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GREEN VEHICLE ADOPTIONS AND ITS IMPEDIMENTS: A BIBLIOMETRIC REVIEW

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ABSTRACT

A green vehicle produces considerably lower emissions than conventional internal combustion engine vehicles, playing a crucial role in fulfilling global commitments to combat climate change. Despite its environmental benefits, consumer adoption is far below expectations. This study addresses this issue by exploring recent publications that highlight challenges in the adoption of green vehicles. The paper aims to analyse and present findings from published documents on green vehicles, utilizing data sourced from the Scopus database. To this end, this paper contributes to the extant literature on green vehicle adoption and its impediments by assessing the publication trends and network visualization leveraging the bibliometric analysis method. Meanwhile, key research clusters are outlined and visualized to analyse the underlying knowledge structure. The 347 articles collected from the Scopus database were later analysed using bibliometric tools, VOSviewer, and Harzing's Publish or Perish. The results presented in this paper assist researchers with a structured understanding and knowledge of green vehicle adoption research and its impediments.

Keywords: Bibliometric, Green Vehicle, Impediments

1.0 INTRODUCTION

Transportation plays an important role as mode of mobility in our daily life. People rely on transport to get them to their businesses, home, and workplaces every day. While undoubtedly vital, the transportation sector contributes more than 24 percent of total carbon dioxide (CO_2) emission, with road transport being the largest emitter (IEA, 2020). The road transport emission and environmental effects continued to be significant due to the fossil fuel burning process derived from conventional internal combustion engine (ICE) vehicle as this ICE or non-green vehicle had dominated the global market. As private vehicle demand increases, the consumption of petrol and diesel also simultaneously increase which will certainly increase the CO_2 emission further. Therefore, alternatives to green vehicles have been considered as an important strategy to reduce public's reliance on fossil fuel and subsequently achieving CO_2 mitigation target (Gulzari et al., 2022; Zhang & Fujimori, 2020).

The road passenger vehicles that run either on battery or electricity are known as a green vehicle, clean vehicle, eco-friendly vehicle, or an environmental-friendly vehicle, categorized

as hybrid vehicle, plug-in hybrid vehicle, and battery electric vehicle. Several countries refer to green vehicles as vehicles that meet or surpassing the stringent European Emission Standards (such as EURO 6) or the low-carbon fuel standards (EPA, 2021). Green vehicles are expected to produce less negative environmental effects, leading to significant health as well as considered as viable option in sustaining the urban road transportation through the reduction of fossil-fuel dependence (Wu et al., 2019). Study by Asadi et al. (2021) indicated that green vehicles can reduce 30 to 50 percent of CO_2 emission and increase 40 to 60 percent in fuel efficiency compared to the conventional fuels' vehicles. As a result, through various legislations, most countries are shifting from conventional oil-based ICE technologies to electric motor-operated vehicles, and hence the automakers are also driven to manufacture varieties of green vehicle models (Vitta, 2021). This implies that the widespread adoption of green vehicles is a sustainable way of improving environmental, economic, and energy concerns in road transportation.

The Adroit Market Research (2021) forecasted that the green vehicles market will hit USD 802.81 billion market value by 2028, with a compound annual growth rate of 22.6 percent from 2021 and 2028. In the United States alone, there are more than 1.5 million electric vehicles on the road as of August 2020, as reported by the Edison Electric Institute. The market is expanding due to the increasing demand for fuel-efficient, high-performing, and low carbon vehicles. Despite the fact that the number of green vehicles on the road has increased dramatically, this industry indicates that it has barely scratched the surface. The truth is the adoption of green vehicles is only about 1 percent globally and it is even lower in some developed countries like Australia (Foley et al., 2020). The slow uptake of green vehicles can be associated to a range of key barriers that ultimately result in low consumer confidence and affordability. According to Gulzari et al. (2022), factors such as higher purchasing cost, limited power and control features, and incomplete after-sales support facilities are some of the element that make consumers to have a wait-and-see attitude in the green vehicle market. Furthermore, individual attitudes and customer trust are also positively significant in influencing the intention to purchase green products (Azizan et al., 2022; Musa et al., 2023).

Numerous reviews have been conducted to build a comprehensive overview of the literature on green vehicles. These reviews vary significantly in their focuses, geographic scope, the numbers of papers examined, and the observed time periods. Noteworthy reviews addressing global electric vehicle have highlighted key research trends and performance insight (Hu et al., 2014). Other reviews focused into specific areas such as the performance and trends of autonomous vehicle (Gandia et al., 2019), carbon emissions in the transportation sector (Tian et al., 2018), and suitable business models for electric cars (Secinaro et al., 2020). Motivated from the studies by Meyer (2020) on decarbonization efforts in road freight transportation, current research directions emphasize technological innovations such as alternative fuel or electrification and sectoral economic developments. Additionally, Qin et al. (2022) identifies environmental challenges as a crucial determinant of green energy adoption. Despite this, there are limited studies focusing on the factors affecting the low demand of green vehicles.

To bridge this research gap and offer an objective review of green vehicle adoption, this paper employs bibliometric and network analysis. These analytical tools aim to provide a comprehensive overview of the literature, to give greater insights into past, current, and future research endeavours. This paper has twofold objectives. Firstly, it aims to scrutinize the trends and productivity of research on the adoption of green vehicle through a bibliometric approach. The bibliometric analysis method involves analysing compiled data from keywords analyses, sorting them based on document and source type, year of publication, language, subject area, and most active source title, as well as conducting authorship and co-citation analyses. To accommodate the present study, documents from the years 2000 to 2021 were chosen to be analysed using the bibliometric analysis. The second objective is to identify the key barriers impeding the adoptions of green vehicles, supported by content analysis. This research

conducted a comprehensive bibliometric analysis of published green vehicle adoption research, addressing three main research questions: (a) the evolution and distribution of green vehicle adoption research, including the number of studies per year, sources and document types, and languages of documents; (b) the key areas discussed in green vehicle adoption publications, encompassing subject areas, sources titles, and the frequency of keywords; and (c) the major players in green vehicles adoption research and their collaborations, examining countries with the most contributions, institutions with the highest involvement, the most active authors, citation analysis, and authorship analysis.

The remainder of the paper is structured as follows: *Section 2* presents the research methodology and sample identification; *Section 3* present the results, *Section 4* discuss about the findings, and *Section 5* concludes the study and provides recommendations for future research.

2.0 RESEARCH METHODOLOGY

The aims of this paper are to trace and monitor the research activities and dynamics related to green vehicles' adoptions, and further reveal the barriers of adoption of green vehicles using bibliometric review method. The bibliometric and network analysis in this paper review the green vehicles' adoption and its impediments more objectively, and provide a thorough literature overview, and greater insight into past, current, and future research. In this study, results are presented using network visualization and bibliometric indicators.

2.1 Bibliometric Analysis

In the early 20th century scholars started analysing collection of data using bibliometric methods (Zhou et al., 2018). Bibliometrics is a subfield of informetric; where the term "informetrics" is a broad term comprising all metrics studies related to information science, including scientometrics, cybermetrics, webometrics, and bibliometrics. The bibliometric analysis study extensively applied to measure the productivity of research through the publication trend, evaluating its impact based on some metrics, and visualizing and mapping the literature based on particular networks analyses (Ahmi & Mohamad, 2019; Zyoud et al., 2017). Bibliometric studies are based on statistical analysis expedited through the review of databases focused on indicators inherent in publications such as authors, sources, geographical distributions, and other varied indicators. Through a transparent and reproducible review process, the result of bibliometric analysis is reliability guaranteed. The subjective bias of the review can be resolved by relying on objective evaluations derived from the software program (Bretas & Alon, 2021). Furthermore, Zhang et al. (2021) agree that the advanced bibliometric review alleviates the literature sampling pressure as this method is not limited by time and data samples.

The bibliometric analysis that includes the network citation analysis is a powerful means for various study fields or disciplines, which are difficult to summarize by traditional review method. This study gives insights into focused research areas by showing detailed information about the collection of publications from specific databases such as publication type, location of publication, h-index, authors, keywords frequency, and the number of citations. There are many tools to analyse the bibliometric data and some of the software tools used in the existing literature includes CiteNetExplorer (Zhang et al., 2021), Bibliometrix (and Biblioshiny) (Aria & Cuccurullo, 2017), CiteSpace (Chen, 2006), VOSviewer (Jan van Eck & Waltman, 2010), and so on.

2.2 Data Source and Collection

As this study employed bibliometric analysis method to identify the main research domain variables in a short time, and contribute towards integrating these elements into the literature,

a bibliographic database must first be selected. In this study, the Scopus database was chosen over the Web of Science database. Both Scopus and Web of Science are the most prominent sources of academic works and each have a reasonably homogeneous and complete bibliographic information record of publications (Vieira & Gomes, 2009). Nevertheless, each database have their own custom bibliographic records, forcing most of the systematic review authors to choose either one of the databases with Scopus found to be 60 percent larger in terms of literature range coverage compared to the Web of Science (Meyer, 2020). As a multidisciplinary database that is suitable for systematic quantitative literature review, Scopus includes the Institute for Scientific Information and Scopus-indexed and ranked papers (Secinaro et al., 2020). Moreover, bibliographic information in Scopus can be further extracted into Research Information System (RIS) format which is particularly suitable for post data processing software such as VOSviewer hence, this study utilized the Scopus database.

Upon deciding which database is more suitable, the next process is data collection strategy and organization. For this bibliometric review, the study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for the operational terms search as presented in Fig. 1 (Zakaria et al., 2021). PRISMA guidelines set up a flowchart covering three steps; identification, screening, and inclusion. For the identification step, different combinations of the key terms “green vehicle” and “impediment” were used to identify the boundary of the field for this study. To form the final query string, i.e, (("green vehicle" OR "green car" OR "electric vehicle" OR "electric car" OR "hybrid vehicle" OR "hybrid car" OR "non-internal combustion engine vehicle" OR "non-internal combustion engine car" OR "energy efficient car" OR "energy efficient vehicle" OR "non-fossil-fuel vehicle" OR "non-fossil-fuel car") AND ("barrier" OR "challenge" OR "impediment" OR "obstacle")), the combination of the defined terms, the Boolean operator and retrieval types were applied. Through the Scopus database, a total of 347 publications record were retrieved on February 16, 2022. To complete the screening and inclusion steps, some data preprocessing work was done. Article published before the year 2000 has been excluded from this analysis as this topic only draws the public’s attention around the start of the 21st century. As a final result, 320 screened literature data were identified and further analysed comprehensively using Harzing’s Publish and Perish and, VOSviewer tools.

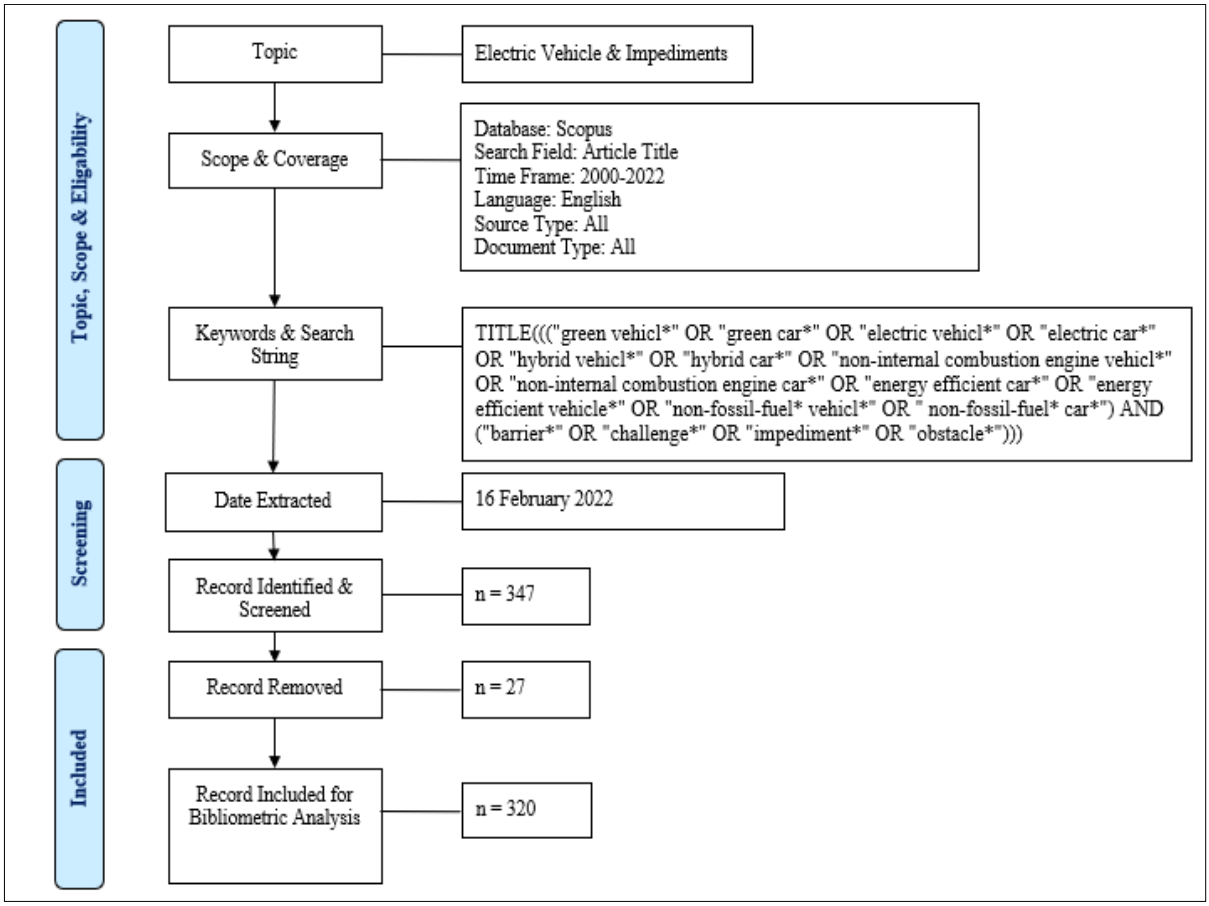

Fig. 1 *PRISMA Flow Diagram*

2.3 Analysis Strategies

For this bibliometric review, we used VOSViewer and Harzing's Publish or Perish tools to analyze data. A freely-available software, VOSViewer helps in constructing, visualizing, and building the networks relationship by mapping citation data extracted from many reputable database including Scopus (Anuar et al., 2022). To graphically visualize the nodal network, VOSViewer put the number and total strength of the link as their standard weight. The size of the nodes and the intertwining lines linking the nodes denote the significance and strength of the links (Donthu et al., 2020). Also, VOSViewer visualized the networks co-occurrence based on the terms extracted from the literature review. The software obliges a threshold signifying the least number of keywords that must be demonstrated together in a paper (Ciano et al., 2019). Another tool used for this bibliometric study is Harzing's Publish or Perish. This software performs the activity of retrieving and analyzing academic citations. By inputting the bibliographic data from Scopus into both VOSViewer and Harzing's Publish or Perish tools, further review on the impact of publications based on citation counts, impact per publication, and citation per publication can be performed.

3.0 FINDINGS

In this section, we devised the intellectual landscape of green vehicle adoption publications, wherein three parts provide an answer to the research question stated. It begins with the evolution and distribution of the green vehicle adoption publications, and valuable insights are accessed from the publication year, document types and source types, and language of the document. Meanwhile, the key areas of the green vehicle adoption are presented by subject

area, source title, and frequency of keywords. These objective findings highlight the contributions of the study components to the green vehicle adoption publications. Apart from the above purpose, science mapping also focuses on the research collaboration among the green vehicle adoptions research. Countries and institutions with the most contributions are pointed out as the major players in the publication of green vehicle adoption. The knowledge structure and publications connections are effectively revealed by using citation analysis, authorship analysis, and co-citation analysis. Thus, by conducting this bibliometric analysis, the evolutionary trends, and knowledge mapping with regard to the adoption of green vehicle field are discovered and visualized. At the end, we extracted and screened the impediments of green vehicles adoption assisted by a clustering algorithm in the VOSviewer software to visualize the in-depth content of this analysis.

3.1 Evolution and Distribution of Green Vehicles' Adoption Publications

To meet the first objective, a performance analysis encompassing publications per year, publication language, document types and source type were evaluated to explore the contributions of the research constituents to the green vehicle adoption publications.

3.1.1 Number of Published Studies per Year

Table 1 summarizes the statistics of annual publications on green vehicle adoption starting from the year 2000 until 2021. As per Scopus records shown in Fig. 2, the first research on electric vehicles was in 1969 titled "Transcontinental electric car race. Dream of quiet, clean city vehicles spurred challenge that brought collegiate competition" by Rippel We. Subsequently, the publication remained stagnant until it starts picking up in early 2000. Since then, people have acknowledged the urgency of green vehicle adoption and due to this concern, research in this field has seen an uptrend in attention from scholars thus justify the reason behind the publication year selection from 2000 until 2021 in this bibliometric analysis. Table 1 presents the total number of publications and growth percentage of documents published on the green vehicle adoption. As the green vehicle relates to the widely debated Industrial Revolution 4.0, it is expected that the number of publications will increase in 2022 onwards.

Table 1. Number of green vehicles' adoption research publications by year

Year	Total of Publication	Percentage (%)
2021	64	20.00%
2020	37	11.56%
2019	40	12.50%
2018	32	10.00%
2017	22	6.88%
2016	21	6.56%
2015	17	5.31%
2014	10	3.13%
2013	11	3.44%
2012	13	4.06%
2011	12	3.75%
2010	16	5.00%
2009	7	2.19%
2008	1	0.31%
2007	3	0.94%
2006	1	0.31%
2005	1	0.31%
2003	2	0.63%

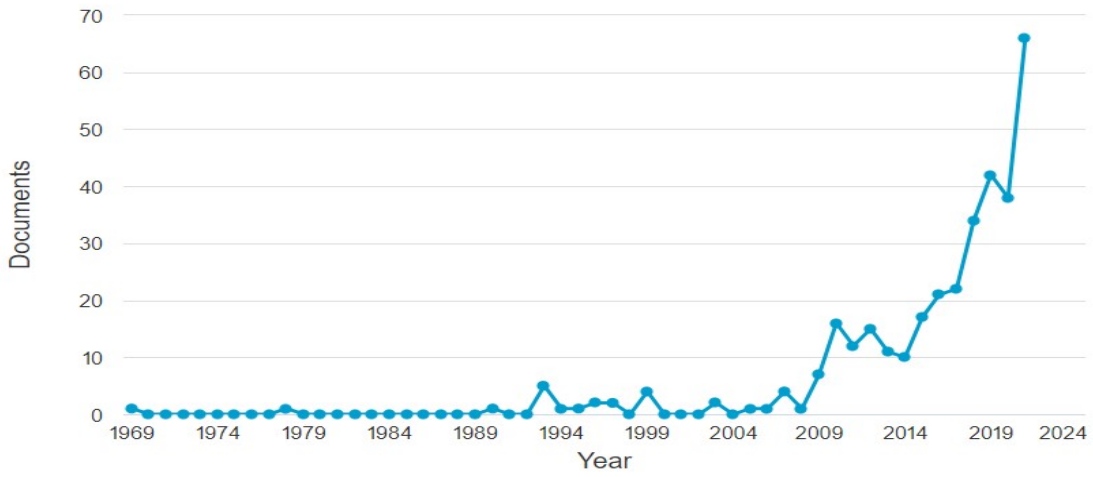

Fig. 2 *The distribution trends of green vehicles' adoption research publications by* year

3.1.2 Document and Source Types

Document types is a type of document based on the document's originality; either article, conference paper, book chapter etc., whilst sources type refers to the type of source document; whether journal, conference proceeding, book series, or trade publication. The results of document types summarized in Table 2, show that documents published on the topic of green vehicle adoption can be classified into nine document types and most of the publication were published as conference papers (41.25%) and articles (40%). Other types of documents presented less than 5% of the total publication respectively.

Table 2. Document type for green vehicles' adoption research

Document Type	Total of Publication	Percentage (%)
Conference Paper	132	41.25%
Article	128	40.00%
Review	45	14.06%
Note	4	1.25%
Book	3	0.94%
Book Chapter	3	0.94%
Short Survey	2	0.63%
Editorial	2	0.63%
Letter	1	0.31%

For source types, the analysis show that there are 5 types of source documents (see Table 3). Of the 320 documents, 53.75% were published in journals, 36.25% in conference proceedings and the remaining 10% of the document were published in trade journals, book series, and books.

Table 3. Sources green vehicles' adoption research

Source Type	Total of Publication	Percentage (%)
Journal	172	53.75%
Conference Proceeding	116	36.25%
Trade Journal	17	5.31%
Book Series	9	2.81%
Book	6	1.88%

3.1.3 Documents Languages

The gathered data sets were further analysed for the language used in the published documents. As shown in Table 4, English is commonplace for most of the publications in this research domain (96.88%). The other languages i.e., German, Chinese and Polish are also used for some research publications and one of the documents had been published in dual languages, i.e., English, and Polish.

Table 4. Publications languages

Languages	Total of Publication	Percentage (%)
English	311	96.88%
German	5	1.56%
Chinese	4	1.25%
Polish	1	0.31%

3.2 Key Areas Green Vehicles' Adoption Publications

The subject area, source title, and keywords frequency revealed the key areas of green vehicle adoption research. This was performed to answer research question 2.

3.2.1 Subject Area

This study then classifies the published documents based on the subject area, as presented in Table 5. On the whole, the distribution indicates that publication on green vehicle emerge in diverse subject areas ranging from engineering, energy, computer science, environmental science, social science, mathematics, material science, decision science, physics, and astronomy as well as business, management, and accounting. According to the analysis, it is found that more than half of the publications were categorized under engineering (65.63%) and followed by energy (42.81%).

Table 5. Subject area

Subject Area	Total of Publication	Percentage (%)
Engineering	210	65.63%
Energy	137	42.81%
Computer Science	70	21.88%
Environmental Science	54	16.88%
Social Sciences	42	13.13%
Mathematics	40	12.50%
Materials Science	28	8.75%
Business, Management and Accounting	24	7.50%
Physics and Astronomy	19	5.94%
Decision Sciences	14	4.38%

3.2.2 Source Title

As green vehicle adoption research was published in various journals, proceedings, and books, thus Table 6 shows the top source title where the articles on the research domain have been published based on the minimum number of 4 publications produced by each source title. As highlighted in Table 6, the Institute of Electrical & Electronics Engineers Access and the Renewable and Sustainable Energy Reviews are among the top journals that contribute to publications on green vehicle adoption.

Table 6. Most active source titles

Source Title	Total of Publication	Percentage (%)
Institute of Electrical & Electronics Engineers Access	10	3.13%
Renewable And Sustainable Energy Reviews	10	3.13%
Energies	9	2.81%
SAE Technical Papers	8	2.50%
World Electric Vehicle Journal	6	1.88%
Energy Policy	5	1.56%
Lecture Notes In Electrical Engineering	5	1.56%
Sustainability Switzerland	5	1.56%
Energy	4	1.25%
IEEE Electrification Magazine	4	1.25%
Journal Of Cleaner Production	4	1.25%
Journal Of Energy Storage	4	1.25%
Resources Conservation And Recycling	4	1.25%
Transportation Research Part D Transport And Environment	4	1.25%

3.2.3 Keyword Analysis

For the keyword analysis, the analyzation is based on two applications tools; Wordsift and VOSviewer. The WordSift application will generate the word cloud based on the keywords entered, while VOSviewer will visualize the co-occurrence of keywords based on the green vehicle adoptions research data sets. Scopus database provides researchers with two types of keywords; author keywords, and indexed keywords (Ahmi, 2021). Author keywords are keywords chosen by author(s) which, in their opinion, reflect the document contents best. On the contrary, indexed keywords are keywords chosen by content supplier (or publishers) and are standardized based on publicly available vocabulary. For this bibliometric analysis, we

utilized both author and indexed keywords listed in downloaded summary file to perform the mapping and visualizing the occurrence of keywords.

3.2.3.1 Keyword Analysed using WordSift

Using WordSift (https://wordsift.org), this analysis created a word cloud for the authors' keywords. Fig. 3 represents the findings of the word cloud with a maximum of 100 words, and √n scale setting. Fig. 3 depicts the top 100 words (or parts of keyword) used in the combination of green vehicle and its challenges research publications. Each word's size denotes the total number of keywords occurrences.

As the purpose of this analysis is to determine the impediment of green vehicle adoption, the word cloud portrays other emerging keywords such as charging, battery, technology, development, power, fuel, lithium, and storage. Other keywords, despite the smaller size, are words that have also been chosen to accommodate the issue of green vehicle adoptions. Therefore, we anticipate that future research will likely emphasize on these keywords.

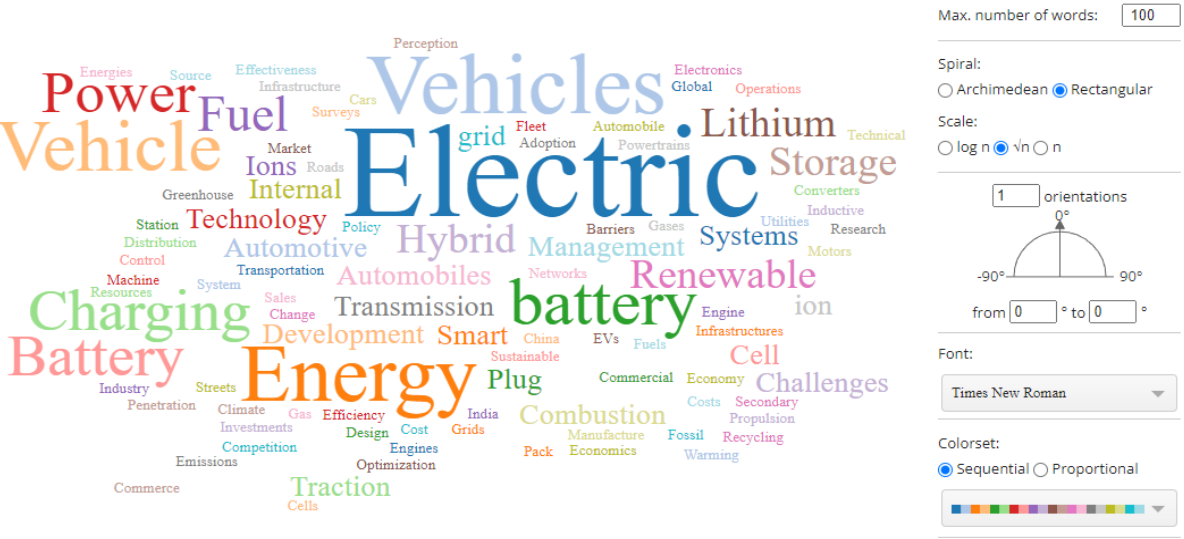

Fig. 3 *Word Cloud of the Authors Keywords*

3.2.3.2 Keyword Analysed using VOSviewer

The network visualization of both authors and indexed keywords visualized by VOSviewer (see Fig. 4) discern the relationship strength between keywords by colour, circle size, font size, and thickness of connecting lines. Related keywords, denoted by the same colour, are commonly listed together. Using 2660 authors and indexed keywords, filtered by minimum of 13 occurrences of keyword, the VOSviewer eventually identified 38 items with 4 clusters. The 4 clusters are marked by 4 distinct colours according to the highest keywords. Further details on each cluster are explained in Section 4.0.

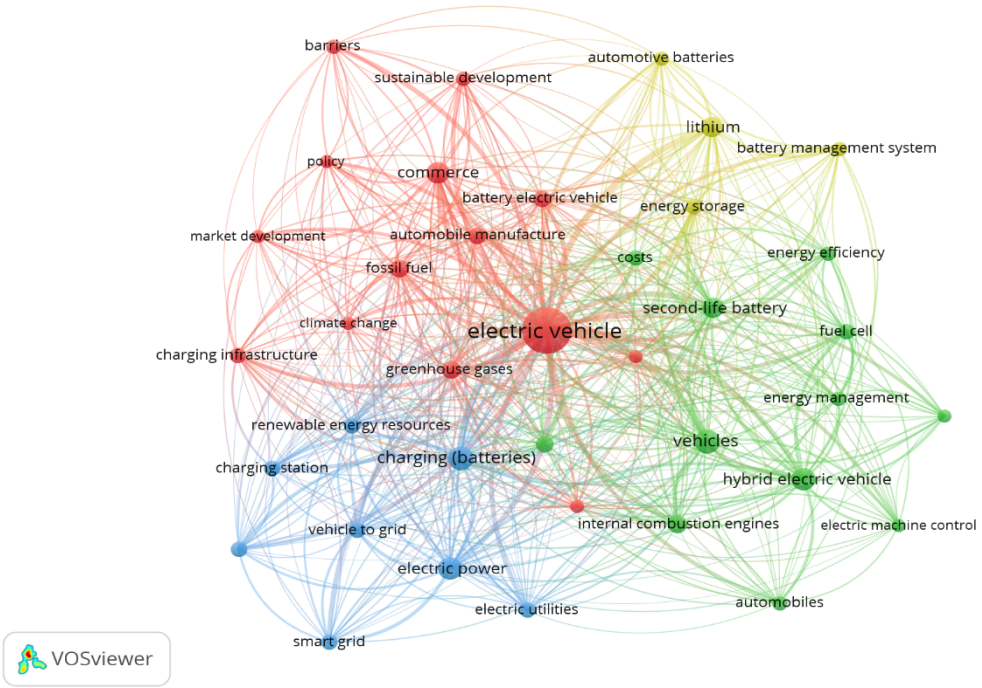

Fig. 4 *VOSviewer network visualization of keyword co-occurrence*

The results show that charging (batteries), commerce, fossil fuels, lithium-ion batteries, electric power transmission network, greenhouse gases, electric utilities are among the highest keywords occurrences after removing core keyword specified in the search query i.e., electric vehicle, hybrid vehicle, and vehicle (see Table 7).

Table 7. Top keywords

Keywords	Total of Publication	Percentage (%)
Charging (batteries)	54	16.88%
Commerce	39	12.19%
Secondary Batteries	37	11.56%
Fossil Fuels	26	8.13%
Lithium-ion Batteries	26	8.13%
Electric Power Transmission Networks	25	7.81%
Greenhouse Gases	25	7.81%
Automobile Manufacture	24	7.50%
Internal Combustion Engines	24	7.50%
Battery Electric Vehicles	21	6.56%
Electric Utilities	20	6.25%
Vehicle-to-grid	20	6.25%
Battery Management Systems	17	5.31%
Charging Infrastructures	17	5.31%

3.3 Major Players and Research Collaboration

In this section, we analysed the geographical distribution of publications by extracting the most publication contributions by countries and institutions. We then reviewed the connection among green vehicle adoption research through citation analysis, authorship analysis and co-citation analysis.

3.3.1 Countries with the Most Contributions

The top 10 out of 57 countries that contributed to the publication's productivity in this issue of green vehicle adoption are itemized in Table 8. These countries have been counted based on the author(s)' affiliation, i.e., if the documents were co-authored by 4 authors (two (2) from Malaysia and another two (2) from United Kingdom) it will be counted as one (1) Malaysia and one (1) United Kingdom. Thus, based on the stated criterion, it can be seen that top on the lists is the United States with total of 50 documents, followed by India, United Kingdom, China, and Germany.

Table 8. Top countries contributed to the publications

Country	Total of Publication	Percentage (%)
United States	50	15.63%
India	44	13.75%
United Kingdom	35	10.94%
China	29	9.06%
Germany	29	9.06%
Canada	16	5.00%
Malaysia	16	5.00%
France	14	4.38%
Japan	11	3.44%
Australia	10	3.13%

3.3.2 Institutions with the Most Contributions

As per Table 9 below, the top affiliation of the author(s) is from Universiti Kebangsaan Malaysia, Universiti Tenaga Nasional, and Newcastle University, United Kingdom. The list of the top affiliations is based on the number of publications they produced. The Scopus database considers only one author per document, even though there are two or more authors from the same institutions who wrote the same documents.

Table 9. Most influential institutions contributed to the publications

Institution	Country	Total of Publication	Percentage (%)
Universiti Kebangsaan Malaysia	Malaysia	10	3.13%
Universiti Tenaga Nasional	Malaysia	6	1.88%
Newcastle University	United Kingdom	5	1.56%
CNRS Centre National de la Recherche Scientifique	France	4	1.25%
Rheinisch-WestfälischeTechnische Hochschule Aachen	Germany	4	1.25%
Université du Québec à Trois-Rivières	Canada	4	1.25%
Femto-St - Sciences et Technologies	France	4	1.25%
Fédération de Recherche CNRS FCLAB	France	4	1.25%
The Royal Institute of Technology KTH	Sweden	3	0.94%
Seoul National University	South Korea	3	0.94%

3.3.3 Most Active Authors

Table 10 listed the top author based on the number of documents published by them within the research fields in the previous two decades (regardless of the author's position, either as the first author, second or even as the corresponding author). Mohammad Abdul Hannan from the Universiti Tenaga Nasional, Malaysia, is one of the top authors actively publishing research in topics like battery management system, and electric vehicle charging system. Out of nine documents, 3 of them are led by him.

Table 10. Most active authors

Author's Name	Total of Publication	Affiliation
Hannan, Mohammad Abdul	9	Universiti Tenaga Nasional, Malaysia
Boulon, Loïc	5	Université du Québec à Trois Rivières, Canada
Mohamed, Azah	5	Universiti Kebangsaan Malaysia
Ayob, Afida	4	Universiti Kebangsaan Malaysia
Franke, Thomas	4	Universität zu Lübeck, Lübeck, Germany
Hussain, Aini	4	Universiti Kebangsaan Malaysia
Sovacool, Benjamin K.	4	Aarhus Universitet, Aarhus, Denmark
Chan, Chingchuen	3	Harbin Institute of Technology, China
Emadi, Ali N.	3	McMaster University, Hamilton, Canada
Lipu, Molla Shahadat H.	2	Universiti Kebangsaan Malaysia

3.3.4 Citation Analysis

Using Harzing's Publish and Perish software, and the retrieved Scopus data from 2000 – 2021, the citation metrics is generated as summarized in Table 11. As indicated, there are 320 documents with 8,096 citations averaging 426 citations per year on the issue of green vehicle adoption research. Each paper is cited 25 times, where the *h-index* and *g-index* is at 42 and 86 respectively, for all the publications.

The *h-index* and *g-index* is one of the metrics measured the productivity and citation impact. As proposed by Hirsch (2005), the *h-index* characterized researchers scientific output, and estimate of an importance, significance, and broad impact of a scientist's cumulative research contributions. Therefore, the *h-index* 42 in this analysis means the 42 publications that each of the publications has at least 42 citations. Meanwhile, *g-index* is ranked based on the largest number of citations received in descending order set of data i.e., the top *g* articles have at least g^2 citations (Egghe, 2006). Therefore, the 86 *g-index* in this analysis represents the 86 published articles that have at least 7,396 citations.

Table 11. Citations metrics

Metrics	Data
Publication years	2003-2021
Papers	320
Citations	8,096
Years	19
Citations/Year	426.11
Citations/Paper	24.61
Citations/Author	2,589.12
Papers/Author	125.57
Authors/Paper	3.68
Hirsh h_index	42
Egghe g_index	86

Meanwhile, the top 20 cited articles are listed in Table 12 below. All these articles are ranked based on the number of times being cited. The document by Egbue and Long (2012) entitled “Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions” has received the highest number of citations (796 citations or an average of 79.6 citations per year). However, if we consider the highest citation per year as the most impactful article, the study by Hannan et al. (2017) is the most impactful study with an average of 154.2 citations per year.

Table 12. Top 20 highly cited documents

No.	Authors	Year	Title	Source	Total Citation	Cites PerYear
1	O. Egbue, S. Long	2012	Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions	Energy Policy	796	79.6
2	M.A. Hannan, M.S.H. Lipu, A. Hussain, A. Mohamed	2017	A review of lithium-ion battery state of charge estimation and management system in electric vehicle applications: Challenges and recommendations	Renewable and Sustainable Energy Reviews	771	154.2
3	M.A. Hannan, M.M. Hoque, A. Mohamed, A. Ayob	2017	Review of energy storage systems for electric vehicle applications: Issues and challenges	Renewable and Sustainable Energy Reviews	439	87.8
4	M.A. Hannan, F.A. Azidin, A. Mohamed	2014	Hybrid electric vehicles and their challenges: A review	Renewable and Sustainable Energy Reviews	409	51.13
5	B.K. Sovacool, R.F. Hirsh	2009	Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition	Energy Policy	392	30.15

6	T. Franke, I. Neumann, F. BÃ¼hler, P. Cocron, J.F. Krems	2012	Experiencing Range in an Electric Vehicle: Understanding Psychological Barriers	Applied Psychology	249	24.9
7	M.S.H. Lipu, M.A. Hannan, A. Hussain, M.M. Hoque, P.J. Ker, M.H.M. Saad, A. Ayob	2018	A review of state of health and remaining useful life estimation methods for lithium-ion battery in electric vehicles: Challenges and recommendations	Journal of Cleaner Production	242	60.5
8	F. Un-Noor,S. Padmanaban, L. Mihet-Popa, M.N. Mollah, E. Hossain	2017	A comprehensive study of key electric vehicle (EV) components, technologies, challenges, impacts, and future direction of development	Energies	237	47.4
9	N. Sulaiman, M.A. Hannan, A. Mohamed, E.H. Majlan, W.R. Wan Daud	2015	A review on energy management system for fuel cell hybrid electric vehicle: Issues and challenges	Renewable and Sustainable Energy Reviews	224	32
10	S. Amjad, S. Neelakrishnan, R. Rudramoorthy	2010	Review of design considerations and technological challenges for successful development and deployment of plug-in hybrid electric vehicles	Renewable and Sustainable Energy Reviews	222	18.5
11	S. Steinhilber, P. Wells, S. Thankappan	2013	Socio-technical inertia: Understanding the barriers to electric vehicles	Energy Policy	172	19.11
12	Z.-Y. She, Qing Sun, J.-J. Ma, B.-C. Xie	2017	What are the barriers to widespread adoption of battery electric vehicles? A survey of public perception in Tianjin, China	Transport Policy	126	25.2
13	S.G. Wirasingha, N. Schofield, A. Emadi	2008	Plug-in hybrid electric vehicle developments in the US: Trends, barriers, and economic feasibility	2008 IEEE Vehicle Power and Propulsion Conference, VPPC 2008	122	8.71
14	S. Habib, M.M. Khan, F. Abbas, L. Sang, M.U. Shahid, H. Tang	2018	A Comprehensive Study of Implemented International Standards, Technical Challenges, Impacts and Prospects for Electric Vehicles	IEEE Access	117	29.25
15	R. Bosshard, J.W. Kolar	2016	Inductive Power Transfer for Electric Vehicle Charging:	IEEE Power Electronics Magazine	110	18.33

			Technical challenges and tradeoffs			
16	I. Vassileva, J. Campillo	2017	Adoption barriers for electric vehicles: Experiences from early adopters in Sweden	Energy	105	21
17	F.H. Gandoman, J. Jaguemont, S. Goutam, R. Gopalakrishnan, Y. Firouz, T. Kalogiannis, N. Omar, J. Van Mierlo	2019	Concept of reliability and safety assessment of lithium-ion batteries in electric vehicles: Basics, progress, and challenges	Applied Energy	99	33
18	G. Haddadian, M. Khodayar, M. Shahidehpour	2015	Accelerating the Global Adoption of Electric Vehicles: Barriers and Drivers	Electricity Journal	90	12.86
19	A.A. Juan, C.A. Mendez, J. Faulin, J. De Armas, S.E. Grasman	2016	Electric vehicles in logistics and transportation: A survey on emerging environmental, strategic, and operational challenges	Energies	89	14.83
20	A.K. Srivastava, B. Annabathina, S. Kamalasadan	2010	The Challenges and Policy Options for Integrating Plug-in Hybrid Electric Vehicle into the Electric Grid	Electricity Journal	84	7

3.3.5 Authorship Analysis

This section further evaluates, visualized, and mapped the relationships among the author(s) in the green vehicles research publications. In Section 3.3.3 and 3.3.4, we have highlighted the number of contributing authors in a publication, while in this section the collaboration between author(s) is explored through co-authorship analysis. The term co-authorship refers to the scientific collaboration between two or more authors on publications to discover new knowledge and solve problems (Sonnenwald, 2007). We utilized the VOSviewer tools to generate the visualized network between authors since this software provides a few types of co-authorship analysis i.e., co-authorship analysis by authors and co-authorship analysis by countries.

3.3.5.1 Co-authorship Analysis by Authors

The analysis, as displayed in Figure 4 visualized and identified a total of 1,110 authors out of 1,236 documents contributing to this research field by the collaboration network and number of documents. In order to generate the simplified author collaboration network as displayed in Fig. 5, the minimum threshold of documents of an author was set as one, and 1,000 authors with the greatest total link strength were chosen. As a result, the map shows

65 connected authors divided into eight clusters, which are marked with diverse colour, who collaborate publishing research in a specific research domain. The size of circles corresponds to the number of documents each author has published, and the links between the circles show the co-authorship relations among authors. The largest category is in red and green, and comprises of 12 and 10 documents respectively.

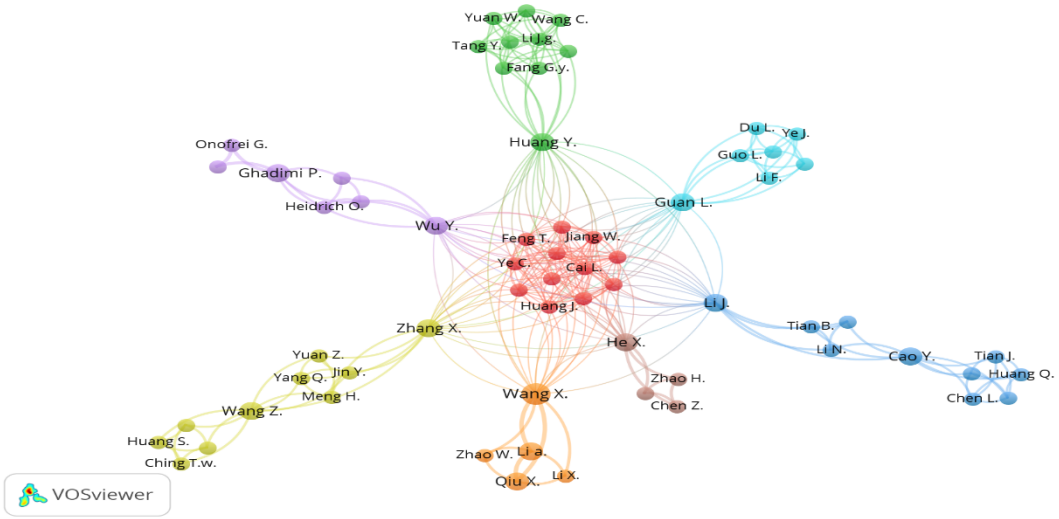

Fig. 5 *VOSviewer Visualization of a Co-Authorship Analysis by Authors*

3.3.5.2 Co-authorship Analysis by Countries

Fig.6 conveys the detailed illustration of the country/region collaboration map. The nodes size refers to the number of citations per country and the lines connecting the nodes represent the collaboration existence between the authors in each country. With the minimum number of citations per document is three, thirty countries separated with six different clusters are displayed in six different colors. The countries with the highest collaboration are clustered together colored in red, and this cluster includes countries like Canada, Colombia, France, Italy, Norway, South Africa, and Sweden. The United States, United Kingdom, and China are among the countries with the widest range of cooperative partners in this green vehicle adoption issues. Due to the clustering algorithm in VOSviewer, these three regions, however, are not grouped together and designated with three different colors. Hence, to a certain extent, geographic location also influenced research orientation. In order to speed up the advancement in this research field, scholars from all countries should strive to breakdown these spatial barriers in researching green vehicle adoption.

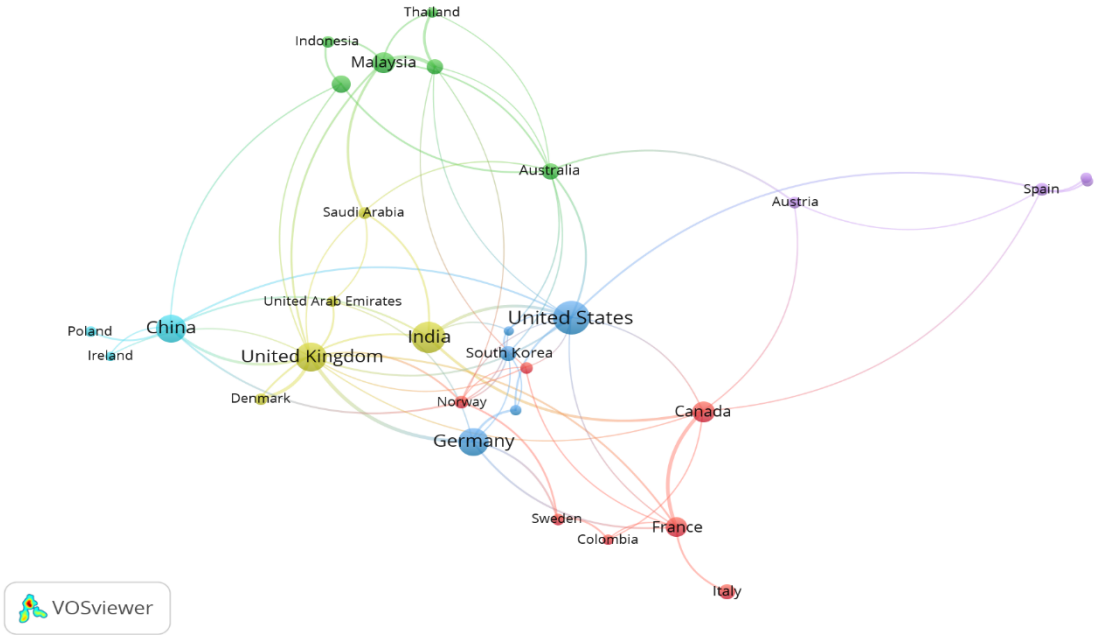

Fig. 6 *VOSviewer Visualization of a Co-Authorship Analysis by Countries*

3.3.6 Citation Analysis

The frequency in which two documents are cited together by a primary publication is measured using co-citation analysis. When publications are co-cited frequently, most probably it belongs to the same clusters (Abduljabbar et al., 2021). According to Eck and Waltman (2014), the larger the number of publications by which two publications are co-cited, the stronger the co-citation relation between the two publications. This paper analysed the co-citation using the cited references and cited authors, as the unit of analysis.

3.3.6.1 Co-citation by Cited References

Fig. 7 shows the network visualization of the co-citation by cited references. The VOSviwer tools help to track two documents that are cited together in the references. To develop meaningful clusters and assign each cluster to a theme and determine the main impediments of green vehicles adoptions, the network size is filtered accordingly. The minimum number of citations of a cited reference is set as three, resulting in 59 publications split in 5 clusters. The clusters show the references that are co-cited by documents within the dataset. Items coloured in red is the primary cluster with the highest number of publications, which is 15. Each publication labelled with the same colour tends to share some common themes.

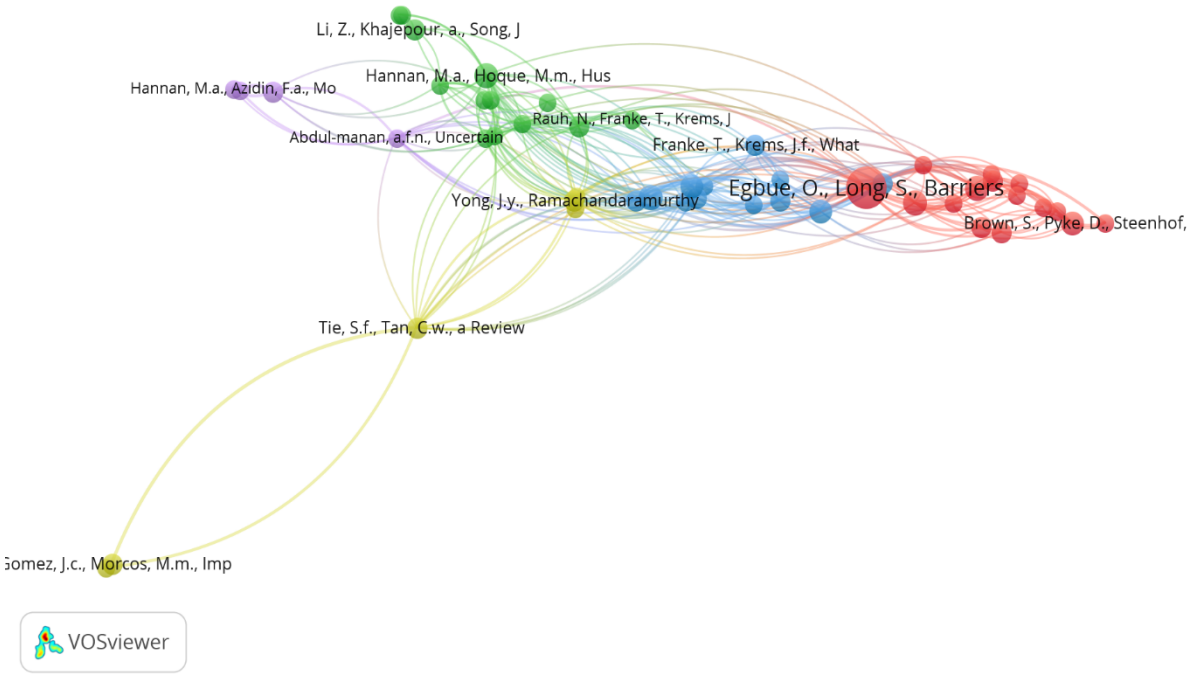

Fig. 7 *VOSviewer Visualization of a Co-Citation Analysis by Cited References*

3.3.6.2 Co-citation by Cited Authors

While co-citation by reference looks at similar references cited in other documents, the co-citations by authors search for similar two authors being cited by other publications. This analysis can be used to visualize the emerging intellectual structure of green vehicle adoption issue from the perspective of authors. The illustrated result in Fig. 8, is mapped with a threshold of 20 citations regarding an author. Out of 17,576 authors found from the reference's column in the datasets, 107 authors meet the thresholds and are divided into 4 different clusters and colour. The size of coloured sphere indicates the number of citations per author.

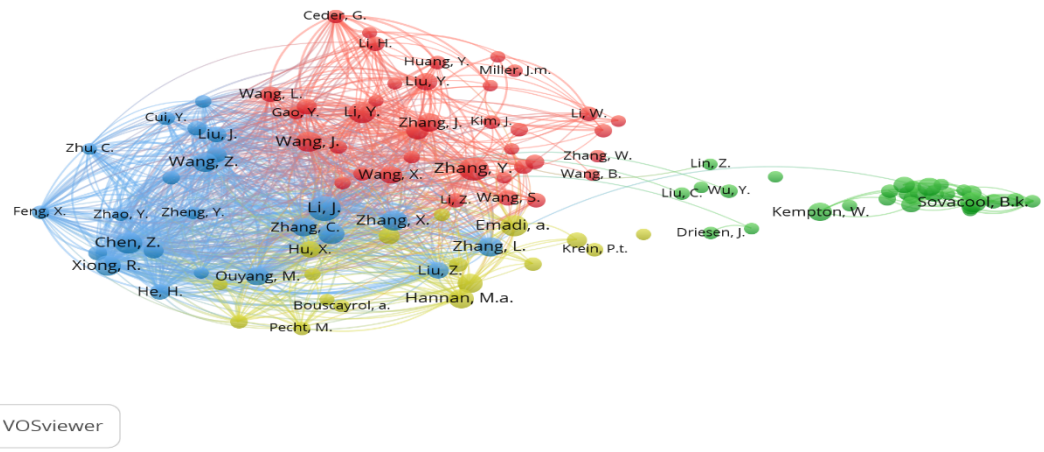

Fig. 8 *VOSviewer Visualization of a Co-Citation Analysis by Cited Authors*

4.0 DISCUSSION

In this section, efforts were made to elucidate the impeding factors for the adoption of green vehicles. Based on the keyword analysis in subsection 3.2.3, the word cloud in Fig. 3 displayed the highest occurrences of keywords in this research dataset. The words like “charging battery”, “energy”, “renewable”, and “storage” are highly visible keywords highlighted using the word cloud. Then, the results in Fig. 4 also highlights the co-occurrence of keywords in this research field and clustered a few keywords that are directly linked to the term “electric vehicle” (see Fig. 9). The keywords of a paper have a high conceptual level of abstraction (Qin et al., 2022), therefore it could be deemed possible as impeding factors affecting the adoption of green vehicle. The first cluster consists of 14 keywords such as “sustainable development”, “market development”, and “commerce” and is coloured in red. These clusters mainly focus on government regulations and policies related to the adoption of green vehicle. Next, the second cluster in green, included 12 keywords such as “energy management”, “powertrain”, and “energy efficiency” likely discussed on topics of environmental management and is associated with issues such as “second life battery” and “electric machine control”. Then, a total of 8 keywords in blue colour represent the issue of green vehicle charging infrastructure, in which the words “charging station”, “vehicle to grid”, and “electric utilities” being the most predominant keywords. The fourth cluster in yellow, which consists of the following 4 keywords, “lithium”, “battery management system”, “automotive batteries”, and “energy storage” is emphasising on the issue of battery management system.

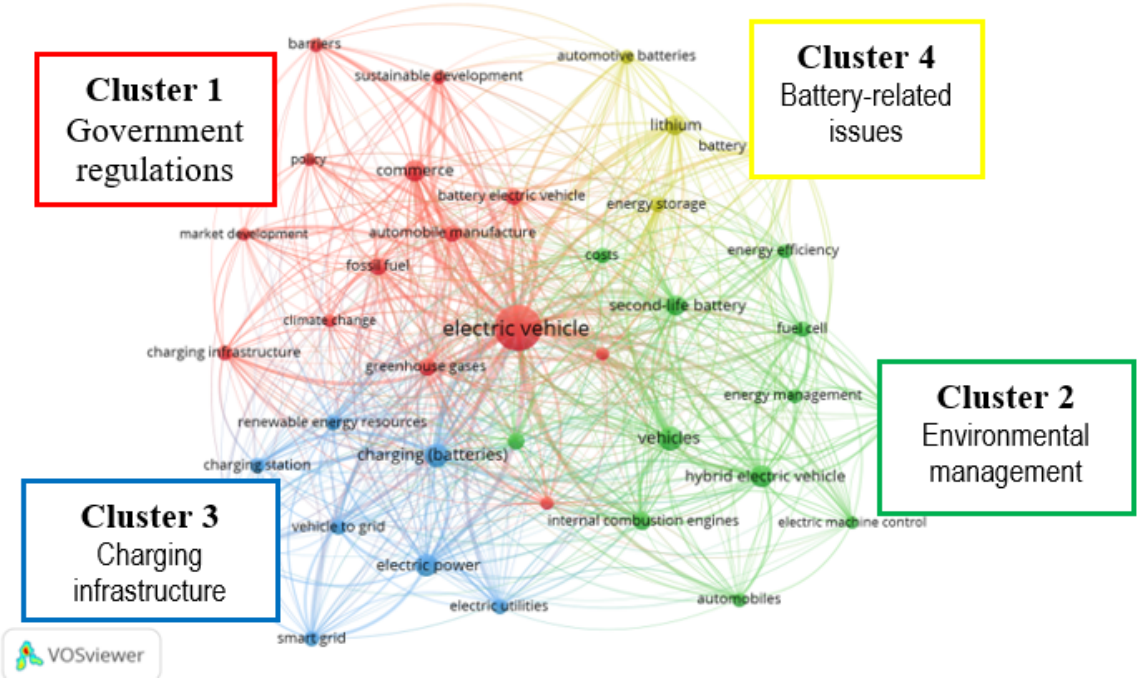

Fig. 9 *Keyword Co-Occurrence Clusters*

In addition, the results from the co-citation analysis also developed meaningful clusters and we assigned each cluster to a specific theme (see Fig.10). For Cluster 1, it is themed as “Socio-technical” with most publication under this cluster focused on the topics such as; battery range and cost (Egbue & Long, 2012), consumers’ psychological aspects (Rezvani et al., 2015), public knowledge (Krause et al., 2013), and incentives and socio-economic factors (Sierzchula et al., 2014). Cluster 2 in the “Battery-related issues” theme included 13 publications. As it is named, this cluster mainly focus on issues of lithium-ion batteries (Jaguemont et al., 2016; Mahammad A. Hannan et al., 2018; Zhu et al., 2018) and battery management system (Rezvanizaniani et al., 2014; Zhu et al., 2018; M. Zhang & Fan, 2020).

For Cluster 3 themed as "Charging infrastructure", the publications centred on topics of vehicle to grid, smart grid (Lund & Kempton, 2008; Sovacool & Hirsh, 2009), and range anxiety (Lund & Kempton, 2008; Neubauer & Wood, 2014). Finally, Cluster 4 contained articles that focused on the "Environmental management" theme comprising publications in energy sources and energy management system (M. A. Hannan et al., 2014; Tie & Tan, 2013) and life cycle assessment (Abdul-Manan, 2015).

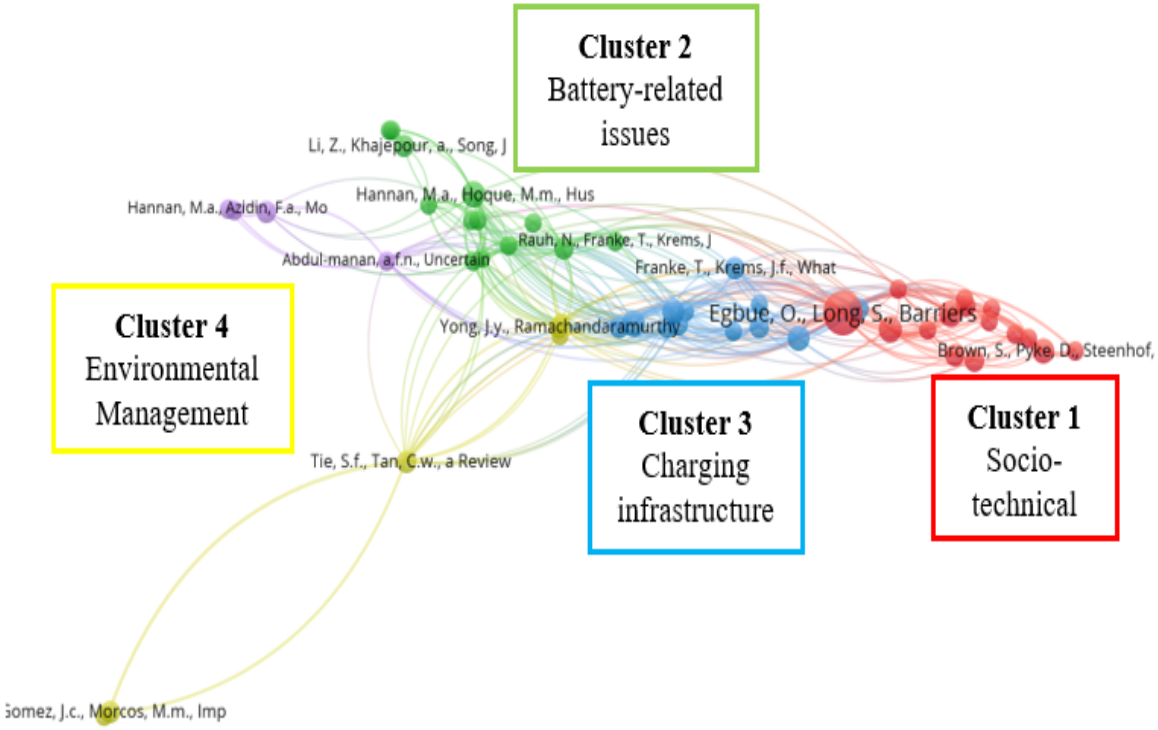

Fig. 10 *Co-citation by Cited References Clusters*

All the main clusters and publications mentioned above is a continuance from the climate change policy of the United States of America launched at the 10th Conference of the Parties to the UNFCCC (United Nations Convention on Climate Change) in 2004. During the Conference, it was declared that electric vehicles as one of the three pillars developed to mitigate the incidence of pollution and carbon dioxide emission (Secinaro et al., 2020). As a result, since 2005, green vehicles especially electric vehicles have sparked the interest of academia and policymakers. Hence, the beginning year of the bibliometric analysis follows the international trend and coincides with the start of the research conducted on the discussed theme.

5.0 CONCLUSION AND RECOMMENDATIONS

In this study, the intellectual landscape of green vehicle adoptions is analysed using bibliometric analysis approach. The contributions from bibliometric analysis also benefit policymakers and academicians. The research performance and impact of the analysed research area help policymakers in decision making before embarking into the specific research domain. Moreover, the important areas highlighted in bibliometrics findings develop clear insights to academicians in producing relevant publications. Building on the urgency of mitigating carbon emission particularly in the road transport sector, this research focused on the issues related to the green vehicle adoptions data gathered from Scopus database. From 2003, there has been a significant growth in the number of publications. The analysis also reveals the existence of inter-countries collaboration on the uptake of green vehicle issues.

Most of the publications were written in English, with more than half published in academic journals and conference proceedings. The results also indicate that the green vehicle publications involved various disciplines such as engineering, energy, computer science, environmental science, and social science. The publication impact can be evaluated based on the citation metric.

Nevertheless, this bibliometric technique has inherent shortcomings despite its contributions. The first aspect is keywords context used in the query process. As common practice in the past bibliometrics studies, this study employed specific query/keywords to locate the initial list of scholarly documents indexed by Scopus. An “article title” is chosen instead of “article title, abstract, and keywords”, which can retrieve more comprehensive search results, thus improving the quality of findings. Moreover, despite the fact that Scopus is one of the top online databases that index scholarly works, other recognized databases such as Web of Science can also be applicable.

Concerning future research, we contend that delving into social and economic factors can advance this topic and indirectly contribute to mitigating transport emission. For example, comprehending the psychological and social influence affecting the embrace of green vehicles and analysing the economic aspects of green vehicle adoption, including the total cost of ownership, incentives, and government policies that can either foster or impede adoption are key issues that needs to be researched further. In addition, exploring the impact of infrastructure development and devising strategies to surmount barriers related to charging availability, convenience, and accessibility is crucial. Moreover, future studies may focus on education and awareness, assessing the efficacy of educational campaign and awareness programs in promoting the adoption of green vehicle. Understanding how information is disseminated can rectify misconceptions and enhance knowledge about green vehicles. In conclusion, there is current deficiency in specific analyses concerning market dynamics and trends, management and policies related to technology innovation, and collaboration among stakeholders in the realm of green vehicle. Research in these areas can significantly augment the understanding of the topic.

CO-AUTHOR’S CONTRIBUTION

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper. All authors contributed equally to the conception and design of the study.

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