

An Intellectual Structure Analysis of Electric Vehicle Research Using Bibliometric Techniques (2015–2025)

Ajaykumar Poojary^{1*} and Dr. Leena Nair²

¹*Research Scholar & Assistant Professor, Department of Commerce,
Vidyalankar School of Information Technology, Mumbai, Maharashtra, India

²Research Supervisor & Associate Professor, Department of Management,
Vidyalankar School of Information Technology, Mumbai, Maharashtra, India

E-mail: ¹ajay.poojary@vsit.edu.in, ²leena.nair@vsit.edu.in

ORCID: ¹<https://orcid.org/0009-0007-6117-5196>, ²<https://orcid.org/0000-0002-6806-695X>

(Received 18 May 2026; Revised 27 June 2026, Accepted 07 August 2026; Available online 29 September 2026)

Abstract - The recent emphasis of the world on sustainable transportation, carbon emission reduction, and renewable energy source usage, there has been considerable expansion in EV research in the last decade. In this paper, an extensive bibliometric analysis of the knowledge structure, trends, citations, collaboration, and themes of the literature covering the period between 2015 and 2025 was carried out for further analysis of the EV research domain. The bibliographic data used in this study were collected from the Scopus database and analyzed with the help of Bibliometrix (Biblioshiny) and VOSviewer in order to perform performance analysis and science mapping. This data collection involves 8,864 papers with a total of 241,843 citations and indicates rapid development and increasing scientific significance of EV research. 30.16% of all the papers belong to the category "international collaboration," with China, the USA, and India being the key contributors to this area. On the basis of the thematic analysis, it can be said that there has been a move away from the earlier research themes of battery technology and charging stations to the themes of integration with renewable energy, smart grids, vehicle-to-grid, battery recycling, sustainable mobility, and intelligent energy management. The findings provide an overall view of the evolution of research on EVs, identify research actors and emerging research topics in the field, and highlight research gaps.

Keywords: Electric Vehicles, Bibliometric Analysis, Bibliometrix, Vosviewer, Research Collaboration, Thematic Evolution, Sustainable Transportation

I. INTRODUCTION

There have been many efforts to move towards sustainable ways of moving around the globe during the past decade owing to rising global warming, GHG emissions, reduced availability of fossil fuels, and energy security. The transport industry is among the biggest contributors of CO₂ globally and is now receiving attention worldwide for becoming carbon neutral and sustainable (Duan et al., 2023). This has resulted in the creation of electric vehicles as a possible solution to overcome the problems facing internal combustion engine vehicles, particularly in respect of environmental pollution, increased energy efficiency, and renewable energy integration into the present transportation system (Sandrini et al., 2023). The fast advancement in

battery technology, charging stations, smart grids, and policies both in developed and developing countries has also contributed to the widespread use of EVs.

Along with rapid technological developments within electric vehicles, a lot of research in different spheres, including electrical engineering, energy systems, transport systems, environment, public policies, and management, has been carried out (De Rubens et al., 2020). At first, scientific studies were aimed at the development of batteries, powertrains, charging systems, and performance of vehicles, but later researchers started investigating renewable energies, smart grids, V2G systems, consumer behavior, battery recycling, sustainable mobility, policies evaluation, and energy consumption management (Noudeng et al., 2022). In this regard, there has been an evident increase in the number of scientific papers published about electric cars, which makes the field's knowledge base extensive and growing.

Traditional literature reviews in narrative form have become impractical in light of the growth in publications, and researchers, policymakers, and practitioners in the industry are unable to get a clear understanding of the intellectual structure and progress of research in EVs from the narrative literature reviews. Literature reviews of a particular subject have the advantage of going into the details of the particular research subject but they are not meant for making quantitative assessments about publication trends, scientific impact, collaboration networks, evolution of themes and knowledge structure in the overall research domain. The bibliometric literature review approach has therefore become an efficient tool for conducting literature reviews using quantitative tools and scientific visualization techniques that are efficient tools for analyzing a large body of scientific literature.

Several bibliometric analyses have been carried out on certain aspects of electric vehicle research; however, some of these analyses have been narrow-scope analyses focusing on technologies, geographical areas, and/or publication years. Moreover, the accelerated research activities concerning

electric vehicles after 2020 due to global decarbonization efforts, subsidies from governments, investments from industries, and advancements in the area of renewable technologies have significantly influenced the research scenario (Rietmann et al., 2020). Against this backdrop, there should be a contemporary and holistic bibliometric analysis of the field of electric vehicle research, which should address influential researchers, collaboration among researchers in studying electric vehicles, and the evolution of themes within this field in the last decade.

Therefore, in this paper, a broad bibliometric review of scientific publications about electric vehicles, which were published between 2015 and 2025, has been provided through the use of the Scopus database (Rizza et al., 2021). In order to examine the publication dynamics, citation impact, authorship, most cited articles, journals, institutions, countries, collaboration network among countries, keywords, and themes of the studies, the bibliographic data have been examined with Bibliometrix (R package/Biblioshiny) and VOSviewer. This bibliometric review aims not only at performance analysis but also at the visualization of the knowledge structure regarding the field of EVs. It helps in identifying new topics which might be important in future research and policies (Sheldon & Dua, 2024).

Key Contributions of the Research

- Provides a comprehensive bibliometric review of global electric vehicle (EV) research published between 2015 and 2025, highlighting publication growth and research trends.
- Identifies the major contributors, including leading authors, journals, institutions, and countries, and examines international research collaboration.
- Explores emerging research themes and future research directions through keyword and thematic analyses, providing useful insights for researchers and policymakers.

The remaining sections of this paper are structured as follows. Section II outlines the current literature on electric vehicles and past bibliometrics. The methodology of this bibliometric analysis is presented in Section III, where the data source, the search strategy, the data preparation procedures, and the analysis methods are introduced. Section IV outlines and discusses the bibliometric findings, including publishing trends, citation metrics, network analysis, and thematic evolution. The important implications of the study and directions for future research are elaborated on in Section V. Section VI concludes the paper and indicates avenues for future research on EVs.

II. LITERATURE REVIEW

Andoni et al., (2019) is an article focusing on the impact of new technologies on the energy transition in connection with the development of electric mobility. From the results of the study, it became evident that technologies for digitalization,

distributed energy systems, and business models played an important role in the process of promoting EVs. It was emphasized that such vehicles would become an integral component of renewable energy systems and smart energy grids. As has been concluded from the research, a sustainable transportation system of the future could only be achieved through the integration of transport and energy systems.

As mentioned by Dileep, (2020), there is a detailed review on the technologies and applications related to the smart grid, where emphasis is laid on the importance of the smart grid for EVs. The study showed the interrelation among the charging stations of electric vehicles, Renewable Energy Sources, Demand Response, and grid reliability. It was pointed out that energy management through the smart grid is an area of research interest.

Kang et al., (2017) have suggested an energy management solution for the network of electric vehicles that comprises P2P energy trading and smart grid communication. The research highlighted the benefits that might be achieved using EVs as distributed energy sources capable of balancing the grid and improving its energy management. It turned out that novel ways of communication and distributed energy management would allow increasing the efficiency of the future electric mobility solutions.

As per Zaino et al., (2024), there is an extensive systematic review of the determinants of the uptake of electric vehicles, taking into account the technical, environmental, organizational, and policy determinants that affect electric vehicle use. It was established that the uptake of electric vehicles needs a multifaceted approach that includes technological innovation, development of charging points, government intervention, consumer consciousness, and sustainable transportation policies. The authors emphasize the necessity to adopt a holistic approach towards the future development of electric vehicles that would include both technical and socio-economic considerations. The results are crucial for appreciating the multidimensionality of the issue of large-scale uptake of EVs.

Opportunities and Challenges Involved in the Integration of Electric Vehicles with Renewable Energy and Smart Grids. Sinha et al., (2023) have carried out research on the integration of electric vehicles with renewable energy and smart grids. Discussed the advantages and challenges in energy management with electric vehicles, such as synchronization of charging, energy grid stability, use of renewable energy, and demand-side management. It has been found that the integration of electric vehicles with renewable energy sources has great significance for reducing carbon emissions and improving energy efficiency.

The journey of Earth to attain a net-zero position by means of adopting electric cars was analyzed by Timilsina et al., (2025). In this analysis, the impact of EVs on the reduction of emissions in the transportation sector was considered apart from examining technical, economic, policy, and

infrastructural obstacles associated with the widespread adoption of electric vehicles. It has been identified that it is mandatory to make collective efforts of government, industry, and research organizations to ensure sustainable growth in the use of electric vehicles. It has been concluded by the researchers that EVs have an essential role in the global sustainability strategy, but there are certain areas where improvements are required in this regard.

The factors affecting the competitiveness of EVs, such as the cost of batteries, the presence of charging stations, the source of electricity generation, as well as the policy towards EVs, were analyzed. It is important to highlight that the authors emphasized the importance of the integration of renewable sources of energy and clean electricity generation as one of the environmental benefits of EVs. According to the results of the study, a comprehensive approach needs to be adopted to ensure the sustainability of EVs.

TABLE I COMPARATIVE ANALYSIS OF EXISTING LITERATURE ON ELECTRIC VEHICLE RESEARCH

Authors	Methodology	Dataset / Simulation Environment	Research Gap
Andoni et al., (2019)	Systematic review of blockchain applications and emerging digital technologies in the energy sector, focusing on EV integration, decentralized energy systems, and innovative business models.	Literature collected from energy, blockchain, and smart grid research domains.	Limited investigation of practical implementation challenges and large-scale integration of digital technologies within EV ecosystems.
Dileep, (2020)	Comprehensive review of smart grid technologies and applications, analyzing energy management, demand response, and grid integration approaches.	Existing smart grid research studies cover renewable energy systems, EV charging infrastructure, and power network applications.	Limited focus on EV-specific energy management strategies and real-time optimization methods for large-scale EV deployment.
Kang et al., (2017)	Proposed a blockchain-enabled peer-to-peer energy trading framework for EV networks using decentralized communication and energy management techniques.	Simulation-based evaluation of EV energy trading networks using blockchain and smart grid communication environments.	Further research is required to improve the scalability, transaction efficiency, and real-world deployment feasibility of decentralized EV energy systems.
Zaino et al., (2024)	Conducted a systematic literature review to identify technological, environmental, organizational, and policy factors affecting EV adoption.	Review of previous EV adoption studies covering consumer behavior, policies, infrastructure, and sustainability factors.	Limited quantitative analysis of global EV adoption trends and insufficient integration of technological and socio-economic factors.
Sinha et al., (2023)	Reviewed EV integration with renewable energy sources and smart grids, focusing on charging strategies, energy management, and grid stability.	Existing research articles related to renewable energy integration, EV charging systems, and smart grid applications.	Need for advanced intelligent charging frameworks and real-time energy optimization models for renewable-powered EV systems.
Timilsina et al., (2025)	Critical review of EV contribution toward net-zero emissions, analyzing technological, economic, policy, and infrastructure challenges.	Global studies related to EV deployment, climate policies, sustainability transitions, and transportation systems.	Limited regional comparative analysis and lack of comprehensive frameworks addressing diverse socio-economic conditions.

Conclusively, table I demonstrates that the current literature in these areas has progressed much concerning EV technology, renewable energy integration, smart grid application, charging infrastructure, and EV adoption. However, it should be noted that the majority of the current literature focuses on particular technological or application-oriented aspects, and there is less emphasis on the bibliometric analysis of the global EV research area as a whole. Particularly, there are no bibliometric reviews on global EV research published in the last few years that would provide information on the following aspects: publication trends, citation analysis, co-authorship network, thematic

evolution, and emerging research topics. Thus, this study attempts to fill the above-mentioned research gap.

III. METHODOLOGY

3.1 Literature Search Strategy and Data Collection

The methodology that was adopted for carrying out the research is a quantitative research methodology based on Bibliometrics. The bibliographic data was derived from the Scopus database, which was selected due to its broad coverage of multidisciplinary topics, accurate indexation of citations, and easy applicability of bibliometrics analysis software. The comprehensive search process was developed

based on the relevant keywords for the topic under investigation, such as electric vehicles, electric mobility, sustainable transportation, energy transition, market growth, policy framework, and electric vehicle adoption. The publications covered the timeframe of 10 years from 2015 to 2025, as it allowed for covering all recent changes in the field

of research about EVs. The articles and reviews were taken into consideration; however, only in the English language. The first data set was refined, including the criteria of duplicate data, irrelevant publications, and highly technical studies related to the battery, power electronics, and vehicle control system.

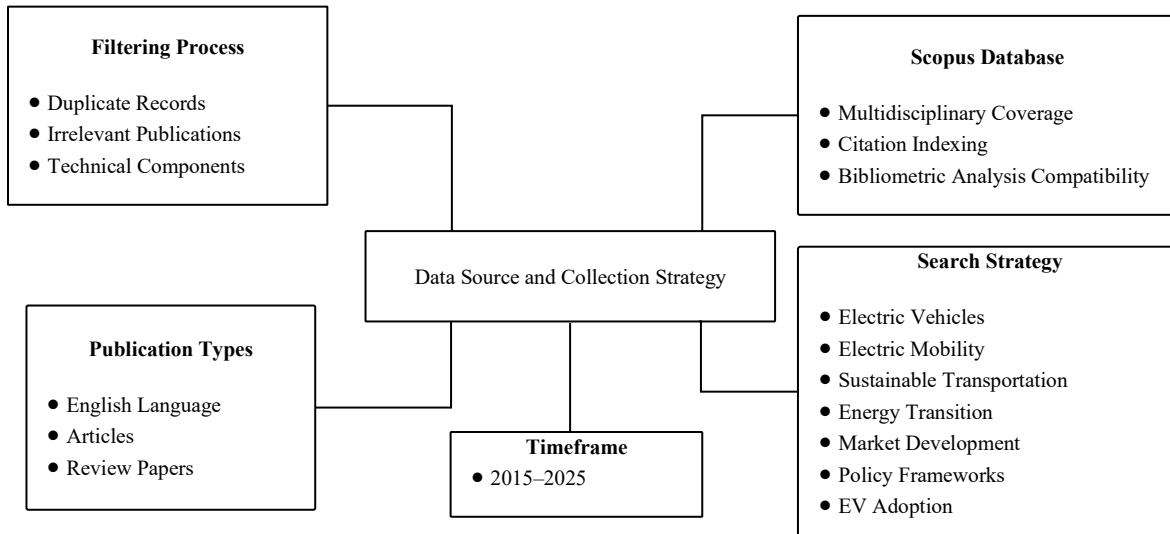


Fig. 1 Data Source and Collection Strategy for Systematic Literature Analysis

Fig. 1 illustrates the process of data sources and the collection approach that has been employed in analyzing research papers on EVs, electric mobility, and sustainable transport in a systematic way. Data collection has been conducted in the Scopus Database, which has been chosen due to its multidisciplinary coverage and possibility of citation indexing. A set of criteria has been developed on the basis of selected key research topics such as electric vehicles, electric mobility, sustainable transport, energy transition, market development, policy framework, and adoption of EVs. Inclusion criteria have been applied to the selected papers in order to ensure that they were written in the English language and published between 2015 and 2025. In order to make sure that the final data set contained high-quality and relevant literature for further analysis, a process of filtering has been used in order to exclude duplicate entries, irrelevant, and non-technical papers.

3.2 Data Processing and Screening

The dataset analysis was performed using a combination of performance analysis and science mapping approaches in order to determine growth trends, contributors, and evolution of the EV research themes. Performance analysis was conducted to reveal the trends in publications, citations, active authors, top journals, and countries. Science mapping approaches were used to study intellectual and conceptual connections in the research field. Co-authorship analysis was conducted in order to reveal patterns of cooperation among

the researchers and countries, while co-citation analysis revealed influential bases of knowledge. Co-occurrence of keywords analysis was conducted in order to determine the main topics of research and connections between these topics. Moreover, in order to trace the change in EV research topics throughout different time periods, thematic mapping and thematic evolution approaches were used. The use of these approaches gives a comprehensive overview of the evolution and structure of EV research as well as its possible future direction.

The research evaluation framework that is applied to conduct an all-round evaluation of the research achievement in the area of electric vehicles (EVs) is presented in fig. 2. The framework consists of the combination of performance evaluation and science mapping approaches to conduct a comprehensive evaluation of the publication trend, its citation impact, key authors, prominent journals, and countries contributing to the research field. The science mapping approaches consist of co-authorship analysis, co-citation analysis, keyword co-occurrence analysis, and thematic mapping with evolution analysis, which are utilized to evaluate the collaboration among researchers and countries, the knowledge base of EV research, and the major topics and their relationships in EV research, and the evolution of EV research, respectively.

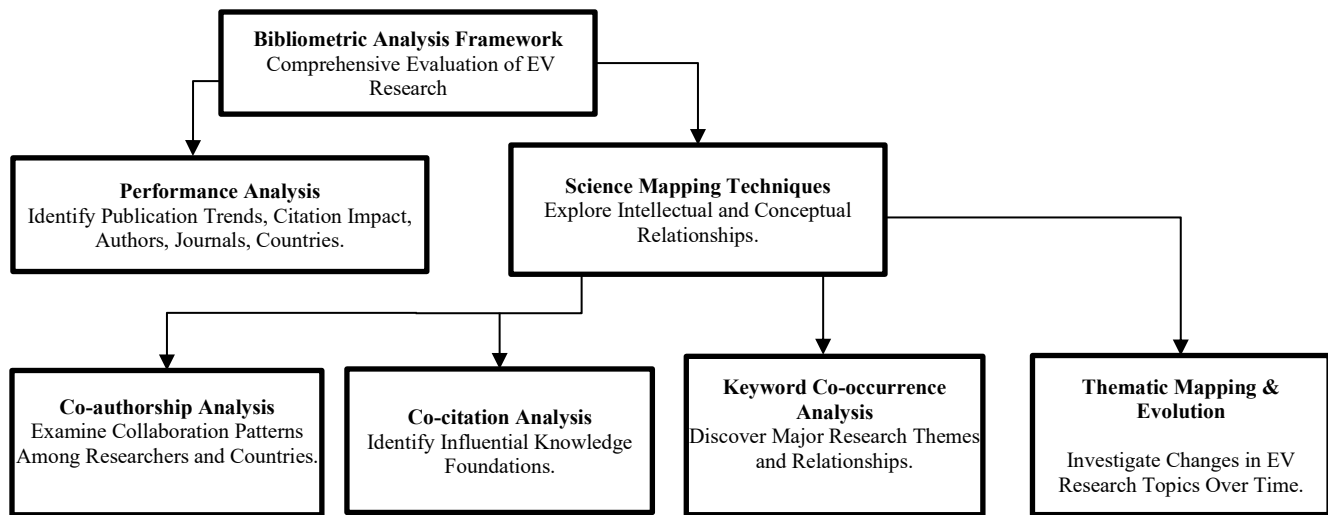


Fig. 2 Bibliometric Analysis Framework for Evaluating Electric Vehicle Research Trends

3.3 Bibliometric Analysis Methods

Data on bibliometrics were analyzed using Bibliometrix (R package) and VOSviewer to gain insight into the statistics and visual representations of research. The bibliometrix software and its web-based interface, Biblioshiny, were used in this study to carry out the analyses involving descriptive analysis, citation analysis, thematic mapping of the research area, and time-series analysis of research themes. The software used for constructing and visualizing scientific networks, known as VOSviewer, was used to construct the various networks, such as author collaboration networks, country collaboration networks, keyword co-occurrence networks, and relationships through citations. Data preprocessing steps were carried out in order to improve the accuracy before performing analysis, such as normalizing the authors' names, institution affiliations, and keywords used. The key relationships in the data set were determined by making use of the network visualization parameters, such as the minimum occurrence and citation limits.

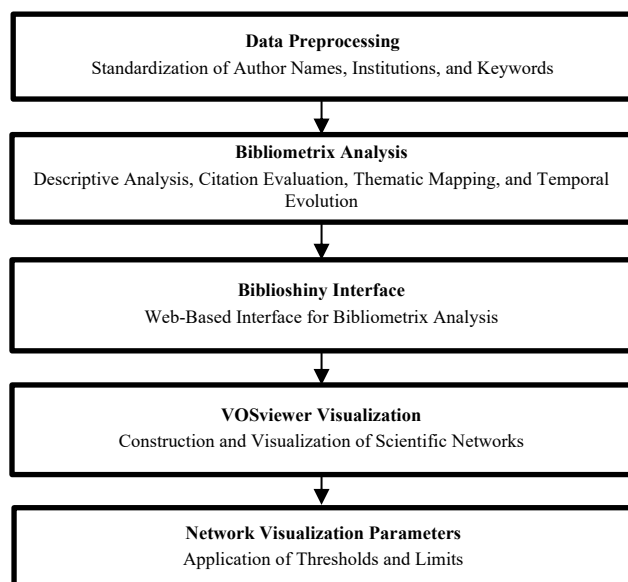


Fig. 3 Bibliometric Data Processing and Visualization Methodology

The methodology of the workflow of processing, analysis, and visualization of bibliometric data in order to construct the scientific network is shown in fig. 3. Research data have been collected and then preprocessed by standardization of authors, institutions, and keywords in order to achieve uniformity and accuracy of data. Preprocessed data have been further analyzed using various bibliometric approaches, which include descriptive analysis, citation analysis, theme mapping, and evaluation of temporal dynamics of the research to find out research patterns and emerging trends. The online platform biblioshiny interface has been utilized to conduct the bibliometric analysis, while VOSviewer has been employed to build science networks. Maps have been generated based on collaborations, citations, and keyword relationships through proper threshold and limit setting.

The process of the bibliometric review was done according to the following process: literature search in the Scopus database, data screening, data preprocessing, bibliometric analysis through Bibliometrix and VOSviewer, collaboration and thematic network visualization, and finally interpretation of research results.

IV. EXPERIMENTAL RESULTS

4.1 Bibliometric Dataset and Analysis Configuration

The bibliometric study was conducted using research articles published in the Scopus database between 2015 and 2025. The articles and books have been extracted through the identification of the predefined keywords relevant to the topic of electric vehicles and sustainable mobility. After application of inclusion and exclusion criteria, exclusion of the duplicated records, and preprocessing of the bibliometric data, a total of 8,864 articles from 1,959 journals by 21,962 authors were collected. Descriptive statistics, citation analysis, and thematic maps have been produced using Bibliometrix (R package/Biblioshiny), whereas the co-authorship, country collaboration, citation, and keyword co-occurrence networks have been built using VOSviewer. The appropriate analysis thresholds were applied for the

identification of the most influential authors, countries, and research topics. Table II presents the summary of the bibliometric data characteristics and the configuration of the analysis.

TABLE II BIBLIOMETRIC DATASET CHARACTERISTICS AND ANALYSIS CONFIGURATION

Parameter	Value
Analysis Tools	Bibliometric Analysis Tools
Database	Scopus
Research Period	2015–2025
Research Area	Electric Vehicle Research
Total Publications	8,864
Total Sources	1,959
Total Authors	21,962
Document Type	Articles and Reviews
Language	English
Analysis Methods	Bibliometric Indicators
Evaluation Metrics	TC, AC, MCP Ratio, CAI, NTC
Visualization	Network maps and thematic analysis

4.2 Publication Trends and Citation Analysis

The trends and the features of citation of electric vehicle (EV) research publications during 2015–2025 are described in this part on the basis of the bibliometric data collected in the Scopus database. As can be seen from table III, there are 8,864 publications with 241,843 citations, which makes 27.3 citations per publication on average. These figures show the impact of EV research on the scientific sphere. The CAGR for the annual publication growth rate is calculated at 25.77%, which demonstrates the rapid growth of the research activity in connection with the increased interest of the world community towards sustainability, renewable energy, and a decreased carbon footprint. The research field is characterized by the cooperation of researchers, and in this case, there are 21,962 authors in the dataset with 4.16 co-authors per document on average, and the Co-authorship Index (CAI) of 2.47. Also, the international cooperation of researchers is shown in 2,674 publications, resulting in the Multiple Country Publication (MCP) ratio of 30.16%. Thus, these bibliometric indicators allow for seeing clearly the development of EV studies in the past ten years (Kumar & Alok, 2020; Dua et al., 2024).

The main bibliometric indicators of the EVs research production over the past decade (2015–2025) are provided in table III and represent an increasing trend in publication counts, significant citation impact, and increasing global collaboration. The present research captures the fast-moving nature of EV research over the past decade.

TABLE III BIBLIOMETRIC INDICATORS OF ELECTRIC VEHICLE RESEARCH (2015–2025)

Metric	Value
Total Publications	8,864
Total Citations	241,843
Average Citations per Document	27.3
Average Citations per Year per Document	4.56
Annual Growth Rate (%)	25.77
Total Authors	21,962
Co-authors per Document	4.16
Co-authorship Index (CAI)	2.47
International Publications (MCP)	2,674
MCP Ratio	30.16%
References	58,172

4.3 Country Contributions and International Collaboration

This section provides a brief overview of the contribution made by different countries to the research on electric vehicles (EVs) along with the level of international cooperation from 2015 to 2025 (Dua et al., 2024). This particular country-based bibliometric analysis helps in identifying the trends of productivity, scientific impact, and collaboration, which in turn have contributed to the advancement of EV research worldwide. As evident from the above data presented in table IV, it can be seen that China is making the highest contribution in the area of EV research with a total number of 2,450 publications, followed by the United States and India, which have contributed 1,520 and 980 publications, respectively to the field of EV research. China is also among the top countries with high numbers of citations due to its high research output and continuous investment in electric mobility technologies (Guo et al., 2020). MCP ratio is relatively higher for countries such as Germany, the United Kingdom, and Australia owing to the fact that international collaboration is quite high in the case of these countries.

TABLE IV LEADING COUNTRIES CONTRIBUTING TO ELECTRIC VEHICLE RESEARCH (2015–2025)

Rank	Country	Publications	Citations	MCP Ratio
1	China	2450	68500	0.32
2	United States	1520	54200	0.41
3	India	980	21400	0.28
4	Germany	720	19800	0.45
5	United Kingdom	610	17600	0.48
6	Japan	560	15200	0.36
7	South Korea	485	12600	0.39
8	Australia	420	10800	0.52

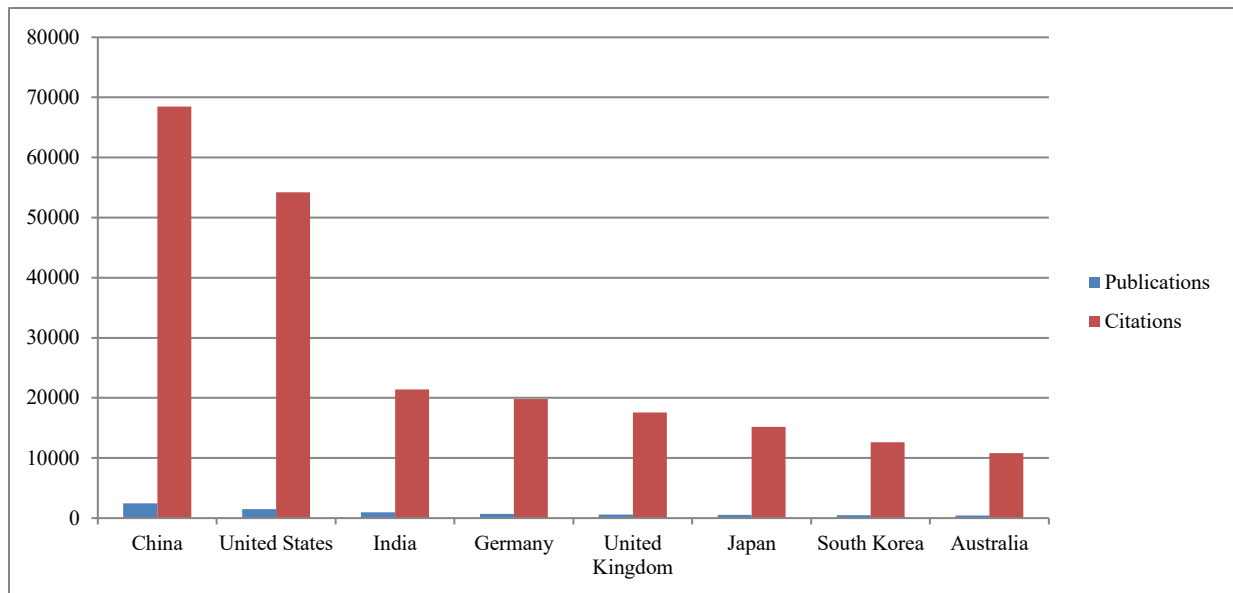


Fig. 4 Publications and Citation Distribution Across Leading Countries in Electric Vehicle Research (2015–2025)

Tables IV and fig. 4 present the distribution of publications and citations across these leading countries. According to the total number of publications, China has been the most developed in its industries and investments in technologies of electric mobility, and comes first on this list. However, the US has the highest impact from citations since its contribution to the field of sustainable transport, battery, and smart grid studies (Aminzadegan et al., 2022) is very high. Other countries such as Germany, the United Kingdom, and Australia have higher MCP ratios; thus, the level of cooperation in international research is high. It can be concluded that EV research is an international research area where collaboration takes place.

Fig. 4 presents a graphical representation of the distribution of publications and citations among the main countries participating in EV research and shows the most important countries as well as the distribution among them. From the graph, it can be seen that China is the most productive country in research, while the US has a large influence on citation, meaning that it is quite efficient in its research. Countries such as Germany, the UK, and Australia have higher "MCP ratio" and therefore greater international cooperation in research.

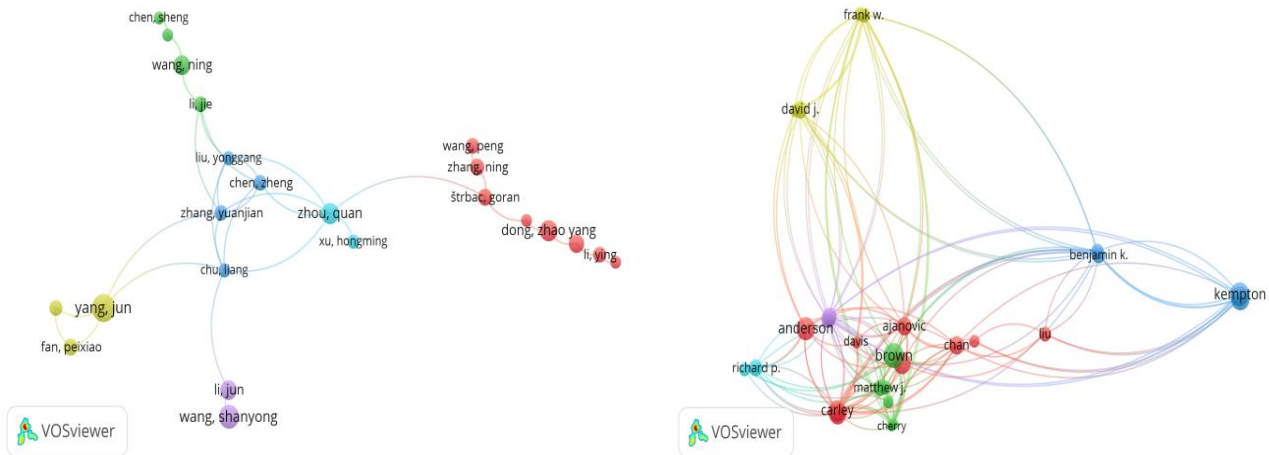


Fig. 5 Author Co-authorship Network of Electric Vehicle Research (2015–2025) Generated Using VOSviewer

The co-authorship network of leading experts in electric vehicle research is given in fig. 5. The co-authorship network suggests the presence of several clustering groups. Each of these groups is identified by a specific color representing the group of authors who are collaborating with one another in the research of electric vehicles. The linking lines indicate the

extent to which collaboration takes place among the different researchers, while the closeness of the different authors in space indicates the extent of research relations. The site contains several interconnected clusters of research.

4.4 Research Themes and Future Research Directions

It is clear from the bibliometric analysis that the area of research in electric vehicles (EV) has progressed from being a technology-based research area to being a multidisciplinary research area encompassing sustainability, renewable energy integration, smart mobility, and policy making (Murugan & Marisamynathan, 2023; Vasanthkumar et al., 2022). Whereas the early research was mostly centered on battery technology,

charging facilities, and the performance of vehicles, the current studies are increasingly taking into consideration areas like smart grid integration, vehicle-to-grid (V2G), battery recycling, consumer uptake, energy management through artificial intelligence, and sustainable transport policy (Majhi et al., 2022; Jin et al., 2024). The need for increased interdisciplinary collaboration reflects the changing dynamics of the use of EVs in the context of carbon neutrality.

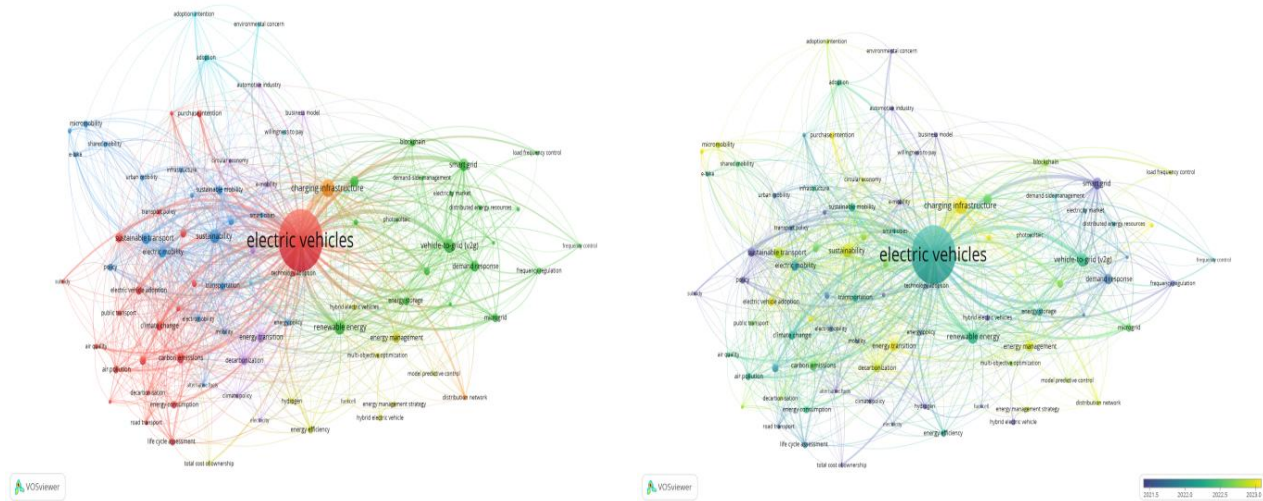


Fig. 6 Keyword Co-occurrence Network of Electric Vehicle Research (2015–2025) Generated Using VOSviewer

The keyword co-occurrence network for electric vehicle (EV) research is illustrated in fig. 6, and it was generated using VOSviewer. The network highlights the salient research themes as well as the associations among the most frequently used keywords in the literature. The central node in the network is "electric vehicles," indicating that the theme of electric vehicles is at the center of attention in research, as it is surrounded by nodes that are interrelated due to the themes of batteries, charging, renewable energy sources, energy management, smart grid, sustainability, and environmental impacts (Krishnan & Kumar, 2022; Nayak et al., 2021). The colors are utilized to indicate the presence of different thematic clusters and to show the interdisciplinary nature of research on EVs and the relationship between energy, technological, and environmental research. The network reveals the progression of research into the following areas: sustainable mobility and intelligent energy management with renewables (Jiang et al., 2022; Andoni et al., 2019).

V. DISCUSSION

EV Research Literature has witnessed substantial development in the past decade, from 2015 to 2025, reflecting the growing importance of sustainability in transportation, minimizing carbon emissions, and harnessing renewable energy at the global level. The steady increase in both publication numbers and citations suggests that EV research is a highly developed multidisciplinary area of research encompassing many fields such as electrical engineering, energy systems, transportation, environment, economy, and

policies. Technological advancement, government intervention, and the entire transition towards green mobility constitute some important factors behind the same.

From the country-wise analysis of the study, it is clear that China, the US, and India are the leading countries making significant contributions to EV research. Major investments in research facilities and electric mobility are made in China, which is clearly evident from its dominant position in publishing output. Germany, the UK, and Australia have higher levels of international cooperation, and the US has a high level of scientific influence, which is evident in terms of citation impact. It can be stated that international cooperation and knowledge sharing have become essential elements of EV research.

Themes of Research Analysis. It is evident from the research themes analysis that there has been a change in the research theme of EVs in the last 10 years. Earlier research was centered around battery technology, charging stations, and vehicle efficiency, while the recent research theme is inclined towards the incorporation of renewable energy sources, smart grid technology, vehicle-to-grid technology, battery recycling, consumer adoption, sustainable transport policies, and intelligent energy management. This theme has been developed by taking into consideration the aspect that the success of EVs would require a comprehensive approach.

Even though a substantial increase in the number of publications has been noted, there are some areas that still

require attention. Research on artificial intelligence in energy management, battery circular economy, green charging stations, autonomous electric mobility, lifecycle sustainability assessment, and sustainable EV usage in developing countries can be considered potential future areas for investigation. In addition, it is vital to note that future collaboration between scientists, industries, and policy-makers will be essential to deal with the new challenges and make the transition to sustainable electric mobility a success at a global level. Therefore, it can be stated that the results of this study provide a good picture of the intellectual structure of the EV field and generate valuable insights that can be used in future research and innovations.

VI. CONCLUSION AND FUTURE WORK

The purpose of this study was to perform a comprehensive bibliometric analysis of the world's literature on EVs between 2015 and 2025 in the Scopus database. Publication trends, citation analysis, key authors, journals, countries, collaboration networks, and research themes were analyzed using Bibliometrix and VOS viewer. The bibliometric method helped to provide a systematic review of the intellectual structure and development of EV research during the last decade. The findings indicate that research in the area of EVs has grown in many areas including publications, impact, and international collaboration. Key contributors to EV research were China, the United States, and India, and theme analysis included developing battery technology and charging facilities, renewable energy integration, smart grid, vehicle-to-grid, battery recycling, and sustainable mobility.

There are novel areas which require attention in the future, such as artificial intelligence for energy management, battery technology innovations, battery recycling, renewable energy sources for charging infrastructure, autonomous electric mobility and lifecycle sustainability of batteries. There is an opportunity for increased collaborative efforts among researchers both internationally and across different disciplines, in order to drive innovation and address research gaps in existing work. The bibliometric analysis conducted above helps provide a good starting point for researchers and policymakers interested in exploring further areas of study related to electric vehicles.

REFERENCES

- [1] Aminzadegan, S., Shahriari, M., Mehranfar, F., & Abramović, B. (2022). Factors affecting the emission of pollutants in different types of transportation: A literature review. *Energy Reports*, 8, 2508-2529. <https://doi.org/10.1016/j.egy.2022.01.161>
- [2] Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., ... & Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and sustainable energy reviews*, 100, 143-174. <https://doi.org/10.1016/j.rser.2018.10.014>
- [3] De Rubens, G. Z., Noel, L., Kester, J., & Sovacool, B. K. (2020). The market case for electric mobility: Investigating electric vehicle business models for mass adoption. *Energy*, 194, 116841. <https://doi.org/10.1016/j.energy.2019.116841>
- [4] Dileep, G. J. R. E. (2020). A survey on smart grid technologies and applications. *Renewable energy*, 146, 2589-2625. <https://doi.org/10.1016/j.renene.2019.08.092>
- [5] Dua, R., Edwards, A., Anand, U., & Bansal, P. (2024). Are American electric vehicle owners quitting?. *Transportation Research Part D: Transport and Environment*, 133, 104272. <https://doi.org/10.1016/j.trd.2024.104272>
- [6] Duan, S., Qiu, Z., Liu, Z., & Liu, L. (2023). Impact assessment of vehicle electrification pathways on emissions of CO₂ and air pollution in Xi'an, China. *Science of The Total Environment*, 893, 164856. <https://doi.org/10.1016/j.scitotenv.2023.164856>
- [7] Guo, J., Zhang, X., Gu, F., Zhang, H., & Fan, Y. (2020). Does air pollution stimulate electric vehicle sales? Empirical evidence from twenty major cities in China. *Journal of Cleaner Production*, 249, 119372. <https://doi.org/10.1016/j.jclepro.2019.119372>
- [8] Jiang, W., Wang, X., Huang, H., Zhang, D., & Ghadimi, N. (2022). Optimal economic scheduling of microgrids considering renewable energy sources based on energy hub model using demand response and improved water wave optimization algorithm. *Journal of Energy Storage*, 55, 105311. <https://doi.org/10.1016/j.est.2022.105311>
- [9] Jin, Z., Li, D., Hao, D., Zhang, Z., Guo, L., Wu, X., & Yuan, Y. (2024). A portable, auxiliary photovoltaic power system for electric vehicles based on a foldable scissors mechanism. *Energy and Built Environment*, 5(1), 81-96. <https://doi.org/10.1016/j.enbenv.2022.08.002>
- [10] Kang, J., Yu, R., Huang, X., Maharjan, S., Zhang, Y., & Hossain, E. (2017). Enabling localized peer-to-peer electricity trading among plug-in hybrid electric vehicles using consortium blockchains. *IEEE transactions on industrial informatics*, 13(6), 3154-3164. <https://doi.org/10.1109/TII.2017.2709784>
- [11] Krishnan, V. A., & Kumar, N. S. (2022). Robust soft computing control algorithm for sustainable enhancement of renewable energy sources based microgrid: A hybrid Garra rufa fish optimization–Isolation Forest approach. *Sustainable computing: Informatics and systems*, 35, 100764. <https://doi.org/10.1016/j.suscom.2022.100764>
- [12] Kumar, R. R., & Alok, K. (2020). Adoption of electric vehicle: A literature review and prospects for sustainability. *Journal of Cleaner Production*, 253, 119911. <https://doi.org/10.1016/j.jclepro.2019.119911>
- [13] Majhi, R. C., Ranjitkar, P., & Sheng, M. (2022). Assessment of dynamic wireless charging based electric road system: A case study of Auckland motorway. *Sustainable Cities and Society*, 84, 104039. <https://doi.org/10.1016/j.scs.2022.104039>
- [14] Murugan, M., & Marisamynathan, S. (2023). Mode shift behaviour and user willingness to adopt the electric two-wheeler: A study based on Indian road user preferences. *International journal of transportation science and technology*, 12(2), 428-446. <https://doi.org/10.1016/j.ijst.2022.03.008>
- [15] Nayak, M. R., Behura, D., & Nayak, S. (2021). Performance analysis of unbalanced radial feeder for integrating energy storage system with wind generator using inherited competitive swarm optimization algorithm. *Journal of Energy Storage*, 38, 102574. <https://doi.org/10.1016/j.est.2021.102574>
- [16] Noudeng, V., Quan, N. V., & Xuan, T. D. (2022). A future perspective on waste management of lithium-ion batteries for electric vehicles in Lao PDR: current status and challenges. *International Journal of Environmental Research and Public Health*, 19(23), 16169. <https://doi.org/10.3390/ijerph192316169>
- [17] Rietmann, N., Hügler, B., & Lieven, T. (2020). Forecasting the trajectory of electric vehicle sales and the consequences for worldwide CO₂ emissions. *Journal of cleaner production*, 261, 121038. <https://doi.org/10.1016/j.jclepro.2020.121038>
- [18] Rizza, V., Torre, M., Tratzl, P., Fazzini, P., Tomassetti, L., Cozza, V., ... & Petracchini, F. (2021). Effects of deployment of electric vehicles on air quality in the urban area of Turin (Italy). *Journal of Environmental Management*, 297, 113416. <https://doi.org/10.1016/j.jenvman.2021.113416>
- [19] Sandrini, G., Gadola, M., Chindamo, D., & Magri, P. (2023). Efficient regenerative braking strategy aimed at preserving vehicle stability by preventing wheel locking. *Transportation research procedia*, 70, 28-35. <https://doi.org/10.1016/j.trpro.2023.10.005>

- [20] Sheldon, T. L., & Dua, R. (2024). The dynamic role of subsidies in promoting global electric vehicle sales. *Transportation Research Part A: Policy and Practice*, 187, 104173.
<https://doi.org/10.1016/j.tra.2024.104173>
- [21] Sinha, P., Paul, K., Deb, S., & Sachan, S. (2023). Comprehensive review based on the impact of integrating electric vehicle and renewable energy sources to the grid. *Energies*, 16(6), 2924.
<https://doi.org/10.3390/en16062924>
- [22] Timilsina, R. R., Zhang, J., Rahut, D. B., Patradool, K., & Sonobe, T. (2025). Global drive toward net-zero emissions and sustainability via electric vehicles: an integrative critical review. *Energy, Ecology and Environment*, 10(2), 125-144.
<https://doi.org/10.1007/s40974-024-00351-7>
- [23] Vasanthkumar, P., Revathi, A. R., Devi, G. R., Kavitha, R. J., Muniappan, A., & Karthikeyan, C. (2022). Improved wild horse optimizer with deep learning enabled battery management system for internet of things-based hybrid electric vehicles. *Sustainable Energy Technologies and Assessments*, 52, 102281.
<https://doi.org/10.1016/j.seta.2022.102281>
- [24] Zaino, R., Ahmed, V., Alhammadi, A. M., & Alghoush, M. (2024). Electric vehicle adoption: A comprehensive systematic review of technological, environmental, organizational and policy impacts. *World electric vehicle journal*, 15(8), 375.
<https://doi.org/10.3390/wevj15080375>