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Electric vehicle adoption and sustainability: Insights from the bibliometric analysis, cluster analysis, and morphology analysis

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Abstract

Electric vehicles (EVs) are a new emerging technological advancement that has apprehended the interest of researchers as well as regulators, primarily due to their connection with sustainability in the broadest sense. EVs are recognized by academics as a viable and potentially game-changing type of transportation due to their ability to improve overall energy efficiency and lower emissions of greenhouse gases. Studies on either the technological or environmental aspects of electric vehicles abound in the literature, but a comprehensive sustainability assessment taking all three into account is the subject of relatively little investigation. This research study has performed a bibliometric analysis, cluster analysis, and morphology analysis on 'EV adoption and Sustainability' to gain insights into the research field. In total, 291 articles were found suitable from 2003 to Jan 2023. Our assessment only considers review papers, articles, and journals from the Scopus database. After going through this procedure, we found 191 articles worthy of bibliometric study, and 73 were chosen for the cluster analysis and morphology analysis. Vosviewer software has been used to generate two-dimensional bibliographic maps for visualization. This study has used cluster analysis to determine which themes predominate and a morphological analysis of author-supplied keywords to determine which sets of words appear most frequently and how often they appear. Six theme-based clusters have been found from the cluster analysis. We have read all the papers within the clusters, and we have discussed and devised the theme for each cluster as per the content covered in the clusters. The findings of this study have provided a research proposition for future researchers working in this area. This study has also suggested policy, societal, and managerial implications of EV adoption. The proposed study will aid engineers, academics, researchers, and policy-makers involved in promoting electric vehicle adoption.

Keywords EV adoption · Sustainability · Bibliometric analysis · Cluster analysis · Morphology analysis

1 Introduction

The transportation sector is one of the top industries in energy consumption, and it is also one of the most problematic in terms of emissions, congestion, and environmental difficulties (Patyal et al. 2021). Electric cars, often known as EVs, have gradually begun to displace traditional automobiles in recent years in response to growing concerns about their environmental impact (Krishnan and Koshy 2021). When considering the fundamental concerns of sustainability—climate change, urban air pollution, and the need to restructure the supply chains of key energy industries, electric vehicle adoption and sustainability is a topic that is both emergent and crucial (Kumar and Alok 2020).

Electric vehicles (EVs) have the potential to reduce carbon emissions and contribute to sustainability greatly. EVs emit significantly less greenhouse gases compared to

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traditional gasoline-powered vehicles and can operate on renewable energy sources like wind and solar (Clewlow 2017). Additionally, EVs often have a longer lifespan and are more energy efficient, reducing the environmental impact (Castelvecchi 2021). However, the sustainability of EVs also depends on the energy source used to power them, the materials used in their production, and the disposal of their batteries. To maximize their benefits, it is important to have a comprehensive and sustainable approach to the production and use of EVs.

The use of electric vehicles (EVs) can also have positive impacts on social and economic sustainability. EVs can reduce dependence on oil, leading to greater energy security and potentially lowering fuel costs (Dhar et al. 2017; Cao et al. 2021). They can also create new manufacturing, maintenance, and charging infrastructure jobs. On the social side, EVs can help to improve air quality in cities and reduce noise pollution, contributing to better health outcomes and a higher quality of life.

However, the adoption of EVs can also have some negative impacts on social and economic sustainability. For example, the production and disposal of EV's batteries can negatively impact communities and the environment (Yu et al. 2021). Furthermore, the upfront cost of EVs can be a barrier to adoption, especially for low-income households. It is important to consider these impacts and to develop policies and programs to address them, such as incentives for buying EVs, charging infrastructure development, and recycling programs for batteries (Nurdiawati and Agrawal 2022).

The process of recycling, reusing, and refurbishing of EV batteries reduces the environmental problem of producing new silicon and the burden associated with discarding PV modules using more conventional methods (Zhang et al. 2023). Considering the sustainable challenges, Gebhardt et al. (2022) found that greenhouse gas emissions, circularity indicators, and human rights and safety issues are considered the most crucial, while the least importance is attributed to economic aspects.

Many governments have begun to adopt policies to promote environmentally friendly and innovative transport technology to mitigate the climate change threat brought on by transportation sector emissions and minimize dependence on other countries for oil (Singh et al. 2023, 2024). An in-depth analysis of the interplay between society, the economy, and the environment is necessary for developing long-term policies for effectively using energy resources (Vidhi and Shrivastava 2018).

Stakeholders have all shown a growing interest in the idea of a circular economy in recent years (CE) (Hettiarachchi et al. 2022). When it comes to promoting economic sustainability, the concept of a "circular economy" (CE) is preferred over a "linear economy," in which materials and products move in one direction only (Alamerew and Brissaud 2020). In doing so, we lessen our impact on the planet and better use our limited resources (Singh and Singh 2023). To create a world that can support future generations, its members work to increase economic growth while protecting the environment and promoting social justice (Akbari and Hopkins 2022; Kester et al. 2019).

Therefore, strong, well-informed judgements based on a thorough sustainability evaluation are necessary throughout the policy creation stage of promoting the adoption of electric vehicle technology. Studies on electric vehicles' technological or environmental aspects abound in the literature. Still, a comprehensive sustainability assessment considering all three is the subject of relatively little investigation.

As we know from the above discussion, more research needs to be done on the EV adoption encompassing assessment of sustainability that considers all three, i.e., economic, social, and environmental impact. The objective of this study is to perform the bibliometric, cluster, and morphology analyses. Which is helpful in identifying the current research trend, elucidate potential new areas of research, cluster's themes, and the results of text mining based on keyword analysis will aid academics in gauging the current state of research and predicting its future direction. This study addresses the following research questions to synthesize better the research that has been conducted on EV adoption and Sustainability and to pave the way for future progress.

RQ 1: Who are the productive authors, and what is current research trend in the research domain, and collaborations among the countries in the research area?
Bibliometric Analysis is a structured method utilized in the field of library and information sciences to determine the progression and development of information in a specific field of knowledge (Shishodia et al. 2021). *Vosviewer software will be used to generate two-dimensional bibliographic maps for visualization. Bibliographic maps of source co-citation, authors co-citation, international collaborations, and keyword co-occurrences will be drawn.*
RQ 2: How many theme-based clusters from the documents' bibliographic coupling map are found and analyze the clusters' insight?
Through this research, we will understand that the evolution of a study field can be aided by creating network clusters and analyzing their progress. For instance, by analyzing co-citations and bibliographical coupling, researchers can gain insight into the underlying intellectual structure and the evolution of important topics in the subject through time (Barbosa 2021; Dash et al. 2022; Singh and Sahu 2019).

RQ 3: What are the outcomes from the keyword-based morphology analysis of all clusters and identify the new possibilities in the field of research study?
Morphological analysis (MA) breaks down the area of study into parts to describe it thoroughly. It simulates complex difficulties without numerical calculations. This research question aimed to develop a method for analyzing EV adoption and Sustainability studies using keyword-based morphology. For the sake of this research, we will rely on the authors' provided keyword data to help us decipher the meaning of the text (Haaker et al. 2021).

The remaining paper is structured as follows: Section 2 presents the literature review related to EV adoption and Sustainability. In the third portion of this paper, the research methodology that guided the study is laid out. In Section 4, the primary findings of the bibliometric analysis are presented. The fifth and sixth sections discussed cluster analysis and morphology analysis, respectively. Seventh cluster has discussed about the implications of study. In the final step, conclusions, limitations of the study, and future research scopes were discussed.

2 Literature review

2.1 Electric vehicle adoption

Electric cars, often known as EVs, have gradually begun to displace traditional automobiles in recent years in response to growing concerns about their environmental impact. Electric vehicles are commonly regarded as an environmentally benign and alternative renewable energy technology that has the potential to hasten the transition to a transportation system with lower carbon emissions without having any detrimental effect on the earth's natural resources. Considering the barriers to the EV adoption, Murugan and Marisamynathan (2022), Prakash et al. (2018), and Patyal et al. (2021) have conducted a research study. Concern for the environment, trust in electric vehicles (EVs), personal norms, attitudes toward electric vehicles (EVs), pricing value, and subjective norms are some important variables driving the adoption of EVs in the market.

Kumar, Jha et al. (2021) highlighted the challenges in the EV adoption. Their study identified that the sharing economy and public utilities significantly promoted EV adoption. Some challenges in EV adoption in the Indian context are the high price of EVs, the absence of infrastructure, and the weak purchasing power of Indian customers. In the same year, Dua et al. (2021) studied India to identify the enablers and disablers of EVs. Their study identified that India's market for inexpensive plug-in electric vehicles (PEVs) will experience supply constraints due to the absence of domestic PEV battery and manufacturing supply chains. Similar to that, Chakraborty et al. (2021) developed a game theoretical model to identify the challenges in EV adoption. In the same year, Khan et al. (2021) has conducted a study in order to better understand and increase the effectiveness of the ELV recycling and remanufacturing industries, this research builds a dual-cycle ELV recycling and remanufacturing system.

Considering consumer intention, Goel et al. (2021) reviewed the current literature and established new barriers. They have attempted to identify and analyze the most significant barriers to the sale of EV adoption. Similar to that, Asadi et al. (2021) findings can help improve our understanding of the behavior of consumers in relation to the adoption of electric vehicles while also providing opportunities to boost the development of electric vehicles. Later, Kore and Koul (2022) identified the barriers in developing EV charging infrastructure. The steps and initiatives taken by the Indian government are highlighted that would help bring about this change. Some other important literature related to EV is discussed in Table 1.

2.2 Electric vehicle supply chain and sustainability

Electric vehicles (EVs) have been recognized in the existing literature as a sustainability-oriented approach to mitigate the harmful consequences of vehicles powered by fossil fuels. Electric vehicles, often known as EVs, are recognized by academics as a viable and potentially game-changing type of transportation due to their ability to improve overall energy efficiency and lower emissions of greenhouse gases (Krishankumar et al. 2022). The integration of the supply chain for electric vehicles (EVs) is becoming increasingly important in the dynamic automotive market for ensuring sustainability (Gharaei et al. 2023). It involves coordinating the many people, systems, and technologies that go into making and delivering electric automobiles.

Considering the barriers to widespread EV adoption and sustainability, Egbue and Long (2015) identified that despite the benefits of electric vehicles, several obstacles must be overcome before widespread adoption. Their study suggested that Consumers tend to oppose emerging technologies that are perceived as alien or unproven. This study examines potential socio-technical challenges in EV adoption. Almansour (2022) conducted a similar study to determine how much of an impact the sustainability perspective has on consumers' decisions to purchase electric vehicles (EVs) or to express a willingness to do so. The study concludes with suggestions on how different stakeholders, including online businesses and digital marketing firms, might contribute to the betterment by disseminating accurate information and encouraging the usage of EVs.

Table 1 Recent studied on EV Adoption

S.No	Authors	Study Objective	Method	Focus area	Findings
1	Das et al. (2019)	Evaluated the performance of EVs in Asian market	FAHP	EV Performance	To meet the needs of an EV consumer, this research focuses on the best model available in the Asian market.
2	Pinto et al. (2022)	Analyzed the mixed data to compare the efficiency of electric vehicles	Bibliometric analysis	EV	The study's findings will shed light on key EV research questions.
3	Asadi et al. (2022)	Identified and analyzed the barriers and drivers in EV adoption	DEMATEL	EV adoption	Environmental concerns, trust in EVs, personal norms, pricing value, attitudes towards EVs, and subjective norms are the important factors in EV adoption.
4	Kumar, Chakraborty et al. (2021)	Analyzed the need for investment in EV charging infrastructure	Modeling	Charging Infrastructure	Government subsidies should be provided to EV buyers, who in turn invest in the installation of charging stations by the EV manufacturer.
5	Digalwar and Giridhar (2015)	Identified the factors that are affecting the development of the EV market	ISM	EV market	Lack of awareness is the prime factor affects EV adoption
6	Dhar et al. (2017)	Assessed the benefits of EV adoption	Modeling	EV Benefits	Co-benefits include improvements to air quality, energy independence, and carbon dioxide emissions in India, whereas co-costs (risks) include difficulties obtaining battery raw materials and disposing of residual waste.
7	Siahaan et al. (2021)	Devised the strategy for EV battery SC to support the industry	SWOT-AHP	EV Battery	Performing research and enhancing human resources via training and technology transfer from investors via rewards were proposed as two overarching initiatives for the electric vehicle supply chain business.
8	Asghar et al. (2021)	Identified key EV adoption challenges	Review	EV adoption	According to the analysis, electric vehicles (EVs) have major barriers to entering in the existing market due to factors such as state financial incentives, market prices, technological difficulties, and social problems.
9	James et al. (2022)	Identified and evaluated the barriers to EV adoption in India	AHP and DEMATEL	EV Adoption	Technical barriers are the prime barriers in EV adoption.
10	Sonar and Kulkarni (2021)	Selection and identification of criteria for EV vehicle selection	AHP and MABAC	EV vehicle selection	Consumers placed a greater emphasis on the pricing than the driving range of the vehicle.
11	Gupta et al. (2023)	Evaluated the risks in EV charging infrastructure	Fuzzy AHP	EV Charging	The risks identified are financial, market, political/legal, and operational risks.

In the same year, Adu-gyamfi et al. (2022) investigated the psychological factors that influence the implementation of battery swap technology. Battery swap technology (BST) is a new approach to reducing the range anxiety associated with using electric vehicles (EVs), furthering the development of decarbonized vehicular transport, and improving environmental sustainability. Onat and Kucukvar (2022) identified knowledge gaps in electric vehicle sustainability evaluation and offered a perspective on the existing state of knowledge, perspectives on research gaps, and prospective avenues for adopting integrated life-cycle modelling methodologies. Before that Based on the results of the sustainability assessment, a compromise programming model was constructed by Onat et al. (2016) to establish the optimal distribution of alternative vehicles, considering the variable importance of different sustainability indicators and the scope of the analysis. Later, Goli et al. (2022) developed a two-echelon electric vehicle routing problem and proposed a novel moth-flame meta-heuristic method for its solution.

Rajaeifar et al. (2022) discussed the most challenging aspects of EV Lithium-Ion Batteries at various times of their lifespan. Batteries, their production, utilization, and disposal, as well as related supply and demand difficulties, are all discussed. Similar to that Nurdiawati and Agrawal (2022) presented “a scenario-driven material flow analysis (MFA) to predict the volume of electric vehicle battery wastes that could potentially be produced in Sweden as well as the future demand for key battery materials. The study considers potential electric vehicle fleets, developments in battery chemistry, and end-of-life strategies for electric vehicle batteries”.

Considering the charging station, Ghosh et al. (2022) evaluated the technological and financial viability of converting a gas station with EV charging infrastructure. The potential for combining Battery Energy Storage Systems with electric vehicle charging infrastructure, which reduces grid connection costs, is being examined to improve the value proposition further. Converting to Battery EVs would expedite the decarbonization of transportation on the road and bring other advantages (Broadbent GH, Allen et al. 2022).

Considering the green policies and quality control in the supply chain, Amjadian and Gharaei (2022) have studied and proposed the design and optimization of a comprehensive five-level Supply Chain (SC) framework. The framework comprises many entities, including a supplier, a producer, a wholesaler, numerous retailers, and a collector.

As we have seen from Table 1, studies on either the technological, consumer, or environmental aspects of electric vehicle supply chain abound in the literature. Still, a comprehensive sustainability assessment considering all three is the subject of relatively little investigation. As we know from the above discussion, more research needs to be done on the EVs adoption encompassing assessment of sustainability that considers all three, i.e., economic, social, and environmental impact. However, no comprehensive bibliometric analysis has been performed on EV adoption and sustainability, as per the author’s knowledge. This study will perform bibliometric, cluster, and morphology analyses. Which is helpful in identifying the current research trend, elucidating potential new areas of research, and the results of text mining based on keyword analysis will aid academics in gauging the current state of research and predicting its future direction.

3 Methodology

An in-depth analysis of the existing body of research in a developing field of study yields a crucial understanding that is necessary for research investigation and elucidates potential new areas of research (Majiwala and Kant 2022; Pizzi et al. 2021). The usefulness of a review can be improved by employing an iterative cycle that consists of determining search phrases (keywords), reading relevant literature, and carrying out the investigation at the very end.

The term "bibliometric analysis" refers to a statistical study of bibliographical data gathered from databases such as Scopus, Web of Science, and others (Yu et al. 2022). It outlines the current research trend and potential future research areas in a specific field (Rana and Daultani 2022). Barbosa (2021) states, “It is used to obtain the trends in publications, sources, collaboration among the authors, co-citation of the documents, and keyword co-occurrences linked to research interest.” Bibliographic maps in two dimensions are utilized to visualize the data effectively (Dash et al. 2022; Zou et al. 2022).

The papers were subjected to a cluster analysis to formulate the topic-based cluster and better comprehend the contents of the documents that were contained within the cluster (Donthu et al. 2021). The clustering results provide information about the development of certain studies throughout time. It has been discovered that a significant amount of bibliometric research is available in various areas of engineering and management. However, no bibliometric study is available for EV adoption considering sustainability.

3.1 Selection database

Literature relevant to these studies was selected from the Scopus database, including the largest peer-reviewed articles. Studies from the field EV adoption and sustainability were found to have relevance to the study's objectives. Scopus database is selected because it contains more journal and article titles in the areas of business, social sciences, technology, and medicine than any other database (Shishodia et al. 2021).

3.2 Keyword selection

Search terms for articles provide the backbone of any good bibliometric review. The keywords should be broad enough to include the most relevant studies in the area of interest. Boolean search terms, including "Electric vehicle adoption" and "sustainability" were used to reduce the Scopus database search for EV adoption and sustainability-related papers to just the topic, article title, abstract, and keywords. "Electric vehicle adoption" and "sustainability" captured all the important publications from the field of study.

3.3 Collection of articles

In total, 291 articles discussed "EV adoption and sustainability" from 2003 to Jan 2023. We only considered review papers, articles, and journals in our assessment. After this procedure, we found 191 articles worthy of bibliometric study.

3.4 Filtering (inclusion and exclusion criteria)

When applied to the Scopus database with the specified inclusion and exclusion criteria, the search resulted in 191 articles. There were 191 articles chosen for the bibliometric study, and 73 were found to be suitable for cluster analysis. Articles with more than 15 citations were used in the cluster and morphology analysis conducted in the Study.

4 Results and discussions

4.1 Year wise trend

As was previously mentioned, 191 were obtained from the study area. The total number of scholarly works from 2003 to 2023 is shown in Fig. 1. According to the Scopus database, there was only one publication in this field in 2003, and from 2004 through 2009, there were zero. Since 2017, the number of published electric vehicle adoption and sustainability (EVS) research articles has increased exponentially. Recently, many governments have begun to adopt policies to promote environmentally friendly and innovative transport technology to mitigate the climate change threat brought on by transportation sector emissions and minimize dependence on other countries for oil.

Authors with affiliation with the universities of Aarhus, Denmark, and Sussex, England, published the largest number of articles. The United States, China, the United Kingdom, India, and the Netherlands are only a few of the countries that have produced a significant number of articles on the subject.

United States of America authors were cited more frequently. Article counts, and citation counts for the top 10 publishing nations are shown in Table 2. It is also clear that the ranking of countries by the number of papers published does not match the ranking of countries by the number of citations of the publications. When looking at the number of articles published, researchers from India rank 4th, but when looking at the number of citations, they ranked 2nd. The USA ranked first in both publication wise and citation wise. USA is doing a lot of research in electric vehicles and battery-related technologies.

It is clear from Table 3 that most published studies have appeared in publications dedicated to *sustainability Switzerland, Transportation Research Part: D Transport and Environment, Journal of Cleaner Production, and Energy policy*.

Sustainability Switzerland has published 13 papers with a total citation of 227. It is published by the MDPI journal. The highest citations belong to the *Energy Policy* journal by publisher *Elsevier*. The highest *citescor*e was obtained by the *Applied Energy* journal. The *Citescore* tell us the quality

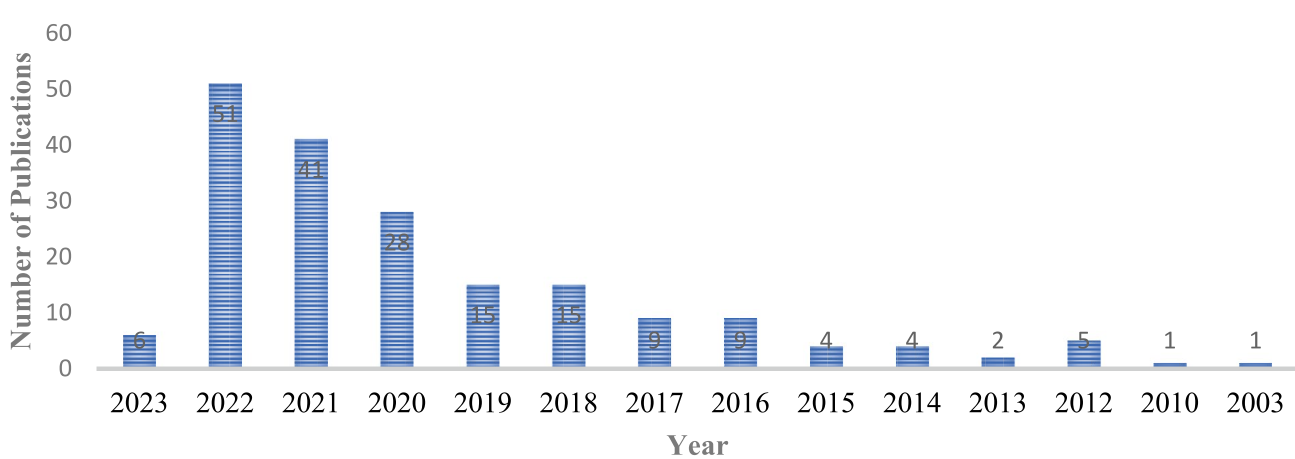

Fig. 1 Year wise profile of publications

Table 2 Publication and citations of the top ten countries

S.No	Countries	Publications	Total Citations	Rank as per Publication	Rank as per citations
1	United States	55	3295	1	1
2	China	28	644	2	4
3	United Kingdom	24	716	3	3
4	India	22	800	4	2
5	Netherland	14	497	5	5
6	Denmark	12	410	6	6
7	Canada	8	261	7	7
8	Germany	8	152	7	9
9	Italy	8	201	7	8
10	Australia	7	134	8	10

of a journal. As per the Elsevier definition, "*CiteScore is the number of citations received by a journal in one year to documents published in the three previous years, divided by the number of documents indexed in Scopus published in those same three years*." The Benjamin K. Sovacool has the highest publication in EV adoption and sustainability, followed by Kester J. He has published eight papers in the research domain and is affiliated with the university of Aarhus, Denmark.

He examined the influence of vehicle-to-grid preferences on the adoption of electric vehicles in the Nordic countries from a socioeconomic, technological, economic, and behavioral perspective. He has also identified the impact of education, gender, age, household size, and consumer occupation on EV's purchasing intention.

4.2 Co-citation analysis

When two sources are cited in the same article, this is called a co-citation. Similarity in research topic is measured by the frequency with which two documents are cited together. To what extent two papers are similar is proportional to the number of times they are cited by one another (Donthu et al. 2021). The frequency with which two references or journals are co-cited increases as the degree of their relationship grows (Barbosa 2021).

Documents are represented as nodes in a co-citation network, and the strength of the connections between them is proportional to the frequency with which the cited papers come together within the dataset. Source and author citation networks were constructed for this investigation. First, co-citation networks between publications were constructed. Through the journal co-citation map, we can illustrate the overall composition of the academic community. The map allows users to locate groups of journals with common themes and then associate those themes with specific scientific disciplines. Proximity on the map between clusters represents fields with strong connections to one another. Figure 2 shows the co-citation analysis of journals. The minimum number of citations taken for the analysis is five and on Vosviewer software, seven clusters are formed. The topmost blue color cluster consists of Journal of Cleaner

Table 3 Most productive journals in EV adoption and sustainability

S.No	Source	Documents	Publisher	Citations	Cite Score (2023)
1	Sustainability Switzerland	13	MDPI	227	5.6
2	Transportation Research Part D Transport and Environment	12	Elsevier	442	12
3	Journal Of Cleaner Production	9	Elsevier	554	18.1
4	Energy Policy	8	Elsevier	1424	14.9
5	Resources Conservation and Recycling	7	Elsevier	166	19.8
6	Technological Forecasting and Social Change	6	Elsevier	124	16.6
7	Applied Energy	5	Elsevier	133	20.6
8	International Journal of Sustainable Transportation	5	Taylor & Francis	67	8.0
9	Case Studies on Transport Policy	4	Elsevier	54	3.9
10	Energies	4	MDPI	122	5.3

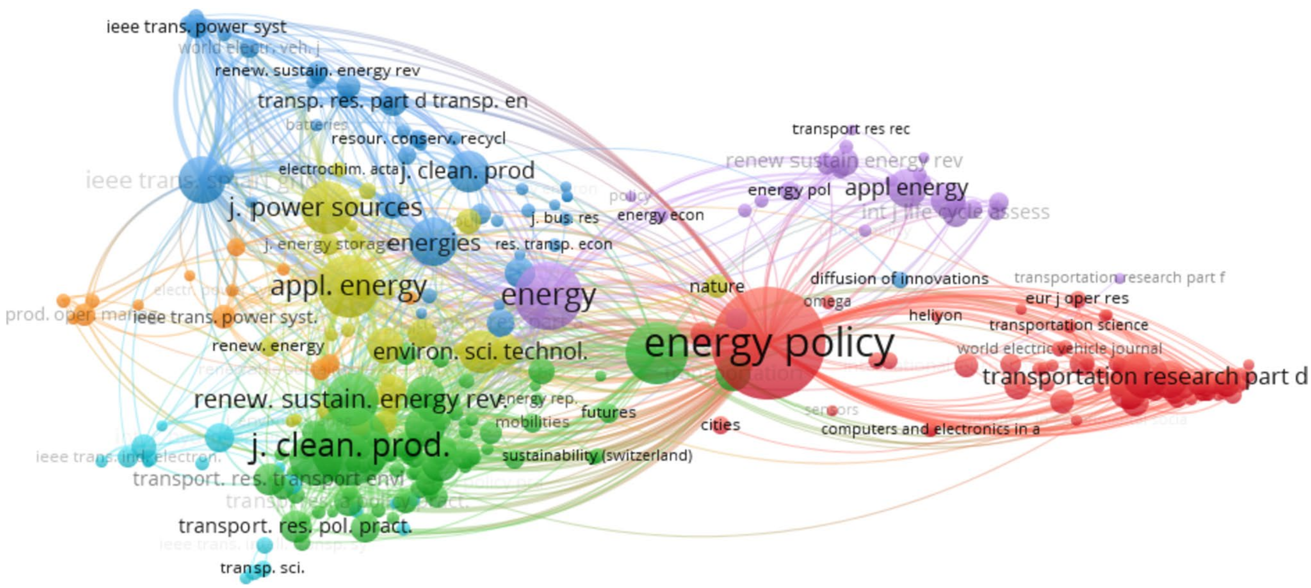

Fig. 2 Bibliographic map of source co-citation

Production, Energies, Resource Conservation and Recycling, Transportation Research Part D, IEEE Transaction, etc. Another cluster at the top violet color consists of Energy, Applied Energy, etc.

To the right, the red cluster journal has some important journals like Energy Policy, Transportation Research, Heliyon, Computer and Electronics, etc., covering a wide range of related topics. The Energy policy serves as the hub for this cluster. Similarly, other clusters can be interpreted from the Fig. 3.

After that, co-citation networks between scholars were constructed. The highest co-citation received by *Sovacool, b. k*, followed by *Axsen J*. Figure 3 depicts the authors' co-citation network. Once again, there are five distinct clusters. The *Sovacool, b. k*, and *Axsen j* are both appeared in the uppermost cluster and got the first two

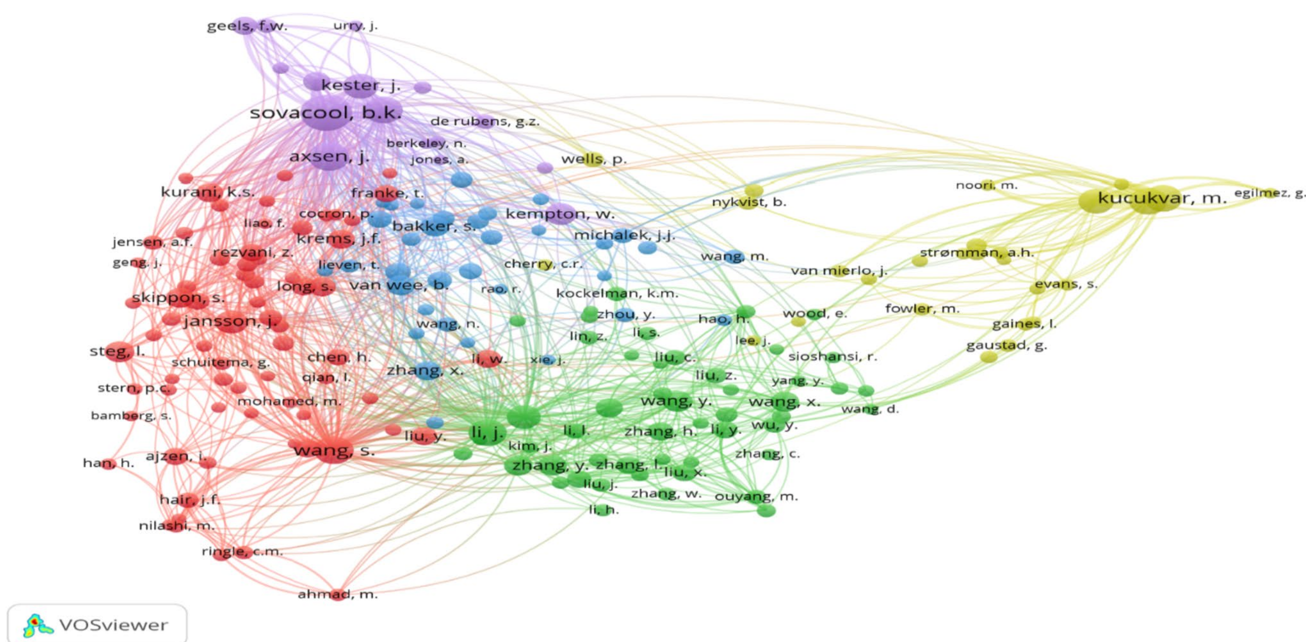

Fig. 3 Co-citation analysis of authors

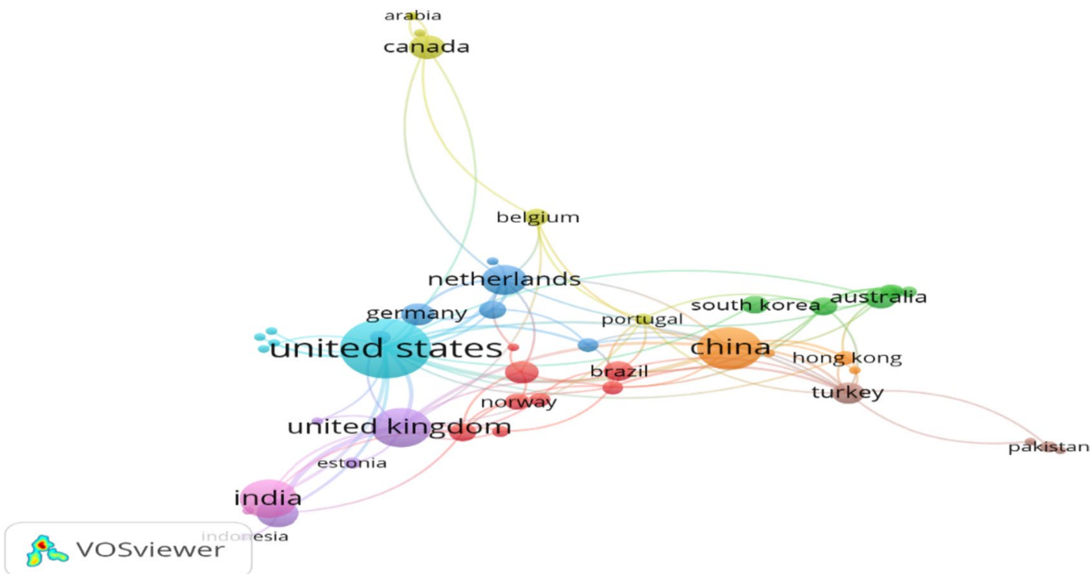

Fig. 4 Analysis of co-authorship among countries

ranks. The quality of the researchers' work is considered by some productivity measures in addition to the quantity of papers they produce. The *h-index* and the *i-10 index* are two examples of such metrics. The h-index measures an author's productivity and the influence of their work as determined by the number of times their works have been cited. It is the most well-known and widely used scientific achievement. These combined indicators better reflect academic productivity. Acknowledgment in the form of a publication's authorship is essential to the scientific process.

Research field communities can be quantified and shown through analyses of co-authorship (Singh and Sahu 2019). Co-authorship analysis can reveal the leading researchers in a subject, while citation analysis can reveal the most influential articles in that field (Donthu et al. 2021). Nodes in a co-authorship network stand in for researchers, and if two authors have worked together on a study, the network will link them (Shishodia et al. 2021). Collaboration maps across countries in terms of authorship have been developed.

Between 2003 and 2023, 54 nations met the minimum requirement of 1 publication in this field of study. For this period, the international network of authors is depicted in Fig. 4. Nine clusters are obtained. The top five countries the United States, China, the UK, the India, and the Netherland, appear in different clusters. Color cluster countries have the largest group of networks in EV adoption and sustainability research. It is clear from Fig. 4, The US has the highest number of publications in the research area.

4.3 Co-occurrences of author keywords

Co-occurrences of keywords and the citation-based and co-authorship networks have also been researched. Publications in which both terms appear in the title, abstract, or keyword list constitute a co-occurrence (van Eck and Waltman 2014). The authors of the included articles provided a list of keywords that were used in this analysis. Multiple-word terms are also considered keywords, not just single-word ones. The article keywords' overlay topic map is shown in Fig. 5. Relevant topics in this network include electric vehicle, sustainability; automobiles; uncertainty; photovoltaic; charging; e-mobility; adoption; life cycle assessment; consumer perception, etc. Following is a discussion of studies that have been conducted on the concepts these words reflect. The topic recently gained attention by the researcher is shown with the yellow color in Fig. 5. Some important area emerging area of studies are sustainable transport; environmental sustainability; recycling; reduction; reuse; charging technologies; fast charging; circular economy; life cycle assessment; decision making; consumer intention; battery swapping mode; and corporate social responsibility. Several nations are investing in electric vehicle technology to mitigate transportation-related environmental harm, such as carbon dioxide emissions and urban air pollution (Onat and Kucukvar 2022). The rapid rise in electric mobility has raised the issue of responsibly managing lithium-ion batteries (LIBs) once they have been removed from End-of-life EV batteries (Reinhardt et al. 2019).

The complexity of recycling and sustainably managing an ever-increasing number of LIBs adds to the list of

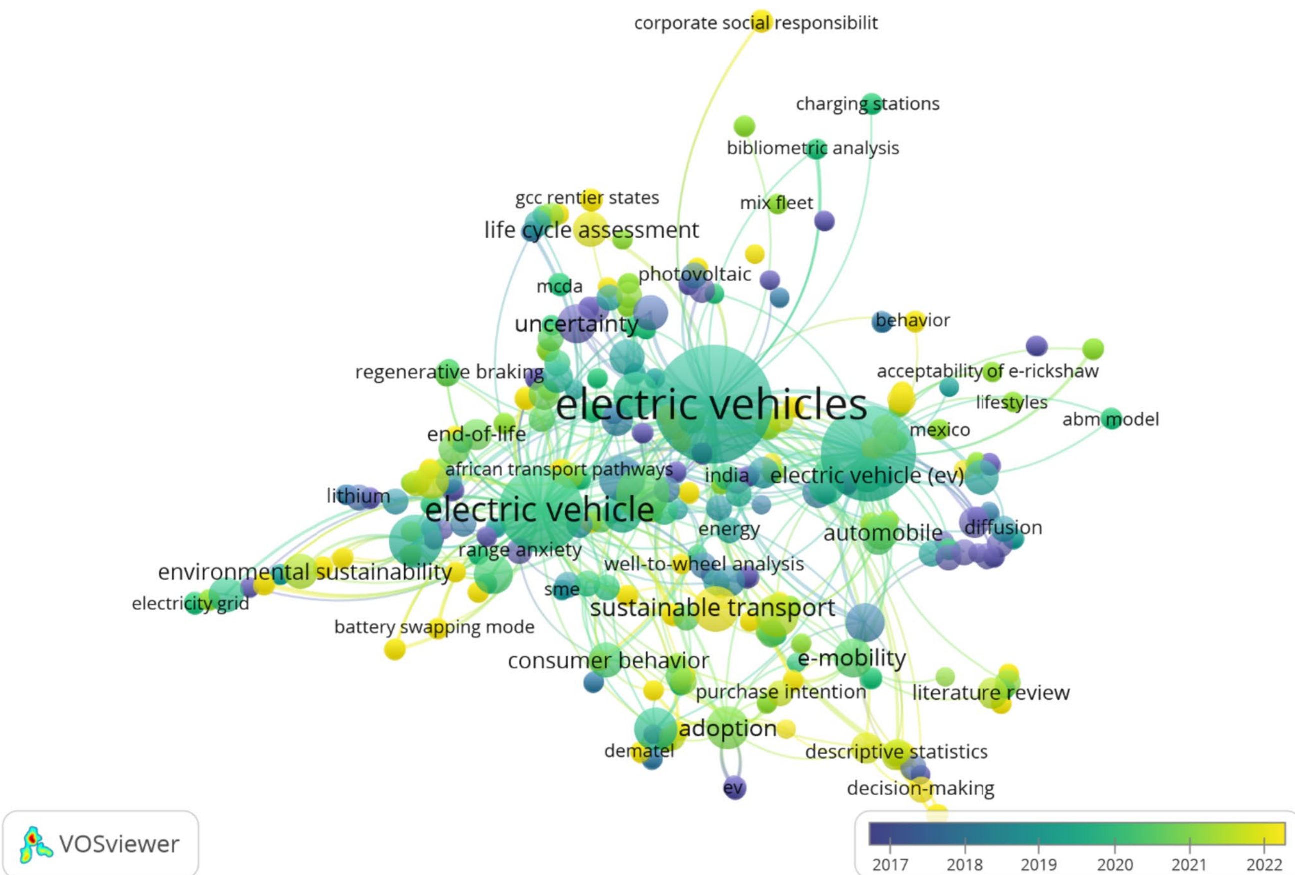

Fig. 5 Keyword co-occurrence analysis (overlay visulaization mode)

environmental problems associated with this development (Roy et al. 2022). By increasing the usable life of LIBs and keeping their inherent value through reuse, repurposing, refurbishing, and recycling, the circular economy can reduce these problems (Baars et al. 2021). So, in this direction more research is needed. We are focusing more on electric vehicle research and the adoption of EV at mass scale. However, we must consider the environmental sustainability of the EV supply chain. There has been much attention paid to the long-term viability of electric vehicle batteries. Despite the importance of the issue, no studies have provided insight into how ES considerations should factor into the process of choosing an EV supply chain supplier.

5 Cluster analysis

The fundamental purpose of clustering is to form thematic or sociological groups, and it is used as an enriching approach in bibliometric analysis (depending upon the type of analysis being conducted) (Shishodia et al. 2021). Understanding the evolution of a study field can be aided by creating network clusters and analyzing their progress (Donthu et al. 2021). By analyzing co-citations and bibliographical coupling, for instance, researchers can gain insight into the underlying intellectual structure and the evolution of important topics in the subject through time (Barbosa 2021; Dash et al. 2022; Singh and Sahu 2019). Through a bibliometric network analysis, we can uncover common themes appear in the EV adoption and sustainability research through the 73 studies. This study has used bibliographic coupling of documents for cluster analysis. Six clusters have been found from the analysis of Vosviewer software as per content of the papers. We have read all the papers within the clusters, and we have discussed and devised the theme for each cluster as per the content covered in that cluster. We have also identified the research questions for future researchers. Discussion of each cluster along with the theme identified from the content review are given below:

Cluster 1: EV batteries and sustainability
Cluster 1 discusses the sustainability of EV batteries. The rapid rise in electric mobility has raised the issue of how to responsibly manage the LIBs once after removing from End-of-life EV batteries. The complexity of recycling and sustainably managing an ever-increasing number of LIBs adds to the list of environmental problems associated with

this development. With the increasing popularity of electric vehicles, there arises a necessity for strategic innovation in effectively managing the disposal and recycling of lithium-ion batteries (LIBs) at the end of their life cycle. After reaching the end of their useful life in vehicles, lithium-ion batteries (LIBs) continue to possess a substantial amount of energy storage capacity. The potential for environmentally friendly innovation, value preservation, and sustainable management of raw materials arises from the ability to utilize lithium-ion batteries (LIBs) for stationary energy storage. Considering resilience and circular economy, Reinhardt et al. (2019) have developed a sustainable business model for the reuse of end-of-life electric batteries. Considering this, their study concludes that reuse has a chance to establish itself as a sustainable and effective model. Important new insights for both academics and professionals have been uncovered. The existing unsustainable practices in the EV sector may be made easier by re-use. Allowing LIBs to be reused for stationary power storage is a step toward a more sustainable way and circular economy that can help businesses keep more of their profits and better manage their material resources (Moore et al. 2020).

Olivetti et al. (2017) conducted a study to examine the potential difficulties in essential metal supply considering the anticipated increase in demand for raw materials for LIBs. According to their analysis of the mineral content of materials used in LIB, there is a sufficient supply of key elements like manganese, nickel, and graphite. Short-term, there may be shortages of lithium- and cobalt-containing materials. Because batteries last longer and can be used for so many different things, they may be recycled and reused to meet a substantial portion of the demand in the short term. Considering the repercussions on society and the economy of extracting lithium, batteries were the primary topic of discussion in a recent study by Agusdinata et al. (2018), which then switched to discussing the long-term viability of battery production and use. Subsequent research by Baars et al. (2021) also examined the long-term viability of EV battery components like cobalt. Their research shows that a surge in battery usage could lead to shortages and other problems in the supply chain. Circular economy techniques are required to enhance the resilience and sustainability of automotive supply chains while reducing primary resource demands. They found that new technologies offer the most potential solutions for significantly reducing cobalt reliance, although they may result in burden shifting, such as a rise in nickel consumption.

Further, Several problems in the EV battery supply chain were identified and examined by Kumar, Jha et al. (2021). Throughout their research into the sustainability of the EV battery supply chain, they have relied on the Delphi technique and the best–worst method. India's electric vehicle (EV) battery supply chain has three main issues: improper battery recycling and reuse, improper battery disposal, and a deficient EV charging infrastructure. Gopal et al. (2018) calculated carbon's long-term marginal abatement cost (MAC) to assess the viability of switching from conventional cars to hybrid and battery-operated EVs in China. Their analysis shows that replacing traditional cars with hybrids and battery-electric light-duty four-wheelers is a cost-effective strategy to reduce their carbon footprint. As a result of climate change and the rapid depletion of fossil fuels, electric vehicles (EVs) powered by batteries have quickly become a viable choice for environmentally responsible transportation. *Research propositions* based on the analysis of cluster one for future researchers.

1. To identify and analyze the environmental impact of mineral extraction for EV batteries.
2. To devise the supplier selection criteria for enhancing the sustainability of EV batteries.
3. To devise policy recommendations for the sustainable use of raw materials for EV batteries.

Cluster 2: Identifying the benefits of EV adoption

This cluster analyzes the challenges in EV adoption for enhancing sustainability. After that, considering the social, economic, and environmental sustainability aspects of EV adoption, Electric vehicles (EVs) are much more energy efficient and produce significantly less pollution than conventionally powered motor cars, as Weiss et al. (2015) investigated. In contrast to traditional two-wheelers, which contribute significantly to air pollution in urban areas, electric two-wheelers have a smaller environmental impact because both vehicle production and electricity generation take place outside of these areas. This demographic is poised to be an EV's first adopter if they believe electric vehicles perform better than conventional ones.

Tran et al. (2013) analyzed the factors that could lead to the widespread use of electric and hybrid vehicles. According to their empirical evidence, early adopters are diversely motivated by financial incentives, environmental appeal, advanced and new technologies, and reliability through energy policies. Their study has also discovered that financial rewards have a greater influence on early adoption than pro-environmental behavior. To back up the policy on energy, they evaluated the variables that could lead to the widespread utilisation of AFVs. A review of empirical data reveals that early adopters are a diverse group, driven by several factors, including financial gain, environmental appeal, and the novelty of the technology itself. Similarly, Daziano and Chiew (2012) gathered the best possible microdata to feed the general demand forecasting model.

Specifically, we considered the cost-reliability-environmental benefits trade-off of low-emission vehicles and the potential for analyzing welfare-improving measures related to adopting energy-efficient technology.

Later, Noppers et al. (2014) identified that the environmental impact of sustainable innovations is directly proportional to the rate at which customers adopt them. Responding to a direct question, "study participants prioritized instrumental and environmental features in their evaluation of sustainable innovations, while symbolic attributes were rated lower in importance". Adoption by customers is essential to the environmental success of sustainable technology. The general opinion is that the inability to implement environmentally friendly innovations effectively is a major barrier to their widespread use.

Considering the micro-mobility benefits of EV adoption, Eccarius and Lu (2020) have proposed as a solution to various problems plaguing large cities today and to more sustainable urban transportation. This research investigates how factors affect college students' propensity to sign up for a scooter-sharing programme.

Qian and Yin (2020) have linked the cultural and ethical values to EV adoption. China promotes the growth of EVs to combat climate change, urban air pollution, and threats to energy security, although consumer interest in EVs is limited. A similar study was conducted by Shalender and Sharma (2021). Their findings suggested that EVs are a sustainable mode of public transport that can lessen the nation's reliance on gasoline while also significantly lowering its carbon footprint. Many people think that switching to electric vehicles is a good way to lessen the negative effects of driving on the environment and our dependence on oil. *Research propositions* based on the analysis of cluster two for future researchers.

1. To identify the barriers in the path of EV adoption.
2. To identify the causal interactions among the barriers and drivers in EV adoption to enhance sustainability.

Cluster 3: Development of EV charging technologies
The ongoing proliferation of privately owned gasoline-powered automobiles, predominantly utilized by single occupants, significantly contributes to various urgent societal issues. These issues encompass the deterioration of air quality, exacerbated climate change, increased congestion, and adverse modifications to the structure and operation of urban areas. Cluster 3 discusses about the recent charging technology development and innovations. Taiebat and Xu (2019) discussed the four main technologies; "shared mobility, fast charging, vehicle-to-grid (V2G) integration, and vehicle automation which can help to promote smart and sustainable urban mobility. Technology based on dynamic wireless power transfer (DWPT) has been increasingly popular in the EV charging market in recent years". Urban transport is crucial in fostering economic prosperity in developed and emerging nations. However, it also serves as a significant contributor to energy consumption, air pollution, adverse effects on human health, and traffic congestion. Electric vehicles (EVs) have the potential to mitigate a portion of the sustainability-related issues encountered in urban transportation. This innovation has the potential to increase the use of electric vehicles (EVs), which would help lessen the impact of vehicle-related air pollution in urban areas (Lazzeroni et al. 2021). Similarly, Ahmad et al. (2018) did a review of the literature to compare and contrast conductive and wireless charging methods, and they explore further into the complexities of static wireless charging, dynamic wireless charging (DWC), and quasi-DWC. Later, Jha et al. (2019) discussed the difficulties associated with charging stations for electric vehicles and drew attention to the increasing role of distributed generators in today's electricity grid. The advantages of using battery storage units in conjunction with photovoltaic (PV) energy sources are researched. Considering the policy intervention, Zhang et al. (2014) examined potential policies for bolstering the electric vehicle market in China. Governments should provide incentives, such as tax benefits, technological support, and charging infrastructure, to encourage wider adoption of electric vehicles. *Research propositions* based on the analysis of cluster three for future researchers.

1. To identify the policy incentives for developing EV charging infrastructure.
2. To identify and analyze the barriers in the development of EV charging infrastructure and technology enhancement.

Cluster 4: Assessment of EV-driven business for sustainability
The relationship between technology and societal advancement is inherently interconnected. The correlation between technology and societal advancement has been significantly reinforced by the emergence of digital technologies in recent years. Moreover, the concept of progress has been broadened to encompass not just economic growth, but also the promotion of well-being and sustainability. Digital developments have significantly altered the landscape of products and services, providing unique avenues for producing value. Cluster 4 discusses about the EV business and its impact on sustainability. Szinai et al. (2020) identified that with proper EV charging management, grid operation costs can be reduced. The widespread use of electric vehicles could have big effects on society, not just in terms of the transportation

technologies we use but also in terms of moving our markets away from oil and lowering the carbon footprint of public transportation (Valogianni et al. 2020).

Considering the role of standards in the EV market, Brown et al. (2010) have conducted a research study. Their study examined the function of standards, associated learning, and certification for electric vehicles. It is suggested that if standards are adequately considered, the potential for electric vehicles will be greatly expanded. Later, similar study was conducted by Rubens (2019) to identify the potential of EV market. Their results support the notion that pricing is a key factor in marketing to all these mainstream customers. The result also emphasized that EV adoption strategies should concentrate on EVs' technology and status features rather than only their financial and environmental benefits. Later, Almansour (2022) conducted a qualitative survey to get feedback from people who own EVs or are planning to buy one soon. The main goal of this study is to find out what makes people buy EVs or want to buy them. Nevertheless, the current study is still in its early stages and requires further investigation. The current analysis has not thoroughly explored into the factors that contribute to the limited diffusion of electric vehicles (EVs), despite their clear economic and environmental advantages in the realm of human mobility. *Research propositions* based on the analysis of cluster four for future researchers.

1. To devise policy recommendations for developing infrastructure for EV market.
2. To identify and analyze the barriers in EV business.

Cluster 5: Development of sustainability assessment framework for EV adoption

Cluster 5 discusses about the EV sustainability framework. Around the world, EVs is a trending topic, and many nations are promoting EV technologies to lessen the environmental effects of transportation, such as greenhouse gas emissions and urban air pollution. Even though such environmental effects have been extensively researched in the literature, little emphasis has been placed on a sustainability assessment considering the three pillars of sustainability. Electric mobility has emerged as a prominent subject of interest on a global scale, with numerous nations actively endorsing electric vehicle technology as a means to mitigate the adverse environmental consequences associated with transportation, including the emission of greenhouse gases and the exacerbation of air pollution inside urban areas. Although the literature extensively examines environmental implications, there is a noticeable lack of emphasis on a complete approach. Onat et al. (2019) have conducted, "a novel comprehensive life cycle sustainability assessment for four different support utility electric vehicle technologies, including hybrid, plug-in hybrid, and full battery electric cars (Greaves et al. 2014)". Before that, Onat et al. (2016) have done a study to overcome the methodological problems and risks in transportation sustainability research by developing a unique approach, the uncertainty-embedded dynamic life cycle sustainability assessment framework. Nevertheless, introducing these technologies brings up novel uncertainties about their environmental, economic, and social ramifications, as well as presenting specific obstacles that hinder their broad implementation.

Considering environmental sustainability, Luna et al. (2020) have utilized a system dynamic modelling approach to explore the effects of an e-carsharing scheme on greenhouse gas emissions and the uptake of electric vehicles. Similar study was conducted by Arena et al. (2015). This paper's objective is to discuss the method used to create an electric vehicle-sharing service for the Italian city of Milan. Later, Chen et al. (2020) studied that, how socio-demographic, behavioural, economic, and technical factors affect people's interest in electric vehicles (EVs) and how vehicle-to-grid mobility affects people's preferences. *Research propositions* based on the analysis of cluster five for future researchers.

1. To analyze the social, economic, and policy-related factors for the sustainability of EV adoption.
2. To identify the influence of e-vehicle sharing on environmental sustainability and carbon footprint.

Cluster 6: Identifying the consumer intentions for EV purchasing

This cluster discusses the purchasing intention of consumers for buying EVs. The pressure that has been put on governments to adopt more environmentally friendly means of transportation has resulted in several governments adopting laws that encourage more people to use electric vehicles (EVs). However, there are only a few studies to determine the customer's purchase intention in buying a new electric vehicle (Kumar and Alok 2020).

Habich-sobiegalla et al. (2019) investigated what Chinese people think about when deciding whether to buy electric cars. The study found that a Chinese person is much more likely to buy an electric vehicle if they have a large social network and know someone who already has one. A similar study was conducted by Krishnan and Koshy (2021). Their study investigated the influence of numerous attitudinal factors on consumers' purchase intentions to buy electric vehicles (EVs), and Structural Equation Modeling (SEM) technique was used. The findings of the study showed that "elements that influence attitudes, such as perceived benefits, social influence, price acceptance,

Table 4 Cluster themes and key findings

S.No	Theme Objective	Findings
1	EV batteries and sustainability	Circular economy techniques are required to enhance the resilience and sustainability of EV batteries.
2	Identifying the benefits of EV adoption	EVs are significantly energy efficient and pollute less than conventionally powered motor vehicles. EV can reduce pollution exposure because their environmental consequences are primarily caused by vehicle manufacturing and electricity generation outside of urban areas.
3	Development of EV charging technologies	Shared mobility, fast charging, vehicle-to-grid (V2G) integration, and vehicle automation can help to promote smart and sustainable urban mobility.
4	Assessment of EV-driven business for sustainability	The widespread adoption of electric vehicles has the potential to transition our markets away from petroleum and reducing the environmental carbon footprint of public transit.
5	Development of sustainability assessment framework for EV adoption	Many nations are promoting EV technologies to lessen the environmental effects of transportation, such as greenhouse gas emissions and urban air pollution
6	Identifying the consumer intentions for EV purchasing	"Attitudes, such as perceived benefits, social influence, price acceptance, performance, technology consciousness, and marketing, distribution, and after-sales, have a positive effect on the intention to buy an electric vehicle".

performance, technology consciousness, and marketing, distribution, and after-sales, have a positive effect on the intention to buy an electric vehicle (EV)."

Considering the Malaysian market, Asadi et al. (2021) investigated the factors influencing the purchasing intention of the customers. According to the findings, "consumers' perceptions of value, attitudes, the sense of personal of responsibility, subjective norms, personal norms, perceived consumer efficacy, and awareness of consequences all had a substantial and positive impact on their desire to buy electric vehicles". Similarly, before that, Adnan et al. (2017) conducted a study to forecast the customer's purchasing intention to adopt an electric vehicle (EV). The widespread adoption of EVs has substantially impacted the long-term health of economies everywhere. Understanding and analyzing the elements influencing consumers' mindsets towards the uptake of electric vehicles is crucial.

Egbue and Long (2015) identified the barriers to the adoption of EVs. The study aims is to establish whether concerns about the environment play a role in a consumer's decision to buy an electric vehicle and to identify potential socio-technical impediments to consumer adoption of EVs. *Research propositions* based on the analysis of cluster six for future researchers.

1. To identify the determinants of consumer perceptions for buying an EV.
2. To investigate the barriers and drivers of purchase intention of consumers for buying an EV in India.

All clusters' themes and objectives with key findings are shown in Table 4.

6 Morphological analysis

Morphological analysis (MA) breaks down the area of study into parts to describe it thoroughly. It simulates complex difficulties without numerical calculations. A general version of MA has been employed in biology, engineering, management, and other fields to organize and explore the full set of linkages in multidimensional, non-quantifiable situations (Haaker et al. 2021). The MA is a subcategory of the systematic literature review (SLR), which is a summary of primary research that makes use of procedures that are transparent and easy to reproduce (Baliga et al. 2021).

This research aimed to develop a method for analyzing EV adoption and Sustainability studies using keyword-based morphology. For the sake of this research, we will be relying on the authors' provided keyword data to help us decipher the meaning of the text. The results of this text-mining project based on keyword analysis will aid academics in gauging the current state of research and predicting its future direction. It has the potential to foresee the current standing of EV adoption and Sustainability and locate new possibilities in the field of study. The first step of this investigation is to categorize potentially relevant keywords for each cluster. Then, in the resulting cell matrix, list all the potential keywords both horizontally and vertically. Now, in the matrix cell corresponding to the intersection of the author's preferred keyword combinations, record the author's name. Below are the results of analyzing the morphology of all the clusters. Table 5 presents the results of a morphology study of the cluster 1 keywords.

The study will use these twelve keywords to determine the keyword combinations that appear most frequently in the papers as well as the keyword combinations that appear least frequently in the papers. It can be seen from the analysis

Table 5 Keyword based morphology analysis of cluster 1 (EV batteries and sustainability)

	Re-use	EV	LIB	CE	Resilience	Sustainability	End-of-life	Clean Technology	Critical metal	Bibliometric study	Recycling	Decision making
Re-use												
EV	Moore et al. (2020); Reinhardt et al. (2019)											
LIB	Moore et al. (2020); Olivetti et al. (2017)	Moore et al. (2020); Olivetti et al. (2017); Baars et al. (2021)										
CE	Moore et al. 2020	Moore et al. (2020)**;** Baars et al. (2021)	Moore et al. (2020)									
Resilience	Moore et al. 2020		Moore et al. (2020)									
Sustainability	Moore et al. 2020; Reinhardt et al. 2019	Reinhardt et al. 2019	Baars et al. (2021)									
End-of-life			Agusdinata et al.2018									
Clean Technology		Gopal et al. 2018										
Critical Metal	Olivetti et al. (2017)	Baars et al. (2021)	Olivetti et al. (2017); Agusdinata et al. (2018)									
Bibliometric study			Agusdinata et al. (2018)									
Recycling	Kumar, Singh et al. (2021)	Kumar, Chakraborty et al. (2021)	Kumar, Singh et al. (2021)	Kumar, Singh et al. (2021)		Kumar, Singh et al. (2021)						
Decision making		Kumar, Singh et al. (2021)										

Where *CE* Circular Economy, *EV* Electric Vehicle, *LIB* Lithium-Ion Batteries

Table 6 Keyword based morphology analysis of cluster (Identifying the benefits of EV adoption)

	Consumer behavior	Innovations	EV	Low emission model	Symbolic motives	Sustainability	Ethical evaluation	Micro-mobility	Conventional models
Consumer behavior									
Innovations	Tran et al. (2013)								
EV	Tran et al. (2013)	Tran et al. (2013); Noppers et al. (2014)							
Low emission model			Daziano and Chiew (2012)						
Symbolic motives			Noppers et al. (2014)						
Sustainability		Noppers et al. (2014)	Noppers et al. (2014); Weiss et al. (2015); Eccarius and Lu (2020); Shalender and Sharma (2021)		Noppers et al. (2014)				
Ethical evaluation			Qian and Yin (2020)						
Micro-mobility			Eccarius and Lu (2020)						
Conventional models			Weiss et al. (2015); Shalender and Sharma (2021)						

that Moore et al. (2020), Olivetti et al. (2017), and Baars et al. (2021) have done a work on the *EV* and *LIB* means this combination of keywords occurs three times. They have done work on the LIBs used in the EVs. By increasing the usable life of LIBs and keeping their inherent value through reuse, repurposing, refurbishing, and recycling, the circular economy can reduce these problems. The LIB industry relies on raw minerals that are difficult to find in nature, such as lithium and cobalt. Brine water is used in the extraction of lithium. It is found in significant quantities in a few areas, such as Bolivia, Chile, China, the United States of America, and Argentina. Considering this challenge, Moore et al. (2020) and Olivetti et al. (2017) have done work on *LIBs* and *Re-use* keyword combination. Moore et al.(2020) and Reinhardt et al. (2019) conducted a study on the re-use of precious resources like Lithium in LIBs for EV. They have done a study on *EV* and *Re-use* of LIB.

Moore et al. (2020) and Baars et al. (2021) have done a study on *CE* and *EV* keyword combinations. Considering the *critical metal* and *LIBs* keyword combination, Olivetti et al. (2017) and Agusdinata et al. (2018) have identified the criticality of resources like lithium. Other keywords combinations either appear once or not appearing at all. The least used keyword combinations are bibliometric study and EV, bibliometric study and LIB, sustainability and resilience, EV supply chain and Resilience, etc. Future researchers can focus on these keywords' combinations.

The Table 6 presents the results of a morphology study of the cluster 2 keywords. The study will use these nine keywords to determine the keyword combinations that appear most frequently in the papers and the keyword combinations that appear least frequently in the papers. It can be seen from the analysis that Noppers et al. (2014),Weiss et al. (2015), Eccarius and Lu (2020), and Shalender and Sharma (2021) have done a work on the *EV* and *Sustainability* means this combination of keyword appears four times in the study. These studies examine the potential socio-technical challenges to EV consumer adoption and investigates the sustainability concerns that impact consumer decisions to acquire an EV. When compared to conventional automobiles powered by internal combustion engines, electric vehicles (EVs) are widely regarded as a more environmentally friendly option. Noppers et al. (2014) and Tran et al. (2013) have done a work on possible *innovations* and *EVs* keyword combination. Sustainable innovations not only help the environment and can be utilized to project a positive image, but they may also inspire people to adopt them because of these beneficial qualities. Other keywords combinations either appears once or not appearing at all. Least use keyword combinations are low emission model and consumer

Table 7 Keyword based morphology analysis of cluster 3 (Development of EV charging technologies)

	EV	Shared mobility	Vehicle to grid	Sustainability	Wireless charging	Local pollutant	Energy storage	IEMS	Policy
EV									
Shared mobility	Taiebat and Xu (2019)								
Vehicle to grid	Taiebat and Xu, (2019); Ahmad et al. (2018); Jha et al. (2019)	Taiebat and Xu (2019)							
Sustainability	Taiebat and Xu, (2019)		Taiebat and Xu (2019)						
Wireless charging	Lazzeroni et al. (2021); Ahmad et al. (2018); Taiebat and Xu (2019)		Taiebat and Xu (2019); Ahmad et al. (2018)						
Local pollutant	Lazzeroni et al. (2021)								
Energy storage	Jha et al. (2019)		Jha et al. (2019)		Jha et al. (2019)				
IEMS	Jha et al. (2019)								
Policy	X. Zhang et al. (2014)								

IEMS Intelligent Energy Management Systems

behavior, sustainability and innovation, consumer behavior and EV adoption, etc. Future researcher can focus on these keywords' combinations.

The Table 7 presents the results of a morphology study of the cluster 3 keywords. The study will use these nine keywords to determine the keyword combinations that appear most frequently in the papers as well as the keyword combinations that appear least frequently in the papers. It can be seen from the analysis that Lazzeroni et al. (2021), Ahmad et al. (2018) and Taiebat and Xu (2019) have done a work on the *EV* and *wireless charging (WC)* and this combination of keyword appears highest number of times in the study followed by *EV* and *Vehicle to grid*. Compared to conventional plug-in charging, WC has many advantages, including better safety, convenience, and user experience. Due to the WC's ability to automate the charging process and reduce human-in-the-loop (operational) costs, it is predicted that fleet operational costs will reduce regardless the larger initial investment. Second important vehicle technology in EV research by the Jha et al. (2019)**,** Ahmad et al. (2018) and Taiebat and Xu (2019) is vehicle to grid. Vehicle-to-grid (V2G) integration, also known as bidirectional charging since electric vehicles (EVs) may send power back to the grid when it's in short supply, is another developing technology that has received a lot of attention. Other keywords combinations either appears once or not appearing at all. Least use keyword combinations are EV and sustainability, vehicle to grid and policy, wireless charging, and sustainability, etc. Future researchers can focus on these keywords' combinations.

Table 8 presents the results of a morphology study of the cluster 4 keywords. The study will use these eleven keywords to determine the keyword combinations that appear most frequently in the papers and the keyword combinations that appear least frequently in the papers. It can be seen from the analysis that keyword combinations *EV and Business*, and *Consumer and Business* have appeared two times in cluster 4 by Valogianni et al. (2020), Almansour (2022) and Rubens (2019). This research looked at how customers think about the EV business and found a strong correlation between acceptability and factors including demographics, environmental consciousness, and the availability of supporting infrastructure. This combination of keywords is appeared highest number of times. Other keywords combinations either appear once or not appearing at all. The least use keyword combinations are renewable energy and sustainability, standard and market, ML and EV, etc. Future researchers can focus on these keywords' combinations.

The Table 9 presents the results of a morphology study of the cluster 5 keywords. The study will use these eight keywords to determine the keyword combinations that appear most frequently in the papers and the keyword

Table 8 Keyword based morphology analysis of cluster 4 (Assessment of EV-driven business for sustainability)

	Business/ E-business	EV	Mobility model	Renewable energy	Smart charging	Market	Sustainability	Vehicle to grid	Standard	ML	Consumer
Business											
EV	Valogianni et al. (2020); Almansour (2022)										
Mobility model		Szinai et al. (2020)									
Renewable energy			Szinai et al. (2020)								
Smart charging			Szinai et al. (2020)	Szinai et al. (2020)							
Market	Valogianni et al. (2020)	Valogianni et al. (2020)									
Sustainability		Valogianni et al. (2020)									
Vehicle to grid	Szinai et al. (2020)	Brown et al. (2010)									
Standard	Szinai et al. (2020)	Brown et al. (2010)						Brown et al. (2010)			
ML	Rubens (2019)	Rubens (2019)					Rubens (2019)				
Consumer	Rubens (2019)	Rubens (2019)				Almansour (2022) Rubens (2019)	Rubens (2019)			Rubens (2019)	

ML Machine Learning

Table 9 Keyword based morphology analysis of cluster 5 (Development of sustainability assessment framework for EV adoption)

	LCSA	EV	Sustainable Transport	EOM	E- Carsharing	CO2 Emission	Uncertainty	Vehicle to grid
LCSA								
EV	Onat et al. (2016); Onat et al. (2019)							
Sustainable Transport	Onat et al. (2016); Onat et al. (2019)	Greaves et al. (2014)						
EOM		Onat et al. (2016); Onat et al. (2019); Chen et al. (2020)						
E-Carsharing		Luna et al. (2020); Arena et al. (2015)						
CO2 Emission	Luna et al. (2020)	Luna et al. (2020); Chen et al. (2020)			Luna et al. (2020)			
Uncertainty		Onat et al. (2016)	Onat et al. (2016)					
Vehicle to grid		Chen et al. (2020)						

Where *EOM* Electrification of Mobility, *LCSA* Life Cycle Sustainability Assessment, *LIB* Lithium-Ion Batteries

combinations that appear least frequently in the papers. It can be seen from the analysis that Onat et al. (2016), Onat et al. (2019), and Chen et al. (2020) have done work on the *EV* and *EOM,* that means this combination of keywords used by the authors at the highest number of times. EOM is a topic that is gaining traction worldwide, and many nations are providing support for the technologies used in electric vehicles to reduce the negative effects of transportation on the climate, such as emissions of greenhouse gases and air pollution in urban areas. Onat et al. (2016) and Onat et al. (2019) have worked on EV and LCSA. Life-cycle assessment (LCA) models have been utilized to a large extent throughout the body of published research to examine the associated environmental consequences that occur during the life cycles of both traditional and electric vehicles. Recently, academic researchers and transportation system operators have shown an increasing interest in road sharing among vehicles as a possible tool to improve the long-term viability of urban transportation or mobility systems. Luna et al. (2020) and Arena et al. (2015) have researched EV and Car sharing. Other keywords combinations either appears once or not appearing at all. The least used keyword combinations are CO2 emission and sustainable transport, LCSA and E-carsharing, CO2 emission and EOM, etc. Future researchers can focus on these keywords' combinations.

Table 10 presents the results of a morphology study of the cluster 6 keywords. The study will use these *seven* keywords to determine the keyword combinations that appear most frequently in the papers and the keyword combinations that appear least frequently in the papers. It can be seen from the analysis that Adnan et al. (2017), Asadi et al. (2021), Egbue and Long (2015), Habich-sobiegalla et al. (2019), Kumar and Alok (2020), and Krishnan and Koshy (2021) have done a work on the *EV adoption* and *purchase intention* that means this combination of keyword used by the authors at highest number of times.

Investigating the causes of consumers' negative reactions to electric cars is crucial. The rapid adoption of more sustainable passenger transport and vehicle-to-grid (V2G) mobility can be accelerated by raising public awareness and acceptance of electric cars (EVs). As per Asadi et al. (2021), "Consumers' intention to buy electric vehicles was strongly and favorably influenced by their perceptions of value, attitudes toward ownership, perceived effectiveness as a buyer, and knowledge of potential outcomes." The second most used keyword combination is *EV adoption* and *sustainability*. It was used by the two research papers (Habich-sobiegalla et al. (2019); Kumar and Alok (2020). Therefore, public opinion is crucial for decarbonizing transportation and capturing the benefits of less pollution, noise, and oil use. Other keywords combinations either appear once or not appearing at all. The

Table 10 Keyword based morphology analysis of cluster 6 (Identifying the consumer intentions for EV purchasing)

	Sustainability	EV Adoption	Purchase Intention	Vehicle emission	Socio-technical barriers	Policy	Attitude
Sustainability							
EV Adoption	Habich-sobiegalla et al. (2019); Kumar and Alok (2020)						
Purchase Intention	Habich-sobiegalla et al. (2019)	Adnan et al. (2017); Asadi et al. (2021); Egbue and Long (2015); Habich-sobiegalla et al. (2019); Kumar and Alok (2020); Krishnan and Koshy (2021)					
Vehicle Emission	Krishnan and Koshy (2021)	Krishnan and Koshy (2021)	Krishnan and Koshy (2021)				
Socio-Technical Barriers		Egbue and Long (2015)					
Policy		Kumar and Alok (2020); Krishnan and Koshy (2021))	Krishnan and Koshy (2021)				
Attitude		(Egbue and Long 2015)			(Egbue and Long 2015)		

least used keyword combinations are socio-technical barriers and EV adoption, Sustainability and policy, EV adoption and policy, etc. Future researchers can focus on these keywords' combinations.

7 Implications of the study

7.1 Policy implications

This study aims to formulate comprehensive policies about the recycling of electric vehicle (EV) batteries, with a specific focus on promoting appropriate disposal practices and mitigating adverse environmental consequences. Some many different policies and initiatives can be implemented on a national, state, and municipal level to encourage the widespread usage of electric cars (EVs). Policymakers can create rules and laws to encourage the manufacturing of EVs that are both environmentally friendly and efficient in their use of energy. They can also regulate EV batteries' disposal to lessen their environmental impact. Governments and nonprofit organizations can act through education and outreach to spread the word about the merits of electric vehicles and the best practices for using them responsibly. Governments can stimulate the use of electric vehicles and charging infrastructure by providing financial incentives, such as tax credits and rebates (Chakraborty et al. 2021). Investing in and fostering the growth of charging networks and stations is something governments can do to make it more convenient for EV drivers to charge their vehicles (Haustein et al. 2021). To further minimize their carbon footprint, governments might encourage the integration of EVs with renewable energy sources like wind and solar (Sovacool et al. 2018).

It is imperative to maintain constant vigilance on the effects of policies and make necessary adaptations to tackle emerging difficulties and secure long-term sustainability effectively. Advocate for incorporating sustainable energy sources into the electrical grid infrastructure to mitigate the environmental impact associated with electric vehicle charging. To foster the production of electric cars (EVs), it is proposed to enforce stringent pollution regulations and adopt a progressive approach towards the phasing out of internal combustion engine (ICE) vehicles. These initiatives and regulations can make it more likely that the market for electric vehicles will expand in an egalitarian and environmentally friendly way.

7.2 Societal Implications

Several societal factors, such as those listed below, may be affected by the widespread use of electric cars (EVs).

- Improved health outcomes have been linked to lower pollution levels in cities where EVs are widely used (Asadi et al. 2022).
- As the EV industry expands, it will generate new opportunities in manufacturing, maintenance, and charging infrastructure, which will help local economies thrive (Kumar, Sing et al. 2021).
- Electric vehicles are better for the environment than gas-powered cars because they produce fewer greenhouse gases (Dua et al. 2021).
- EVs have the potential to lessen reliance on foreign oil, which in turn might increase energy independence and decrease fuel prices (Broadbent G, Allen et al. 2022).
- Increasing mobility and boosting quality of life by making transportation available to those who might not have been able to afford it before, thanks to EVs.

However, some potential difficulties and trade-offs may be involved in adopting EVs, and it is crucial to keep this in mind while thinking about the societal implications of EVs. For instance, the upfront cost of EVs might be a barrier to adoption for low-income households, and the production of batteries for EVs can have detrimental effects on communities and the environment. Thus, it is essential to give due consideration to the societal consequences of EVs and to create policies and programs that guarantee the benefits of EVs are shared fairly and that their negative aspects are mitigated to the greatest extent possible.

7.3 Managerial implications

Electric vehicle (EV) adoption and use has significant managerial implications, especially for businesses in the transportation, energy, and automotive sectors. Here are a few illustrations:

- Strategic preparation involves thinking about how electric vehicles (EVs) fit into the bigger picture of an organization's business strategy and what might need to change because of the introduction of this new technology (Sonar and Kulkarni 2021).
- Supply chain management: Businesses must evaluate and mitigate the hazards inherent in the manufacturing and sourcing of electric vehicle (EV) parts, as well as any adverse effects on local communities and the environment (Kumar, Singh et al. 2021).
- Businesses must provide opportunities for their staff to learn about and gain experience with EVs and related technology.
- Customer engagement: Organizations need to engage with their customers to understand their needs and preferences, and to educate them about the benefits and uses of EVs.
- Sustainability reporting: Companies should be forthright about their efforts to lessen their negative impact on the environment using EVs and other sustainable initiatives.

These management ramifications stress the importance of businesses taking a holistic, preventative stance towards EV adoption and use to reap the greatest benefits and suffer the fewest drawbacks. By taking such steps, businesses can establish themselves as pioneers in the movement toward a greener, more sustainable future (Egbue and Long 2015).

8 Conclusions, future research scopes, and limitations

This research study has performed a bibliometric analysis, cluster analysis, and morphology analysis of ‘EV adoption and Sustainability’ area to get the insights of the research field. In total, 291 articles were found that discussed “EV adoption and sustainability” from 2010 to Jan 2023. Since 2017, the number of electric vehicle adoption and sustainability (EVS) research articles published has increased at an exponential rate. We only considered review papers, articles, and journals in our assessment. After going through this procedure, we found 191 articles worthy for bibliometric study and 73 were chosen for the cluster analysis.

The United States, China, the United Kingdom, India, and the Netherlands are only few of the countries that have produced a significant number of articles on the subject. The United States of America authors were cited more frequently. Sustainability Switzerland has published 13 papers with total citation 227. It is published by the MDPI journal. The highest citations belong to the *Energy Policy* journal by publisher *Elsevier*. The Benjamin K. Sovacool has highest publication in EV adoption and sustainability area. He has published eight papers in the research domain, and he is affiliated from the university of Aarhus Denmark.

A comprehensive bibliometric analysis of the *EV adoption and sustainability* was undertaken by using bibliographic maps of source co-citation, author co-citation, and international collaborations. Some important emerging areas of studies are sustainable transport; environmental sustainability; recycling; reduce; reuse; charging technologies; fast charging; circular economy; life cycle assessment; decision making; consumer intention; battery swapping mode; and corporate social responsibility as per keyword co-occurrence analysis visualization mode.

The six clusters in EV adoption and sustainability research have been identified through bibliographic coupling of the documents, and research propositions for each cluster have been proposed. By analyzing co-citations and bibliographical coupling, for instance, researchers can gain insight into the underlying intellectual structure and the evolution of important topics in the subject through time. Each cluster in this study has also undergone a morphological analysis based on keywords. Here, we'll examine the text with the help of the authors' provided keywords to shed light on its meaning. The important keywords are identified from the six clusters. The keywords like lithium-ion batteries, reuse, recycling, sustainability, end-of-life, electric vehicle, vehicle charging, vehicle to grid, smart charging, pollution, and consumer perception are most occurring keywords in the research study. Socio-economic sustainability, resilience, charging infrastructure, bibliometric study, machine learning, etc. are the least occurring keywords in the research study.

There is no bibliometric analysis that can provide you a complete picture of the research development and present state of the topic. However, the search strategy employed to compile the body of literature on EV adoption and sustainability research may have missed certain studies that might have strengthened the findings of this investigation. The findings of this analysis might be expanded by future researchers by integrating new categories of publications and by utilizing different databases (such as web of science). Furthermore, this research utilized just author-supplied keywords to conduct a morphology analysis. Keywords are in tended to highlight the most important aspects of a paper, but a lack of a keyword in a list does not rule out the possibility of a paper having content linked to a certain term. Future researchers can use another context of morphology approach other than keyword-based texting mining morphology analysis, for in-depth analysis of the content. Future researchers can do systematic literature review and other methodologies for the better understanding of research area.

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