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Overcoming Critical Barriers to Electric Vehicle Development: A Comparative Analysis Using Fuzzy DEMATEL and Fuzzy AHP

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ABSTRACT

Electrical vehicles have been identified as a main component in reducing future emissions and energy consumption in the mobility sector. This study aims to identify the most critical obstacles to the development of electric vehicles. In this context, an analysis is established using the fuzzy DEMATEL technique. In addition, a comparative analysis is carried out using the fuzzy AHP method. The findings can pave the way for the investors for their strategic management. The main contribution of this study is that a new model is created for the minimization of the problems regarding electrical vehicles. It is concluded that range anxiety is the most significant barrier for the improvements of the electrical vehicles. Similar to this issue, long charging times also play an important role in this framework. On the other side, inadequate charging infrastructure, second-hand value concerns and the high initial purchase cost have the lower weights in comparison with other determinants. In addition to them, a comparative evaluation has also been performed by using fuzzy AHP methodology. It is also identified that the results of both fuzzy DEMATEL and fuzzy AHP are the same. This situation gives information about the reliability of the findings. Governments and local authorities should provide public investment and private sector incentives for the installation of fast-charging stations across the country, especially on highways, in urban centers, and in rural areas. Financial support, tax breaks or low-interest loans should be offered to electric vehicle owners to install charging units in their homes and workplaces. Research funds should be provided for university-industry collaborations and technology initiatives to develop long-range and short-charge battery technologies.

Keywords: electrical vehicles; barriers; strategic management; DEMATEL; AHP

JEL Classification: G21, L26, O16

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1. INTRODUCTION

Electrical vehicles have been identified as a main component in reducing future emissions and energy consumption in the mobility sector. The concept of working of an electric car is simple: the electric set has the duty of converting the direct current produced by the battery into mechanical energy (Das et al., 2024). The drive assembly includes all the components that transform the direct current from the batteries into the traction force and torque required to turn the wheels and propel the vehicle. The most noticeable features of electric cars are range and capacity (acceleration, speed, incline and loading and flexibility), time needed for charging and battery costs. Electrical vehicles have undeniable advantages in modern reality (Singh et al., 2024). The advantage of electric vehicle is attributed the environmental friendliness and nonexistence of emissions, the cheaper cost and cheap "fuel" – electricity. The electric car's cost is around 10-15 thousand dollars, which is cheaper than the cars on petroleum. This factor makes them undoubtedly the best alternative for vehicles to which we are accustomed to (Feng et al., 2024).

Therefore, besides the advantages, there are also disadvantages. The main problem is battery capacity. One charge is only enough for 60-100 kilometers at best. The prospects of expanding the battery are not planned. There is also rapid battery wear. If the car was driven in good conditions, it can last for 3-5 years, at best and then it will need a replacement and quite a lot of money – sometimes the amount of money which equals the price of car itself (Niri et al., 2024). Storing can also be considered a disadvantage because some problems may arise because of the bad storage conditions. Cold in winter and heat in summer can seriously damage the micro schemes of battery. The advantage of electric cars – their silence is also a problem in some conditions (Karmaker et al., 2024).

There are main issues that prevent the development and spread of electric vehicles. Insufficient charging station network is an important issue in this process. The lack of a sufficient number of fast and reliable charging stations in a wide geography causes potential users to be hesitant. Another issue that should be taken into consideration in this process is the long charging time (Pasha et al., 2024). Compared to traditional fuel filling, long charging times create difficulties in daily use. This situation reduces the interest of users in these vehicles. High costs are also a significant obstacle to the development of these vehicles. The life of the batteries is limited, and their replacement is quite costly. This situation can negatively affect the financial profitability of the projects. Investors are increasingly worried about projects with low profitability (Malozyomov et al., 2024). There are some technological restrictions for these vehicles. Low temperatures can negatively affect battery performance.

This study aims to identify the most critical obstacles to the development of electric vehicles. In this context, an analysis is established using the fuzzy DEMATEL technique. In addition, a comparative analysis is carried out using the fuzzy AHP method. The findings can pave the way for the investors for their strategic management. The main contribution of this study is that a new model is created for the minimization of the problems regarding electrical vehicles. In this model, two different decision-making techniques are taken into consideration. This situation provides an opportunity to make a comparative evaluation. Owing to this situation, the validity and reliability of the proposed model can be tested. Hence, more effective solutions can be identified.

2. LITERATURE REVIEW

The popularity of green bonds as fixed-income assets increased in the past few years with the growing interest in renewable energy and electric vehicles. Green bond principles says that a green bond is any bond instrument where the proceeds will be exclusively applied to finance or re-finance, in part or in full, new and /or existing eligible green projects (Raj et al., 2024). Green bonds are financial security assets which are helping to reduce greenhouse gas emissions. Income from issuing a green bond is directed towards financing technologically advanced projects to mitigate the adverse effects of industrialization throughout the globe (Malozyomov et al., 2024). Green bonds have

advantages and disadvantages. We can say that advantages are good environmental impact, ESG investors attraction and positive reputation for green bond supporters (Aliyev et al., 2024). Possible disadvantages are higher issuance costs, greenwashing risk, limited use of proceeds, complex monitoring and reporting and market liquidity (Dua et al., 2024). Earnings from green bond issuance can help to funding and developing the infrastructure for electrical vehicles: creating new charging stations and grid optimization. Auto manufacturing companies are using proceeds to invest in research projects, which are helping to develop the EV industry overall (Yuvaraj et al., 2024).

With the development of electrical vehicles industry, banks actively financing those projects. They see that it is not only beneficial for their reputation but also a very liquid investment type. People are actively buying electric cars and other e-vehicles and are showing interest in the green industry (Kharabati and Saedodin, 2024). In Scandinavian and some European countries, it has become a trend to switch to renewable energy. This promises great prospects and profits for those banks that will finance these projects. Financing green projects by banks has several advantages for them. These are risk mitigation in the long-term because loaning green projects help to reduce climate-related financial risks, which can harm the asset values (Barakat et al., 2024). Some countries provide tax privileges for financial organizations which are lending money for "green" companies. However, there are also several disadvantages like limited financial returns (Nazari et al., 2024). Some projects have a long payback period which means they face lower returns in the short-term period (Kartal and Pata, 2023). Choosing which projects to invest in also requires some expertise from banks, since this sector is uncertain now, it is important to find valuable business (Farinloye et al., 2024). The impact of bank loans on this sector could be significant. By lending money to these projects, they are helping to create new jobs and opportunities, which is potentially increasing the number of solvent people who can become their future customers (Cheng et al., 2024).

Crowdfunding became very popular to finance the ideas on a starting stage. The startups upload their ideas, and the details related to these ideas on special platforms and users who are interested in those projects financing them (Gicha et al., 2024). Some of the businesses which are now very popular in the US and in the EU are financed by a crowdfunding platform. The advantage of this way of financing is increasing the awareness of people about electrical projects, especially about electric cars (Srividhya et al., 2024). Moreover, that can help to attract the specialists who have expertise in this area when they see these projects on the platforms, then they can get involved in these projects and help improve the product (Sun et al., 2024). The main disadvantage of crowdfunding is the projects of electric cars and vehicles may be left without funding due to low interest from users (Li et al., 2024. Because not everyone understands the new techniques in the production of chips and microcircuits (Bharaneedharan et al., 2024).

When the business or startup is recognized at the state level, it automatically attracts the attention of the public. There are a lot of advantages to that partnership. Government can help to create an infrastructure for electric cars like power stations and repairing places (Higueras-Castillo et al., 2024). The municipality also can change its petrol cars to the electric ones and increase the sales of producers. The e-vehicles in police, ambulance, and public transport will significantly improve the environment and help to decrease the costs of maintenance (Abdelfattah et al., 2024). The disadvantage is government can order large numbers of cars in one order, while companies will not be able to produce on such a scale (Zhao et al., 2024). Also, contracts with public services increase the responsibility so the companies have no room for error and mistakes (Yuan et al., 2024).

3. METHODOLOGY

In this study, it is aimed to identify the most critical barriers for the improvements of the electrical vehicles. For this purpose, a novel decision-making model has been created by using fuzzy DEMATEL methodology (Gökalp and Eti, 2025). In addition to this situation, a comparative evaluation has also been conducted by using fuzzy AHP methodology (Eti et al., 2023). With the help of this issue, the reliability of the findings can be identified (Eti et al., 2024). DEMATEL is a method used in multi-criteria decision-making problems (Ebrahimi et al., 2024). It can analyze the cause-effect relation-

ships between criteria, especially in complex systems (Baş and Eti, 2022). In addition, it is used to visualize the interaction between criteria and determine the priority factors. The stages of this technique are given below (Shi et al., 2024).

Step 1: Defining the Problem and Determining the Criteria

Step 2: Obtaining Expert Opinions

Step 3: Creating the Average Direct Relationship Matrix

Step 4: Performing Normalization

Step 5: Calculating the Total Relationship Matrix

Step 6: Determining the Criteria Weights

The first step of this analysis is defining the problem and determining the criteria. The main factors that prevent widespread use of electric vehicles can be grouped under several main headings. For this purpose, 5 different criteria can be identified based on the literature review results. The details of these items are given in Table 1.

Table 1: Criteria List

Criteria	Codes
Inadequate charging infrastructure	C1
The high initial purchase cost	C2
Range Anxiety	C3
Long charging times	C4
Second-hand value concerns	C5

Inadequate charging infrastructure is an important problem to be considered in this process. The number and prevalence of charging stations are still insufficient in many regions. In addition, the lack of charging points in rural areas limits widespread use. The limited fast charging infrastructure also makes long journeys difficult. The high initial purchase cost is another important obstacle in this process. The initial cost of electric vehicles is generally higher than gasoline or diesel vehicles. This situation makes investors significantly nervous. Investors are very reluctant to focus on projects with low profit margins. Range anxiety is another barrier that plays a very important role in this framework. The limited distance that can be covered with a single charge makes users nervous. This situation prevents electric vehicles from being preferred by customers. On the other hand, long charging times are another danger that reduces the use of electric vehicles. Many electric vehicles can take hours to fully charge. This situation may not suit user habits. The fact that fast charging stations are not widespread also increases this problem. Second-hand value concerns also cause investors to choose these vehicles less. Since the second-hand market for electric vehicles is not yet well-established, the perception of investment risk is high.

In the DEMATEL method, the collection of expert opinions is a very critical step. The main reason for this is that the fundamental basis of the method is the evaluations made with the experts' knowledge of the relationships between the criteria. In this study, opinions are obtained from three different experts to increase the reliability of the decision-making process. In the selection of experts, criteria such as field knowledge, sectoral experience and academic knowledge are taken into consideration. In this context, experts from different disciplines are preferred, one of whom is an academician, one of whom is a manager who actively works in the energy sector and the other is an expert who has worked in policy development processes in a public institution. The experts are informed in detail about the purpose, method and expectations of the study and are assured of the confidentiality of their opinions.

During the data collection process, an explanatory form containing the criteria and their impact levels is sent to the experts for their evaluation. Each expert independently evaluates the effects of the determined criteria on each other. In the process, one-on-one interviews are held with the experts after the evaluation forms are filled in and additional explanations are requested regarding

the relationships between the criteria when deemed necessary. The first of the meetings is held to introduce the DEMATEL method to the experts and to explain the evaluation process. In the second stage, direct relationship matrices were created in line with the data obtained from the experts and in case of any contradiction or deficiency, clarity was ensured by contacting the experts again. Finally, the findings obtained were presented to the experts to make verification and the necessary approval is obtained for the final analysis. Table 2 gives information about the criteria weighting results.

Table 2: Criteria Weighting Results

Criteria	Weights
Inadequate charging infrastructure	0.105
The high initial purchase cost	0.205
Range Anxiety	0.302
Long charging times	0.211
Second-hand value concerns	0.177

It is concluded that range anxiety is the most significant barrier for the improvements of the electrical vehicles. Similar to this issue, long charging times also play an important role in this framework. On the other side, inadequate charging infrastructure, second-hand value concerns and the high initial purchase cost have the lower weights in comparison with other determinants. Range anxiety is the concern of electric vehicle users or potential users that the vehicle's battery will not be able to cover the desired distance on a single charge. When a person travels with an electric vehicle, they think that the vehicle's range will run out on the road, and they will be stranded without finding a suitable charging station. This anxiety becomes more pronounced, especially on long-distance journeys or in areas where charging infrastructure is inadequate. Range anxiety is a factor that seriously slows down the adoption and spread of electric vehicles in society. Users may feel insecure because there is no system where they can refuel whenever they want, as in gasoline vehicles. Similarly, people have to make their plans according to range on long-distance journeys, which reduces the feeling of freedom. The small number of charging stations increases this anxiety. This situation is more common in rural areas or small cities. One of the main technical challenges affecting the proliferation of electric vehicles (EVs) and their preference by users is the long charging time of the batteries. This situation becomes even more evident when compared to internal combustion engine vehicles. While gasoline or diesel vehicles can be refueled in a few minutes, many electric vehicles can take hours to fully charge. Long charging times make it difficult for users to plan their daily lives. Users who use their vehicles frequently during the day lose flexibility due to the long charging time. The vehicle quickly becomes unusable, which is negative in terms of safety or efficiency. In addition to them, a comparative evaluation has also been performed by using fuzzy AHP methodology. AHP reduces complex decision problems to a more manageable structure. This method organizes the decision problem in a hierarchical structure as purpose, criteria, sub-criteria and alternatives (Yüksel et al., 2023). Moreover, it determines the importance of the criteria with the help of pairwise comparisons. The details of the comparative weighting results are given in Table 3.

Table 3: Comparative Weighting Results

Criteria	Fuzzy DEMATEL	Fuzzy AHP
Inadequate charging infrastructure	5	5
The high initial purchase cost	3	3
Range Anxiety	1	1
Long charging times	2	2
Second-hand value concerns	4	4

Table 3 demonstrates that the results of both fuzzy DEMATEL and fuzzy AHP are the same. This situation gives information about the reliability of the findings.

4. CONCLUSION

In this study, it is aimed to identify the most critical barriers for the improvements of the electrical vehicles. For this purpose, a novel decision-making model has been created by using fuzzy DEMATEL methodology. In addition to this situation, a comparative evaluation has also been conducted by using fuzzy AHP methodology. With the help of this issue, the reliability of the findings can be identified. The main contribution of this study is that a new model is created for the minimization of the problems regarding electrical vehicles. It is concluded that range anxiety is the most significant barrier for the improvements of the electrical vehicles. Similar to this issue, long charging times also play an important role in this framework. On the other side, inadequate charging infrastructure, second-hand value concerns and the high initial purchase cost have the lower weights in comparison with other determinants. Range anxiety is the concern of electric vehicle users or potential users that the vehicle's battery will not be able to cover the desired distance on a single charge. When a person travels with an electric vehicle, they think that the vehicle's range will run out on the road, and they will be stranded without finding a suitable charging station. Long charging times make it difficult for users to plan their daily lives. Users who use their vehicles frequently during the day lose flexibility due to the long charging time. The vehicle quickly becomes unusable, which is negative in terms of safety or efficiency.

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