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IDENTIFICATION OF THE FACTORS PROMOTING THE ADOPTION OF ENERGY-EFFICIENT VEHICLES IN KARACHI, PAKISTAN

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Abstract
The main subject of this research paper is to examine the critical factors that encourage the use of energy-efficient vehicles in Karachi, which is the largest metropolitan city in Pakistan. The research adopts the Diffusion of Innovation Model by Rogers to examine the effect of perceived characteristics, social factors, and attitude toward behavior in influencing customer acceptance of energy-efficient vehicles. The survey was a structured survey of 104 respondents to analyze the socio-economic, environmental, and technological determinants in influencing purchase decisions. The results are expected to help the policy-makers, marketers, and urban planners to determine the strategic steps that will help to increase people's awareness, supportive policies, and speed up the internalization of energy-saving cars, helping to make the transportation system more sustainable and environmentally resilient in Karachi.

INTRODUCTION
The world transportation systems are becoming a subject to a growing amount of criticism as significant sources of greenhouse gas (GHG) emissions, air pollution, and overreliance on fossil fuels. These issues have been increased by the rapid urbanization of developing countries, with high vehicle use of internal combustion engine (ICE) vehicles contributing to the deterioration of the environment, health hazards, and economic instability caused by energy imports (Aguirre-Urreta MI et al., 2019).
The country is the most susceptible to the effects of climate change (Pakistan has limited adaptive capacity, restricted economic potential, and difficulties related to infrastructure), which is why it is in dire need of the transition to more eco-friendly mobility solutions (Pakistan Bureau of Statistics; Engineering Development Board, Government of Pakistan). The biggest metropolitan city in the country, Karachi, is on the frontline of this problem as it already struggles with serious traffic congestion rates, high fuel prices, and the growing intensity of air pollution, so the implementation of environmentally friendly vehicles may become one of the possible solutions to the sustainable development of big cities (Javid MA et al., 2021).

Although there has been increased awareness of environmental problems, the uptake of energy-efficient vehicle technologies in Pakistan has been slow. The major hurdles are the high cost of purchases and consumer ignorance, as well as the government policy not being conducive. Other deterrents like elevated importation tax, limited financing options and a poor incentives system also deter market penetration. Furthermore, a lack of sufficient after-sales services, a lack of spare parts, and skilled technicians decreases consumer confidence and discourages their adoption (Anwar S et al., 2022).

The Diffusion of innovations (DOI) Theory by Rogers is useful to explain the process of technology acceptance. This model describes the spread of new technologies among a population within five main stages, namely knowledge, persuasion, decision, implementation, and confirmation (Adithya Remitasari et al.).

At the knowledge stage, people get acquainted with the innovation and its benefits; at the persuasion stage, they create attitudes based on perceived advantages and disadvantages; the decision stage is the act of choosing or refusing to use it; implementation is the active introduction to use the innovation; and the confirmation stage is assessing the results to use it or not to use (Qureshi et al., 2019; Mahmoud M et al., 2021). Knowledge of these stages assists the researcher in determining the elusive variables that ease or impede each of the stages in the adoption of energy-efficient vehicles.

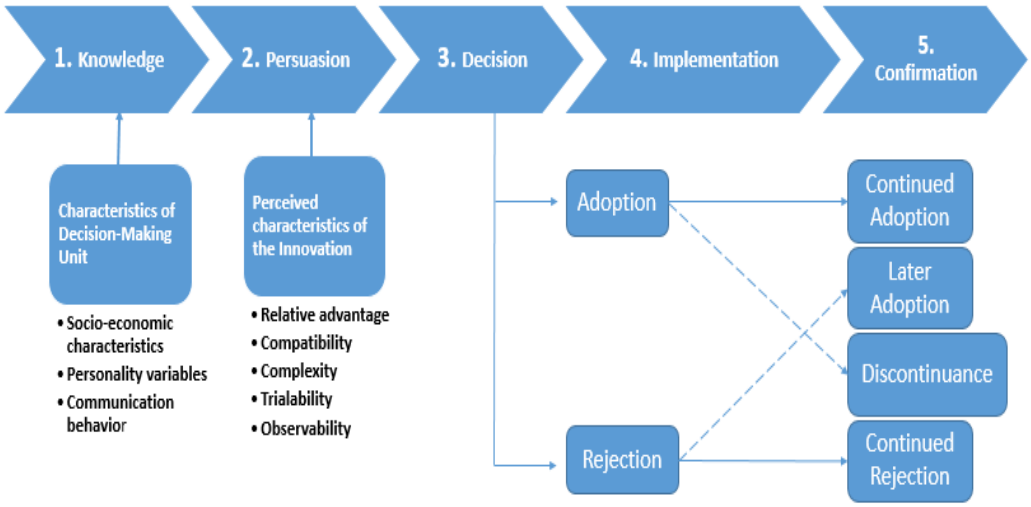

Figure 1: Shows the five phases innovation-decision process of the Diffusion of Innovations model.

The main aim of this study is to establish and discuss the motivation that leads to the uptake of energy-efficient vehicles in Karachi, Pakistan. This paper is based on the Diffusion of Innovations framework by Rogers to understand the way in which attitudes to the adoption of these vehicles are formed due to a combination of consumer awareness, persuasion, decision-making, implementation, and confirmation (Ashfaq M et al., 2021). In particular, the study will attempt to:

- Research consumer perception and buying behaviors towards energy-efficient cars;
- Determine the economic, psychological, social, and policy-related issues that affect adoption; and
- Offer recommendations that can be implemented by policy makers, manufacturers and marketers to hasten the process of developing sustainable and energy-efficient means of transportation in Pakistan (Roger E.M, 2003).

LITERATURE REVIEW

International Environmental Issues

The accelerated industrial and urban growth in most parts of the world has increased the world's energy demand, leading to a massive rise in the emission of greenhouse gases (GHGs) and environmental degradation. In the context of other industries, transportation has risen as one of the greatest contributors of carbon dioxide (CO_2) to the atmosphere because companies largely use fossil fuels like petrol and diesel (Fransen et al., 2019). It has been found that the transport sector accounts for an estimate one-third of the overall global CO2 emissions, which shows its high significance in the climate mitigation policy (Fontaras et al., 2017).

The steady increase in the temperature of the Earth over the past 100 years highlights the necessity of finding sustainable solutions in transport. Research indicates that the period between 1983 and 2012 was the warmest three decades in more than a thousand years, which highlights the threat that the environment is increasingly facing (Lohse-Busch et al., 2020). Unless a significant change is made in current trends on emissions, CO_2 levels in the atmosphere will be at critical levels by the close of this century.

In that regard, the emergence of cars that consume less energy, such as hybrids and electric vehicles, has become an option that, in many ways, helps to save a large amount of fuel and carbon emissions and enhance the mobility of sustainability (Mulholland et al., 2023).

Pakistan Environmental Issues

Pakistan is one of the countries that is highly susceptible to the negative impacts of climate change, even though the country contribution less than 1% of the total GHG emissions worldwide. The government is often faced with severe climatic conditions like floods, drought, and heat waves that have cost a lot of lives and resulted in massive economic destruction. Such repetitive processes keep affecting the key sectors, including agriculture, water provision, and food security (Adithya Remitasari et al.).

Pakistan was ranked as one of the ten most impacted countries due to climate-related disasters because of the devastating floods that happened in 2010 and 2011, forcing millions of people out of their homes and devastating essential infrastructure.

As a response, the Government of Pakistan came up with a National Environmental Policy in 2005 to encourage sustainable growth and to minimize GHG emissions. To show its involvement in international environmental processes, Pakistan is also a member of such international environmental activities as the Kyoto Protocol (Abid et al., 2015). The policy has, however, not been very effective due to implementation difficulties, lack of funds and poor enforcement systems.

Significant cities like Karachi, Lahore, and Islamabad still experience acute air pollution, and this has been largely caused by the predominance of vehicles that are fueled by fossil fuels. The deployment of energy-efficient vehicles is transformative in reducing emissions, enhancing the air quality, and promoting the sustainable development goals of Pakistan (Mulholland et al., 2023).

Economic Concerns for Pakistan

Economic aspects have a great impact on the uptake of energy-efficient cars. To sustain its growing energy needs, the economy of Pakistan is very reliant on imported oil and gas. This reliance puts a considerable strain on the reserves of foreign exchange and makes the national economy vulnerable to changes in global oil prices. Emission of energy-efficient cars, especially hybrid and electric, will lead to less oil use, economic stabilization, and a reduction in the financial cost of fuel import (Abas et al., 2017).

Karachi, being the economic center of the country, is so dynamic in its daily mobility, where millions of commuters use both private and public transport. There is increased concern amongst the population about the cost of transportation due to the high fuel prices, lack of good infrastructure, and high maintenance costs.

There are long-term cost savings associated with energy-efficient vehicles: the cost of fuel used as well as the maintenance is low, the mileage is high, and the reliance on foreign fuels is diminished. Nonetheless, the low cost, the lack of

awareness, and government incentives restrain the uptake among consumers (Anwar S et al., 2022).

Rogers proposed the Theory of Diffusion of Innovation.

The Diffusion of Innovations (DOI) Theory by Everett Rogers can be an effective method of studying how new technology, such as energy-efficient vehicles, is adopted. The theory describes the process of innovations disseminated in a social system over time, relying on a number of factors that influence it (Adithya Remitasari et al.).

Rogers identified five primary characteristics that determine the diffusion process: relative advantage, compatibility, complexity, trialability, and observability (Mapoma et al., 2018). Relative advantage is defined as the extent to which an innovation is deemed as being better than the available alternatives, in this case, the environmental, economic and performance advantages of environmentally efficient vehicles.

The compatibility aspects relate to the degree of synchronization of the innovation with cultural values, lifestyle and the infrastructure that is in place. Complexity is associated with the perceived difficulty of the technology to understand or use, and trialability and observability define the ease with which consumers can experiment and see the positive outcome of the innovation. Consumer perception, social norms and the availability of infrastructures are found to play significant roles that influence the adoption of energy-efficient vehicles in the context of Pakistan (Ashfaq M et al., 2021).

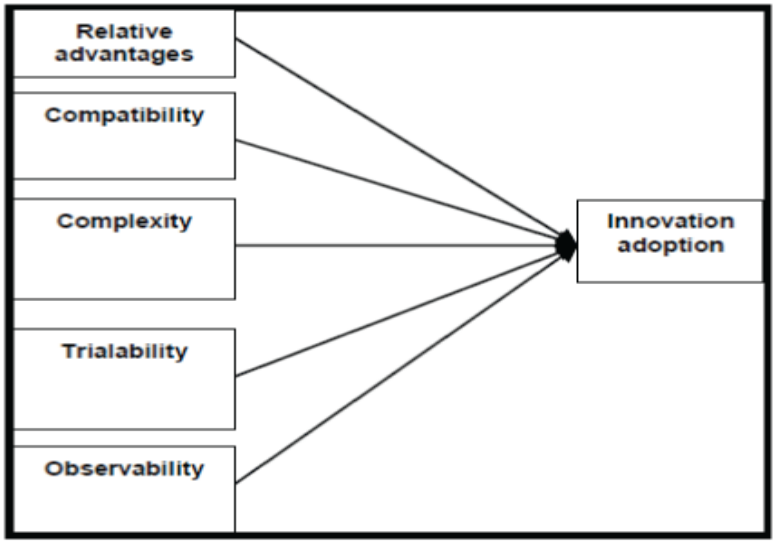

Figure 2: The perceived characteristics of innovation are represented

RESEARCH METHODOLOGY

Participants

A total of 104 responses were gathered through an online questionnaire survey disseminated via Google Forms. The participants were car drivers from different parts of Karachi, chosen to make sure that people from various socio-economic backgrounds were represented. The survey took place in places like Clifton, Gulshan-e-Iqbal, Gulistan-e-Jauhar, Defence, Saddar, P.E.C.H.S., Korangi Town, Shah Faisal Town, North Nazimabad, and Orangi Town.

A screening question made sure that the answers were relevant by ensuring that the people who answered were currently driving cars. Other questions found people who were familiar with hybrid vehicle technology. The time it took to collect the data was about six weeks.

To help people understand, the questionnaire started with a short description and an example figure that explained how hybrid cars work.

Before the survey was sent out to everyone, a pilot test with 12 people was done to check the face and content validity of the survey. The survey included both drivers and non-drivers of hybrid cars, which helped us better understand the factors that affect the adoption of hybrid vehicles in Karachi.

Table 1: Overview of the types of respondents

Number of Interview Respondents	
Hybrid car drivers	80
Hybrid car non-drivers	24
Total	104

Study Site

The study took place in Karachi, Pakistan, a city chosen for its economic importance and variety of transportation options. Karachi is Pakistan's biggest and most populous city, with more than 11 million people living there. It is also Pakistan's main industrial and financial centre, with a GDP of about USD 164 billion.

Karachi is not only an economic powerhouse, but it is also a major transportation hub. It has two of Pakistan's biggest seaports, the Port of Karachi and Port Qasim, as well as the Jinnah International Airport, which is the busiest airport in the country. The city also has a well-developed network of car dealerships, which makes it a great place to look at how people are buying energy-efficient cars.

Table 2: Categorization of Roger's adoption attributes and associated key determinants

Adoption Decision Attributes	Determinant Categorizations
Relative Advantage	Better fuel efficiency
	Lower emissions
	Annual cost savings
Compatibility	Compatible with modern lifestyle
	Compatible with Environmental policies
Complexity	Purchase Price is high
	Less knowledge of technology
	Less technicians available
	Operation and Maintenance is complex
	Less variety is available
	Personality mindset
Trialability	Import Duty on Hybrid cars should be reduced
	More incentives should be given by the government
Observability	Satisfaction with new technology
	Willing to suggest Hybrid cars to peers
	Future willingness to invest in Hybrid technology

Study Design

The study framework is based on Rogers' Innovation Diffusion Theory, which looks at the five most important parts of persuasion:

1. Advantage over others
2. Compatibility
3. Complicatedness
4. Tryability
5. Seeing

A thorough review of the literature was done to find the main factors that affect the spread of hybrid vehicles' technology on a global and local scale. This review changed how the questionnaire was put together and how the data would be gathered. The survey method was selected as the most appropriate technique for this quantitative

study, utilising a five-point Likert scale to assess items (from 1 = strongly disagree to 5 = strongly agree).

Demographic questions asked about things like gender, age, income level, and level of education.

Descriptive Statistics

There were 104 people in the sample, and they ranged in age from 18 to 45 years old. Most of the people who answered were men (84.6%), and only 15.4% were women. Most of the people who took part had a college degree, which means that the people who answered the questions were fairly well-informed.

Table 3: Summary of the descriptive statistics

Variable	Category	n	%
Gender	Male	88	84.6
Age (By Jun 30 2021) - (Years)	Female	16	15.4
	18-24	24	23.1
	25-34	38	36.5
	35-44	30	28.8
	45+	12	11.5
Monthly Household Income (Rs.)	< 50,000	25	24
	50,000-150,000	29	27.9
	150,001-250,000	27	26
	250,001-350,000	12	11.5
	350,000+	11	10.6
Education	Matriculation	1	1
	Intermediate	5	4.8
	Undergraduate (Bachelors)	39	37.5
	Graduate (Masters) and Post-Graduate (PhD)	55	52.8
	Other	4	3.8

RESULTS AND DISCUSSION

This part includes the most important results and discussion of the determinants of the use of energy-efficient vehicles in Karachi, Pakistan, based on the theoretical concept of Rogers, namely, the Diffusion of Innovation Model (DOI). The determinants are classified based on the key elements of the model, which are relative advantage, compatibility, complexity, observability, and trialability, and are justified with the help of descriptive and statistical understanding. The analysis identifies the drivers that encourage and the barriers that discourage the adoption of energy-efficient vehicles.

Determinants by Attributes

1. Relative Advantage

As the results show, fuel efficiency is viewed as the most important benefit of energy-efficient cars. About 94 percent of the interviewees admitted that those cars are superior to normal cars in fuel economy. Besides, 47 percent strongly believed that high fuel-efficient vehicles can play a significant role in curbing carbon emissions.

Another major triggering factor was economic feasibility. Approximately three-quarters of those surveyed claimed that these cars to save on fuel prices, and therefore a viable and very affordable option in the long term. These results highlight the fact that the tangible benefits of cost savings, fuel economy, and environmental performance are key motivational factors in Karachi, according to consumers, and this aspect corresponds to the relative advantage dimension of the Rogers model.

2. Compatibility

By compatibility, the degree of how an innovation fits the already existing values, lifestyle and socio-environmental beliefs among the consumers is meant. The findings revealed that forty-seven percent of the respondents strongly

concurred that energy-efficient cars are also in tandem with a contemporary and environmentally sensitive life. This goes in line with the Congruency Theory, which posits that people who embrace environmental sustainability are more likely to use technologies that are in congruence with those values.

Moreover, 84 percent of the participants said that fuel-efficient cars fit in with the domestic environmental objectives and initiatives to enhance sustainability. These findings show that the compatibility of culture and environment is a decisive factor in determining consumer attitudes towards the adoption of energy-efficient vehicles in Karachi.

3. Complexity

The researchers concluded that high initial purchase prices are the greatest discouragement to adoption. Most respondents mentioned that the increasing cost of cars, mostly because of the depreciation of the currency, and the fact that most of the vehicles require a high percentage of imported parts, make cars less affordable.

Also, 34 percent of the respondents stated that it is harder to maintain energy-saving cars than traditional ones, and 45 percent said that they are worried about the shortage of qualified technicians. The lack of spares and the lack of variety in the models also contribute to consumer reluctance. Such results are in line with the previous research that revealed that financial risk, maintenance uncertainty and lack of technological infrastructure are some of the factors that make it difficult to diffuse innovative automotive technologies in developing markets.

4. Observability and Trialability.

The features of observability and trialability reflected a positive effect on consumer willingness to buy energy-efficient cars. Approximately 64 percent of the respondents replied that such government incentives as tax rebates or subsidies would speed up the adoption, whereas 52 percent were in favor of the notion of lowering importation duties to make such vehicles more affordable.

Also, when the respondents were asked about their satisfaction with using hybrid automobiles or energy-saving vehicles, more than 80% said they are satisfied and will recommend those vehicles to other people in case they want them. This implies that increased visibility and positive firsthand experiences can go a long way in boosting consumer trust and resulting in mass adoption in the future.

The following are the rankings of the Determinants of Significance.

1. Cumulative Importance of Drivers.

Relative advantage and compatibility were found to be the two most powerful determinants of adoption when we analyzed the cumulative effect of the determinants of the DOI attributes. Some of the major driving forces are fuel saving, environmental awareness and keeping up with the current lifestyle trends. All these aspects point to the fact that consumers become more inclined to use energy-efficient vehicles in case the innovation proves to be not only economically helpful but also socially relevant.

2. Cumulative Importance of Obstacles.

On the other hand, the research established that the greatest challenges are high prices of purchasing models, lack of inventories, and lack of skilled maintenance personnel. These barriers not only inhibit the penetration of the market but also curtail the consumer confidence to switch to new vehicle technologies. These obstacles are key factors that require financial support, the formation of infrastructure, and training people to implement energy-efficient vehicles in the developing Karachi car industry.

DATA ANALYSIS

We used SPSS software to do statistical analyses to see how the five attributes were related to each other. The tests listed below were used:

1. Test of Pearson Chi-Square
2. Test of Phi/Cramer
3. Tables of Contingency
4. Principal Component Analysis (PCA)
5. **Exploratory Factor Analysis (EFA)**

The Kaiser-Meyer-Olkin (KMO) test showed that the sample was good enough, and Bartlett's Test of Sphericity showed that it was sufficiently good for factor analysis. PCA found four important

components with Eigenvalues greater than 1. These components explained most of the differences between the variables.

Following Exploratory Factor Analysis (EFA) confirmed these four components, showing that relative advantage and compatibility are the most important positive factors and that complexity is the main barrier.

These results show that the main reasons people in Karachi buy hybrid cars are that they think they will save money and help the environment. However, they are limited by money, technology, and infrastructure issues.

Table 4: KMO and Bartlett's Test

To verify data-set is suitable for factor analysis (suitability of data for structure detection):

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.595
Bartlett's Test of Sphericity	Approx. Chi-Square	337.889
	df	120
	Sig.	.000

Kaiser-Meyer-Olkin Measure of sampling Adequacy (KMO): Indicates the proportion of variance in your variables that might be caused by underlying components. [{factor analysis probably won't be very useful} (0.50<KMO >= 0.60 →1) {factor analysis may be useful}].

- Bartlett's test of Sphericity (significance value):
- 1→ variables are unrelated (unsuitable for structure detection)
- 0.05< → factor analysis may be useful

Table 5: Total Variance Explained

Using Kaiser criteria (Eigen value >=1) – Checking Total Variance explained table (1st column - 'Total')

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.862	24.138	24.138	3.862	24.138	24.138	3.288
2	2.855	17.841	41.979	2.855	17.841	41.979	2.775
3	1.713	10.707	52.686	1.713	10.707	52.686	1.962
4	1.443	9.018	61.704	1.443	9.018	61.704	2.161
5	1.071	6.697	68.401	1.071	6.697	68.401	1.790
6	.985	6.159	74.559				
7	.847	5.293	79.853				
8	.635	3.970	83.823				
9	.535	3.347	87.169				
10	.515	3.219	90.388				
11	.404	2.527	92.915				
12	.340	2.128	95.042				
13	.296	1.850	96.893				
14	.235	1.468	98.361				
15	.195	1.222	99.583				
16	.067	.417	100.000				
Extraction Method: Principal Component Analysis.							

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The first 4 components explain much more variance than the remaining components, so after this plot using best judgement the recommended number of components for extraction are 4, because after component 4 very little variance is observed.

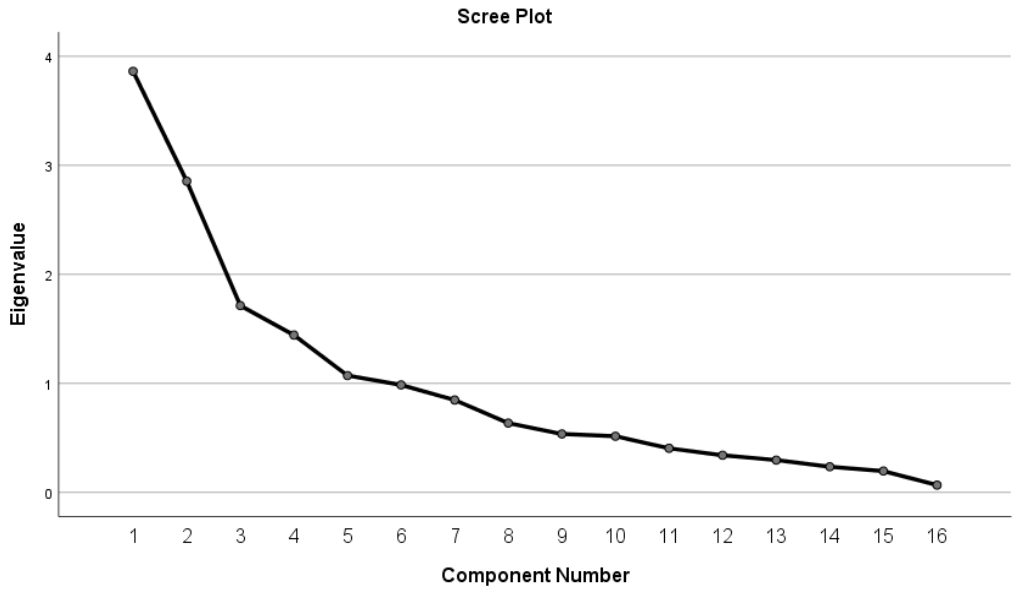

Figure 3: Scree plot showing component variation

Monte Carlo PCA for Parallel Analysis Version.
11-Aug-21 1:03:49 AM
Number of variables: 16
Number of subjects: 71
Number of replications: 100

Table 6: Check list of Eigen values in 'Total Variance determine extraction through Parallel Analysis'

Eigenvalue #	Random Eigenvalue	Standard Dev
1	1.9209	.1243
2	1.7093	.0795
3	1.5350	.0650
4	1.4009	.0602
5	1.2723	.0539
6	1.1721	.0531
7	1.0727	.0463
8	0.9861	.0475
9	0.8968	.0450
10	0.8148	.0451
11	0.7383	.0397
12	0.6506	.0394

13	0.5684	.0382
14	0.4965	.0385
15	0.4197	.0385
16	0.3455	.0542

++

Table 7: Shows component Matrix[a]

	Component				
	1	2	3	4	5
V1_Observability	.803	-.284	.173	.094	-.072
V3_Observability	.759	-.326	.068	-.353	-.044
V3_RA	.712	-.154	-.260	-.168	.015
V2_Observability	.710	-.415	.207	-.288	-.298
V1_Compatibility	.585	.022	-.068	.572	-.081
V3_Complexity	.570	.440	-.254	-.357	-.317
V4_Complexity	.224	.776	-.059	-.235	.050
V6_Complexity	.277	.721	-.164	.250	-.075
V5_Complexity	.305	.697	.024	.129	-.090
V2_Complexity	.102	.437	-.645	-.012	.065
V1_Trialability	.181	.368	.637	-.198	.223
V1_Complexity	.208	.160	.500	.488	-.089
V2_Trialability	.246	.431	.477	-.117	.407
V2_Compatibility	.527	-.214	-.114	.562	.023
V2_RA	.290	-.287	-.393	.026	.624
V1_RA	.485	-.050	-.028	-.020	.485
Extraction Method: Principal Component Analysis.					
a. 5 components extracted.					

- The table shows 4 strongest interrelationship components
- So after finding the appropriate number of components to retain, as the solution is a 5 factors solution so in order to keep only 4 components, the tests are re-run for only 4 components:
- Based on fixed number of factors (factors to extract) - Maximum Iterations for convergence = 25
- Method: Using Orthogonal Rotation (Direct Oblimin) - Excluding cases pairwise
- Rotation of 4 component solution explains higher percentage of variance explaining suitability of 4 component solution (Total Variance explained table):

Table 8: Extraction Method: Principal Component Analysis.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.862	24.138	24.138	3.862	24.138	24.138	3.288

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13	.296	1.850	96.893				
14	.235	1.468	98.361				
15	.195	1.222	99.583				
16	.067	.417	100.000				
Extraction Method: Principal Component Analysis.							
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance							

After finding the appropriate number of components to retain (4) to justify suitability of data for structure detection:
Exploratory Factor Analysis (Principal Axis Factoring) is performed on these 4 components:

- Based on fixed number of factors (factors to extract)
- Maximum Iterations for convergence = 25
- Method: Using Orthogonal Rotation (Direct Oblimin)
- Excluding cases pairwise
- Suppress small coefficients (Absolute value below): 0.30

Table 9: Pattern Matrix[a]

	Factor			
	1	2	3	4
V3_Observability	0.908			
V2_Observability	0.888			
V1_Observability	0.640			.416
V3_RA	0.599			
V1_RA	0.309			
V4_Complexity		0.697	.312	
V3_Complexity	0.470	0.671		
V6_Complexity		0.662		
V2_Complexity		0.601	-.309	
V5_Complexity		0.548	0.301	
V1_Trialability			0.707	
V2_Trialability			0.508	
V2_RA				
V1_Compatibility				.701
V2_Compatibility				.596
V1_Complexity			.338	.340
Extraction Method: Principal Axis Factoring.				

Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 11 iterations.

- Extraction Method: Principal Axis Factoring.
- Rotation Method: Oblimin with Kaiser Normalization.
- a. Rotation converged in 11 iterations.

In the 'pattern matrix' table the loadings are reflecting the relationship between a measured variable and a factor, controlling the fact that these factors are allowed to co-relate with each other.

CONCLUSION AND RECOMMENDATION

Conclusion

The paper has determined the key drivers behind the use of energy-efficient cars in Karachi. Results indicate that fuel economy, cost savings and environment are great factors that affect consumer decisions. Relative advantage and compatibility are the innovation attributes that promote the application, and complexity, high costs and the inability to obtain technical assistance are the main challenges. All in all, Karachi residents are keen on sustainable transportation, yet the economic and infrastructural factors are a drag on the uptake.

Recommendations

1. Offer a taxation incentive and lower import tax on fuel-efficient cars.
2. Carry out sensitization about financial and environmental advantages.
3. Provide technical training on the maintenance of hybrid and electric vehicles.
4. Increase the number of charging centers and stations in prime locations.
5. Encourage local production to lower prices and accessibility.
6. Continue research and policy analysis to track the development and consumer patterns.

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