



BIBLIOMETRIC ANALYSIS OF NEARLY A DECADE OF RESEARCH IN ELECTRIC VEHICLES: A DYNAMIC APPROACH

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ABSTRACT

A bibliometric study was developed based publications of investigation in electric vehicle from 2007 to 2016 available in the science citation Index-expanded database from Web of science, the information was identified in the version on line of SCI-Expanded, Web Thomson Reuters of Science, supported in addition on a powerful tools of information processing like Hitscite. The extracted files were analyzed to determine the number of citations, including publications by year, language, country or region, Journals, articles and authors in order to determine the evolution of this field of study.

Keywords: electric vehicle, web of science database, bibliometric analysis.

1. BACKGROUND

An electric vehicle can be defined as any vehicle that uses electric or traction motors for its propulsion. An electric vehicle must be powered by a source of electricity from sources outside or inside the vehicle using a battery, solar panels or an electricity generator to convert gasoline into electricity. Some models include rail or road vehicles, ships or submarines, aircraft or electric spacecraft. The emergence of electric vehicles was addressed in the mid-14th century, when electricity began to be an effective method of propulsion of the vehicle's engine, offering comfort and efficiency of operations not provided by gasoline vehicles. Today's internal combustion vehicles have remained dominant as engine systems for nearly 100 years, but electric vehicles have already gained a recognized place in more than just small trains and vehicles. Despite the popularity of these vehicles [1], There are implications for slowing down these studies. [2] due to emissions and other factors [3]. However, studies are beginning to compare a traditional model against the new vehicle model [4] it is well known that in the long run, these vehicles could bring economic benefits. [5]. It can also be mentioned that although there are more environmentally friendly fuel alternatives available [6] even electric vehicles can contribute much more in this field [7][8] he subject of electric vehicles is growing every day, from the perspective of improving batteries for greater efficiency that in the long run is the essence of these vehicles. [9][10]. Analysing previous data on financial viability la Figure-1 shows the electric car market from 2010 to 2016, which projects an extensive and promising market for years to come. [11].

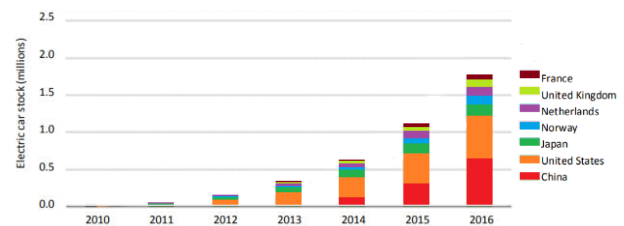


Figure-1. Evolution of the global electric car stock between 2010 and 2016. Source: The InternationalEnergy Agency.

A bibliometric analysis is an efficient method for investigating publication patterns from a database of academic literature [12] used to analyse any topic [13]. Bibliometric analyses have historically been used to explore the relationships between citations from scholarly journals and to provide a detailed view of the research topic. [14]. The bibliometric analysis has been implemented to detect the relevance of a study topic in a given field [15], covering the analysis of sporting goods [16], including medical subjects and even study projections of the same. [17][18], to the report of topics such as industrial engineering or computing [19] among others [20][21]. However, no study involves electric vehicles at a bibliometric level, for this reason, bibliometric is presented for the analysis of the profile of electric vehicles of almost a decade (2007-2016).

2. METHODOLOGY

A. Objective of study

The primary objective of this study focuses on the analysis of the different bibliometric indicators related to the investigation of electric vehicles with the articles obtained in Web of Science, which then worked in HistCite to obtain the indicators for their subsequent analysis. The obtained articles were developed from 2007 to 2016.



This study allows us to define the information search equation that facilitates the achievement of the database to be analyzed by analyzing information obtained through a tool that allows us to visualize the information distributed by countries, published documents, authors and institutions and that finally identify publications with better research quality with higher TGCS in order to have a reference for future research.

B. Process

For the analysis of the information obtained and the generation of the results, it was necessary to follow the steps shown in Figure-2. The flowchart shows the five steps to follow for the bibliometric study of the obtained scientific information.

In the first stage, the search of a subject is defined. This search is determined by the keywords that facilitate the obtaining of the information to be analyzed. The general theme of this article is the electric vehicles, so the appropriate keywords were electric and vehicle.

In the second stage, the previous keywords are used to search the articles for the bibliometric analysis. For this, a metasearch called Web of Science is used that shows all the articles related to the keywords.

In the third stage is where the tool called HistCite [22] is used, which facilitates the visualization of the bibliometric indicators, the input data for this is the file that the metasearch generates. With this, you get the various indicators to analyze.

The fourth stage is where the analysis of all the results obtained with the HitsCite tool is performed. If the results present solid and consistent information the data can be analyzed. The fifth stage is where these studies are shown in graphs and tables presented in the results and discussion of the present article.

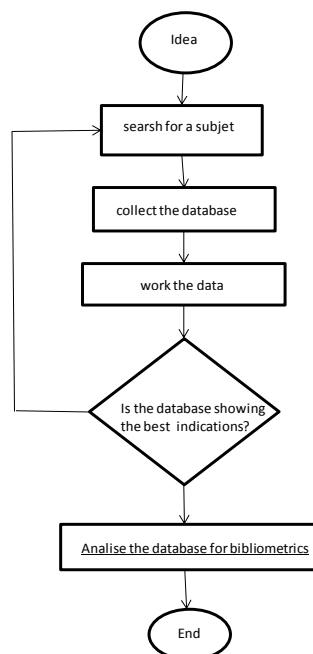


Figure-2. Flowchart for bibliometric analysis.

3. RESULTS

A. Distribution of document types

A total of 4105 articles in electric vehicles, published between 2007 and 2016, were extracted from Web of Science. The distribution of article types is shown in Table-1. Of these, 3658 (89.1%) were original articles and 153 (3.8%) were review articles. These 4105 articles were included in the subsequent analysis.

Table-1. Distribution of types of articles on electric vehicles published between 2007 and 2016 (N=4105).

Article	Recs	%Recs
Original article	3658	89.1
Article; Proceedings Paper	183	4.5
Review	150	3.7
Editorial Material	45	1.1
News Item	27	0.7
Correction	19	0.5
Letter	10	0.2
Meeting Abstract	9	0.2
Book Review	2	0.0
Article; Retracted Publication	1	0.0
Review; Book Chapter	1	0.0

B. Publication trends - language

Figure-3 indicates that the number of articles has increased during these 9 years with 885 articles published in 2016. Most of these articles were written in English (99%) as shown in Table-2. Authors from a total of 83 countries contributed to the publication of the 3808 articles. The People's Republic of China has the highest number of published articles (28.1%), followed by the United States (22.2%). In terms of h-index, People's Republic of China was the leading country (47%) shown in Figure-4.

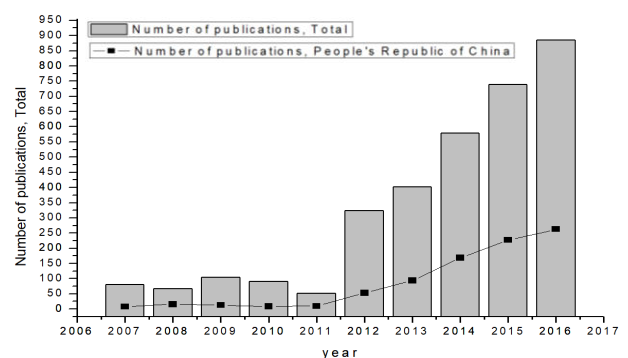


Figure-3. Time trend of the number of articles on electric vehicles published per year from 2007 to 2016.



Table-2. Languages on electric vehicles published between 2007 and 2016 (N=4105).

Language	Recs	%Recs	TGCS	Citations/Article
English	4065	99.0	57080	14,04
German	13	0.3	6	0,46
Spanish	7	0.2	4	0,57
Korean	5	0.1	0	0,00
Polish	5	0.1	1	0,20
Portuguese	5	0.1	5	1,00
French	2	0.0	2	1,00
Croatian	1	0.0	0	0,00
Japanese	1	0.0	0	0,00
Turkish	1	0.0	0	0,00

TGCS total global citation score - total number of citation received

Citations/Article - TGCS/Number of articles

C. Authors

Of the 8399 authors, Li Jianqiu of Tsinghua University, People's Republic of China has directed or co-directed the largest number of articles on electric vehicles (35 articles), followed by Ouyang Minggao of Tsinghua University, People's Republic of China (34 articles). In addition, 5783 authors (68.9%) have published a single article, 1347 authors (16%) has published two articles, 557 authors (6.6%) have published three articles and 712 authors (8.5%) have published 4 or more articles.

D. Countries with the greatest research impact

The People's Republic of China was the country with the highest number of articles (28.1%) with an h-index of 47, followed by the United States (22.2%) with h-index of 67. This is because they are highly developed countries (Figure-4).

E. Journals

The 4105 articles were published in 595 journals. Table- shows the top 20 magazines with the largest number of articles in electric vehicles. Twelve of the twenty journals shown in Table-3 were ranked by scimago on the subject of "engineering" and nine of these were on "energy". The most prestigious independent magazine would be APPLIED ENERGY with 3,058 and 18 magazines had subject categories in quartile 1, three in quartile 2 and one in quartile 3. It is clear from this information that ENERGIES have published the largest number of articles (215 articles), followed by IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY (169 articles) and APPLIED ENERGY (168 articles). In addition to this, 3 journals contain a range of 100-160 articles, 76 journals contain one of 10-9 articles, 86 journals contain one of 9-4 articles, 53 contain three articles, 89 contain two articles and 285 contain only one article.

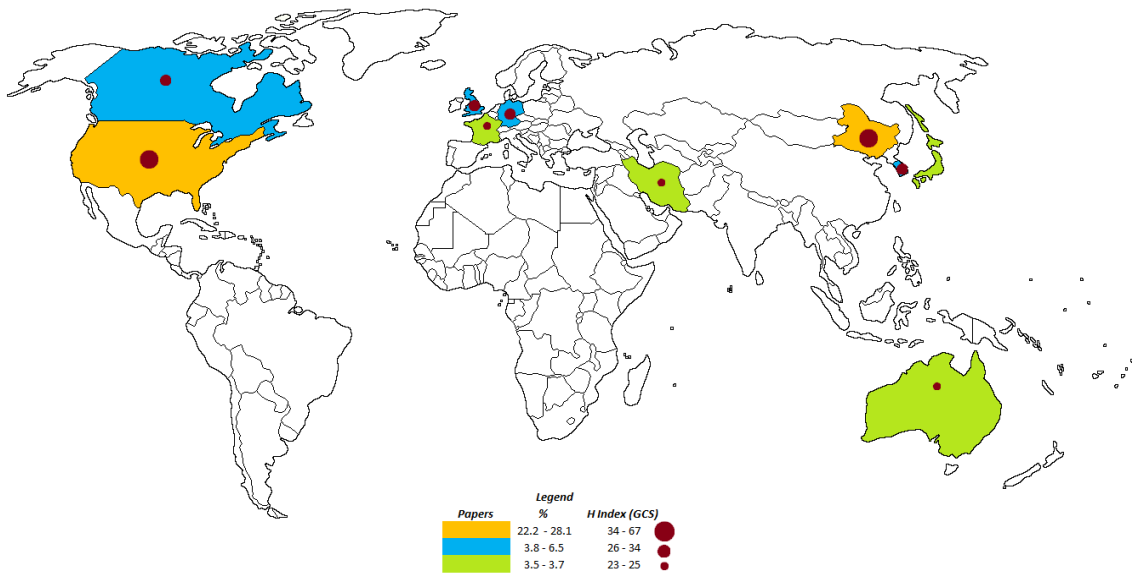


Figure-4. Country and h-index relationship.



Table-3. Top 20 journals with the highest number of original and review articles on electric vehicles published between 2007 and 2016 (N=4105).

Rank	Journal	scimago subject area*	quartile*	Recs	%Recs	TGCS	SJR*
1	ENERGIES	Computer Science	1	215	5.2	1099	0.691
2	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	Computer Science, Engineering and Mathematics	1, 1 and 1	169	4.1	4557	0.855
3	APPLIED ENERGY	Energy and Engineering	1 and 1	168	4.1	2973	3.058
4	JOURNAL OF POWER SOURCES	Chemistry, Energy and Engineering	1, 1 and 1	155	3.8	5413	1.945
5	IEEE TRANSACTIONS ON SMART GRID	Computer Science	1	119	2.9	3415	2.851
6	ENERGY	Energy and Environmental Science	1 and 1	113	2.8	1493	1.999
7	ENERGY POLICY	Energy and Environmental Science	1 and 1	91	2.2	2463	2.197
8	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	Computer Science and Engineering	1 and 1	91	2.2	4207	2.742
9	PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART D-JOURNAL OF AUTOMOBILE ENGINEERING	Engineering	1,5	91	2.2	502	0.626
10	IEEE TRANSACTIONS ON POWER ELECTRONICS	Engineering	1	83	2.0	2968	2.728
11	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	Environmental Science and Social Sciences	1 and 1	76	1.9	922	1.195
12	INTERNATIONAL JOURNAL OF AUTOMOTIVE TECHNOLOGY	Engineering	1	73	1.8	446	0.771
13	RENEWABLE & SUSTAINABLE ENERGY REVIEWS	Energy	1	73	1.8	1932	3.051
14	IEEE TRANSACTIONS ON POWER SYSTEMS	Energy and Engineering	1 and 1	58	1.4	2409	3.757
15	INTERNATIONAL JOURNAL OF HYDROGEN ENERGY	Energy and Physics and Astronomy	1 and 1	56	1.4	692	1.142
16	ENERGY CONVERSION AND MANAGEMENT	Energy	1	54	1.3	1153	2.287
17	ELECTRIC POWER SYSTEMS RESEARCH	Energy and Engineering	1 and 1	52	1.3	421	1.167
18	MATHEMATICAL PROBLEMS IN ENGINEERING	Engineering and Mathematics	2 and 3	52	1.3	69	0.277
19	IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS	Engineering	1	46	1.1	803	1.154
20	IEEE TRANSACTIONS ON MAGNETICS	Engineering and Materials Science	2 and 2	45	1.1	780	0.480

* Data extract from scimagojr website from the year 2016 [23]

Quartile shown is the average of the categories in a subject.

SJR - is a size-independent prestige indicator that ranks journals by their 'average prestige per article'.

Additionally, the top 100 magazines (16.8% of the 595 magazines) managed to publish 3161 or 77% of the articles referring to electric vehicles.

F. Article analysis

Table-4 shows the top 20 most cited articles in electric vehicles published between 2007 and 2016. The most cited article, with 809 citations was published in IEEE TRANSACTIONS ON POWER SYSTEMS in 2010, the second most cited article was a review published in JOURNAL OF POWER SOURCES in 2013 with 687 citations. Since an article is published in one year, the longer it has the opportunity to be cited, a citation percentage per year is then calculated to provide different points of comparison.

The data presented were taken from Histcite's graphmaker tool. The Figure-5 shows the analysis of 50 articles which have the highest number of global citations and their correlation with each other, larger circles indicate a greater number of citations and arrows indicate whether the article shown has quoted another article of the fifty compared, large numbers indicate the position they occupied in the same period of time. Table-4 It also shows the year in which they are published and on the left side of the year the number of articles published that year, no articles from the year 2016 are shown because none of these acquired the number of total global citations to enter the top 50.

4. CONCLUSIONS AND DISCUSSIONS

In this bibliometric study, the results of publications on electric vehicles published between 2007 and 2016 are presented. Analyses of increasing trends in the number of articles published per year, the language

used, and the countries they publish did not yield unexpected results. Although more than half of the 4105 articles came from authors in non-English-speaking countries, 99% of the articles were written in English. These results reflect not only that English is the language used for communication in scientific areas [24] but also a characteristic of scientific citations, which contain sparse citations to non-English-speaking journals.

Of the 8399 authors, the two most focused on the subject of electric vehicles, Li Jianqiu and Ouyang Minggao proved to be the most productive authors on the subject in addition to subjects related to the same area.

According to the data obtained, the articles have been distributed in different ways; it is so that less than a quarter of the articles have been published in the top 20 journals, however, there is a considerable difference in the number of articles published by the top four, called ENERGIES, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, APPLIED ENERGY and JOURNAL OF POWER SOURCES. These can then be considered as the most important journals for acquiring knowledge about electric vehicles.

The top 20 most cited articles on electric vehicles published between 2007 and 2016 were analyzed to provide information on the types of research on electric vehicles (Table-4). The top-ranked article was published in 2010 and reveals the influence on a residential electric grid by charging an electric vehicle in a residence as well as minimizing energy losses and maximizing the charging power of the grid [25]. The top-ranked player, published in 2013, gives a review of how lithium-ion batteries interact in an electric vehicle, which are the problems they have so that studies can be carried out to improve the battery system in the future [26]. Additionally, the few review



articles published in the top 20 are appreciated, however, it can be noted that when they are published they have a great impact on the environment [27]. Not surprisingly,

reviews and meta-analyses are the most sought-after file types [28].

Table-4. Top 20 most-cited articles on electric vehicles published between 2007 and 2016 (N=4105).

Rank	Title	Journal	Autors	Year	GCS	GCS/y
1	The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid.	IEEE TRANSACTIONS ON POWER SYSTEMS	Clement-Nyns K, Haesen E, Driesen J	2010	809	89.89
2	A review on the key issues for lithium-ion battery management in electric vehicles.	JOURNAL OF POWER SOURCES	Lu LG, Han XB, Li JQ, Hua JF, Ouyang MG	2013	687	114.50
3	The state of the art of electric, hybrid, and fuel cell vehicles.	PROCEEDINGS OF THE IEEE	Chan CC	2007	567	47.25
4	Overview of permanent-magnet brushless drives for electric and hybrid electric vehicles.	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	Chau KT, Chan CC, Liu C	2008	474	43.09
5	Electrical machines and drives for electric, hybrid, and fuel cell vehicles.	PROCEEDINGS OF THE IEEE	Zhu ZQ, Howe D	2008	445	37.08
6	Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles.	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	Emadi A, Lee YJ, Rajashekara K	2008	436	39.64
7	Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles.	IEEE TRANSACTIONS ON POWER ELECTRONICS	Yilmaz M, Krein PT	2013	433	72.17
8	Using fleets of electric-drive vehicles for grid support.	JOURNAL OF POWER SOURCES	Tomic J, Kempton W	2007	401	33.42
9	Battery, Ultracapacitor, Fuel Cell, and Hybrid Energy Storage Systems for Electric, Hybrid Electric, Fuel Cell, and Plug-In Hybrid Electric Vehicles: State of the Art.	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	Khaligh A, Li ZH	2010	388	43.11
10	Batteries and ultracapacitors for electric, hybrid, and fuel cell vehicles.	PROCEEDINGS OF THE IEEE	Burke AF	2007	318	26.50
11	Control of hybrid electric vehicles.	IEEE CONTROL SYSTEMS MAGAZINE	Sciarretta A, Guzzella L	2007	313	26.08
12	Control strategies for hybrid electric vehicles: Evolution, classification, comparison, and future trends.	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	Salmasi FR	2007	254	21.17
13	Optimal Design of ICPT Systems Applied to Electric Vehicle Battery Charge.	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	Sallan J, Villa JL, Llombart A, Sanz JF	2003	252	25.20
14	Ultracapacitor-based auxiliary energy system for an electric vehicle: Implementation and evaluation.	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	Ortuzar M, Moreno J, Dixon J	2007	232	19.33
15	Energy storage devices for future hybrid electric vehicles.	JOURNAL OF POWER SOURCES	Karden E, Ploumen S, Fricke B, Miller T, Snyder K	2007	220	18.33
16	Decentralized Charging Control of Large Populations of Plug-in Electric Vehicles.	IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY	Ma ZJ, Callaway DS, Hiskens IA	2013	215	35.83
17	Optimal Decentralized Protocol for Electric Vehicle Charging.	IEEE TRANSACTIONS ON POWER SYSTEMS	Gan LW, Topcu U, Low SH	2013	215	35.83
18	Electric, Hybrid, and Fuel-Cell Vehicles: Architectures and Modeling.	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	Chan CC, Bouscayrol A, Chen KY	2010	214	23.78
19	A review of energy sources and energy management system in electric vehicles.	RENEWABLE & SUSTAINABLE ENERGY REVIEWS	Tie SF, Tan CW	2013	214	35.67
20	Rapidly falling costs of battery packs for electric vehicles.	NATURE CLIMATE CHANGE	Nykvist B, Nilsson M	2015	214	53.50

GCS - Global citation score

GCS/y - Global citation score per year

In addition, this large number of citations may be due to the citation of older articles of electric vehicles, it is observed that the most cited globally are relatively recent, by Figure-5 we see that the article reviews many older articles, in addition, the article of the first place of the top serves as a basis for many other more resentful articles less referenced [29], hence it comes that this does not have references but if it is the most referenced. Referring to Figure-5, we observe a visual analysis of the correlation of the 50 most cited articles and how the 10 of Table-4

influence them, this map made in the Histcite graphmaker complement. We observed how most of the articles that laid the foundation for the study of electric vehicles were published in 2007, yet more resilient articles that set a new course for research and make more impact for the new journals. This is reflected in how Table-4 rankings 1 and 2 have no citations referring to the articles most cited in much later years than they do but they are cited very frequently after publication (89,8 and 144,5 respectively)[30]. Many limitations of this bibliometric



analysis must be taken into account. First, it is possible that some articles may be losing the use of a citation in the database. Second, the citation of scientific articles in the database is made for English-speaking journals and therefore, the results must be interpreted from them. Additionally, non-English-speaking journals included in the database were found to have almost no impact compared to English-speaking journals [31], result that is closed to the obtained in [32]. Comparison of publications in each country could, therefore be affected. Finally, this study was the first bibliometric analysis carried out in the investigation of electric vehicles. Major journals, research authors and other factors in nearly a decade were identified. This study provides a systematic study of the productivity and feasibility of research work on electric vehicles and its results can be used to prioritize and organize future research in electric vehicle research.

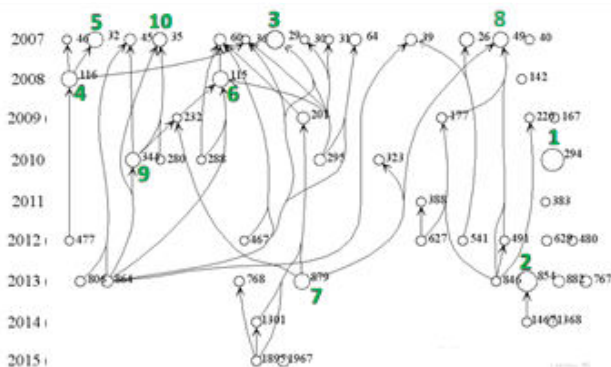


Figure-5. Co-citation network of the top 50 articles on electric vehicles published between 2007 and 2016.

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