A novel hybrid Fuzzy AHP-TOPSIS Approach towards Enhanced multi-criteria Feature-based EV Recommender System

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Introduction

Importance and Current Challenges

EVs have gained immense attention in recent years due to their numerous advantages as a green alternative. Four-wheeler EVs are often expensive and not affordable by many people, but a high demand for two-wheeler EVs is being witnessed in the Indian market segment.

Due to the novelty of the technology, many buyers in emerging EV markets lack a clear understanding of EV selection compared to their fuel-based equivalents, which have been on the market for decades. Therefore, customers often face difficulties in selecting models for purchase. Moreover, multiple features in EV models further make it challenging to develop appropriate criteria for building a recommendation system. Thus, there is a present need for a robust recommendation system that can rank the best alternative EV.

Previous methods and limitations

- Previous work on electric vehicle selection is primarily based on government incentives, improved infrastructure, and global warming. (Brady et al., Langbroek at al., Sierzchula et al., Vidhi et al.)

(-) The literature lacks an in-depth recommendation system model designed for two-wheeled electric vehicle models explicitly targeting the Indian electric vehicle market segment.

- Integrated AHP-MABAC approach for electric vehicles classification was proposed recently. (Sonar and Kulkarni)

(-) But focus mainly on expensive four-wheelers rather than cost-effective two-wheelers.

- Other decision-making approaches have utilized various decision making models for a variety of problems, including, in q-rung otho pair fuzzy set, etc. (Wang et al.)

(-) There is a comprehensive need to develop decision-making models to aid the customer in selecting electric vehicles, primarily for two-wheelers.

Brady et al., “Travel to work in dublin. the potential impacts of electric vehicles on climate change and urban air quality,” Transportation Research Part D: Transport and Environment, 2011.
Langbroek et al., “The effect of policy incentives on electric vehicle adoption,” Energy Policy, vol. 94, pp. 94–103, 2016.
Sierzchula et al., “Influence of financial incentives and other socio-economic factors on electric vehicle adoption,” Energy Policy, 2014.
Vidhi et al., “A review of EV lifecycle emissions and policy recommendations to increase ev penetration in india,” Energies, 2018.
Sonar and Kulkarni, “An integrated ahp-mabac approach for electric vehicle selection,” Research in Transportation Business & Management, 2021.
J. Wang et al., “Mabac method for multiple attribute group decision making under q-rung orthopair fuzzy environment,” Defence Technology, 2020.

Introduction

Our Contributions

The present work is the first to propose a fuzzy- TOPSIS based recommender system for two-wheeler EVs, explicitly targeting the Indian market segment.

Evaluates which of the current two-wheeler EV in the Indian market may be the best option. Multi-criteria based decision-making approach is followed, wherein the Cost, Driving Range, Power, Charging time, top speed, and the battery capacity of the electric vehicles are input as features. The proposed model is tested on 8 different electric vehicle models.

Can aid low-performing EVs in determining their benchmarks. Since organizations invest heavily in EVs, this study would assist decision-makers by assessing prospective consumer preferences before launching new EVs.

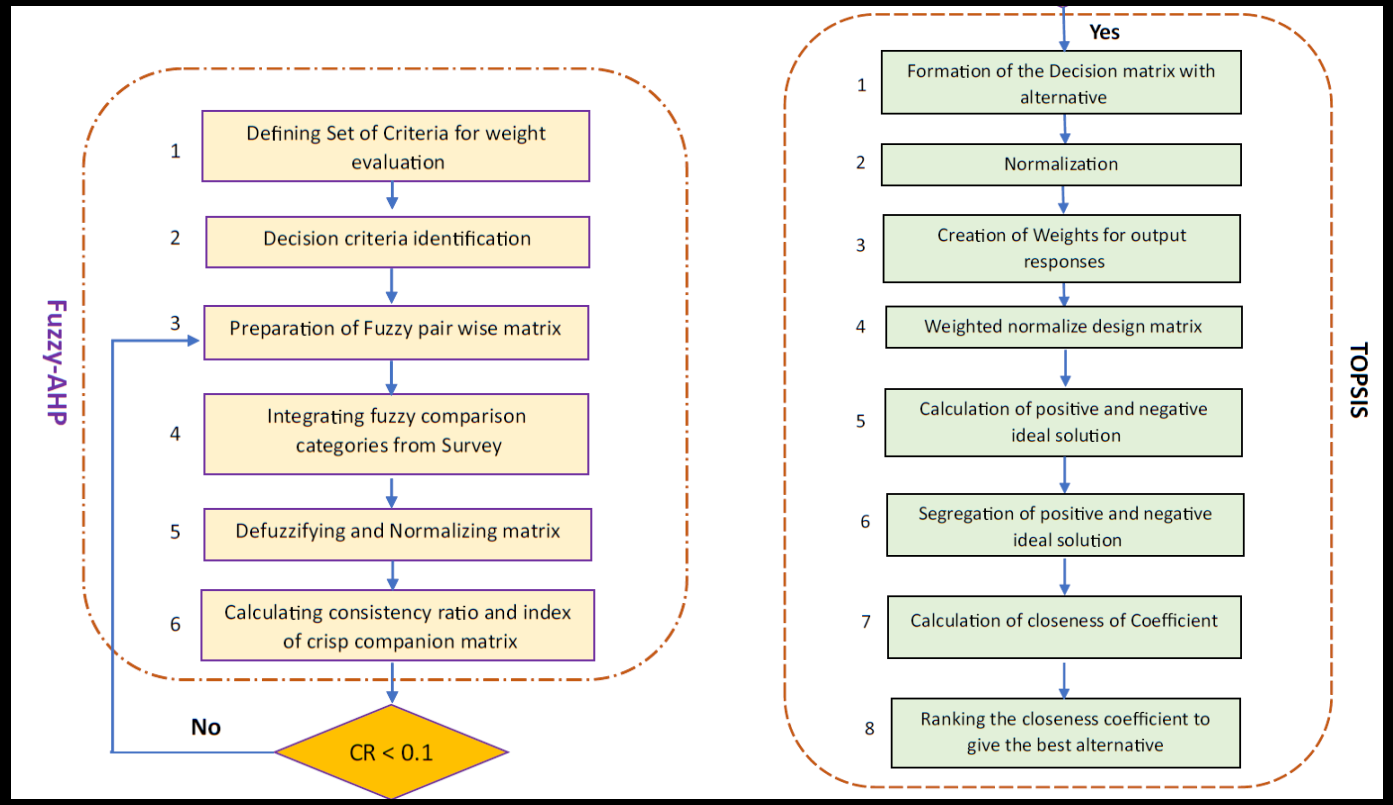
Proposed Approach

In the first phase, the selection criteria were identified from the literature and the expert's opinion, later the respondents were asked to rate the criteria according to their relative importance in selecting an EV. The profile of the respondents is shown in Table 01.

TABLE I: Profile of the Respondents

Feature	No. of Respondents	Percentage (%)
Gender		
Male	20	67
Female	10	33
Age		
Below 25 years	2	7
25-35 years	15	50
45-55 years	10	33
Above 55 years	3	10
Qualification		
Graduate	8	27
Ph.D.	14	47
Professional	8	27
Work Experience		
$<$ 2 years	4	13
2-5 years	10	33
5-10 years	10	33
$>$ 10 years	6	20

Model Flowchart



Working flowchart of hybrid Fuzzy-AHP TOPSIS model developed for the enhanced multi-criteria feature-based recommendation of two-wheeled electric vehicles (EVs), specifically targeting the Indian market segment.

TABLE II: Linguistic variable and equivalent Numerical Crisp values and TFNs

Linguistic Value	TFNs
Equally important	(1, 1, 1)
Equally important to moderately more important	(1, 2, 3)
Moderately more important	(1, 3, 5)
Moderately more important to strongly more important	(3, 4, 5)
Strongly more important	(3, 5, 7)
Strongly to very strongly more important	(5, 6, 7)
Very Strongly more important	(5, 7, 9)
Very Strongly to extremely more important	(7, 8, 9)
Extremely more important	(7, 9, 9)

Model Flowchart

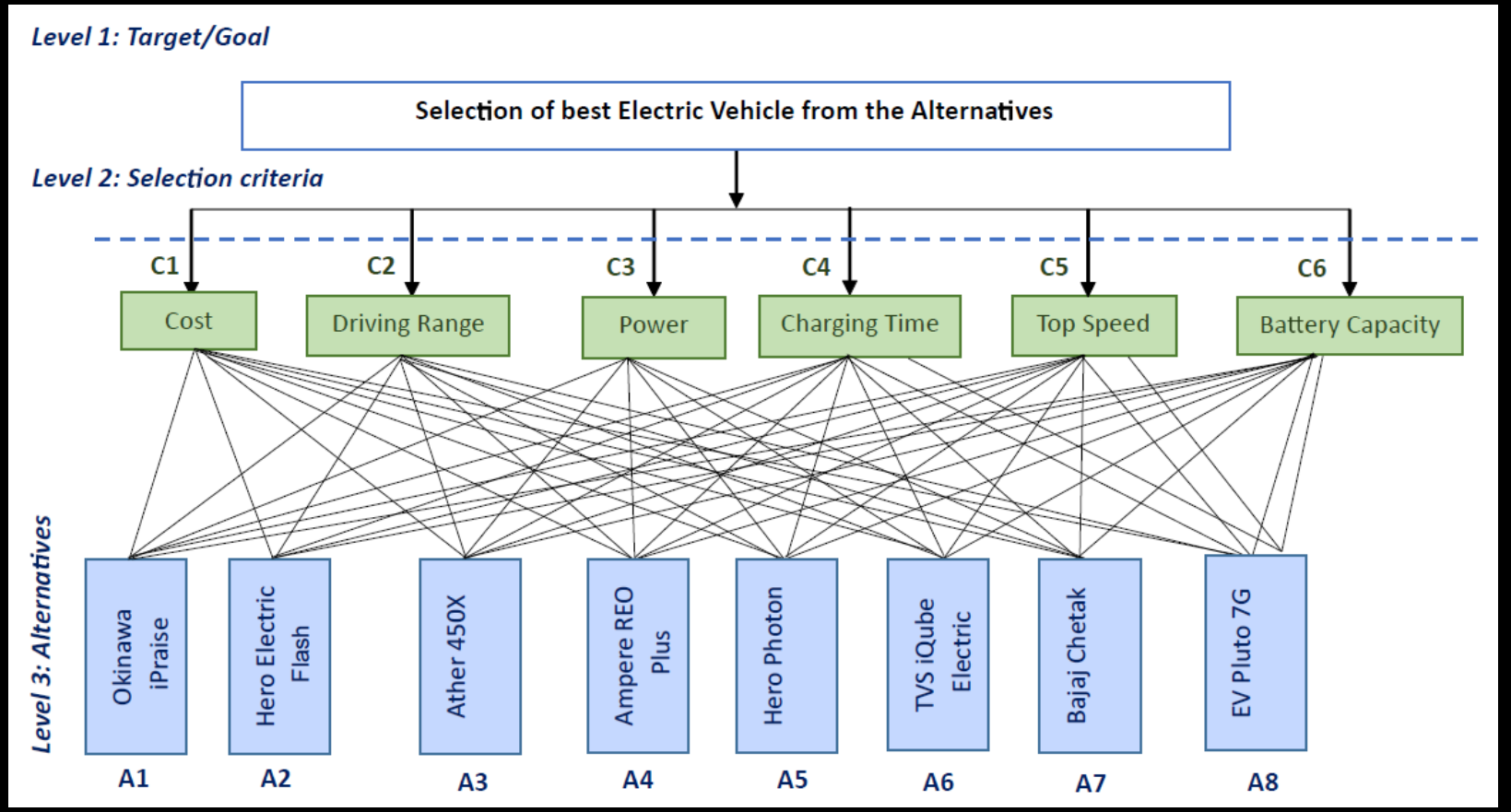


Illustration of the developed Hierarchy model. In the figure, A1 to A8 represent the alternatives, while C1 to C6 represent the criteria of the multi-criteria feature based recommendation system

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Results Obtained

TABLE III: Random Index

Matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

TABLE IV: Defuzzified Matrix

	Cost	Power	Top Speed Speed	Battery Capacity	Charging time	Driving Range
Cost	1.00	3.00	6.00	8.00	4.00	2.00
Power	0.42	1.00	5.00	6.00	3.00	0.56
Top Speed	0.17	0.21	1.00	2.00	0.42	0.17
Battery Capacity	0.13	0.17	0.56	1.00	0.26	0.13
Charging Time	0.26	0.42	3.00	4.00	1.00	0.21
Driving Range	0.56	2.00	6.00	7.00	5.00	1.00

TABLE V: Normalized Matrix

	Cost	Power	Top Speed Speed	Battery Capacity	Charging time	Driving Range	Weighted Sum	Criteria Weight	
Cost	0.33	0.61	0.29	0.24	0.41	0.58	2.45	0.33	7.501033651
Power	0.14	0.20	0.24	0.18	0.31	0.16	1.23	0.20	6.100446721
Top Speed	0.06	0.04	0.05	0.06	0.04	0.05	0.30	0.05	6.099531803
Battery Capacity	0.04	0.03	0.03	0.03	0.03	0.04	0.20	0.30	6.650072881
Charging Time	0.08	0.08	0.15	0.12	0.10	0.06	0.60	0.10	5.813188585
Driving Range	0.18	0.40	0.29	0.21	0.51	0.29	1.89	0.29	6.515345853
								λ_{max}	6.446603249
								CI	0.08932065
								CR	0.072032782

Results Obtained

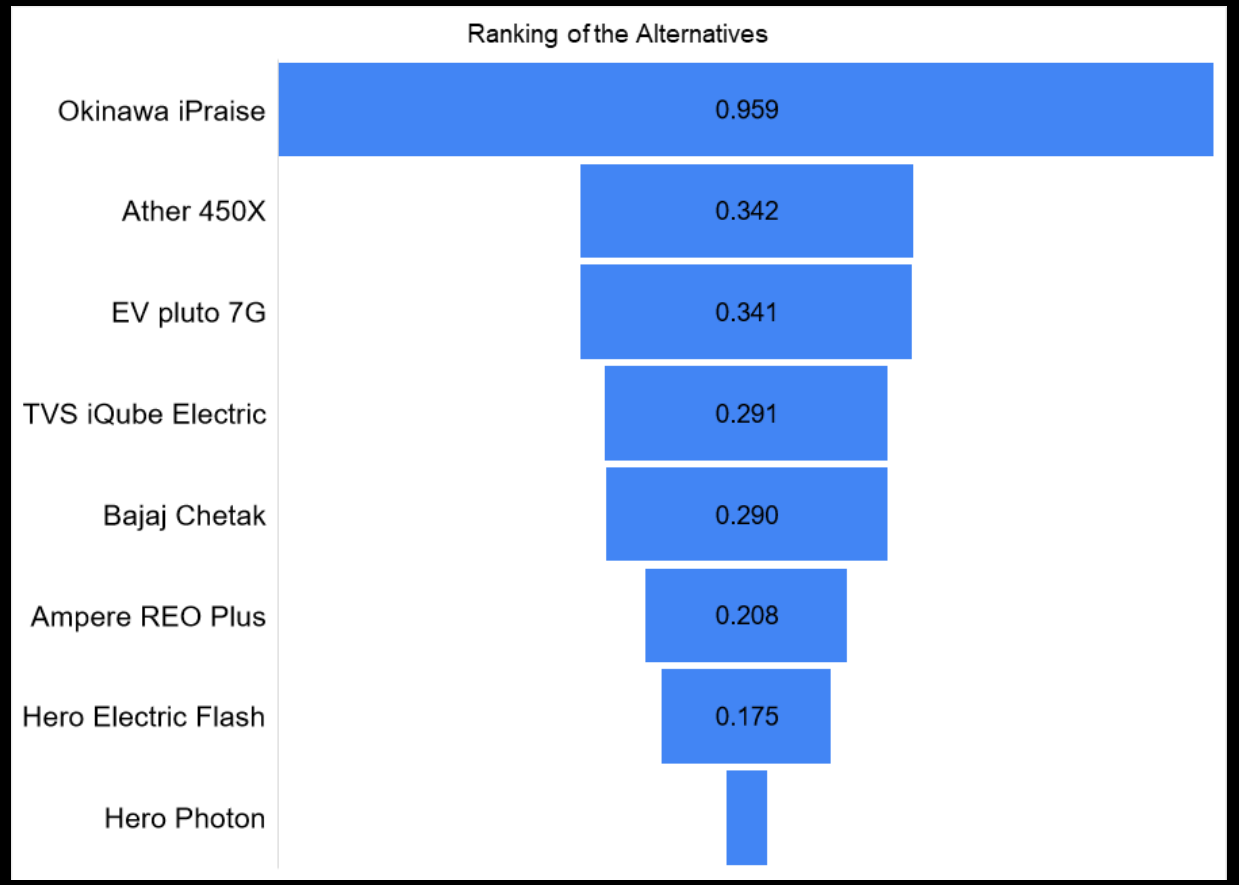
TABLE VI: Input Values for TOPSIS

Criteria	Weight (Ws)	Okinawa iPraise (A1)	Hero Electric Flash (A2)	Ather 450X (A3)	Ampre REO (A4)	Hero Photon (A5)	TVS iQube Electric (A6)	Bajaj Chetak (A7)	EV Pluto 7G (A8)
Cost (C1)	0.327	99.708	56.94	144.5	56.19	79.94	102	114.369	83.7
Driving Range (C2)	0.290	139	85	85	60	108	75	95	120
Power (C3)	0.202	2.5	0.25	6	1.2	1.8	4.4	3.8	2.2
Charging Time (C4)	0.103	5	5	4	6	5	4.3	5	4
Top Speed (C5)	0.049	58	42	80	25	45	78	70	60
Battery Capacity (C6)	0.030	3.3	1.34	2.61	1.15	1.89	2.25	3	2.5

TABLE VII: Normalized Matrix for TOPSIS

Criteria	A1	A2	A3	A4	A5	A6	A7	A8		A+	A-
C1	0.119796	0.068412	0.173612	0.067511	0.096045	0.12255	0.137411	0.100563	-	0.06751054	0.173612
C2	0.144243	0.088206	0.088206	0.062263	0.112074	0.077829	0.098583	0.124526	+	0.144242921	0.062263
C3	0.054488	0.005449	0.130771	0.026154	0.039231	0.095899	0.082822	0.04795	+	0.130771367	0.005449
C4	0.037622	1.830679	1.464543	1.757452	2.196815	1.574384	1.574384	1.464543	-	0.037622381	2.196815
C5	0.016753	0.012132	0.023108	0.007221	0.012998	0.02253	0.020219	0.0173311	+	0.023107885	0.007221
C6	0.014576	0.005919	0.011528	0.00508	0.008384	0.009938	0.13251	0.011043	+	0.01457621	0.00508

Comparison and Results



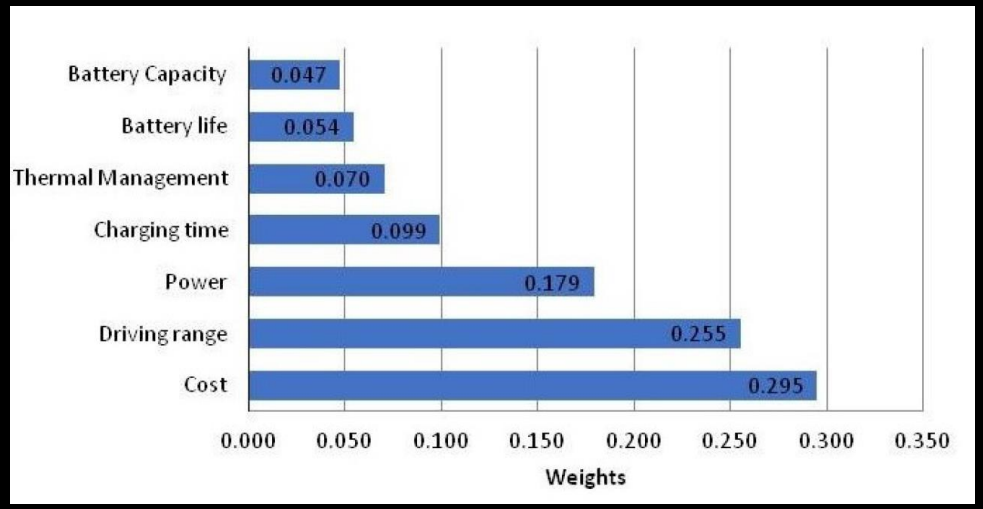
Relative Ranking of the Alternatives (A1-A8)

Practical Implications

The outcomes of this study provides a deep insight to the customers and the decision-makers to select the best alternative among the available two-wheeled EVs. In the Indian market, there are many alternatives for two-wheeler electric vehicles that it can be difficult for buyers to choose the most suited vehicle. This research would help the organizations and industries to overcome the competitive pressure of manufacturing the most customer friendly EV.

TABLE VIII: Ranking of two-wheeler EV model alternatives

Two-Wheeler EV Model Alternatives	Si	Ranking
Okinawa iPraise	0.959	1
Ather 450X	0.342	2
EV Pluto 7G	0.341	3
TVS iQube Electric	0.291	4
Bajaj Chetak	0.290	5
Ampere REO Plus	0.208	6
Hero Electric Flash	0.175	7
Hero Photon	0.044	8



Criteria (C1-C6) taken corresponding to EV

Conclusion

Key findings

- The combined Fuzzy AHP-TOPSIS technique was found to be an effective technique in identifying the best electric vehicle.
- A total of six criteria were identified based on the literature and expert's opinions to select an electric vehicle.
- Okinawa iPraise was found to be the best alternative according to this study.

Future work

- In future work, a comparative analysis could be done considering the alternatives globally.
- Another motivation of the study is to discretize it to the different states of India, the choices and criteria in states varying according to the geological conditions, government policies and public demands. This will affect the value of weights, and thus the ranking of the alternatives. Discretization will make the study flexible and according to the needs of the customers.
- Also, future work may also focus on making the study robust is to expand the size of respondents overseas. This will provide more precise results.