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RESEARCH ARTICLE

Mapping electric vehicle adoption paradigms: A thematic evolution post sustainable development goals implementation

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Abstract

This study assesses the worldwide research trajectories of the Scopus-indexed literature on electric vehicle adoption spanning three decades. Employing the five-phase framework proposed by Zupic and Carter (2015) and utilizing the Vosviewer and Biblioshiny software, the research analyses the intellectual and social networks within the literature. The analysis of international collaboration reveals a strong regionalization in the domain, evidencing the limited collaboration between developed and developing countries. The thematic map illustrates the emerging focus on the key themes, including battery charging, environmental concerns, and transportation infrastructure in the realm of electric vehicles. Co-citation analysis further illuminated four clusters, shedding light on the prominence of monetary incentives, consumer behavioral factors and the necessity of charging infrastructure for speedy electric vehicle uptake. The study exhibits novelty by illustrating theme-based cluster analysis, distinguishing trends before and after the introduction of UN sustainable development goals. The study provides a roadmap for future researchers by identifying the prominent, emerging and niche themes, especially post-2015, which can be explored in greater depth. The findings of the study offer valuable insights for the policymakers and marketers aiming to accelerate the electric vehicle uptake by revealing the crucial role of monetary incentives and charging infrastructure.

Keywords: Bibliometric analysis, Sustainable transportation, Electric vehicle adoption, Thematic map, Co-citation analysis.

Introduction

The steady increase in automobiles over the last few decades has raised concerns about rising carbon dioxide emissions and the transportation sector has made a major contribution in rising CO_2 emissions. Road transportation alone accounts for 12% of worldwide CO_2 emissions (Statista, 2024) and the latter percentage is anticipated to rise to 50% by 2030 if no mitigation efforts are undertaken to curb the rising demand for energy sources that are not renewable. Since the transportation industry has historically relied on oil as its main form of energy, the rising costs of oil due to increasing worldwide demand and shrinking oil reserves are placing significant strain on this industry to find an alternative.

To mitigate these growing emissions, the transportation sector is paving the way for sustainable transportation by introducing EVs (electric vehicles), which are either completely or partly powered by electricity, encompassing hybrid, plug-in hybrid and plug-in EVs (Choi *et al*., 2013). EVs are leading the way to environmentally friendly transportation by reducing the emissions of greenhouse gases and dependency on fossil fuels. On an average basis, it will boost engine performance by 40-60%, thereby cutting down carbon emissions by 30-50% (Wang *et al*., 2017).

Subsequently, electric vehicle sales are on an upward trajectory and are expected to rise about 35% by the end of this year globally and the market is projected to touch US$422.8bn in 2024 (Statista, 2024). Numerous studies investigated this domain to unravel its intricacies but still, it is a pertinent domain receiving substantial focus from academia, the automobile sector and country lawmakers. Hence, it is imperative to synthesize the existing literature to present a comprehensive understanding of the contribution of EVs in sustainable transportation. This study reviewed the three decadal studies from the bibliometric lens, offering quantitatively correct conclusions. The current study has some theoretical and practical contributions as it highlights

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the evolution of EVA (electric vehicle adoption) over three decades using bibliometric analysis, demonstrating the thematic shifts from general environment consciousness to specific issues like transportation infrastructure and battery lifecycle. This research is pivotal for industry as well as government stakeholders by providing insights of the shifting paradigms from driving range to the need for robust charging networks and implementation of fiscal as well as monetary policies for the rapid shift towards EVs. The findings of social collaboration underscore the potential for researchers to adopt integrated global research to delineate the impact of technological advancements in the realm of EVA especially where regional disparities are noticeable.

Rationale of Study

Being a trending topic, EVA grabbed the attention of several scholars who have conducted various traditional review studies in this field. For instance, Kumar and Alok (2020) and Singh *et al*. (2020) reviewed the research work to identify the prime factors influencing EVA. Rezvani *et al*. (2015) and (Hannan *et al*., 2014) conducted an extensive review to determine the motivators along with barriers for plug-in EVs and the obstacles to consumer acceptance of hybrid electric vehicles, respectively. Even though these descriptive reviews facilitate retrospective examinations, they are vulnerable to subjective bias and can only analyze a limited amount of research (Tanrıverdi *et al*., 2020). The bibliometric study makes it easier to identify the significant quantitative factors of a specific study area (Junquera & Mitre, 2007).

The current study makes a novel and pioneering contribution by synthesizing diverse findings in the discipline of EVA spanning three decades. Although a few implementations of bibliometric analysis have popped up in prior research studies, their scope and focus have been limited. For instance, (Pinto *et al*., 2022) highlighted the significant areas in the domain of electric vehicles from 1989 to 2020, (Kovačić *et al*., 2022) determined the trends in the utilization of autonomous electric automobiles in urban settings and (Secinaro *et al*., 2020) conducted a bibliometric examination on electric car business models by employing the keywords "electric vehicles," "urban mobility" and "autonomous vehicles".

Despite these studies, there exists a notable gap in the existing literature highlighting the paucity of studies that explore the influence of global sustainability initiatives on trends and developments in the EVA domain. This study explicitly differentiates itself from the prior studies by integrating the widely accepted global sustainability framework, "The 2030 Agenda for Sustainable Development" which identified electric vehicles as one of the three anchors to reduce CO2 emissions (Wright & Fulton, 2005). Moreover, the current study synthesizes the literature by demonstrating the evolution of both widely explored as well as niche themes across different time phases using advanced clustering techniques.

Hence, the current study offers a more holistic bibliometric analysis, providing new insights into the EVA discipline that have not been explored previously. Furthermore, being an emerging technology, its constant evolution distinguishes every study of this field.

The present study will make a substantial addition to enriching the EVA literature by addressing the RQ **(**research question) mentioned below.

RQ1. What is the global trend of research publications in the field of EVA, considering factors like journals, countries, and influential scholarly articles?

RQ2. What is the current state of collaboration among countries in the field of EVA?

RQ3. How are the themes currently evolving and what are the potential research avenues in the EVA field?

RQ4. How is the co-citation trend among seminal publications reflecting the development of research clusters in the EVA field?

The organization of the remaining part of this article is as follows: Section 2 mentions the methodology applied in the research work. Section 3 lists the significant findings of the research questions. Finally, the last section concludes the article with the limitations and implications of the study.

Research Methodology

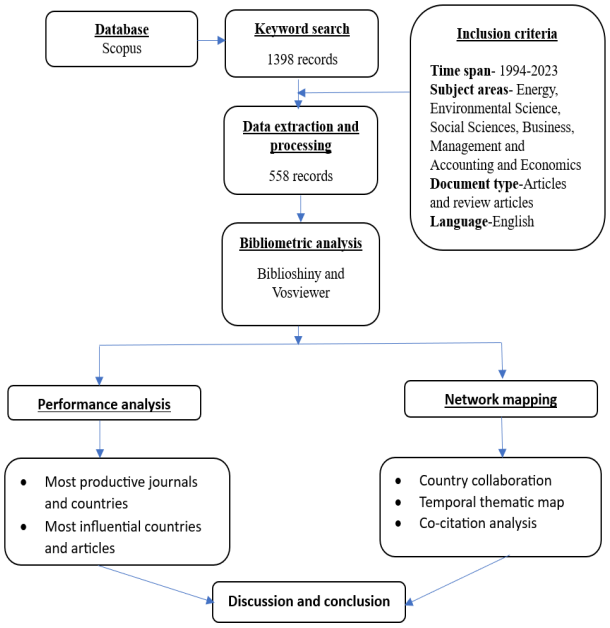
Bibliometric network analysis is a well-established quantitative technique that studies the year of publication of articles, citation pattern, etc., to explore the knowledge base and significance of already published literature in a particular field (Aria & Cuccurullo, 2017) by conducting network mapping that studies the links between the elements of the field (Baker *et al*., 2020) and performance analysis which investigates the valuable contributions of research constituents to a particular field via a wide range of measures. Although the most effective or optimal measures for performance analysis are not universally agreed upon, the present corpus of research typically uses a few well-established measures (Donthu *et al*., 2021; Tanrıverdi *et al*., 2020), including TP ("total number of publications"), TC ("total number of citations"), IF ("2-year impact factor") and the "H-index."

The fundamental five-phase methodology of network mapping (Zupic & Čater, 2015) is used in this study, as followed by various researchers (Li *et al*., 2023; Scussel *et al*., 2022). In the first phase, five research questions, keywords for search strategy and the specific database are selected, which comprised the study design. The keyword "electric vehicle adoption" was used to denote the boundaries of the study from the "Scopus" data source as it is a better alternative for reviewing the literature in management (Falagas *et al*., 2008) and data mining resulted in 1398 documents covering the

broad spectrum of EVA. To extract only relevant literature, an inclusion criterion is followed by applying a few filters to these extracted documents mentioned in Fig 1, which returned 558 documents spanning from 1994 to 2023. Screening of publications by applying different filters assists in discovering relevant literature in the research domain (Donthu *et al*., 2021). In the second phase, the data comprising keywords, cited references and other bibliographical details is extracted. Then, for carrying out further analysis, the two most robust and reliable bibliometric visual analysis tools, which include "Biblioshiny" and "VOSviewer," are employed and the final phase presents the interpretation and discussion of the findings.

The R-based unique open-source tool, namely, Bibliometrics, used for thorough analysis, distinguishes itself from other tools due to its innovative visualization features (Ali *et al*., 2021). The data extracted as a .bib file was analyzed via Biblioshiny, an internet-based data analysis platform established on a shiny package that encapsulates the core functionality of Bibliometrics (Aria & Cuccurullo, 2017). In the current study it is used to map the temporal thematic evaluations and collaborations among various countries in the domain of EVA.

Additionally, "VOSviewer" is committed to developing and visualizing bibliometric networks for academic data (Van Eck & Waltman, 2010) by reviewing the data derived as a "comma-separated value" (.csv) file. These networks can be created by researchers on the basis of co-citation analysis, bibliographic coupling, or co-authorship relationships using journals, authors, or individual publications. "VOSviewer" has two main measures to visually represent the nodal network (Donthu *et al*., 2020), which are the quantity and total strength of the linkages. Several facets of the current study including co-citation analysis, listing most productive journals, articles and nations, etc., have been demonstrated via performance analysis and scientific mapping by developing tables and charts to represent the quantitative results of the analysis.



Source: Author's compilation

Figure 1: Research framework and data screening

Findings

Performance Analysis

The analysis studied 558 papers from 166 sources on EVA covering 30 years of scientific production (Table 1). On average, each paper got 32.35 citations and the aggregate references mentioned in the documents on a cumulative basis is 29225. There are 1596 author keywords that describe the content presented by the authors in their documents (Goh & See, 2021), which are approximately half of the

Table 1: Main information table

Description	Results
Timespan	1994:2023
Sources (Journals, Books, etc.)	166
Documents	558
Annual Growth Rate %	14.75
Average citations per doc	32.35
References	29225
DOCUMENT CONTENTS	
Keywords Plus (ID)	3016
Author's Keywords (DE)	1596
AUTHORS	
Authors	1560
Authors of single-authored docs	35
Authors of multi-authored docs	1525
Authors per document	2.79
AUTHORS COLLABORATION	
Authors appearances	1925
Single-authored docs	37
multi-authored docs	521
Co-Authors per Doc	3.45
Countries	51
DOCUMENT TYPES	
Article	508
Review article	50
Collaboration index	2.92
Docs per author	0.357

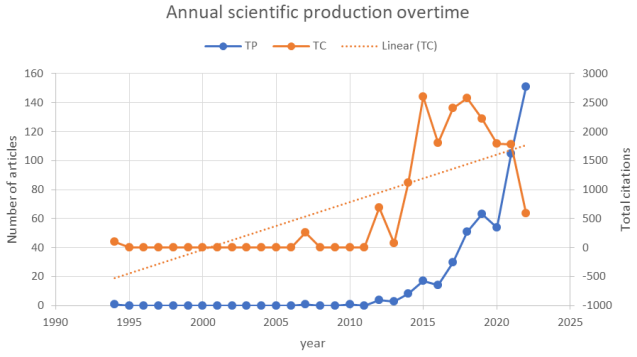
Source: Biblioshiny

keywords plus (n = 3016) which are produced automatically by an extensive analysis of the phrases or words which appear repeatedly in the title of a document's references. With an average of 0.35 documents per author, most of the documents are multi-authored and an average of 2.79 authors per document suggests that two authors author each document

The temporal trends of scientific production of EVA are reported by TP and TC (Fig. 2). According to this study, the first article was published in 1994, and there was no other publication record until 2007. Over the period from 2015 to 2023, an increasing interest in EVA research is noticeable, which is evidenced by the publication volumes, which grew substantially each year after 2015, resulting in the cumulative publications of 538 (96.41%) articles. This might be explained by the fact that the focus of researchers has been shifted towards this subject because of increasing environmental concerns due to the adoption of the "Paris Agreement on Climate Change" and "The 2030 Agenda for Sustainable Development" by all United Nations Member States in 2015 which declared vehicle emissions as a major contributor to emissions of carbon dioxide and pollution (Sustainable development, 2023). As a result, after 2015, academics and national authorities gave a lot of attention to electric automobiles. Fig. 2 also shows the yearly (TC) citation pattern and a significant rising trend is visible in the TC also, whereas a growth in cumulative citations has only been visible after 2013. The reason behind this could be the rising number of publications related to the research area or the academic articles published between 2015 and 2023, which contain more valuable contributions and the impact of the "Paris Agreement on Climate Change".

Most Productive Journals

The prominent journals identified based on TP revealed that three distinct publishers own the top 10 most productive journals (Table 2). "Elsevier" tops the list as it covers seven journals out of the top ten, followed by "Multidisciplinary Digital Publishing Institute (MDPI)" and "Taylor & Francis".



Source: Authors' compilation

Figure 2: The distribution trends of TP and TC regarding EVA publications

With 46 articles, "Transportation Research Part D: Transport and Environment," published by "Elsevier" is the most productive and influential journal, with "Advances in consumer electric vehicle adoption research: A review and research agenda" as its highest cited article published in 2014. It encourages papers on sustainability, resiliency and infrastructure of the transport system, as well as the effects of a changing climate on cities, regions, and networks. Journal of "Renewable and Sustainable Energy Reviews" has the highest IF score (28.5) and TCP (Total citations per publication) (87.1) which implies that maximum acknowledgment per article has been received by it. It can be inferred that the literature on EVA is published in extremely significant journals as all top 10 sources got a good IF score, which is higher than three.

Most Influential Articles

The top ten papers on EVA based on the TC are listed in Table 3. With 717 citations, an article titled "The influence of financial incentives and other socio-economic factors on electric vehicle adoption" by Sierzchula, W. is the most frequently referenced work that aims to explore the impact of financial incentives on EVA. Then, it is followed by Rezvani, Z. with 671 citations published in "Transportation Research Part D: Transport and Environment" journal in 2015 entitled "Advances in consumer electric vehicle adoption research: A review and research agenda". This work identified the barriers and drivers for plug-in electric vehicle adoption. Although this article is the second most referenced article as per total citations but, it leads in terms of the citations per year (CPY) (74.56), which reflects its increasing influence in the research field.

Most Influential and Productive Countries

The diffusion of EVA research among different nations is analyzed in this section to highlight the geographies of the research field. Out of 51 contributing nations, Table 4 provides insights into the top ten productive and influential countries.

Network Mapping

International collaborations

This section intends to observe international cooperation and networking among nations and demonstrates the count of each nation's multiple as well as single publications. Table 5 reveals that China has the broadest diversity of working partners (n = 29), the USA being the most significant one, followed by the USA (25) and Norway (12). Besides expanding networks, exchanging knowledge, and sharing skills, international collaboration also helps in raising the influence and reach of research work because articles with international co-authors perform better in the context of citations and quantity. The dispersed blue shade in Fig. 3 illustrates international cooperation across various nations,

Table 2: Most productive journals

Rank	*Journal*	*TP*	*TC*	*TCP*	*Publisher*	*Most cited article*	*IF Score (2 years)*
1	*Transportation Research Part D: Transport and Environment*	46	2737	59.5	Elsevier	(Rezvani *et al*., 2015)	7.041
2	*Energy Policy*	34	2678	78.7	Elsevier	(Sierzchula *et al*., 2014)	7.57
3	*Sustainability (Switzerland)*	31	401	12.9	MDPI	(Tu & Yang, 2019)	5
4	*Energies*	28	744	26.5	MDPI	(Berckmans *et al*., 2017)	3.252
5	*Journal of Cleaner Production*	25	1471	58.8	Elsevier	(Canals Casals *et al*., 2016)	11.072
6	*Applied Energy*	22	604	27.4	Elsevier	(Brinkel *et al*., 2020)	11.446
7	*Transportation Research Part A: Policy and Practice*	21	1079	51.3	Elsevier	(Helveston *et al*., 2015)	6.615
8	*Transport Policy*	18	667	37	Elsevier	(She *et al*., 2017)	6.173
9	*Renewable and Sustainable Energy Reviews*	15	1307	87.1	Elsevier	(Yong *et al*., 2015)	16.799
10	*International Journal of Sustainable Transportation*	14	249	17.7	Taylor & Francis	(Haustein & Jensen, 2018)	3.963

TP = total publications, TC = total citations, TCP = total citation per publication IF Score = impact factor
Source: Authors' compilation

Table 3: Most cited articles

Rank	Authors	Journal	TC	CPY	Objective
1	(Sierzchula *et al*., 2014)	*"Energy Policy"*	717	71.70	To investigate the influence of monetary benefits on EVA.
2	(Rezvani *et al*., 2015)	*"Transportation Research Part D: Transport and Environment"*	671	74.56	To study the barriers and movers for consumer adoption of plug-in EVs.
3	(Yong *et al*., 2015)	*"Renewable and Sustainable Energy Reviews"*	564	62.67	To review the latest improvement in EV technology and the impact of its introduction to the public.
4	(Hawkins *et al*., 2012)	*"The International Journal of Life Cycle Assessment"*	355	29.58	To review the existing studies to understand the environmental impacts of electric vehicles.
5	(Berckmans *et al*., 2017)	*"Energies"*	348	49.71	To predict the battery pack cost in 2030.
6	(Bjerkan *et al*., 2016)	*"Transportation Research Part D: Transport and Environment"*	327	40.88	To define the significance of incentives in BEVs' promotion and to establish which incentives are essential for which types of purchasers to purchase a BEV.
7	(Helveston *et al*., 2015)	*"Transportation Research Part A: Policy and Practice"*	305	33.89	To investigate the impact of subsidies on EVA and consumer preferences for conventional EV technologies.
8	(Schroeder & Traber, 2012)	*"Energy Policy"*	282	23.50	To provide an insight into the case "study of public fast chargers' technology for electric vehicles in Germany".
9	(Langbroek *et al*., 2016)	*"Energy Policy"*	266	33.25	To study the impact of policy motivators and socio-psychological determinants on EV adoption.
10	(Heffner *et al*., 2007)	*"Transportation Research Part D: Transport and Environment"*	260	15.29	To understand the reason behind the buying of electric vehicles and the spread of new symbolic meanings in the automotive market.

TC=total citations CPY=citations per year NAY=number of active years
Source: Authors' compilation

Table 4: Most influential and productive countries

Rank No.	*Country*	*TC*	*Country*	*TP*
1	USA	4389	USA	133
2	China	2058	China	78
3	Netherlands	1129	Norway	68
4	Norway	761	India	46
5	Germany	714	UK	21
6	UK	632	Korea	20
7	Sweden	578	Germany	17
8	Canada	406	Canada	16
9	India	388	Australia	12
10	Denmark	383	Netherlands	11

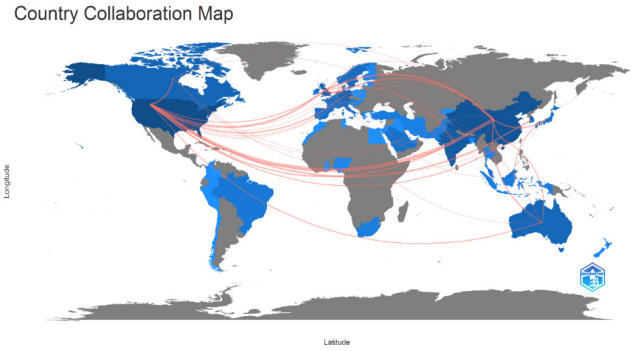
Source: Authors' compilation

including Germany, the USA, Norway, Japan, and Sweden in contrast to the lack of participation in the Middle East region. Additionally, the degree of the authors' participation is reflected by the thickness of the pink lines connecting the nations (Qin *et al*., 2022). Little cross-national cooperation is visible, especially among scholars from developed and developing countries.

Temporal Thematic Evolution

The temporal thematic evolution study offers comprehensive demonstrations of field developments, shifts in research orientations, and field trend progression (Xie *et al*., 2020). To comprehend the hotspots of research in the two-time slices, "keywords plus" terms are used in this study (Bhat & Verma, 2023) because keywords plus effectively demonstrate the scientific structure of the document as they eventually capture the publication's subject matter more profoundly.

Considering the two sub-periods, 2015 was taken as the cutting year as described earlier in this year the "The 2030 Agenda for Sustainable Development" was adopted by all the UN Member States, which mentioned CO2 emissions from vehicles as a leading contributor to pollution and promoted the electric vehicle adoption among countries which paced the growth of research in this field. Hence, the authors took this year as the cutting year to comprehend the evolution of the EVA theme in the research field. Hence, two



Source: Biblioshiny

Figure 3: Country collaboration map

thematic maps and a Sankey diagram for thematic evolution between the two sub-periods, i.e., 1994-2015 and 2016-2023, have been developed.

The themes are graphed on a two-dimensional chart via a thematic map comprised of a system of coordinates based on the measures of density (y-axis), which measures the strength of the linkages of the keywords that form a theme and centrality (x-axis), depicts the strength of links between them (Bakır *et al*., 2022). The theme becomes closer to centrality if its connection in the framework of themes strengthens. As a theme's intramural cohesiveness rises, its density and capacity for development over time also increase (Giannakos *et al*., 2020).

Phase before the introduction of the Sustainable Development Agenda 2030

Regarding sub-period A, from 1994 to 2015 (Fig. 4a) the most discussed themes that laid down the foundation of the field were in the motor theme quadrant depicting "United States", "greenhouse gas," and "transportation infrastructure" clusters. These were extremely relevant themes that have enormous research potential in this field (Nasir *et al*., 2020). The clusters of these themes and their associated topics were backed by early 20th-century research, for instance, research work on the "United States". (Choi *et al*., 2013; Heffner *et al*., 2007) "greenhouse gas" (Nichols *et al*., 2015) and "transportation infrastructure" (Larson *et al*., 2015).

"Environmental concerns" was positioned as a niche

Table 5: Top collaborating countries in publications

Rank	*Country*	*Articles*	*SCP*	*MCP*	*Rank*	*Country*	*Articles*	*SCP*	***MCP***
1	China	78	52	26 (33.33%)	6	Japan	9	3	6 (66.66%)
2	USA	133	108	25 (18.79%)	7	UK	21	16	5 (23.80%)
3	Norway	68	56	12 (17.64%)	8	Korea	20	15	5 (25%)
4	Canada	16	9	7 (43.75%)	9	Denmark	7	2	5 (71.42%)
5	India	46	40	6 (13.04%)	10	Australia	12	8	4 (33.33%)

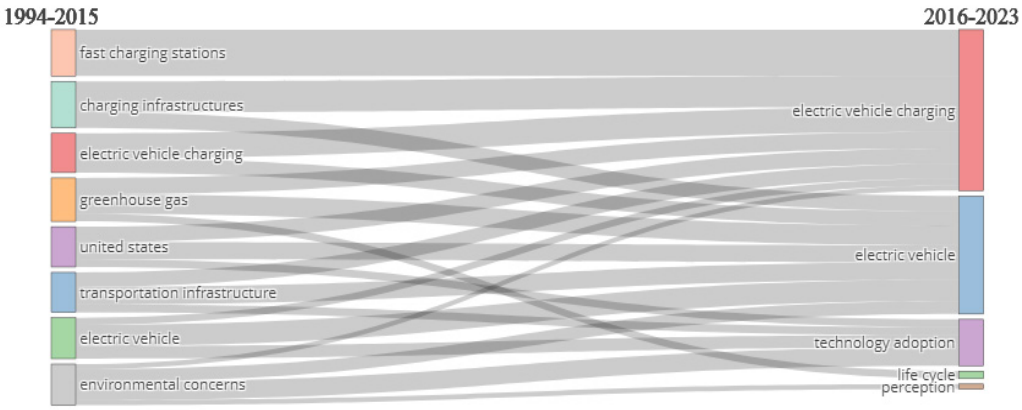
SCP single country publications, MCP multiple country publications
Source: Authors' compilation via biblioshiny software

Source: Biblioshiny

Figure 4: a Time slice 1

Source: Biblioshiny

Figure 4: b Time slice 2



Source: Biblioshiny

Figure 4: c Sankey diagram

theme with adequately developed internal linkages but poor outside ties. Under this subperiod, the "fast charging" and "charging infrastructure" clusters showed up as declining themes as they disappeared in the following sub-period, although both themes were absorbed in the "electric vehicle charging" cluster that emerged between 2016 and 2023.

Additionally, no theme appeared solely in the transversal quadrant as a basic theme. However, "electric vehicle" and "electric vehicle charging" appeared between the motor and transversal quadrants.

Phase after the introduction of Sustainable Development Agenda 2030

Regarding sub-period B, from 2016 to 2022 (Fig. 4b), the most notable observation was a substantial fall in the overall count of themes with a surge in the number of transversal themes, evincing "electric vehicle" and "technology adoption" as the notable clusters demonstrating significant and highly researched area that is consistently developing.

Additionally, "electric vehicle", which turned into a transversal theme, subsumed a lot of other themes which appeared as numerous clusters formerly. The tendency was also observed with the cluster "electric vehicle charging." "Technology adoption" (Corradi *et al*., 2023) made a remarkable appearance as a transversal theme, while "Perception" surfaced as an emerging theme (Aria & Cuccurullo, 2017; Huang *et al*., 2020), highlighting its marginal significance with inadequate development but great potential for future study. By appearing in the middle of the upper quadrants, "Life cycle" highlighted its relevancy in terms of internal as well as external interactions. "Denmark" and "recycling" appeared as niche themes depicting extremely developed topics but isolated from the context of EVA.

Interaction of themes across two phases

Sankey diagram (Fig. 4c), presents the interaction among various themes within the sub-periods. Blocks denoted themes comprising the most used keyword within the corresponding sub-period. The total length of a theme's block was in proportion to the total number of keywords associated with that theme. Furthermore, the major evolutionary linkages of themes have been demonstrated (Shi *et al*., 2020) and the matching thickness of the links described the flow conditions of distinct themes within two sub-periods.

From a broad view, a significant number of linkages and substantial conversion interactions were discovered and "electric vehicle" and "electric vehicle charging" came out as the most solid themes throughout the thematic evolution. These themes were propelled by publications related to electric vehicles and environmental sustainability (Hopkins *et al*., 2023; Mahmud *et al*., 2023). In sub-period A, one and four articles were published belonging to "electric vehicle" and "electric vehicle charging" themes while in sub-period B, 90 and 53, respectively, demonstrating significant growth in the research field. In addition, the fast-charging theme swiftly got converted into electric charging from sub-period A to sub-period B.

Themes can be classified as long-term and short-term as some themes have been consistently perpetuated and developed since their inception while others have only appeared in the early years or either just blossomed in recent years. For instance, the themes "electric vehicle" and "electric vehicle charging" initially appeared in the sub-period 1994–2015 and developed consistently in the second sub-period also, whereas "life cycle" and "perception" flourished as the novel themes in the second sub-period only.

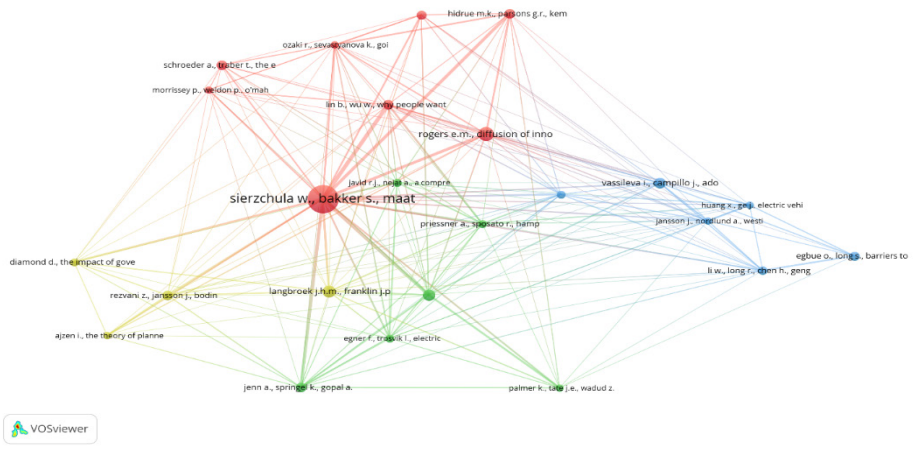
Co-citation analysis

"Co-citation analysis" is utilized to comprehend the progression of study in the chosen field from numerous perspectives and assumes that works that are often referenced together share similar thematic content (Li & Hale, 2015). This study is conducted using the "cited references" as the unit of analysis following several studies (Bakır *et al*., 2022). To obtain a precise and comprehensible network map, a reference was required to be cited fourteen times or more. Of the 28,573 cited references, 24 met this threshold with 184 total links having a total link strength of 459. Out of these, the most influential publication is (Sierzchula *et al*., 2014), which received the maximum number of co-citations (91 citations) with 22 links, resulting in a total link strength of 144. Nodes represent the cited publications and their size is proportional to the count of citations they got. The identical color nodes indicate a common theme. The thickness of lines connecting the nodes depicts the influence of a study on others (Modgill *et al*., 2023).

The analysis resulted in four clusters (Fig 5), i.e., a red cluster representing studies related to various incentives for EVA, a green cluster depicting the role of innovative attributes of EVs and infrastructure dynamics in EVA, a blue cluster representing the influence of fiscal incentives and cost of ownership on market penetration of EVs and yellow one highlighting the behavioral factors and government policies towards EVA. Each of the four clusters is given the proper label after looking at the titles of articles inside them. The main themes of these clusters, along with relevant references, are illustrated in Table 6.

Role of innovative attributes of EVs and infrastructure dynamics in EVA

This research cluster sheds light on the influence of specific attributes of EVs and associated infrastructure facilities promoting EVA. Hidrue *et al*. (2011) highlighted five unique attributes of EVs, including driving range, fuel cost saving, charging time, and CO_2 reduction, and found that people were willing to pay a premium for the desirable attributes



Source: Vosviewer

Figure 5: Co-citation network map

offered by EVs over gasoline vehicles. Lin and Wu (2018) complemented this by empirically confirming vehicle performance upfront price acceptability by consumers, along with various demographic factors as prime factors affecting EVA among the four first-tier cities of China. Morrisey *et al*. (2016) focused on discerning the prominence of charging infrastructure by illuminating the charging behaviors of existing EV owners like charging location, timing, and mode of charging, etc. the study showcased the highest preference for fast chargers and night hours as the most preferred time of charging EVs at home whereas for outer locations car parks were preferred by most of the consumers. Ozaki and Sevastyanova (2018) reported a case study on hybrid EVs, specifically Tata Pirus, and identified the experience with EVs besides basic attributes of EVs, which acted as antecedents of motivation for EVA. Taking this further, Rogers *et al*. (2014) established a foundation by associating the role of innovation and consumer behaviors of adoption towards novel technologies. Advancing this concept, Schroeder and Traber (2012) underscored the lack of fast charging infrastructures by illuminating the low return on investment for fast charging stations due to the current low adoption rate of EVs. Sierzchula *et al*. (2014) offered insights into additional factors linking charging infrastructure and setting up of manufacturing plants locally with the uptake of EVs. Further delving into this, Zhang *et al*., (2011) provided empirical evidence of the significant influence of maintenance cost and the degree of safety on EVA. Together, these studies offered comprehensive knowledge about the complex behavioral intentions of consumers in association with features offered by EVs and the required infrastructure.

Influence of fiscal incentives and cost of ownership on market penetration of EVs

The studies in this cluster unravel the relationship between incentive policies and the upfront cost of owning an EV with the uptake rate of EVs in the market. Egnér and Trosvik (2018) emphasized the significance of local policy on new EV registrations by confirming a positive influence on EVA, especially in urban areas. Expanding on this, Javid and Nejat (2017) further explored the factors affecting the penetration rate of EVs and highlighted the significance of gas price, household income, and the EVs cost of ownership in the speedy uptake of EVs. Jenn *et al*. (2018) furthered this knowledge by accentuating the importance of tax credits, rebates, bus lane access and other financial as well as non-financial incentives for accelerating the rate of EVA. Lévay *et al*. (2017) further delved into this and evidenced that financial incentives in the form of flat taxes favor big EVs, whereas the lump-sum subsidies accelerated small EV sales as these incentives decrease the upfront high cost of EVs. The market rate of EVs is significantly associated with the cost of owning an EV and with the introduction of incentives and developing technology, the cost of EVs is cheaper (Palmer *et al*., 2018). Priessner *et al*. (2018) supplemented this by validating that the rate of adoption was high in the regions where policy incentives were offered to consumers for owning an EV. Collectively, this cluster underscored the relevance of incentives for promoting EVA.

Hurdles and drivers towards adoption of sustainable transportation

This cluster offers a comprehensive view of the barriers and drivers influencing consumer's acceptance of sustainable transportation. Egbue and Long (2012) identified socio-technical obstacles and the influence of sustainability issues on EVA. They offered intricate insights into the perceptions of tech-savvy consumers who would become early adopters of EVs only if it is perceived as superior to gasoline vehicles. Huang and Ge (2019) extended this by mentioning product perception, crowd characteristics, etc. as drivers of EVA. Digging deeper into this, Jansson *et al*. (2017) emphasized that eco-innovations like EVs, if promoted as socially

Table 6: Research clusters derived from co-citation analysis

Colour of cluster	*Cluster*	*Main themes*	*References*
	Cluster 1	Role of innovative attributes of EVs and infrastructure dynamics in EVA	Hirdue *et al*., (2011); Lin & Wu, (2018); Morrissey *et al*., (2016); Ozaki & Sevastyanova, (2011); Rogers *et al*., (2014); Sierzchula *et al*., (2014); Schroeder & Traber (2012); Zhang *et al*., (2011)
	Cluster 2	Influence of fiscal incentives and cost of ownership on market penetration of EVs	Egnér & Trosvik, (2018); Javid & Nejat, (2017); Jenn *et al*., (2018); Lévay *et al*., (2017); Palmer *et al*., (2018); Priessner *et al*., (2018)
	Cluster 3	Hurdles and drivers towards adoption of sustainable transportation	Egbue & Long, (2012); Huang & Ge, (2019); Jansson *et al*., (2017); Kim *et al*., (2018); Li *et al*., (2017); Vassileva & Campillo, (2017)
	Cluster 4	Behavioral factors and government policies towards EVA	Ajzen, I. (1991); Diamond, (2009); Langbroek *et al*., (2016); Rezvani *et al*., (2015).

Source: Authors' compilation

desirable items reflecting environmental responsibility, will drive the pace of adoption rate. Probing further, the environmental concern among individuals acts as a driver towards EVA as it enhances their perceived sustainable value, whereas the risk associated with charging them acts as a critical barrier (Kim *et al*., 2018). Li *et al*. (2017) expanded this exploration by systematically reviewing 40 articles and categorized EVA drivers into three groups, i.e., demographic, psychological and situational drivers. Augmenting on this, researchers explored better education and medium-high income groups as socio-economic factors influencing EVA by surveying the private owners of EVs (Vassileva & Campillo, 2017). In unison, this cluster offered nuances of motivators and barriers influencing EVA.

Behavioral factors and government policies towards EVA

The articles of this cluster elucidate the intricacies of the behavioral intentions of consumers and the role of government support policies in accelerating the pace of EVA. Ajzen (1991) laid the theoretical groundwork by connecting the cognitive and affective factors of consumers with their behavior. Many articles have implemented this theory for predicting the EVA. Further illuminating the domain of EVA, Diamond (2009) explored various policy variables evidencing the positive association of policies that provide upfront payments with EVA. Langbroek *et al*. (2016), further validated the positive influence of government policies on EVA. Their study also highlighted the behavioral aspects of consumers, evidencing the impact of self-efficacy on EVA. Rezvani *et al*. (2015) complemented the intricate dynamics of consumer behavior by presenting the prominence of pro-environmental attitude, joy, and pride felt while driving an EV to contribute towards a sustainable environment. Hence, this cluster democratized the knowledge structure by highlighting the role of government policies besides nuances of consumer behavioral reactions towards EVA.

Conclusion

By conducting a comprehensive review of EVA literature spanning the past three decades, this study explored the emerging dimensions and synthesized the scattered literature. Addressing the RQ1, the annual publication analysis demonstrated an exponential growth in the number of research papers from 1994, with a notable surge in the publications after 2015 because of the increased awareness of governments of various nations towards the environment and the journal and country analysis revealed "Transportation Research Part D: Transport and Environment" and the USA followed by China as the most productive journal and nations respectively in the field of EVA. Additionally, Sierzchula *et al*., (2014), with 717 citations, was the most influential work which highlighted the influence of monetary benefits on EVA throughout the monitoring duration. Furthermore, in response to RQ2, the global network analysis revealed strong collaborative relations among some nations (China, the USA, UK, and Japan), but the geographical disparity was also evident as little cross-national cooperation was visible among the scholars from developed and developing countries. In response to RQ3, the thematic map showcased charging infrastructure and fast charging perceptions as emerging themes shedding light on the priority of fast charging infrastructure among consumers for EVA uptake and revealing sustainable energy utilization as the current research hotspot. Finally, the co-citation analysis revealed four clusters addressing the RQ4.

Implications of the Study

The study offers substantial practical as well as theoretical implications for stakeholders. Beginning with a theoretical viewpoint, the research article will help academicians and researchers to understand the growth, regional distribution, and comprehensive overview of previous and ongoing studies along with highlighting the emerging themes in this domain that require further investigation. This research also proposes several practical implications for electric automobile producers and the government. Electric automobile producers should improve the technology to decrease the concern regarding range anxiety and safety among customers. The government should offer financial

incentives like tax relaxation for owners of electric vehicles along with framing a committee for devising, establishing, and monitoring EV adoption strategies.

Limitations

Even though this research has enormous potential to enhance the EVA knowledge structure, it also possesses several limitations that must be considered before generalizing the findings of the study. The research used only one database, i.e., Scopus, which is an influential database according to the theme of the study but the inclusion of a wider range of databases will increase the robustness of the study. Furthermore, the bibliometric study depends primarily on frequently revised databases. Hence, the findings of this study may differ significantly over time. Additionally, the bibliometric technique also has some intrinsic shortcomings, such as the inability to capture the contextual essence of articles. Even though it provides statistical information and stunning visualization mapping, it only presents a macroscopic view of the domain's present status. The research can be improved by integrating bibliometric analysis with qualitative analysis like systematic literature review or meta-analysis, etc., to enrich the research domain with additional insights.

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