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ORIGINAL RESEARCH

Examining the causal factors of the electric vehicle adoption: a pathway to tackle climate change in resource-constrained environment

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Abstract
Electric vehicles (EVs) serve an important role in lowering greenhouse gas emissions, which helps to mitigate global warming while also contributing to long-term growth. Thus, this research explores various criterions relevant to electric vehicle (EVs) adoption and causal relationships using the decision-making trial and evaluation laboratory (DEMATEL) method. From the comprehensive literature review, a set of criteria for EVs adoption were identified and are finalised through the Delphi method. The data was gathered from eleven experts and was analyzed using the DEMATEL method to develop the causal relationship between each criterion. The sensitivity analysis was performed to check the robustness of the model. The findings revealed that the key criteria for EV adoption include their causal relationships. It is observed that charging time, driving range and price are the most important criteria for an EV purchase. Battery capacities have a major and influential impact on other criteria like charging time, torque, driving range, and maximum power. Professionals and managers in the EV manufacturing industry can benefit from this prioritization of criteria by understanding the causal relationships between them. This study can also serve as guidance for EV engineers when it comes to implementing client preferences into vehicle design. It can also assist low-performing electric vehicles in determining their benchmarks. This work contributes to building an improved understanding of causal factors of electric vehicle adoption in resource-constrained environments for policy making.

Keywords Electric vehicles · DEMATEL · Climate change · Delphi · MCDM

1 Introduction

Many serious environmental issues have resulted from global warming and climate change, including severe and frequent fires and floods, excessive rainfall and strong hurricanes (Song et al., 2022b). The sustainable means of covering economic, environmental, and social issues

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along with new design requirements are important for evolving operations systems (Das et al., 2021a; Li et al., 2022). Transportation is the largest contributor to greenhouse gas emissions that are causing the global climate change (Hung et al., 2021a). The transportation sector is undergoing fundamental improvements that may help to reduce emissions (Srivastava et al., 2022). The past century has shown how Toyota, General Motors, Ford Motors, BMWs have dramatically changed their operations strategy decision areas and performance. Those organizations that do not keep up with the strategic innovations in products, operations management are bound to fail. Natural gas, methanol, ethanol, biodiesel are examples of alternative fuels that can be used to replace gasoline or fossil fuels (Bhat et al., 2022). As a result, taking efforts to reduce harmful carbon emissions appears to be important.

Adoption of alternative fuel vehicles, such as electric vehicles (EVs), is widely regarded as a viable approach to reduce carbon emissions and accelerate the transportation sector's low-carbon transition (Chen & Fan, 2020; Zhang & Zhao, 2021; Tripathy et al., 2022; Song et al., 2022a). Electric vehicles (EVs) are a critical component in achieving global climate change targets (Chapman, 2007; Yagcitekin et al., 2015; Vidhi & Shrivastava, 2018; Feng & Magee, 2020; Wei & Dou, 2023). Adopting electric vehicles is feasible now and might contribute significantly to fulfilling climate change mitigation targets. Most of the researchers (Anjos et al., 2020; Kumar et al., 2020; Nolz et al., 2022) started understanding the role of EVs in addressing the global climate change problem. As is being talked about, fossil fuels are getting exhausted in 2030, hence there is a need to look at sustainable means of transportation (Digalwar & Giridhar, 2015; Kumar et al., 2015; Sonar & Kulkarni, 2021). Electrical vehicles look to be one of the best alternatives at this stage. The strategic supply chain action right at the beginning is needed for Electric Vehicle in comparison to the Internal Combustion Engine based vehicle is needed for the sustainability of this innovation (Heredia et al., 2020; Liu et al., 2020). Many government agencies are now pushing the use of electric vehicles by enacting regulations, incentives, and subsidies aimed at lowering CO2 emissions.

The majority of the researchers (Franzò & Nasca, 2021; Hung et al., 2021b; Quddus et al., 2021; Sadati et al., 2022) conducted experiments and concluded that electric vehicles can help reduce greenhouse gas emissions in numerous areas. Mitigation of greenhouse gas emissions not only lowers the likelihood of climate change but also lowers air pollution, which benefits natural ecosystems by reducing fossil fuel usage (Pamučar & Ćirović, 2015; Egnér & Trosvik, 2018; Deuten et al., 2020; Jaiswal et al., 2021;). Due to the rapid growth of the global electric vehicle market, a variety of EV models with a variety of notable characteristics have emerged to meet the escalating demand of customers. The majority of automobile manufacturers started producing EVs with various innovative features (Das and Bhat, 2022). Customer preferences for EVs selection including driving range, price, charging time, battery capacity, electric motor type, torque, etc. were measured by Das et al. (2019). Biswas and Das (2019) studied EV adoption by identifying different criterions using fuzzy-AHP and MABAC analysis.

Recent studies have attempted to understand the role of electric vehicles in combating climate change on a global scale. Before aggressively rushing toward the future with EV acceptance, Henderson (2020) advised that sectoral research on EVs are required. Alhindawi et al. (2020) looked at five distinct electric vehicle (EV) scenarios based on a switch from gasoline to electric batteries. According to the study, electric vehicles help to reduce CO2 emissions in the transportation sector. Higueras-Castillo et al. (2021) determined the variables that predict EV purchase from computational intelligence algorithm. An agent-based model is developed by Shafiei et al. (2012) to compare dominance of EVs over IC engine vehicles. Recently, Zhang and Zhao (2021) developed analytical model to analyse RVG strategy towards Ev adoption and supply chain performance. Climate change mitigation efficiency has been evaluated by Li et al. (2022) with respect to EV charging infrastructure in China. However, EVs must be re-evaluated in various environments and regions. Despite the significance of EV studies to mitigate climate change issues, there is still a research gaps in evaluating the cause-effect relationship between important criteria for EV adoption which has not been explored in the literature.

There has been many studies (Pamučar and Ćirović, 2015; Wu et al., 2017; Asadi et al., 2022) which have used DEMATEL approach for EV adoption. However, systematic approach for identifying important criteria for adoption of electric vehicles using Delphi method and to develop cause-effect relationship has not been discussed in the literature. Many of the past academic literature does not focuses on EV adoption through the operations research (OR) lens and lacks the testable frameworks build on the sub-discipline of OR. Nevertheless, unless the associated concepts are implemented, none of the proposed questions from past literature can be properly answered for EV adoption to tackle the climate change issues. Therefore, to fill this research gap, a systematic approach is required for managers to prioritize and develop the causal relationship between important criteria. This study focuses on the identification of essential criteria for EV adoption and developing a causal relationship between them using the DEMATEL method. The research questions discussed in this study are shown below:

Question 1 What are the important criteria for the successful adoption of electric vehicles?

Question 2 What are the cause and effect relationships among these criteria?

Question 3 What are the different priority levels of each criterion?

In this work, several criterions affecting the performance of electric vehicles are shortlisted from past academic literature and are validated through Delphi method. The DEMATEL approach has been used to rank the drivers and analyze the causal relationship between all criteria. This method employs inputs from the experts to provide structural model of the of the system. As a result, it not only provides a mechanism to visualise the causal relationships of criteria via an impact-relationship map, but also illustrates the degree to which the criteria influence one another. It primarily assesses the degree of interaction between two system components to provide quantitative understanding of the complex relationships that underpin a problem. DEMATEL can offer likely outcomes with minimal data, which is one of its key advantages over other methodologies. Matrix or digraphs illustrate the contextual relationship between the system's components, while numerals show the impact strength.

The novelty of this work lies in the development of the causal relationship between EV adoption criteria. The work presented in this paper tackled the management problems from a broader point of view including a new perspective of EV adoption. This study is based in India to motivate the managers of EV manufacturing industries to focus on important criteria for EV selection to boost market efficiency and profitability. The data was collected from industry experts and the results revealed that charging time, driving range and price are the most important criteria for an EV purchase in India. All the criteria are classified into cause and effect groups. The sensitivity analysis was performed to check the robustness of the model. To summarize, we believe the methodology presented in this work shows conclusively that OR methods are successful in practice and make a strong contribution in the OR field.

This work contributes by employing a decision-support tool to provide real preferences of customers for EV adoption. Because many manufacturers are investing heavily in electric vehicles, this study would also aid manufacturers by studying probable customer preferences. The remaining part is organized as follows. Section 2 continues with motivation for this study. Research methodology has been discussed in Sect. 3 followed by results and discussion in Sect. 4. Finally, Sect. 5 provides the conclusion and future research avenues.

2 Literature review

Several efforts have been made in the literature to identify crucial barriers towards electric vehicles adoption. However, these barriers are too generic and having too many factors are not useful in practice. In this section, we describe the process of literature search to identify potential barriers for EV adoption in India. A systematic literature review (SLR) has been employed to identify the body of literature on EV adoption across the globe.

Initially, most widely accepted databases like Scopus, Web of Science and Pro-Quest are used to give a high level of rigour and identify relevant literature on the field of study. To identify the relevant literature and adoption barriers of electric vehicles, keywords including "electric vehicle", "sustainable transportation", "barriers", and "adoption" are used in the search field (refer Table 1). The articles were searched in title, abstract and keywords of the publications. This search has been inspired by many similar articles like Hohenstein et al. (2014); Durach et al. (2015); Wong et al. (2015); and Mohamad Mokhtar et al. (2019). To ensure high quality, book and book chapters, conference proceedings, doctoral thesis, white papers, editorial notes are eliminated from the dataset. The articles published in English language only are considered for review.

The initial search is resulted in identification of 806 articles from Scopus, Web of Science and ProQuest databases (Refer Table 1). The articles with incomplete bibliographic data points and irrelevant articles were removed from the dataset leading to a set of 354 articles. In the next stage, 225 articles were removed due to clearly inappropriate category and beyond the scope of the topic. Remaining 129 articles were independently reviewed by two authors by abstract reading and theme matching. This phase has removed 79 articles. Therefore, our final sample contains 50 articles selected for final review. The summary of articles is provided in Appendix A.

The dynamics of electric vehicles (EVs) market have been studied by many researchers (Kumar and Alok, 2020; Tarei et al., 2021; Das and Bhat, 2022) in various geographical locations, identifying significant barriers towards adoption of EVs. Tarei et al. (2021) have ranked and prioritized barriers towards EV adoption using best-worst and ISM method. Shortage of charging infrastructure, cost of ownership, performance and range are identified as major barriers in EV adoption. Barriers to consumer adoption of EVs has been studied by Egbue and Long (2012) considering the attributes such as battery life, driving range and cost. Recently, Kucukvar et al. (2022) performed the empirical analysis of environ-

Table 1 Search protocol

Search String	Scopus	Web of Science	ProQuest
Search Field	Title, abstract, keywords	Title, abstract, keywords	Anywhere except full text
((TITLE-ABS-KEY (“electric vehicle”) OR TITLE-ABS-KEY (“sustainable transportation”))) AND ((TITLE-ABS-KEY (“adoption”) OR TITLE-ABS-KEY (“barriers”))) AND (LIMIT-TO (DOCTYPE , “ar”)) AND (LIMIT-TO (LANGUAGE , “English”)) AND (LIMIT-TO (SRCTYPE , "j"))	1128	1037	268
Articles after duplicate removal		806	
Articles after incomplete bibliographic data points		354	
Inappropriate articles		225	
Independently reviewed articles by abstract reading		129	
Final set of articles		50	

mental efficiency of EVs across 27 European countries. It is observed from the results that Finland and Netherland are most environment efficient countries who adopted EVs due to high shares of renewable electricity sources. Ziegler and Abdelkafi (2022) in their studies discussed each business models available in past literature on diffusion of electric vehicles and identified the potential future research directions. Inconvenient charging concerns have hampered the adoption of electric vehicles. The use of blockchain technology to enhance the EV charging services have been studied by Fu et al. (2021) by adopting multi-agent based model. Recently, rising government attention and concentration on private-public partnerships to improve the electric vehicle ecosystem in India. In order to comply with international norms and expand e-mobility in the wake of rising urbanisation, the Indian government has launched a number of efforts to promote the manufacturing and usage of electric vehicles in India.

With India’s BS6 standards set to take effect in April 2020, electric vehicles will be more cost-competitive with conventionally powered vehicles, boosting the country’s electric vehicle sales (Sonar & Kulkarni, 2021). Given India’s established automotive manufacturing industry, rising transportation demand, and current interest in electric vehicles, the country has the potential to develop a local EV industry and become a global EV manufacturing leader. Nowadays, much of the literature focuses on various aspects of EV adoption including a selection of Li-Ion batteries (Loganathan et al., 2020), electric car incentive scenarios (Deuten et al., 2020), smart charging for EVs (Heredia et al., 2020), electric mobility (Zarazua de Rubens et al., 2020), EV lifecycle emission (Vidhi & Shrivastava, 2018), policy incentives for EV (Langbroek et al., 2016), strategy for EV penetration (Digalwar & Giridhar, 2015; Kumar et al., 2015; Sonar & Kulkarni, 2021), and socioeconomic factors for EV adoption (Sierzchula et al., 2014). Recently, Jaiswal et al. (2021) empirically tested the role of EVs knowledge for consumer adoption using the technology acceptance model (TAM). It is observed that EV’s knowledge drives consumer adoption. Feng and Magee (2020) decomposed the EVs into four domains including electric motor, battery, power electronics, and charging and discharging subdomains.

Despite the significant literature on electric vehicle adoption by Brady and O’Mahony (2011); Langbroek et al. (2016); Vidhi and Shrivastava (2018), many of the studies focused on government subsidies and incentives, infrastructural requirements, and climate change. Biswas and Das (2019) studied EV adoption by identifying different criterions using fuzzy-AHP and MABAC analysis. However, the cause-effect relationship between important criteria for EV adoption has not been explored in the literature. As a result, a systematic approach is required for managers to prioritize and develop the causal relationship between important criteria. This study focuses on the identification of essential criteria for EV adoption and developing a causal relationship between them using the DEMATEL method.

3 Research methodology

In this study, the EV selection criterions were demonstrated using two phase hybrid research methodology. In the first phase, a list of EV selection criterions has been identified from the previous literature and analyzed with one round of Delphi study to finalize important criterions. Expert comments from the Delphi study were used to refine the list even more. The second phase incorporated the DEMATEL method to develop causal relationship between them. The complete roadmap of research methodology is shown in Fig. 1.

3.1 Phase 1: Delphi method

The Delphi method is a structured, iterative process that includes anonymous assessments and systematic improvement to obtain a collective view from experts from many fields (Linstone & Turoff, 1975). The Delphi Method was established to eliminate the negative effects of expert influence caused in face-to-face discussions. The Delphi Method is used to emphasise expert viewpoints that are similar and to uncover areas of consensus on specific themes. Many of the previous researchers (Kalantari & Khoshalhan, 2018; Emovon et al., 2018; Hashemi et al., 2022;; Tripathy et al., 2022) have used Delphi method. The list of criterions was discussed with the experts in the first round of Delphi. The data was gathered during March-April 2022. The criterions were validated with the support of domain experts.

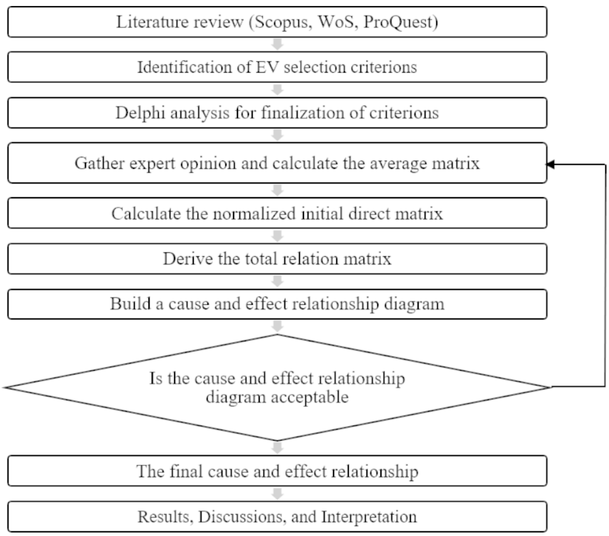


Fig. 1 Roadmap of research methodology

The experts were primarily academicians and professional background who purchased EVs in recent past. A total of 11 experts participated in our study from the Maharashtra state. Many of the studies used 10 to 15 experts in Delphi method (Ahmad et al., 2022; Liang et al., 2022; Sharma et al., 2021; Trivedi et al., 2021). Thus 11 is adequate number of experts for this study. The questionnaire was circulated among each expert, and they were panel of experts answered all questions. The consensus is reached after first round of study. These responses were coded to finalize the 10 criterions for the further analysis. A list of each criterion for EV selection is shown in Fig. 2.

3.2 Phase 2: DEMATEL method

In this work, a DEMATEL method has been employed to identify the cause-effect relationship between the recognized criteria. This method emerged from the Geneva Research centre from Battelle Memorial Institute to develop a cause and effect relationship of the factors (Nimawat & Gidwani, 2021). As a systemic approach, each criterion is linked with each other directly or indirectly, therefore it is essential to determine the influence of each criterion on other criteria for a decision-making process to prioritize the criteria (Tzeng et al., 2007). Many of the methods such as AHP, best-worst method, TOPSIS, VIKOR, and DEA do not consider the interrelation between criteria, whereas the DEMATEL method develops the causal relationship between the barriers. Most of the researchers (Kamble et al., 2020; Luthra et al., 2020; Parmar & Desai, 2020; Li et al., 2020; Yadav et al., 2021; Pinto et al., 2022) applied this methodology in different application areas.

This study is based in India which is an emerging nation focusing on sustainability aspects. The aim is to motivate the managers of EV manufacturing industries to focus on important criteria for EV selection to boost market efficiency and profitability. This work aims to identify important criteria for EV adoption and develop the causal relationship between them. From extensive literature review and discussions with industry experts, 10 criteria have been identified.

For this study, a group of eleven experts consisted of eight experts who already purchased electric vehicles and three experts are willing to purchase an electric vehicle. This work employed a non-probabilistic sampling method for expert selection. All experts have good knowledge about EV adoption. All experts were contacted by email and telephone to

Fig. 2 Criteria for EV selection

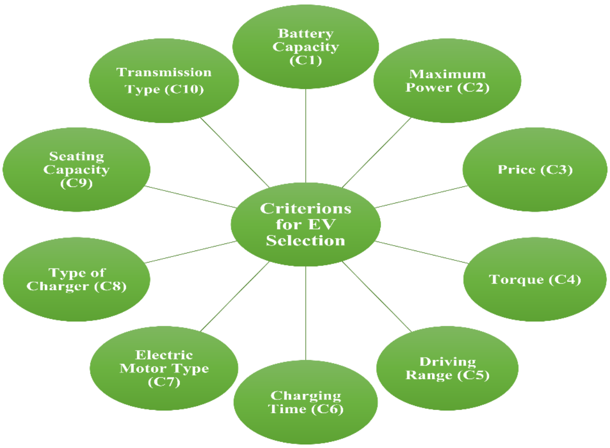


Table 2 Scale of comparison for the DEMATEL approach

Number	Definition
0	No impact
1	Low impact
2	Medium impact
3	High impact
4	Very high impact

Table 3 Direct-relation matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	0	2	3	3	3	4	1	2	3	1
C2	2	0	2	2	4	1	1	3	2	1
C3	2	3	0	3	1	4	1	1	1	2
C4	1	3	3	0	3	2	1	1	2	3
C5	2	2	2	4	0	4	2	1	1	2
C6	3	2	4	1	1	0	2	2	2	1
C7	1	1	2	1	3	3	0	3	1	2
C8	2	2	1	1	3	2	1	0	4	2
C9	1	2	1	1	2	4	3	3	0	1
C10	2	2	3	4	1	2	1	3	2	0

participate in this study. Agarwal et al. (2021); and Nimawat and Gidwani (2021) conducted empirical research using the DEMATEL method using five experts for data collection that were treated as adequate expert's numbers. The expert profiles are summarized in Appendix B. The authors developed a questionnaire for a direct relationship matrix. The data was collected from all eleven experts each indicator's relative relevance matrix, which we used to evaluate each criterion. The relationship between identified barriers has been assessed using an integer scale ranging from 0 to 4 as shown in Table 2.

Based on Tzeng et al. (2007); Gupta and Barua (2018); Agrawal et al. (2020); Kamble et al. (2020);Jaiswal et al. (2021); Nimawat and Gidwani (2021); and, steps involved in DEMATEL are summarized in brief as follows.

3.2.1 Step 1: generating direct relation matrix

The direct relation matrix is determined by using expert opinion shown in Table 3.

$$A = [a_{ij}]_{nxn}$$

$$[a_{ij}]_{nxn} = \frac{1}{H}\sum_{K=1}^{H}\left[a_{ij}^{k}\right]_{nxn} \quad \mathrm{i,j} = 1, 2, \ldots, \mathrm{n} \tag{1}$$

Where, a_{ij} = judgment of the decision-makers

H = no of experts.

Table 4 Normalized matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	0.0000	0.0909	0.1364	0.1364	0.1364	0.1818	0.0455	0.0909	0.1364	0.0455
C2	0.0909	0.0000	0.0909	0.0909	0.1818	0.0455	0.0455	0.1364	0.0909	0.0455
C3	0.0909	0.1364	0.0000	0.1364	0.0455	0.1818	0.0455	0.0455	0.0455	0.0909
C4	0.0455	0.1364	0.1364	0.0000	0.1364	0.0909	0.0455	0.0455	0.0909	0.1364
C5	0.0909	0.0909	0.0909	0.1818	0.0000	0.1818	0.0909	0.0455	0.0455	0.0909
C6	0.1364	0.0909	0.1818	0.0455	0.0455	0.0000	0.0909	0.0909	0.0909	0.0455
C7	0.0455	0.0455	0.0909	0.0455	0.1364	0.1364	0.0000	0.1364	0.0455	0.0909
C8	0.0909	0.0909	0.0455	0.0455	0.1364	0.0909	0.0455	0.0000	0.1818	0.0909
C9	0.0455	0.0909	0.0455	0.0455	0.0909	0.1818	0.1364	0.1364	0.0000	0.0455
C10	0.0909	0.0909	0.1364	0.1818	0.0455	0.0909	0.0455	0.1364	0.0909	0.0000

Table 5 Total relation Matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	D
C1	0.5200	0.6856	0.7807	0.7290	0.7461	0.9433	0.4670	0.6457	0.6761	0.5130	6.7065
C2	0.5169	0.5035	0.6281	0.6005	0.6912	0.7049	0.3965	0.5926	0.5515	0.4405	5.6262
C3	0.5189	0.6242	0.5576	0.6301	0.5689	0.8024	0.3903	0.5175	0.5091	0.4732	5.5922
C4	0.4998	0.6494	0.6982	0.5447	0.6687	0.7657	0.4102	0.5416	0.5649	0.5340	5.8772
C5	0.5606	0.6366	0.6980	0.7215	0.5758	0.8720	0.4657	0.5625	0.5529	0.5176	6.1632
C6	0.5531	0.5822	0.7039	0.5505	0.5670	0.6557	0.4298	0.5548	0.5462	0.4316	5.5748
C7	0.4564	0.5148	0.6008	0.5262	0.6115	0.7367	0.3301	0.5668	0.4836	0.4539	5.2808
C8	0.5151	0.5812	0.5884	0.5539	0.6466	0.7409	0.4017	0.4791	0.6268	0.4706	5.6043
C9	0.4715	0.5678	0.5814	0.5320	0.5991	0.7960	0.4695	0.5912	0.4577	0.4258	5.4920
C10	0.5563	0.6382	0.7234	0.7182	0.6233	0.7954	0.4244	0.6387	0.5984	0.4345	6.1508
R	5.1686	5.9835	6.5605	6.1066	6.2982	7.8130	4.1852	5.6905	5.5672	4.6947	

3.2.2 Step 2: formation of normalized matrix

The direct-relation matrix is then converted into a normalized direct relation matrix using the formula. Table 4 shows the normalized matrix. The direct relation matrix is then converted into normalized direct relation matrix X using the formula,

$$X = \frac{A}{s} \tag{2}$$

Where, $s = \left(\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij} \right)$

3.2.3 Step 3: formation of total relation matrix

Followed by the normalized matrix, the total relation matrix is calculated by using MATLAB software. The total relation matrix is given in Table 5. The total relation matrix T is determined by as follows,

$$T = X + X^2 + X^3 + \ldots + X^h = X(I - X)^{-1}, \text{when h} \to \infty \tag{3}$$

Table 6 Inter-relation matrix

No.	Criteria	D	R	D-R	D+R	Rank	Group
C1	Battery Capacity	6.7065	5.1686	1.5379	11.8751	5	Cause
C2	Maximum Power	5.6262	5.9835	-0.3573	11.6097	6	Effect
C3	Price	5.5922	6.5605	-0.9683	12.1527	3	Effect
C4	Torque	5.8772	6.1066	-0.2294	11.9838	4	Effect
C5	Driving Range	6.1632	6.2982	-0.1350	12.4614	2	Effect
C6	Charging Time	5.5748	7.8130	-2.2382	13.3878	1	Effect
C7	Electric Motor Type	5.2808	4.1852	1.0956	9.4660	10	Cause
C8	Type of Charger	5.6043	5.6905	-0.0862	11.2948	7	Effect
C9	Seating Capacity	5.4920	5.5672	-0.0752	11.0592	8	Effect
C10	Transmission Type	6.1508	4.6947	1.4561	10.8455	9	Cause

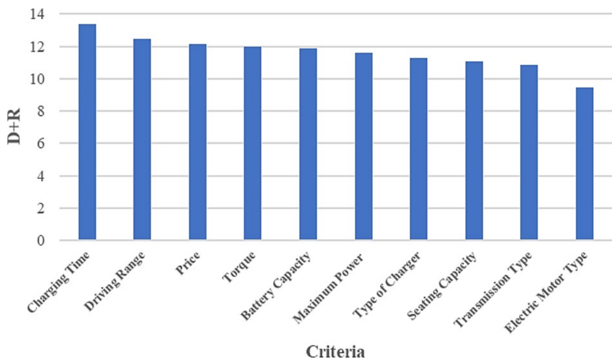


Fig. 3 Degree of significance for each criterion

3.2.4 Step 4: summation of rows and columns

The D and R values are calculated to get the cause-and-effect relationship among the barriers of SSCM. (D+R) and (D-R) values are evaluated based on Table 6 to get an idea about the importance of each factor. The values of D and R are calculated as follows,

$$T = [t_{ij}]_{nxn}, \ \mathrm{i,j=1,2,\ldots,n} \tag{4}$$

$$D = \left[\sum\nolimits_{j=1}^{n} t_{ij}\right]_{nx1} = [t_i]_{nx1} \tag{5}$$

$$R = \left[\sum\nolimits_{i=1}^{n} t_{ij}\right]_{1xn} = [t_j]_{nx1} \tag{6}$$

Where D and R values represent the total sum of rows and columns of the total relation matrix,$T = [t_{ij}]_{nxn}$

The inter-relation matrix has been developed to evaluate the relationship between identified barriers as shown in Table 6. The D and R-values are calculated to get the cause-and-effect relationship among the criteria of EV adoption. The degree of significance for each criterion is shown in Fig. 3. Table 6 also shows the degree of total influence of each criterion.

3.2.5 Step 5: draw a cause-effect diagram

The cause and effect diagram is plotted on the x and y-axis using the values of D+R and D-R respectively to evaluate the key criteria as shown in Fig. 4.

4 Results and discussions

This work aims to examine the causal relationship between various criteria for EV adoption. To identify causal relationships, the DEMATEL method was employed, and the data were collected from experts to form a direct relationship matrix. According to degree of significance (D+R) values as shown in Fig. 3, the priority ranking based on the importance are "Charging Time (C6)" (13.3878), "Driving Range (C5)" (12.4614), "Price (C3)" (12.1527), "Torque (C4)" (11.9838), "Battery Capacity (C1)" (11.8751), "Maximum Power (C2)" (11.6097), "Type of Charger (C8)" (11.2948), "Seating Capacity (C9)" (11.0592), "Transmission Type (C10)" (10.8455), "Electric Motor Type (C7)" (9.4660). Based on the D+R values, Charging time (C6) is the most important criterion having the highest D+R value (13.3878) and electric motor type (C7) is the least important criterion having the least D+R values (9.4660).

Remarkably, three criterions "Battery Capacity (C1)" (1.5379), "Transmission Type (C10)" (1.4561), "Electric Motor Type (C7)" (1.0956) were listed in the cause group category based on D-R values. These results are also aligned with the past academic literature by (Digalwar & Giridhar, (2015; Egbue & Long, (2012; Egnér & Trosvik, (2018; Sonar & Kulkarni, (2021). Battery capacity has the highest D-R value (1.5379). Biswas and Das (2019) also revealed that battery capacity is a crucial criterion in the selection of electric vehicles. Experts are also agreed that battery capacity and electric motor type are seen as one of the most important criteria for the charging time, torque, and driving range of any EV.

Additionally, effect group barriers are indicated by a negative D-R value. Seven criterions "Maximum Power (C2)" (-0.3573), "Price (C3)" (-0.9683), "Torque (C4)" (-0.2294), "Driving Range (C5)" (-0.1350), "Charging Time (C6)" (-2.2382), "Type of Charger (C8)" (-0.0862), and "Seating Capacity (C9)" (-0.0752) are identified as effect group criterions. These criteria were affected by other cause group criteria. Charging time (C6) is the most affected criteria by all other criteria. The result also shows that purchasers are given more importance to the charging time and driving range which is placed at rank 1 and rank 2

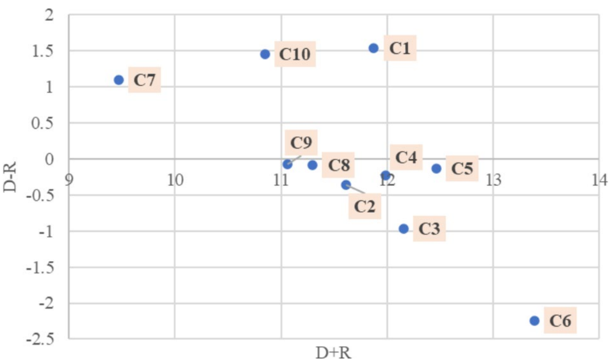


Fig. 4 Cause-effect diagram

respectively with the highest D+R value. This is followed by the price of the vehicles. Customers nowadays are more interested in the vehicle's driving range at a particular battery capacity. Customers are less concerned about seating capacity, transmission type, and electric motor type when making vehicle purchases, and these criteria carry less weight.

Considering the cause and effect diagram (Fig. 4), battery capacity (C1) has the maximum effect on other criteria. This ensures that battery capacity has a major and influential impact on other criteria like charging time, torque, driving range, and maximum power. Manufacturers investing in the development of electric vehicles must consider customer inclinations for buying electric vehicles and create infrastructure accordingly to optimize a few parameters. Charging networks, especially the fast-charging stations are limited. Wireless Battery charging would be the breakthrough solution for the mass acceptance of EVs. The acceptability of EVs would go up when high-powered wireless is used for charging the vehicles in the chosen pickup and drop-off parking places. The charging parks for private taxis could be developed on similar lines to keep vehicles charged. There could be multiple charging plates for automatic changing installed underground to engage with the vehicle automatically. Original Equipment Manufacturers could come out with a seamless charging infrastructure so that customers get some kind of comfort level during driving.

The driving range is coming out to be the second option. Customers will need to have EVs with a much higher range. Current Internal combustion (IC) Engine cars have more than 1000 km range. Customers are looking for a similar range in Electric vehicles. The price of the vehicle has the third rank. Price has a direct linkage with the type of battery. Currently, Lithium – ion-based batteries are being used for driving electric vehicles, however, other cheaper technologies are likely to be available in the future. Research by auto manufacturers and battery technology start-ups is showing the potential for other more efficient, long-range high-power density battery technologies in the future. Current lithium-based batteries are expensive and hence proportionately EV costs are high. One alternative material which is making buzz for the battery is sodium. The manufacturers are looking forward to sodium-based batteries going ahead. Whereas lithium is scarce and is concentrated in a specific part of the world, sodium is available in ample quantity, 1200 times more than lithium. Having availability in all parts of the world makes it favorable material in the battery cell. Furthermore, batteries based on sodium-ion are lighter compared to lithium-based batteries. Since sodium-ion batteries will be more cost-efficient they will bring down the cost of EVs. Manufacturers and government organizations would profit from this, as it would help them understand the need of embracing electric vehicles and become the worldwide market leader in the EV business. The flow of influence for both cause and effect group criteria is shown in Fig. 5. Also, summary of findings on EV adoption decision criteria is highlighted in Table 7.

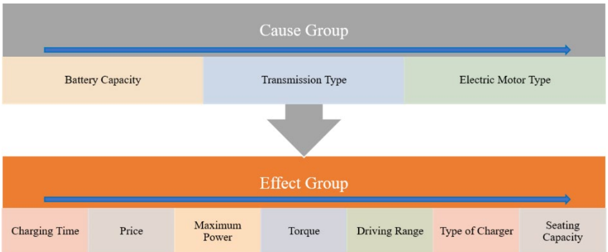


Fig. 5 Cause and effect criterions

Table 7 Summary of findings on EV adoption decision criteria

Author	Findings from existing literature	Findings from this work
Asadi et al. (2022)	The study revealed that environmental concerns and trust to EVs are most important criteria for EV adoption in Malaysia.	Our study revealed that charging time and driving range are the most important criterions for EV adoption in India. In addition, battery capacity has a major and influential impact on other criterions.
Das and Bhat (2022)	This study used case study approach and found that lack of policy and technology availability for disposal and reprocessing of batteries is a major challenge for EV adoption in India.	This study does not consider policy level challenges and other perspectives of EV adoption like disposal and reprocessing of batteries, resale value, subsidies available, and energy consumption.
Bhat et al. (2022)	This study found that environmental as well as technological enthusiasm is positively related with EV adoption.	Customers nowadays are more interested in the vehicle's driving range at a particular battery capacity. From technological enthusiasm perspective, companies must focus on optimizing few parameters which would be the breakthrough solution for the mass acceptance of EVs.
Higueras-Castillo et al. (2021)	The result shows that driving range and incentives are most reliable factors for adopting EVs.	This study also identified that driving range is an important aspect before purchasing any electric vehicle. High power, more density battery technologies are coming in the near future for long driving range.
Tarei et al. (2021)	This study found that driving range and performance are critically influential for driving EV adoption.	Our study also found the same results that driving range is most important towards adoption of EVs specially in India. Chen and Fan (2020) in their work suggested improvement strategies for battery driving range in an EV.
Kumar and Alok (2020)	This study revealed many interesting insights on EV adoption such as dealership experience, charging infrastructure resilience, and marketing strategies.	This study considered only technical parameters for EV adoption however other factors may be considered in future which may lead to mass acceptance of EVs.

The work presented in this paper tackled the management problems from a broader point of view including a new perspective of EV adoption. To summarize, we believe the methodology presented in this work shows conclusively that OR methods are successful in practice and make a strong contribution in the OR field. Many of the past academic literature does not focuses on EV adoption through the OR lens and lacks the testable frameworks build on the sub-discipline of OR. There are many options available, all resulting from changing OR. Nevertheless, unless the associated concepts are implemented, none of the proposed questions can be properly answered for EV adoption to tackle the climate change issues.

Throughout the past 40 years, fresh approaches and procedures have been created to address complex issues or "messes" (Mingers, 2011). They are organised and strict, but not mathematical which includes DEMATEL, ISM, SEM, SD Modelling, qualitative system dynamics, the viable systems model etc. Collectively they are known as Soft OR. Soft OR focuses on the practices and the problems to be solved to ensure the utility of the solution and its real-world applicability (Vidoni, 2022). The techniques used in this study clearly contribute to the new and well recognized branch of OR (i.e., soft OR). Other techniques including interpretive structural modelling (ISM), system dynamic (SD) modelling, structural equation modelling (SEM) and other such techniques also clearly contribute to the OR field to develop a testable framework. Even yet, as systems engineering did throughout its history in OR, this study still need to be carefully and regularly assessed by academics and practitioners.

4.1 Sensitivity analysis

Sensitivity analysis is used to check the robustness of the model for respondent bias (P. Kumar et al., 2021). This is accomplished by giving one respondent a different weight while keeping the weight of the other respondent constant. In scenario 1, each expert was given identical weights, whereas, in the other situations, one expert was given larger weights while the other remained the same. Calculations were carried out for a variety of scenarios. The net cause-effect values for all scenarios are presented in Table 8 below. It is observed from Figs. 6 and 7 that no major change was found in each scenario except for only slight deviations. All of the results appear to be quite consistent, thus it's possible to assume that the respondent assessments are accurate, and there was no respondent bias in this study.

4.2 Theoretical implications

Many governments throughout the world are encouraging people to switch to electric vehicles in order to reduce greenhouse gas emissions and reliance on fossil fuels, and the inclusion of electric vehicles in a country's transportation strategy demonstrating their growing relevance. Despite several advantages, EV adoption is challenging in most of the countries. Much of the extant literature started researching on EV penetration and challenges in different geographical locations. The study focusing on important barriers of EV adoption and developing interrelationships between them has not received much attention specially in India. Our research addresses the limitations by past academic literature such as Asadi et al. (2021); P. K. Das and Bhat (2022); Ziegler and Abdelkafi (2022).

Government plays a crucial role in promoting EV adoption by developing proper charging infrastructure, subsidising the tax regimes, and policy evaluation for long term sustainability. Several governments have taken different approaches to promote the adoption of EV around the world, depending on things like regional economic development, government political priorities, and technological innovation. As a result, each country and region needs a unique context-based study that takes into account the market dynamics and consumer trends. This work would benefit organizations, researchers, and government to reforms various policies and measures for effective strategy formation. Researchers will be benefited by applying different methodologies on the similar barriers in different geographical locations. This work contributes to building an improved understanding of causal factors of electric vehicle adoption in resource-constrained environments for policy making. This work will help academicians and scholars to improve the understanding of EV adoption to pursue sustainability benefits it offers for society.

4.3 Practical implications

This work contributes by employing a decision-support tool to provide real preferences of customers for EV adoption. Because many manufacturers are investing heavily in electric vehicles, this study would also aid manufacturers by studying probable customer preferences. In the case of Electric Vehicle as the development and manufacturing costs are high it has to be shared by suppliers for de-risking. For part manufacturers, to plan for economy of scale, the cost of manufacturing has to be lowered. This work will help practitioners to focus on important criteria according to customer preferences. For electric auto manufactur-

Table 8 Net cause-effect values from sensitivity analysis

No.	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 9	
	D-R	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**	**D-R**	**D+R**
C1	1.538	11.875	1.542	11.851	1.531	11.904	1.515	11.887	1.522	12.034	1.513	11.961	1.578	11.798	1.602	12.045	1.517	11.815
C2	-0.357	11.610	-0.368	11.791	-0.394	11.684	-0.322	11.506	-0.335	11.647	-0.342	11.812	-0.384	11.598	-0.394	11.687	-0.396	11.657
C3	-0.968	12.153	-0.951	12.137	-0.950	12.214	-0.955	12.194	-0.940	12.203	-0.955	12.289	-0.994	12.455	-0.935	12.234	-1.061	12.215
C4	-0.229	11.984	-0.231	11.957	-0.216	12.064	-0.205	11.894	-0.200	12.135	-0.235	11.912	-0.289	12.146	-0.269	12.187	-0.265	11.924
C5	-0.135	12.461	-0.142	12.514	-0.158	12.547	-0.142	12.394	-0.129	12.534	-0.158	12.354	-0.174	12.035	-0.181	12.428	-0.161	12.514
C6	-2.238	13.388	-2.210	13.413	-2.221	13.351	-2.154	13.294	-2.215	13.396	-2.295	13.287	-2.514	13.398	-2.345	13.258	-2.265	13.245
C7	1.096	9.466	1.189	9.491	1.008	9.413	1.106	9.406	1.106	9.531	1.072	9.396	1.126	9.524	1.015	9.415	1.099	9.269
C8	-0.086	11.295	-0.089	11.310	-0.090	11.365	-0.084	11.269	-0.089	11.351	-0.095	11.214	-0.089	11.365	-0.096	11.397	-0.096	11.346
C9	-0.075	11.059	-0.075	11.091	-0.078	11.105	-0.072	11.067	-0.072	11.134	-0.084	10.997	-0.079	11.159	-0.089	11.154	-0.078	11.106
C10	1.456	10.846	1.491	10.981	1.446	10.974	1.499	10.943	1.415	10.897	1.514	10.856	1.465	10.964	1.481	10.924	1.502	10.897

ers, aggregate modules like Battery, Motor, Software need to be sourced by modules common sources as is done in electronic sourcing. This study can also serve as guidance for EV engineers when it comes to implementing client preferences into vehicle design. It can also assist low-performing electric vehicles in determining their benchmarks. This work would help them to formulate different strategies for long-term competitive advantage among their rivals. Management should develop a comprehensive action plan for improving critical criteria. Senior management should support the investment and resources that are necessary for implementing EVs to ensure long-term sustainability. This work would have several policy implications also. Government decision-making, rules, subsidies, and evaluation of national policies for business sustainability all play a key role in the development and adoption of electric vehicles. Policymakers should reform various performance measure criteria to maintain economic growth. To encourage EV adoption in the country, national and local governments should focus on subsidies and various incentive schemes.

5 Conclusions

Most buyers are still having trouble deciding which of the available electric vehicles is the best option based on available selection criteria. The purpose of this work is to prioritize important criteria for EV adoption and develop the causal relationship between them. A total of ten important criteria have been identified from the past academic literature and are validated via Delphi method. The DEMATEL approach has been employed to develop a causal relationship. The data was gathered from eleven experts. Prioritization has been done using D+R values. Criteria with higher D+R value ranked 1 and so on. Results revealed that charging time, driving range and price are the most important criteria for an EV purchase. All the criteria are classified into cause and effect groups. The sensitivity analysis was performed to check the robustness of the model. The novelty of this work lies in the development of the causal relationship between EV adoption criteria using the DEMATEL method. Professionals and managers in the EV manufacturing industry can benefit from this prioritization of criteria by understanding the causal relationships between them. The research outcome was discussed with the experts and no further improvements were suggested.

This work has some limitations also. The present study results are not generalized across the country. This work includes eleven experts to develop a direct relation matrix however additional experts may provide a distinct perspective on important criteria for EV adoption. OR scholars may conduct empirical validation using grey-DEMATEL, best-worst method, analytic network process, or structural equation modeling approach. There is a need to study technology adoption of EV through the OR lens for quick decision making. Additionally, experts from different regions of India may be considered for the generalization of findings (Kore & Koul, 2022). Additionally, life cycle assessment of electric vehicles needs to be studied from different aspects. OR scholars may get a new insight by comparing the EV adoption beers between developed and developing countries.

Fig. 6 Sensitivity analysis of D-R values

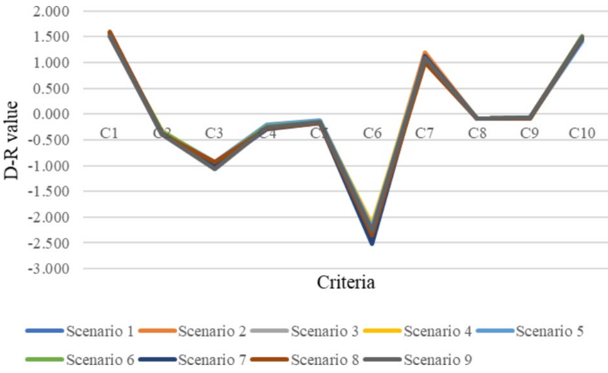
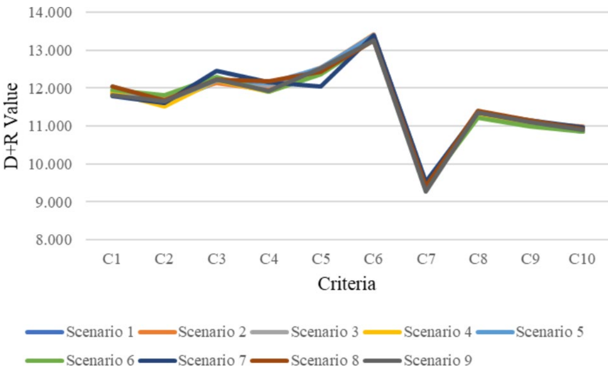


Fig. 7 Sensitivity analysis of D+R values



Appendix A: summary of articles

Author	Findings
Biswas and Biswas (1999)	The conclusions of a study on the market potential of electric vehicle (EV) technologies in India are the basis for this report. According to the report, electric vehicles are currently a more natural alternative in emerging countries such as India than in industrialized countries. Given the existing status of the environment and the warm climate.
Maini (2005)	This study traces the development of the tiny car from concept to commercialization, highlighting the problems encountered along the way considering the REVA electric company case.
Brady and O'Mahony (2011)	This study analysed 2010 emissions as well as expected emissions under three EV market penetration scenarios and a BAU scenario for 2020. In every area of their emissions, our research reveals that the adoption of EVs has an advantage over the BAU case.
Egbue and Long (2012)	This study identified the potential socio-technical impediments to consumer adoption of electric vehicles and to see if consumer concerns about sustainability impact their decision to buy one. Survey findings reveal that, while EV sustainability and environmental benefits are important, they are ranked after cost and performance in terms of EV adoption.
Miao et al. (2014)	Based on surveys conducted in Shanghai, China, this research first designs a multi-scale model for customer perceived value measurement of electric vehicle. The impact-relations map (IRM) is then used to evaluate the importance of each scale and illustrate the internal relations among different scales using the decision-making trial and evaluation laboratory approach.

Author	Findings
Sierzchula et al. (2014)	The study tries to determine the relationship between consumer financial incentive to electric vehicle adoption. Linear regression analysis was used and financial incentives, charging infrastructure, and the availability of local production facilities to be significant and positively correlated to a country's electric car market share by the model.
Kumar et al. (2015)	This paper attempts to increase the cost advantage of electric vehicle by exploring vehicle to home scheme and implementing battery management system algorithm.
Muneer et al. (2015)	An experimental evaluation of an electric vehicle was carried out in this study. One of the most important aspects to investigate is the source of the required electricity for electric vehicles since this will determine their level of sustainability.
Yagcitekin et al. (2015)	The evaluation of the environmentally friendly operation of electrically driven vehicles, as well as the analysis of different penetration ratios of electrically driven vehicles in energy and investment requirements, as well as environmental variables, are the key contributions of this work.
Digalwar and Giridhar (2015)	With the use of an Interpretive Structural Model, the current article addresses the most important variables for the promotion and development of the EV industry in India (ISM). Awareness, government commitment and financial constraints are identified as important factors.
Naor et al. (2015)	The study examines infrastructure product/service design advances, as well as multi-stage organizational dissemination tactics for electric vehicles, to address both functional (use, value, and risk) and psychological (tradition and image) hurdles to mass-market adoption.
Langbroek et al. (2016)	This study investigates the policy incentives on electric vehicle adoption and socio-psychological factors, which is focused on a state choice experiment, using factors given by Transtheoretical Model of Change and the Protection Motivation Theory.
Vassileva and Campillo (2016)	The influence of widespread adoption of electric vehicles on current power distribution systems is examined in this work. After understanding the early adopter of technology and also examining the effect of alternative electric vehicle penetration on power grid, the conclusions given in this study gives crucial insights for ensuring a sustainable large-scale penetration of electric vehicles.
Wu et al. (2017)	The HF-DEMATEL and HF-VIKOR are used in this study to incorporate the HF-DEMATEL and HF-VIKOR into the QFD process for determining the priority of Engineering characteristics in a hesitant fuzzy environment of electric vehicle.
Javid and Nejat (2017)	The current study looked into probable factors that could be linked to purchasing plug in electric vehicles in order to evaluate plug in electric vehicles penetration in 58 California counties using a Multiple Logistic Regression Analysis.
Zhang et al. (2018)	The Electric Vehicle Routing Problem (EVRP) is introduced in this study, along with the mathematical model that goes with it. The EVRP aims to reduce the amount of energy used by electric vehicles. The EVRP model provides a detailed calculation of energy usage for electric vehicles.
Egnér and Trosvik (2018)	The impact of municipal policy instruments aimed to promote the adoption of electric vehicles is investigated in this study. Swedish municipalities data from 2010 to 2016 was used for newly registered battery vehicle. The findings also imply that government procurement of battery electric vehicles has the potential to be a useful policy tool.
Vidhi and Shrivastava (2018)	This article looks at the many stages of an electric vehicle's (EV) life cycle, their impact on environmental emissions, and policy recommendations for various socio-economic groups in the Indian market.
Das et al. (2019)	This study identifies the finest electric car model in the Asian market, allowing an EV buyer's needs to be met. The fuzzy analytic hierarchy technique was utilized to calculate the weight of the criterion, while mixed data evaluation was employed for performance evaluation and ranking.
Biswas and Saha (2019)	The paper proposes a holistic model for selecting and ranking a group of battery electric vehicles (BEVs) using the multi-attributive border approximation area comparison (MABAC) method, which takes into account a variety of technical and operational characteristics such as fuel economy, base model pricing, quick acceleration time, battery range, and top speed.

Author	Findings
Biswas and Das (2019)	The purpose of this study is to determine whether factors, such as kerb weight, mileage, top speed, fuel tank capacity, and price, have a significant effect in working women's scooter purchasing decisions. The relative weights of the criteria were obtained using the fuzzy-AHP method, and the alternatives were evaluated using updated MCDM.
Erdem and Koç (2019)	This study investigates a variation of the home health care routing problem in which a group of health care workers uses electric vehicles to complete a specified number of tasks. This study considers a multi-depot, heterogeneous fleet, time windows, preferences, competencies, connected activities, the range of electric vehicles, charging status, and charging strategies.
Loganathan et al. (2020)	In this research, an MCDM-based methodology weighted sum model for categorizing Li-ion batteries into cathode/anode material types is proposed. The strategy can help electric vehicle OEMs (Original Equipment Manufacturers) choose the optimum battery and optimize the cost and performance of their vehicles.
Zhen et al. (2020)	This study offers a novel research of the hybrid electric vehicle mode selection routing problem formulated by mixed integer linear programming model.
Zarazua de Rubens et al., (2020)	The challenges of electric vehicles are examined in this paper, with a focus on their current and future commercial consequences. Semi structured interview was conducted. The condition and monopoly of petrol and diesel automobile industries, as well as condition of national market, show that EVs today confront an unfavourable business case.
Heredia et al. (2020)	This work is based on the benefits of EV charge scheduling should be examined in terms of installation costs, operating costs, implementation difficulty, and grid flexibility.
Feng and Magee (2020)	To gain a better knowledge of the technology innovation in electric vehicles, author investigated the improvement rate, technology trajectories, and major assignees for EV domains and subdomains. Main findings are the predicted annual performance increase rates for power electronics are 18.3%, 7.7% for electric motors, 23.8% for charging and discharging, and 11.7% for batteries.
Deuten et al. (2020)	In this study, the PTTMAM system dynamics model was updated to include latest information on incentives in the Netherlands and Norway, which is the global leader in the electric car market when measured in sales market share.
Liu et al. (2020)	This paper compared the Toyota Mirai HFCEV's well to wheels energy use and emissions to those of the Mazda 3 conventional ICEV, using two sets of data on specific fuel consumption: (1) EPA's window-sticker FE and (2) fuel consumption data measured at Argonne. The well on wheels results reveal that an HFCEV emits 5-33% less well on wheels fossil-energy use and 15-45% less WTW GHG emissions than a gasoline conventional ICEV, even when powered by H2 via a fossil-based production pathway (through SMR of natural gas).
Fang et al. (2020)	The demand for charging stations is continuously increasing due to the rapidly growing market share of electric vehicles. The effects of legislative incentives and consumer preferences are examined to support the installation of electric vehicle charging infrastructures in this paper. The findings demonstrate the benefits of a well-balanced dynamic subsidy and taxation policy for the development of electric charging infrastructure.
Kabli et al. (2020)	Author describes a two-stage stochastic programming approach in this research which is used to establish a power grid expansion plan which helps in getting the energy needs, or load, from an unpredictable collection of electric vehicles scattered throughout a region.
Kumar and Alok (2020)	Through an integrative review methodology, this work attempts to review 239 articles from top journals that were compiled using a protocol for extensive review. It includes identifying variables in five categories: antecedents, mediators, moderators, outcomes, and socio-demographics.
Lopez-Arboleda et al. (2021)	This paper presents a system dynamics model of the Colombian electric vehicle market, as well as the links between market dynamics and long-term sustainability. This model is used to figure out how the Colombian market dynamics and the sustainability system interact.

Author	Findings
Kim et al. (2021)	The goal of this research is to look at the impact of subsidy policies on regional variance and environmental advantages of electric car adoption in Korea, considering changes in the country's power mix. Author investigates four distinct scenarios of subsidy policies using system dynamics modelling and find that a 35% yearly increase in the existing subsidy budget can raise the use of electric vehicles by 350%, which is the national electric vehicle propagation goal by 2030.
Hung et al., (2021a)	This study introduced ReDyFEV, a simple open-source software tool for calculating attributional, understanding impact of climate on battery electric vehicle lifecycle in Europe including near real-time. They Compared national lifecycle carbon footprints for four BEV size segments across all EU member states similar-sized fossil-fuelled vehicles.
Xing et al. (2021)	This research provides a novel EV behavioural model based on a data-driven methodology and behavioural economics theory. For EVs with charging requirements, the best charging station is advised.
Fernández (2021)	In terms of the prospect of having an indeterminate number of electric vehicles plugged in at the same time, this study examines the current and future implications of uncontrolled electric vehicle charging operations on the electrical grid. The findings demonstrate that charging battery electric vehicles has a significant impact on daily electric power demand, making peak times for electricity usage unmanageable.
Fescioglu-Unver et al. (2021)	For priority service in electric car charging stations, this work presents feedback controlled express station management model (FC-EXP).
Das et al. (2021a, b)	This work uses a real-time multi-objective optimization method in which an electric vehicle charging/discharging profile is scheduled in real-time to attain a balance between various objectives, such as lowering electricity costs, reducing battery degradation, and reducing grid stress, as well as achieving the user's requirement about departure time.
Tarei et al. (2021)	Despite the announcement of favourable governmental measures to stimulate EV adoption, a slew of possible impediments with mutual interaction has stymied its adoption in several countries. This study applies ISM and Best worst method for ranking the barriers.
Quddus et al. (2021)	This study presents a novel disruption avoidance model that considers both long-term expansion decisions and short-term operating decisions. The model is first linearized using McCormick relaxation extensions, which is solved using a combined Sample Average Approximation and Scenario Decomposition algorithm.
Gu et al. (2021)	To show the processes of electric vehicle battery manufacturing with the help of return, sorting, secondary usage, and remanufacturing, author propose a two-period electric vehicle battery closed loop supply chain model in this study.
Franzò and Nasca (2021)	Using a Life Cycle Assessment technique, the article intends to establish a thorough evaluation framework for estimating the environmental effect associated with Electric Vehicles and Internal Combustion Engine Vehicles. The methodology is then applied to quantify the environmental impact of electric and internal combustion engine vehicles in four different cases, each considering different countries having different phases of a vehicle's life cycle occur.
Bhat et al. (2022)	This study uses structural equation modelling to examine the effects of eight factors on consumers intention to adopt electric vehicles, including environmental enthusiasm, technological enthusiasm, anxiety, social image, social influence, perceived benefits, performance expectancy, and facilitating conditions, all based on the extended unified theory of acceptance and use of technology model.
Ziegler and Abdelkafi (2022)	The purpose of this article is to review and understand the business model literature on electric mobility, with consideration on electric vehicles, and using the five different aspect of business model framework and getting the relevant idea from literature.
Liu et al. (2022)	This study calculates the monetary impact values of exhaust and non-exhaust emissions emitted by internal combustion engine vehicles (ICEVs) and suitable electric vehicles (EVs) from an economic-environmental standpoint, to determine the environmental impact of switching from ICEVs to equivalent EVs.

Author	Findings
Kucukvar et al. (2022)	The goal of this study is to give the first empirical analysis of battery electric vehicle environmental efficiency in 27 European nations, considering the average electricity mix, marginal electricity mix (2015–2020), and renewable energy-based electricity mix (2030–2040) scenarios. Finland and the Netherlands were shown to be the most environmentally friendly countries when adopting BEVs in all the electricity mix scenarios.
Wang et al. (2022)	The eco-driving optimization of a hybrid electric car queue in urban traffic circumstances is investigated in this study, considering the driving characteristics in following the recommended pace. Simulation findings show that the proposed technique outperforms the competition in terms of lowering hybrid electric car fuel consumption and pollutants.

Appendix B: summary of expert profiles

Expert	Expert Profile	Experience in years
Expert 1	Logistics coordinator	4
Expert 2	Academician	12
Expert 3	Manager and head	5
Expert 4	Consultant	11
Expert 5	Project manager	9
Expert 6	Academician	16
Expert 7	Operations manager	8
Expert 8	Deputy Manager	9
Expert 9	Academician	5
Expert 10	Consultant	13
Expert 11	Purchase officer	7

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