	10.71	13.75	12.35	9.84	20.75
	Update vehicles technology	35.71	39.38	34.57	60.66	22.64
	The technical specifications of the vehicles should be suitable, like the high power of its engine	38.89	35.63	42.59	24.59	45.28
	The vehicles should not be a used vehicles	13.49	10.00	9.88	4.92	9.43
If not (same price factor) = cancellation of purchase	Its low fuel consumption	21.43	26.25	22.84	24.59	33.96
	Large and comfortable interior	9.13	3.75	13.58	11.48	11.32
	High safety	51.59	57.50	41.98	31.15	47.17
	Authentic brand	17.86	12.50	21.60	32.79	7.55
	Installment of vehicles purchase value	26.98	36.25	24.69	16.39	5.66

The most important financial aspect while buying a vehicles	The cost of repairs and maintenance	70.63	60.63	67.28	80.33	90.57
	Vehicles tax	0.79	0.00	3.09	1.64	0.00
	The annual vehicles insurance value	1.59	3.13	2.47	0.00	3.77
	The amount of annual taxes to the municipality	0.00	0.00	2.47	1.64	0.00
Which factor causes the cancellation of buying a vehicles?	Low safety	34.52	40.00	30.25	37.70	16.98
	High fuel consumption	16.67	18.13	22.84	14.75	11.32
	Low technology level	13.10	10.63	17.90	18.03	9.43
	Unable to find vehicles parts due to sanctions	35.71	30.00	29.01	29.51	62.26
Values considered while buying a vehicles	Choosing a vehicles that suits your social needs	11.11	11.25	14.81	21.31	13.21
	The vehicles must be domestically produced	3.17	3.13	3.70	1.64	0.00
	Its resale value is high	17.86	8.75	19.14	19.67	20.75
	Auto parts should not be svehiclesce in Iran (due to the country's sanctions).	43.25	46.25	31.48	31.15	52.83
	The vehicles should be environmentalall y friendly/low CO ₂ emissions like a hybrid vehicles	24.60	30.63	30.86	26.23	13.21
Have you ever had a hybrid	I currently own a hybrid vehicles	3.57	0.00	1.85	26.23	0.00
	I have decided to buy a hybrid vehicles	7.14	2.50	9.26	21.31	9.43
	I want to buy it,	74.60	70.63	58.02	14.75	66.04

vehicle?	but I cannot afford it					
	I have not thought about buying a hybrid vehicles	14.29	14.38	29.63	37.70	24.53
	I do not drive, and I do not need a vehicles	0.40	12.50	1.23	0.00	0.00
The most priority while buying a hybrid vehicles	Low emission of CO ₂ and its compatibility with the environment	25.40	30.63	21.60	21.31	24.53
	Unhindered traffic in traffic plan areas	8.33	9.38	6.17	13.11	35.85
	Reducing fuel costs and saving fossil fuel resources	55.16	50.00	51.85	44.26	37.74
	The high acceleration of these vehicles is due to the lighter weight of their gasoline engines	11.11	10.00	20.37	21.31	1.89
The biggest obstacle while buying a hybrid vehicles	Lack of knowledge about the technology of these vehicles	6.75	10.00	6.17	9.84	13.21
	Limited selection	4.37	3.13	8.64	27.87	3.77
	Their high price	58.33	61.25	54.94	9.84	45.28
	The resale value of these vehicles is low due to the limitations of their buyers	6.75	4.38	6.17	3.28	22.64
	after-sale service is weak in the field of hybrid vehicles batteries	23.41	21.25	24.07	47.54	15.09
	The purchase price of a hybrid vehicles should be considered	40.08	41.25	48.77	18.03	35.85

Infrastructure strengthening factor	reasonable.					
	Financial facilities such as loans and installments should be considered for their purchase.	17.06	18.75	16.05	19.67	3.77
	Increase the variety of imported brands and hybrid vehicle models.	10.71	10.00	17.90	52.46	18.87
	The hybrid vehicles industry and production should be formed in Iran, which will also bring down the price.	31.75	30.00	17.28	9.84	41.51
The factor stopping the development of hybrid vehicles technology	High initial price of the vehicles	42.86	38.13	45.06	40.98	33.96
	Inability to produce on a large scale	11.90	14.38	15.43	18.03	11.32
	Lack of technological infrastructure	31.35	27.50	24.69	14.75	47.17
	Low fuel prices in the country	6.35	4.38	3.70	6.56	1.89
	Cultivation of its use has not been vehiclesried out in Iran	7.54	15.63	11.11	19.67	5.66
The most important factor in not accepting hybrid vehicles technology in Iran	Their fuel savings are not significant, and CO ₂ emissions have not been eliminated	5.56	8.13	3.09	4.92	9.43
	Their purchase price is high compared to gasoline vehicles, while their difference is not noticeable	62.30	52.50	53.70	40.98	28.30

	They are not completely electric and still depend on gasoline	4.37	6.25	5.56	13.11	16.98
	Political factors like sanctions and so on	20.63	27.50	32.72	29.51	33.96
	Low fuel prices compared to other countries	7.14	5.63	4.94	11.48	7.55

Cluster zero (0): This cluster is the most populous cluster and, demographically, mostly consists of men, married people, and 30 to 40 years with a bachelor's degree. Their highest priority while buying a vehicle is the price factor; the fact that the vehicle have not worked is effective in their decision-making. Most people in this cluster want to buy hybrid vehicle, but they do not have the financial ability. The most priority of Cluster Zero people when buying hybrid vehicle is reducing fuel costs and saving fossil fuel resources. Compared with other clusters, the people of this cluster consider the low fuel price as an obstacle in accepting the technology of these vehicles in Iran. The reason is that the purchase price of hybrid vehicles is high compared to gasoline vehicles, while their difference is not significant, has been considered a factor that has caused the non-acceptance of hybrid vehicle technology in Iran.

Cluster one (1): This cluster mostly consists of men, singles, ages 18-30 years with a bachelor's degree. Vehicle safety is the criterion when buying vehicles (regardless of the price). Compared to other clusters, the people of this cluster give significance to the vehicles payment in installments from the financial aspect, and the technical specifications of the vehicles are also essential to them. Compared to other clusters, the people of this cluster value low CO₂ emission and environmental friendliness of the vehicles. The biggest hurdle to them while buying a hybrid vehicle is the price.

Cluster two (2): This cluster is mostly composed of men, singles, age group 18-30 years old with a master's degree. Compared to other clusters, we reached the following results: While buying a vehicle (regardless of the price), they consider the large and comfortable space inside the vehicle as a criterion. For Cluster

Two people, the most important thing from the financial point of view while buying a vehicle is the vehicle tax and the annual taxes to the municipality. The factor of high fuel consumption causes people in this cluster to refuse to buy a vehicle, and it is considered a value that the vehicle are domestically produced while buying a vehicle. Compared to other clusters, the most valuable factor for people in this cluster is that the vehicle are environmentally friendly with low CO₂ emissions, such as hybrid vehicle. If the price of a hybrid vehicle is suitable to a considerable extent, they consider it the factor of strengthening the infrastructure of the adoption of the technology of these vehicles in Iran, and they consider the high initial price of these vehicles as the deterring element in the development of hybrid vehicle technology in Iran.

Cluster Three (3): This cluster mostly consists of men, married, self-employed, 40-50 years old, with a graduate degree and income above 15,000,000 Romans per month. The highest priority while buying vehicles for Cluster Three people is a reputable brand manufactured in the industrialized countries of the world - if the vehicle brand is unreliable, it is a factor that discourages them from buying a vehicle. The model and design style of the vehicles is important for these people. The updated vehicle technology is the most effective factor in deciding while buying vehicles. They argue that the vehicles must be chosen according to people's social affairs. More people from this cluster have hybrid vehicle compared to other clusters. Their highest priority while buying hybrid vehicle compared to other clusters is the high acceleration of these vehicles because of the lighter weight of their gasoline engine. The biggest hurdle to them while buying hybrid vehicle is the poor after-sales service of hybrid vehicle batteries and the limited selection of these vehicles in Iran. The factor in strengthening the adoption of hybrid vehicle technology infrastructure is the diversity in

imported brands and models of hybrid vehicles and considering financial facilities such as loans and installments for their purchase. The factor that deters the development of hybrid vehicle technology in Iran is the inability to produce it on a large scale and the fact that it has not been cultured in Iran. Compared to other clusters, the most important factor in non-acceptance of hybrid vehicle technology in Iran is the low fuel price compared to other countries.

Cluster four (4): This cluster comprises women, singles, and private sector employees aged 25-35 years with a master's degree. The most effective factor in deciding buying vehicles is the appropriate technical traits of the vehicle, such as the high power of its engine. The most important thing financially while buying vehicles for people in this cluster is the cost of repairs and maintenance and the annual vehicle insurance. The factor making the people in this cluster cancel buying a vehicle is not finding vehicle parts because of the sanctions, which is considered a value for them. Other values for the people of this cluster are the high resale value of vehicles and the unimpeded traffic of hybrid vehicles in the traffic plan areas. The biggest hurdle while buying hybrid vehicle is the lack of knowledge about the technology of these vehicles and the fact that the resale value of these vehicles is low because of the limitations of their buyers. If the industry and production of hybrid vehicles are established in Iran, which results in price reduction, the

infrastructure for developing the technology of these vehicles in Iran will be strengthened. The lack of technological infrastructure in Iran is an obstacle to developing hybrid vehicle technology. They consider the critical factors in the non-acceptance of hybrid vehicle technology in Iran as political factors such as sanctions and so on.

Cluster Zero is named the price cluster because of the significance of the price index for the cluster members. Cluster One is named the safety cluster because of the importance of the vehicle safety index for the cluster members. Cluster Two has been named the environment-loving cluster, given the significance of environmental compatibility and low CO₂ emissions for cluster members. Cluster Three has been named a technology cluster given the significance of updated technology for cluster members. Cluster Four is named the maintenance cluster, given the significance of the indicator of the cost of repairs and maintenance.

Comparison of the clusters

1. The variables that affect the preferences of hybrid vehicles buyers

The variables that affect the preferences of hybrid vehicles buyers have been examined and compared according to the percentage of answers given in each cluster. Figures in Table (4) are in percentage.

Clusters	Price	Safety	Low CO ₂ emission	Update technology	Fuel consumption	Parts are not rare (Sanctions)	Technical specifications	Large and comfortable interior	Design	Reliable brand	Not used vehicles
0	44.44	51.59	24.60	35.71	55.16	35.71	38.89	9.13	7.94	17.86	13.49
1	38.75	57.50	30.63	39.37	50.00	30.00	35.63	3.75	12.50	12.50	10.00
2	37.04	41.98	30.86	34.56	51.85	29.01	42.59	13.58	8.64	21.60	9.88
3	6.56	31.15	26.23	60.65	44.26	29.51	24.59	11.48	22.95	32.79	4.92
4	18.87	47.17	13.21	22.64	37.74	62.26	45.28	11.32	18.87	7.55	9.43

Table 4. The variables that affect the preferences of hybrid vehicles buyers

Chart 1 shows the comparison of the examined variables in the clusters.

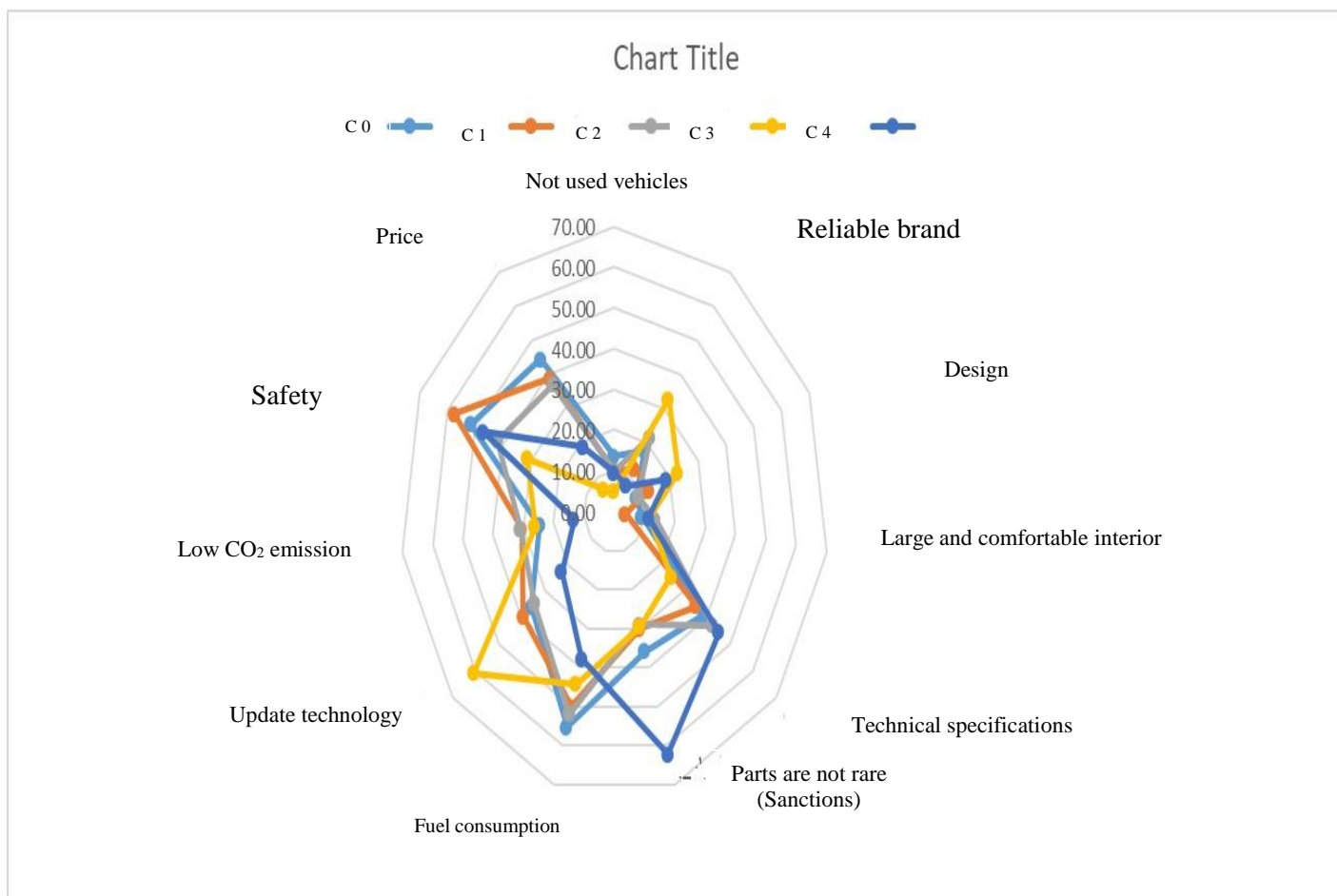


Chart 1. Comparison of variables affecting the preferences of hybrid vehicles buyers in clusters
Figures in Table (4) are in percentage.

2. Obstacles to buying a hybrid vehicles

The variables that affect the non-development of hybrid vehicles technology have been examined and compared according to the percentage of answers given in each cluster.

Clusters	Lack of sufficient knowledge	Limited choices	High prices	Low resale value	The poor after-sale battery service	Lack of high-scale production	Lack of proper infrastructure	Low fuel prices in Iran	Lack of culture	Little difference between a gasoline vehicles	Not fully electric	Political factors
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0	6.75	4.37	58.33	6.75	23.41	11.90	31.35	7.14	7.54	62.30	4.37	20.63
1	10.00	3.13	61.25	4.38	21.25	14.38	27.50	5.63	15.63	52.50	6.25	27.50
2	6.17	8.64	54.94	6.17	24.07	15.43	24.69	4.94	11.11	53.70	5.56	32.72
3	9.84	27.87	9.84	3.28	47.54	18.03	14.75	11.48	19.67	40.98	13.11	29.51
4	13.21	3.77	45.28	22.64	15.09	11.32	47.17	7.55	5.66	28.30	16.98	33.96

Table 5. The variables that affect the non-development of hybrid vehicles technology

Chart 2 shows the comparison of the examined variables in the clusters.

technology in each cluster

3. Encouraging variables to adopt hybrid vehicles technology

Variables that encourage the adoption of hybrid vehicles technology have been examined and compared according to the percentage of answers given in each cluster. The figures in Table (5) are

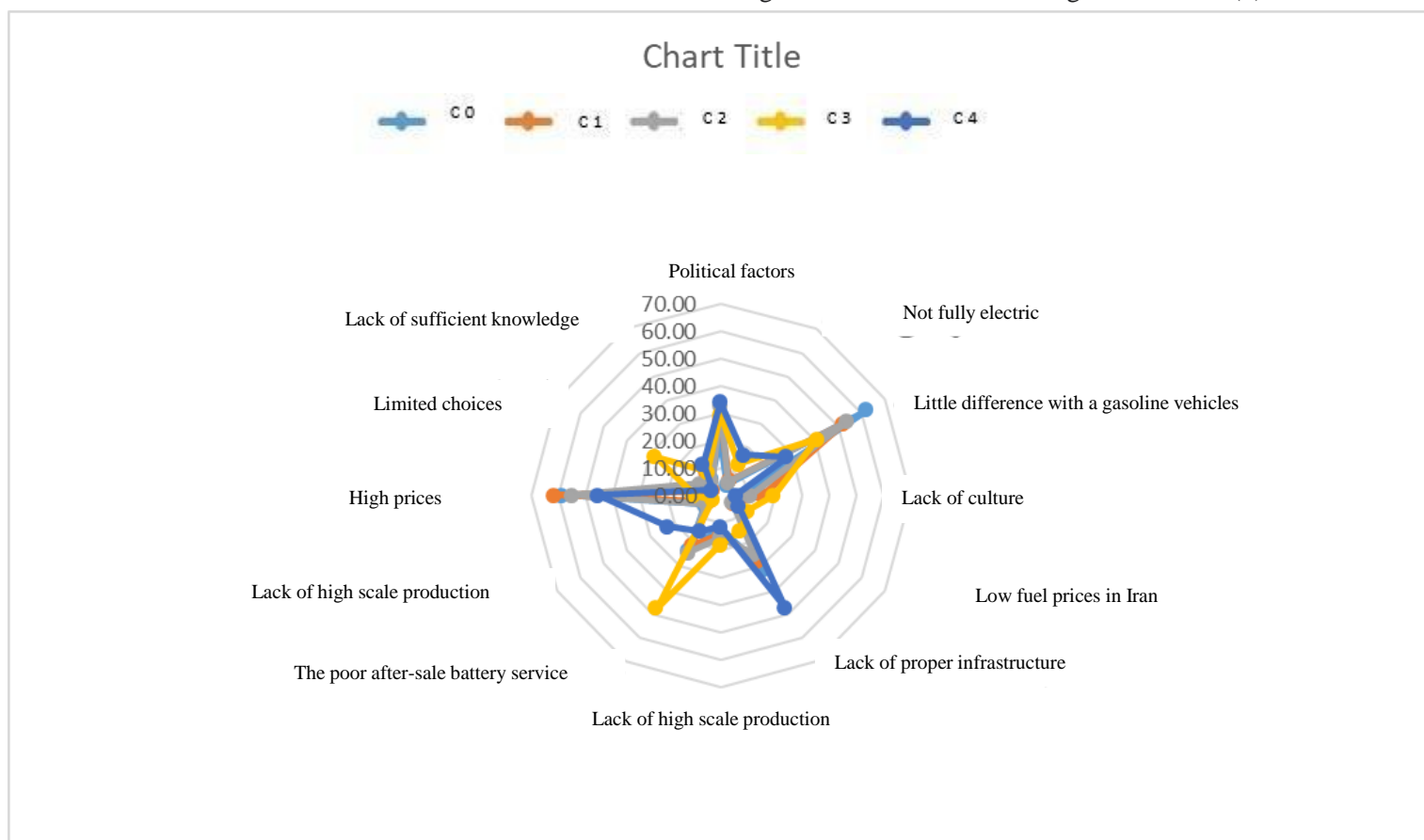


Chart 2. Comparison of variables affecting the non-development of hybrid vehicles

in percentage terms.

Clusters	Reasonable price	Financial facilities (loan)	Diversity in the brand	Domestic production	Reasonable cost of maintenance and	High acceleration	Unhindered traffic in the high-	Reduction of fuel costs	Social position
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		ns, etc.)			repair s		speed traffic plan		
0	40.08	17.06	10.71	31.75	70.63	11.11	8.33	55.16	11.11
1	41.25	18.75	10.00	30.00	60.63	10.00	9.38	50.00	11.25
2	48.77	16.05	17.90	17.28	67.28	20.37	6.17	51.85	14.81
3	18.03	19.67	52.46	9.84	80.32	21.31	13.11	44.26	21.31
4	35.85	3.77	18.87	41.51	90.56	1.89	35.85	37.74	13.21

Table 6. The variables that encourage the adoption of hybrid vehicle technology

Chart 3 shows the comparison of the examined variables in the clusters too.

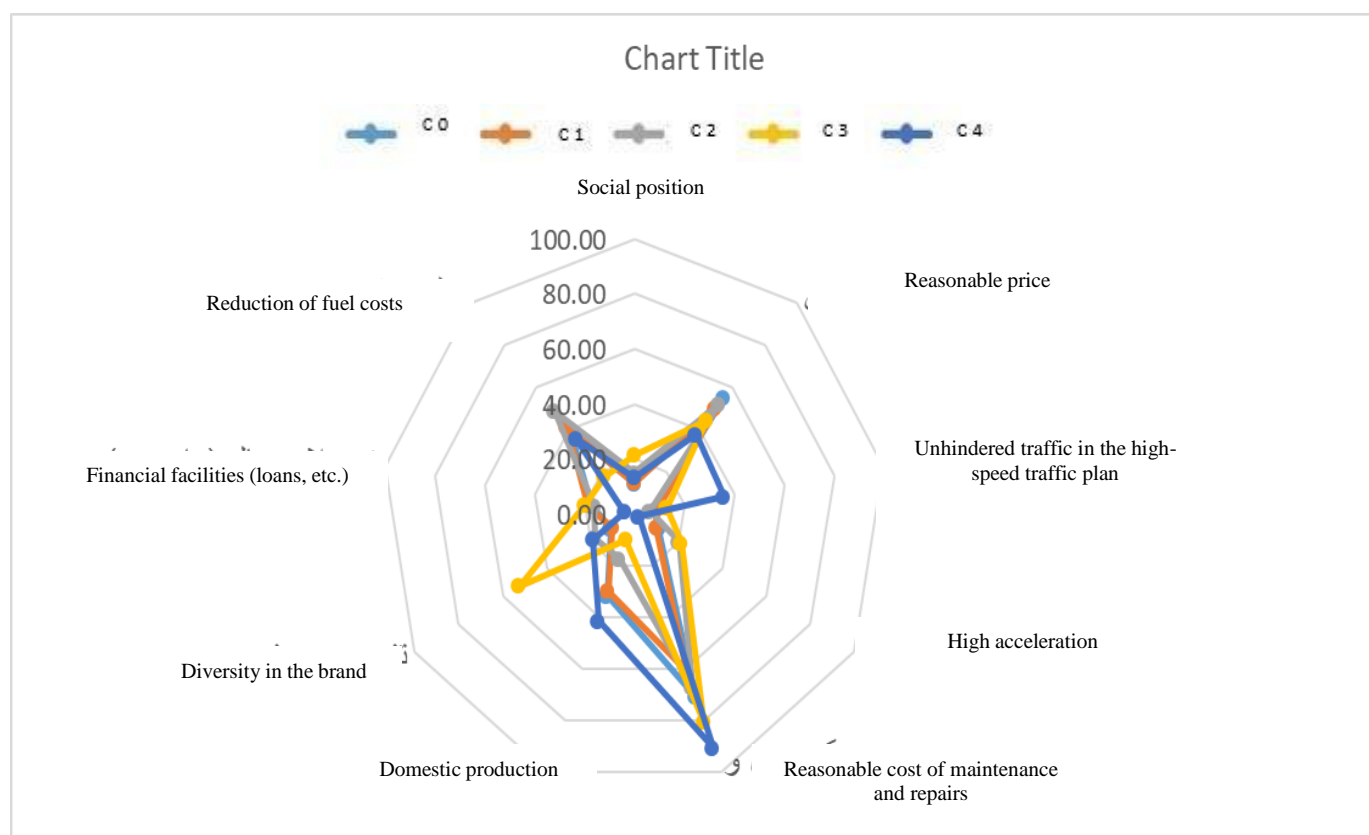


Chart 3. Comparison of the variables that encourage the adoption of hybrid vehicles technology in each cluster

Conclusion

The study was vehiclesried out to model the factors that affect the adoption of electric vehicles technology with a machine learning approach. The findings indicated that the buyers are divided into 5 clusters according to the hierarchical clustering of potential buyers of

electric vehicles in Iran. Each cluster has the behavioral traits that distinguish it from other clusters.

The findings indicated that the behavior of clusters 0, 1 and 2 contain some similarities in some cases (given the hierarchical clustering algorithm, the lower clusters have similar traits), and most people are placed in these three clusters,

with Clusters Three and 4 having a relatively smaller population. The people of Cluster Three characterize a group of societies among which hybrid vehicles technology is more accepted than other clusters, and this cluster must be targeted, and policies to expand this cluster should be adopted to expand the acceptance of hybrid vehicles technology in Iran. Update technology is important for the people of this cluster; the design of the vehicles, as well as the reliable brand, are the factors that affect their choice while buying a vehicles. The diversity of hybrid vehicles brands in Iran is an effective factor in the wider acceptance of this technology in Iran. The limited selection of these vehicles and the poor service after the sale of their batteries are considered hurdles to the development of these vehicles in Iran.

After Cluster Three, the people of Cluster Four are more prone to buy hybrid vehicles, with one of their preferences while buying a vehicles being that its parts are not svehiclesce in Iran, and the technical specifications of the vehicles being more important to them than other clusters. Cluster Four people consider the most important factor in the development of hybrid vehicles technology in Iran to be the reasonable cost of its maintenance and repairs, the production of these vehicles in Iran, which will result in a reduction in their purchase price, and unhindered traffic within the traffic plan. The lack of technological infrastructure for hybrid vehicles in Iran and the low resale value of these vehicles are among the obstacles to developing its technology in Iran.

After clusters three and four, people in Cluster two, zero and one tend to buy hybrid vehicles. These three clusters have behavioral similarities to each other. High safety, fuel consumption and price influence their decisions while buying a hybrid vehicles, and the safety index is more important for people in Cluster One. The people of these three clusters consider the reduction in the initial price of a hybrid vehicles and the fuel costs effective factors in expanding the adoption of its technology in Iran. The people of these three clusters consider the high price of hybrid vehicles and the fact that there is no significant difference between hybrid vehicles and gasoline vehicles, as compared to the higher price of hybrid vehicles, as obstacles to the adoption of their technology in Iran. The high price index is far more important as one of the obstacles for Cluster One people, and the other obstacle, which is little different from a gasoline vehicles, is more important for Cluster Zero

people.

After examining the factors that determine the choice of an electric vehicles, a higher percentage of people consider the cost of proper maintenance and repair, the reduction of fossil fuel costs, the lack of vehicles parts due to sanctions, the updated technology and high safety were among the effective factors while buying a vehicles. After identifying the clusters with the desire to buy these vehicles or are using them, adopting policies to remove the obstacles that cause the people of that cluster not to buy these vehicles comes next, and the next step is to identify the factors as an incentive and reinforcement for the purchase of these vehicles by those people and their use.

By analyzing each cluster, separate policies can be adopted that are in accordance with the behavior of the people of that cluster to expand the adoption of hybrid vehicles technology, and the obstacles in the way of each cluster can be assigned, identified, and eliminated after clustering hybrid vehicles buyers. Indeed, by identifying the behavioral pattern of the people of that cluster, one can strengthen the platform for the adoption of hybrid vehicles technology in Iran. Even beyond that, one can find a cluster that is completely unwilling to buy a hybrid vehicles. Thus, adopting policies does not affect their behavior and wastes time and money. On the other hand, one can choose the target cluster and adopt the necessary policies to expand the hybrid vehicles in Iran according to their behavior.

It is suggested to provide the infrastructure for developing electric vehicle technology in Iran in line with modeling the adoption of electric vehicle technology in Iran. Automotive companies in the country must produce domestic models using foreign electric vehicle technology engineering. Given the high level of air pollution in Iran metropolises, it is suggested to increase the number of electric vehicles in the country and remove the obstacles to producing these vehicles in Iran. Moreover, their buyers must consider financial facilities as hybrid vehicles in Iran are costly.

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