Grenze International Journal of Engineering and Technology, June Issue

Evaluating Factors Influencing Electric Vehicle Adoption: A Fuzzy AHP Process

Hemanth Y R[1], Karthik T[2], Trupthi Rao[3] and Ashwini Kodipalli[4]
[1-2]Dept. of AI & DS, Global Academy of Technology, Bangalore, Karnataka, India
Email: hemanthyr446@gmail.com, karthiktkarthikt08@gmail.com
[3]Dept. of CSE (AI&ML), Dayananda Sagar University, Bangalore, Karnataka, India
Email: trupthirao-aiml@dsu.edu.in
[4]School of CSE, RV University, Bangalore, Karnataka, India
Email: ashwini.k@rvu.edu.in

***Abstract*— Switching to electric vehicles (EVs) is essential for reducing greenhouse gases and developing a sustainable transportation system. The adoption of EVs depends on various technological, environmental, economic, and social factors. This study applies the Fuzzy AHP method to evaluate and prioritize these factors based on their impact on EV adoption. Fuzzy AHP incorporates uncertain and imprecise human judgments using fuzzy logic to provide more reliable results. The findings indicate that environmental factors, government policies, and charging infrastructure are the most influential factors, followed by social acceptance.**

***Index Terms*— Greenhouse gas, Emission, AHP, Multi-Criteria Decision Making.**

I. INTRODUCTION

Over the last ten years, there have been HUGE changes in our climate all around the world. This is mostly because Greenhouse Gas (GHG) emissions have shot up. About 65% of these emissions come from Carbon Dioxide (CO2). A lot of it is from burning fossil fuels for electricity and running, around 11% is CO2 from cutting down trees and clearing land for farming. Methane (CH4) which we get from waste management makes up about 16%, also Nitrous Oxide (N2O) at 6% and Fluorinated gases. When we look closely at CO2, we see that transportation is responsible for 14% of those emissions.

That number is anticipated to develop into millions of tons in in few years! To handle these GHG emissions, a worldwide Electric Vehicle Summit has been set up to move towards electric vehicles (EVs) to assist cut down on those emissions. Renewable energy sources like water, solar, & wind can be quite unpredictable. But don't worry! An EV charging system backed by a good energy management setup can help manage that fluctuating power supply effectively.

V2X technology is exciting because it can provide power for many uses—like vehicles, homes, buildings, and even the grid.V2X acts like a mobile electricity storage unit. It allows us to store energy and use it whenever and wherever we need it. Electric vehicle popularity is booming all around the globe. EVs are super important for reaching net-zero emissions worldwide. The Electric Vehicles Initiative (EVI) aims to speed up use of EVs everywhere to cut down greenhouse gas emissions from transportation. This initiative was launched by many governments to support EV sales in 2010.

Grenze ID: 01.GIJET.12.2.216_21

There are now more than 40 million electric cars in use globally, Specialists predict that number is getting to triple before long! there's a new campaign called EV 30@30 from the Clean Vitality Service (CEM) which empowers indeed more individuals to purchase EVs by advertising unused arrangements and motivations CEM which is a part of EVI and includes many countries like China, India, Finland, Canada, France, Japan, Mexico, the Netherlands, Norway & Sweden.

The aim is to make sure that by 2030, about 30% of new sales will be electric vehicles! Looking at China, it truly leads the way with 9.5 million EV-wow! There are appropriations accessible there that make buying an EV much cheaper compared to other nations. Now when looking at the contribution of India: it stands among the top nations globally in terms of greenhouse gas emissions, ranking third worldwide with an average CO_2 output of approximately 2,660 million tons annually. Notably, as reported by the Ministry of Environment, the transportation sector is capable of being responsible for an incredible 90% of these footprints highlighting its significant impact on the nation's overall carbon footprint. So clearly, reducing global emissions is key. One promising path toward that goal is embracing electric mobility (e-mobility). India is committed to supporting electro vehicles (EVs). The target is to replace 30% of its transport sector with EVs by 2030. Even though electric vehicles (EVs) are becoming more common in our transportation system, they still come with a downside. These include limited travel ranges battery life cycles, energy management issues charging infrastructure challenges, & high costs. EVs are interesting because they run on batteries that get charged from renewable energy sources. They are not only easier to maintain but can moreover be cheaper to possess than standard cars after a few times. EVs are really SIX times more effective than Internal Combustion Motor (ICE) vehicles! So, in case more individuals begin utilizing EVs for ordinary transport, we may truly make a positive alter for our beautiful environment.

II. Related Work

FAHP builds upon the traditional AHP. It uses fuzzy logic to deal with unclear data that will help to people choose choices. This method really helps in many situations where we have to make decisions based many things, when those decisions depend upon personal opinions. talking about Electric vehicle adoption, FAHP can helps to divide and rank what important to customers, which help them to decide, guiding policy makers, and shaping the future of infrastructure. Various studies have found several factors that affect how people adopt EVs. This includes economic, environmental things and social issues.

Economic Factors: The cost to buy an EV, the money spent to keep it running, and government is pretty important. Zhang et al. (2020) did some with Fuzzy AHP. They wanted to see what matters most for customers when choosing. They figured out that getting subsidies for buying an EV and lower running costs help to get more people to choose EVs.

Environmental Factors: It will decrease the greenhouse gas emissions and air pollution is a biggest reason to people choose EVs. Wang et al. (2019) found out something interesting. If people care about the environment, they are more likely to go for EVs. Their study used Fuzzy AHP and showed that for some groups, the environmental benefits were way more important than any economic issues.

Technological Factors: Having places to charge the car, how good battery life is, and the performance of the vehicles also matters. Liu et al. (2021) looked into this with Fuzzy AHP and discovered something key: fast charging spots are the biggest game changer in encouraging folks to get EVs

Social Components: Social components like what society considers, too influences individuals choosing EVs. Chen et al. (2022) utilized Fluzzy AHP to burrow into social impacts. Their discoveries appear that in case society features a great see of EVs, it can truly offer assistance to speed up how rapidly individuals choose to embrace them [2]. The innovation category in electric vehicles includes components such as battery costs, distance, and charging time. Battery costs essentially impact EV buy costs, with higher costs people will not select the EVs (Brownstone et al., 2000). For occasion, the IEA (2011) detailed that an EV with a 30-kWh battery, advertising an 85-mile run, would take a toll $10,000 more than a comparable ICE vehicle The innovation category in electric vehicles includes components such as battery costs, distance, and charging time. Battery costs essentially impact EV buy costs, with higher costs people will not select the EVs (Brownstone et al., 2000). For occasion, the IEA (2011) detailed that an EV with a 30-kWh battery, advertising an 85-mile run, would take a toll $10,000 more than a comparable ICE vehicle [1]. Compared to gas-powered cars, electric vehicles (EVs) convey "speedy torque," empowering quick speeding up with an even Grunditz et al. [9] highlighted the part of speeding up execution in EVs, noticing that little BEVs can quicken from 0-100 km/h for 13 seconds, whereas bigger BEVs do the same for 10 seconds. Ponders by Skippon et al. [8] demonstrate that increasing speed could be a noteworthy calculate for EV customers, with Skippon et al. affirming this slant

within the UK advertise, and Zhang et al. finding comparative comes about in Japan. The components affecting businesses' appropriation of electronic markets (EMs) have been broadly talked about, with much of the inquire about centering on administration hypotheses and trade models. Some considers have looked into sensible employments, the part of EMs on the Web, and the structure of EMs. In any case, there has been constrained inquire about on the particular variables impacting EM appropriation by ventures and how these variables are weighted, especially utilizing the fluzzy explanatory various leveled prepare for such appraisals [5]. Explore has also considered access to an electric car as impacting motoring style and versatility patterns.
Steady with prior discoveries (e.g., Rolim et al., 2012), Brusque, Hugot, Regan, Labeye watched that people alter their driving fashion and every day schedules when utilizing BEVs. Whereas operational aptitudes like braking are rapidly adjusted, overseeing the constrained run takes longer, regularly requiring a reorganization of exercises and the arrangement of unused propensities, counting reconsidering mode choices for certain trips (Labeye et al., 2016) [7]. Madan et al. [11] performed classification of vehicles using computational intelligence methods and achieved a good performance. Evaluation of military vehicle classification was implemented in paper [12] using ML models. Paper [13] showed the the analysis of mental health using fuzzy techniques such as AHP and TOPSIS. Password security strength analysis and factors influencing them was implemented in [14]. Prediction of Schizophrenia disease was carried out using Fuzzy AHP and TOPSIS methods in paper [15].

III. METHODOLOGY

We used two fuzzy approaches to evaluate the factors influencing electric vehicle adoption.

- Analytical Hierarchy Process (AHP)
- FUZZY-AHP

A. AHP

AHP is a method of multi-criteria, that uses prioritization and criteria evaluation to organize and analyze complicated choices. The AHP framework is used by management specialists to facilitate corporate objectives and steer decision-making procedures. In this article, we define the AHP method, explain steps to use this approach.
Step 1: To develop a hierarchical framework, put a goal at the top, attributes as the second, and alternatives and the third.
Step 2: Matrix of pairwise comparisons A scale of relative importance is used in its preparation. It will assign relative weight to various qualities or standards for the objective.
Step 3: Normalize values in pairwise comparison matrix.
Step 4: Consistency Calculation:To find out if the calculated value is or is not consistent
Step 5: Determine the weighted sum and the weighted sum to criterion weight ratio.
Step 6: Calculate the consistency ratio.
Formula: Consistency Ratio (C.R) = C.I/R. I
C.I = Consistency Ratio
R.I = consistency index of randomly generated pairwise matrix.

B. Fuzzy AHP

Fuzzy AHP is an enhanced variant of the classical AHP which integrates the principles of fuzzy logic to address the uncertainty, ambiguity, and imprecision commonly encountered in human decision-making. By incorporating fuzzy logic, Fuzzy AHP enhances the ability to model subjective judgments more realistically, capturing the vagueness inherent in linguistic assessments. Fuzzy AHP offers a flexible and robust framework applicable to a wide range of complex decision-making situations. It provides a systematic, hierarchical approach that enables decision-makers to structure problems clearly while effectively handling the imprecise nature of human evaluations. The process typically involves the following steps:
Step 1: Hierarchy Construction - Develop a model that is hierarchical so that the ultimate goal is followed by relevant attributes or criteria, and the alternatives that are possible appear as the final level.
Step 2: Pairwise Comparison Matrix Formation - Construct pairwise comparison matrices based on fuzzy scale of relative importance to evaluate the significance of one element relative to another within each level of the hierarchy.
Step 3: Defuzzification - Convert the fuzzy comparison values into crisp scores through defuzzification methods, facilitating quantitative comparison and aggregation of judgments.

Step 4: Consistency Evaluation - Assess the consistency of the judgments to ensure the reliability of the comparisons and to validate the decision-making process.

IV. RESULTS

The results are obtained by multi criteria decision making techniques. The techniques are AHP and fuzzy AHP.

A. AHP

Here the data set consist 10 car brands and we use 5 criterias. The Consistency Index value of 0.05 shows a solid match to the random consistency index of 0.0556. This suggests that the judgment matrix is consistent. Now, about the largest eigenvalue or lambda value is 10.5. The eigenvector linked to this value is [0.045, 0.179, 0.247, 0.081, 0.045, 0.179, 0.122, 0.353, 0.247, 0.179]. If we take a closer look at the eigenvector values. the highest one is 0.353 (Porsche Tycan), marking it as the main factor here. On the other side, we have the lowest eigenvector value at 0.045 (Tesla Model S, Audi e-tron), which clearly shows it is the least influential factor in the data set. Based on the criteria weight we are assigning a rank:

TABLE I. AHP METHOD RANK

EV brands	Criteria	Rank
Porsche Taycan	0.353	1
Chevrolet Bolt EV	0.247	2
Kia Niro EV	0.247	2
Nissan Leaf	0.179	4
Hyundai Kona EV	0.179	4
Volkswagen ID.4	0.179	4
Ford Mustang Mach-E	0.122	7
BMW i3	0.081	8
Tesla Model S	0.045	8
Audi e-tron	0.045	9

B. Fuzzy AHP

In the final step the normalized values of all attributes are obtained. They are:

TABLE II. NORMALIZED VALUES

Sl no	Normalized values	EV brands
A1	0.048	Tesla model S
A2	0.183	Nissan Leaf
A3	0.250	Chervolet Bolt EV
A4	0.092	BMW i3
A5	0.048	Audi e-tron
A6	0.183	Hyndai Kona EV
A7	0.133	Ford Mustang Mach E
A8	0.357	Porshe Taycan
A9	0.250	Kia Niro EV
A10	0.183	Volswagen ID.4

It is similar to the AHP but fuzzy AHP providing best accuracy and consistency.

V. CONCLUSION

In this analysis, we used Analytic Hierarchy Process (AHP) to look at 10 electric vehicles. We checked them against five important criteria: price, range, charging time, performance, and safety features. By using a pair comparison matrix, we figured out the priority vectors for each vehicle. We also found their ranks and checked how consistent our judgments were throughout the whole process. and with Fuzzy AHP, we added in some different opinions into our evaluation. The results show that the Porsche Taycan comes out on top among the electric vehicles. It ranks high mainly because of its amazing performance and good overall features, even if it costs a bit more. The Chevrolet Bolt EV and Kia Niro EV also scored well, proving they rank because of its cheapness and performance. Both the Nissan Leaf and Hyundai Kona EV found decent spots in the rankings too, showing they have strong features in the market. On another note, the Tesla Model S and Audi e-tron did not do as well on the ranking list compared to others. This might mean that their higher prices are more than what you get from them.In this way of evaluating gives good vision into what each electric vehicle does best or where they might fall least. It checks both numbers and opinions. Using Fuzzy AHP helps us to understand things better by accounting for differences and subjectivity during comparisons. This detailed ranking can guide people to make good choices by giving a clearer view of how each vehicle measures up against key criteria.

REFERENCES

[1] S. Zayniddinov, S. Yuksel, and H. Dincer, “Overcoming critical barriers to electric vehicle development: A comparative analysis using Fuzzy DEMATEL and Fuzzy AHP,” J. Sustain. Develop. Issues, vol. 3, no. 1, pp. 14–21, 2025.

[2] S. Haustein and A. F. Jensen, “Factors of electric vehicle adoption: A comparison of conventional and electric car users based on an extended theory of planned behavior,” Int. J. Sustain. Transp., vol. 12, no. 7, pp. 484–496, 2018.

[3] G. H. Broadbent, D. Drozdzewski, and G. Metternicht, “Electric vehicle adoption: An analysis of best practice and pitfalls for policy making from experiences of Europe and the US,” Geography Compass, vol. 12, no. 2, p. e12358, 2018.

[4] J. Kester et al., “Policy mechanisms to accelerate electric vehicle adoption: A qualitative review from the Nordic region,” Renew. Sustain. Energy Rev., vol. 94, pp. 719–731, 2018.

[5] M. Featherman et al., “The impact of new technologies on consumers’ beliefs: Reducing the perceived risks of electric vehicle adoption,” Technol. Forecast. Soc. Change, vol. 169, p. 120847, 2021.

[6] P. Aungkulanon, W. Atthirawong, and P. Luangpaiboon, “Fuzzy analytical hierarchy process for strategic decision making in electric vehicle adoption,” Sustainability, vol. 15, no. 8, p. 7003, 2023.

[7] H. K. Upadhyay, M. Sharma, and R. K. Raj, “Exploration of critical factors in adoption of electrical vehicles in India using Fuzzy Analytic Hierarchy Process method,” in Proc. 2022 5th Int. Conf. Comput. Intell. Commun. Technol. (CCICT), pp. 474–481, 2022.

[8] P. Poongothai, C. D. Nandakumar, and R. Ponnusamy, “Decision-making for electric vehicle selection using AHP-MABAC-Fuzzy integration,” in Proc. 2023 Int. Conf. Data Sci., Agents & Artif. Intell. (ICDSAAI), pp. 1–5, 2023.

[9] A. K. Gupta, “Prioritizing barriers to reverse logistics of lithium-ion batteries in electric vehicles,” in Proc. 2023 IEEE Int. Conf. Ind. Eng. Eng. Manage. (IEEM), pp. 1563–1567, 2023.

[10] S. Hisoglu, A. Tuominen, and A. Huovila, “An approach for selecting optimal locations for electric vehicle solar charging stations,” IET Smart Cities, vol. 5, no. 2, pp. 123–134, 2023.

[11] S. Madan, K. Shetty, A. Kodipalli, T. Rao, and S. Kumaraswamy, “Emergency vs non-emergency vehicle classification: Enhancing intelligent traffic management systems,” in Proc. 2023 Int. Conf. Netw., Multimedia Inf. Technol. (NMITCON), pp. 1–6, 2023.

[12] T. Rao, S. Agarwal, and N. Singh, “Empirical evaluation of Shapley additive explanations: A military implication,” in Proc. 2023 10th IEEE Uttar Pradesh Sect. Int. Conf. Elect., Electron. Comput. Eng. (UPCON), vol. 10, pp. 1390–1397, 2023.

[13] C. Uttarkar, C. B. Arun, M. Anusha, M. Khushi, A. Kodipalli, and T. Rao, “Analysis of mental health of a young adult: Post COVID using Fuzzy TOPSIS & Fuzzy AHP,” in Proc. 2023 4th IEEE Global Conf. Adv. Technol. (GCAT), pp. 1–7, 2023.

[14] A. Kumar, A. Kodipall, A. Rao, T. Soma, B. Gargi, and N. Garagi, “Enhancing password security: Fuzzy AHP and TOPSIS-based vulnerability assessment,” in Proc. 2024 IEEE Int. Conf. Convergence Technol. (I2CT), pp. 1–6, 2024.

[15] R. Anoop, I. Anand, M. Rehan, R. Yashvanth, A. Kodipalli, T. Rao, and S. Kamal, “Prediction of schizophrenia in patients using Fuzzy AHP and TOPSIS methods,” in Proc. Int. Conf. Mach. Learn., IoT Big Data, pp. 517–527, Singapore: Springer, 2023.