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TREND ANALYSIS OS ELECTRIC VEHICLES THROUGH WEB OF SCIENCE: A BIBLIOMETRIC ANALYSIS

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Abstract: ***The automotive industry has stepped into a new era of a "pollution free and environmental friendly" world with electric vehicles. Increased awareness about environment and sustainable development has caused the leading vehicle manufacturers to produce electric and hybrid vehicles to replace the internal combustion engines. So it is very crucial for all vehicle manufacturers to be up to date with the current trends and on-going research in the field of electric vehicles.***

In this paper, a trend analysis will be done using bibliometric analysis, wherein data will be collected from Web of Science database from the period 1980-2020 using keywords like "Electric vehicles" and "Energy fuels" in order to identify contributions relevant in the field of electric vehicles. The data will be used to find out the on-going trends in electric vehicles research including major contributing countries, number of citations, year wise publications etc. This analysis will help researchers and academicians to understand the developments in the field of electric vehicles and organize future research in electric vehicle research.

Keywords: Electric vehicle, Bibliometric analysis, Web of Science

Introduction:

Hydrogen and fuel cells have had a positive effect on consumers and manufacturers of automobile industry for the past three decades. The main objective of automobile manufacturers were to reduce the exhaust emissions and fuel consumptions while increasing the energy efficiency and adopting the latest technologies. This led to the rise of Fuel Cell Electric Vehicles (FCEVs) and Battery Electric vehicles (BEVs). FCEVs are much more efficient than the conventional Internal Combustion Engines (ICE) vehicles because of emission of water vapor and warm air. By 2050, the demand for hydrogen FCEVs will be at its peak under the circumstances of decrease in expensive technology, enhanced optimization of energy, and increase in hydrogen refueling stations. (Arat et al., 2019).

The adoption of Electric Vehicles (EVs) will mitigate problems such as environmental pollution, global warming and oil dependency. In spite of strong promotion policies implemented by government, the market penetration of electric vehicles is very low. This paper focuses on the consumer preferences for electric vehicles in order to help policy makers to make better informed decisions and further improve research in the field of electric vehicles. A review of consumer preferences on financial, technological

and policy attributes was made and the influential factors were categorized into psychological, social and socio-economic variables. This research was used to improve the preference studies for electric vehicle consumers. (Liao et al., 2017).

There are various types of energy sources that have been used in electric vehicles and hybrid electric vehicles. Among these are lithium-ion battery and proton exchange membrane (PEM) fuel cells, which proves to be the favorable ones because of their high energy and power density. While designing of the energy management strategies for battery electric vehicles, the degradation issues of these sources of energy are neglected. The paper reviews the degradation modelling methods and energy management strategies for these energy sources and integrating them into a health conscious energy management. (Yue et al., 2019)

A bibliometric analysis was conducted on business models for electric vehicles by analysis of 104 articles, related publications using various parameters such as most ranked authors, geographic locations, number of citations and so on (Leena and Gochhait, 2020). The analysis focused on innovative technologies, optimization of resources, electricity management systems and product life cycle. The purpose of this paper is to help the formulation of environmentally sustainable policies for government and electric car manufacturers to restructure their business models. (Sylvana et al., 2019)

Objective:

Electric Vehicles has been a huge topic since the past three decades. It can help address the sustainability and environmental challenges in the transportation industry. Hence it is important to understand how the trend is going in Electric and Hybrid vehicle industries. This paper focuses on analyzing the growth of Electric vehicles and explores its various trends adopted globally. 9655 records were collected from the Web of Science Core Collection database within the period 1980 – 2020. The major keyword used for this study was ‘Electric Vehicles’. The records were analyzed to make a qualitative as well as quantitative assessment on research output such as main research areas, growth of publications, geographical locations, the languages used and highly cited publications.

Analysis and Result:

Core research areas:

For this study, the main keyword used was ‘Electric Vehicles’. All the records that have the keyword ‘Electric Vehicles’ in the title within the years 1980 - 2020, have been considered for the trend analysis and a total of 9655 records were obtained. The key research areas for this study have been shown in the table below:

Research Area	**Percentage (%)**
Engineering	53.62
Energy Fuels	25.23
Transportation	21.51

Environmental Science Ecology	9.71
Science Technology other topics	7.83
Telecommunications	6.71
Computer Science	6.66
Chemistry	6.27

Table 1: Key research area for the analysis

Other areas included are Material Science, Business Economy, Automation Control Systems and Physics.

Journals used:

The main journals used for this study along with their record count are shown below.

Journals	**Record Count**
Energies	525
IEEE Transactions on Vehicular Technology	342
Journal of Power Sources	329
Applied Energy	321
Energy	274

Table 2: Journals with the record count

Annual Publication Growth Output:

Table 3 shows the table between the block years and the total number of papers published during those years. There is a positive growth in the number of papers published. Out of the 9655 records, it was found that 8699 were articles. Other document types include proceedings paper, reviews, editorial materials and book chapters.

Block Years	**Total Papers**
1980-1985	127
1986-1990	32
1991-1995	160
1996-2000	211
2001-2005	228

2006-2010	547
2011-2015	2677
2016-2020	5673

Table 3: Year-Wise Output

The graph below shows the number of papers published from the year 1996-2020. During the years 2016-2020, there were 5673 papers published which accounted for 58.75 % of 9655 records. This shows that in the last few years, research on electric vehicles has been greatly increased. The research on electric vehicles started in 1980 and year by year the trend grew positively due to the advent of information and communication technology.

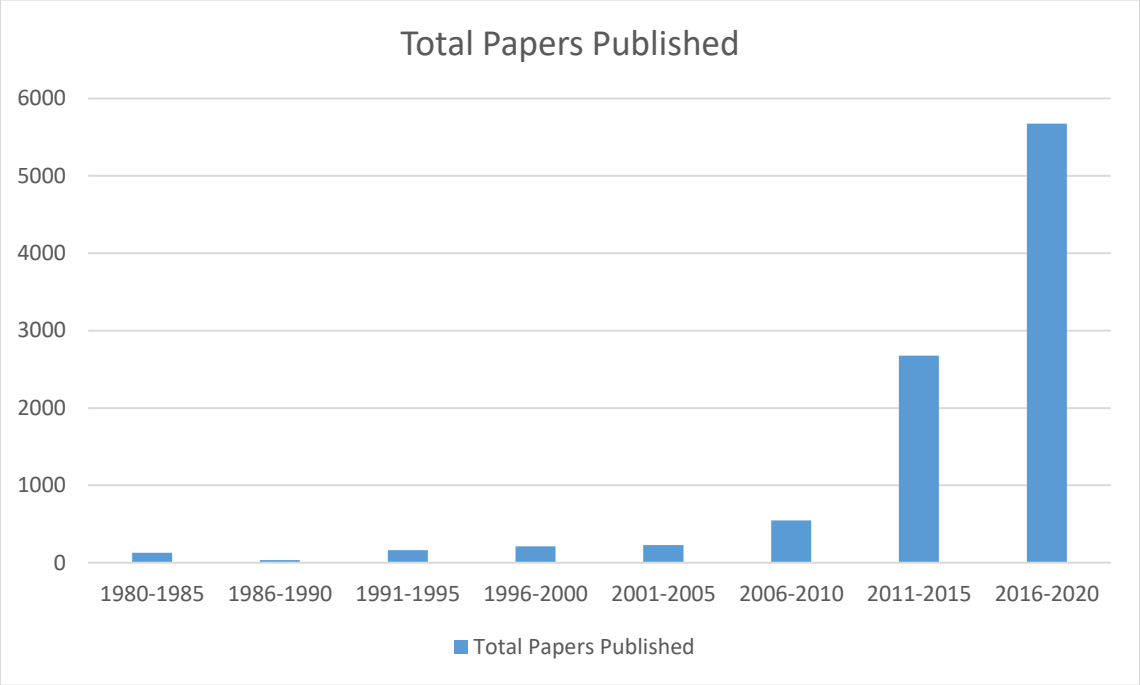

Figure 1: Number of records published during 1980-2020 on Electric Vehicles

Country-wise analysis of Publications:

A total of 9655 records were published by more than 20 countries. China stands in the 1st position according to the analysis with 2908 records. It accounts for 30.12% of the total number of records published. China is followed by USA with 2017 records (20.87%) and England with 566 publications (5.85%).

H-index: An index of h means that there are h papers that have each been cited at least h times for a time period of 1980-2020. This is a metric required to evaluate the author's output, quality and performance. In terms of h-index, USA occupies the top position with an index of 124.

The below table shows the top 10 countries with the highest number of publications. It includes the statistical and trend analysis of the citations of records country wise with the following details: Percentage of the total, h-index, sum of times cited and total number of citing articles.Self-citation refers to the external citations. There are few other countries whose publications have not been mentioned in the table since their contributions are less than 1.5 % of the total publications.

Country	No. of Publications	Percentage (%)	H Index	Sum of times Cited	Sum of times Cited (Without Self citations)	Total no. of citing articles	Total no. of citing articles (Without Self citations)
China	2908	30.12	91	47,043	38,895	26,124	23,937
USA	2017	20.87	124	67,000	61,302	35,963	34,605
England	566	5.85	58	12,817	12,144	9,964	9,672
South Korea	536	5.54	51	10,408	9,980	8,522	8,300
Germany	518	5.36	53	11,640	10,932	8,928	8,665
Canada	498	5.15	60	12,973	12,412	10,053	9,795
Japan	358	3.70	43	6,802	6,565	5,469	5,357
Italy	336	3.47	44	6,773	6,567	5,919	5,786
Australia	329	3.40	48	7,797	7,465	6,121	5,954
France	319	3.30	42	6,650	6,459	5,818	5,703

Table 4: Top 10 countries with the highest publications and citation details

Language wise Analysis:

9490 records were published in English, which accounted for about 98.23% of the total publications. The other languages in which the records were published are shown in the below graph.

Languages	RecordCount	Percentage
English	9490	98.23
German	38	0.39
Spanish	24	0.24
Korean	21	0.21
Polish	18	0.18
Japanese	17	0.17
Italian	15	0.15
Russian	9	0.09
Portuguese	8	0.08
Turkish	7	0.07

Table 5: Top 10 Languages with the highest publications

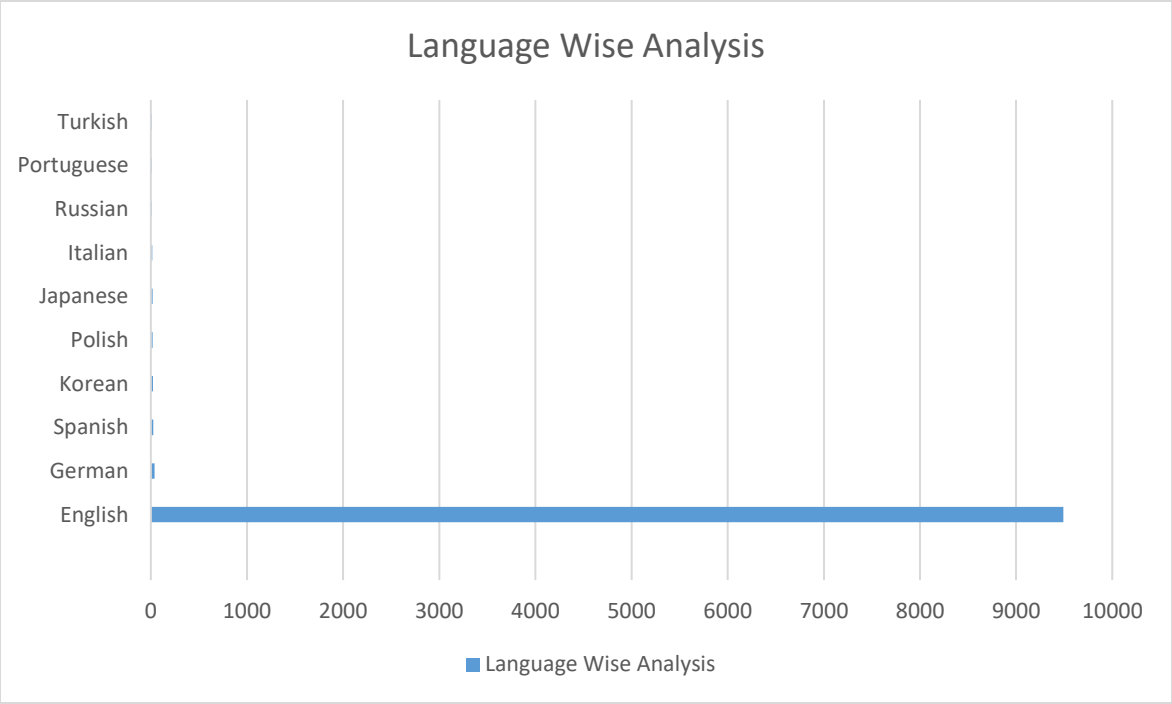

Figure 2: Number of records published during 1980-2020 language wise.

Most Cited Records:

- After the analysis of 9655 records, the sum of citations of all records under analysis is **201,941.**
- The total number of citations without self-citations (external citations in the paper) is **142,474.**
- The H-index of all 9655 collected record is **168.**
- The average citation per article is **20.9**. This value is given by the total number of times cited divided by the total number of records collected.
- The total number of citing articles that have cited any of the records under the analysis is **74,723**.

The table below shows the top 10 cited records published within the 9655 records collected. It also includes other information like the authors of the publications, the year they were published in and the country as well.

Article	**Author**	**Country**	**Year**	**Citations**
A review on the key issues for lithium-ion battery management in electric vehicles	Lu, Languang; Han, Xuebing; Li, Jianqiu	China	2013	1699
The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid	Clement-Nyns, Kristien; Haesen, Edwin; Driesen, Johan	Belgium	2010	1330

Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles	Yilmaz, Murat; Krein, Philip T.	USA, Turkey	2013	1004
The state of the art of electric, hybrid, and fuel cell vehicles	Chan, C. C.	China	2007	855
Design considerations for a contactless electric vehicle battery charger	Wang, CS; Stielau, OH; Covic, GA	New Zealand	2005	828
Rapidly falling costs of battery packs for electric vehicles	Nykvist, Bjorn; Nilsson, Mans	Sweden	2015	719
Overview of permanent-magnet brushless drives for electric and hybrid electric vehicles	Chau, K. T.; Chan, C. C.; Liu, Chunhua	China	2008	688
Electrical machines and drives for electric, hybrid, and fuel cell vehicles	Zhu, Z. Q.; Howe, David	England	2007	650
Integration of Electric Vehicles in the Electric Power System	Pecas Lopes, Joao A.; Soares, Filipe Joel; Rocha Almeida, Pedro M.	Portugal	2011	644
Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles	Emadi, Ali; Lee, Young Joo; Rajashekara, Kaushik	USA	2008	637

Table 6: Top 10 highly cited publications with details on author, country and year

Author:

The author with highest number of publications have been tabulated and shown below. Li Ying, Xiong R and Zhang Y C. have the highest number of record publications with 52 counts each.

Author	Record Count
Li Ying	52
Xiong R	52
Zhang Y	52
Ouyang MG	49
Zhang L	49
Chen H	46
He Hw	46
Chau Kt	45
Zhang H	45
Zhang Q	43

Table 7: Authors and record count

Author Keywords:

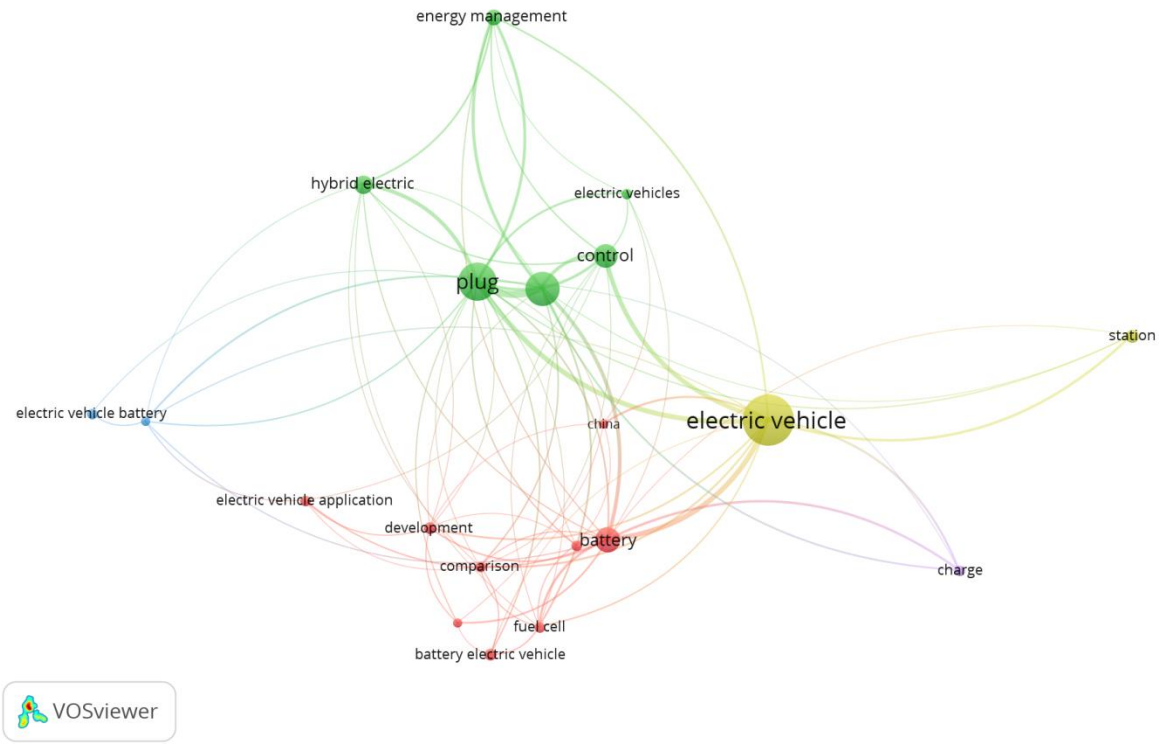

Figure 3: The co-occurrence of authors' keywords.

Network visualization map of author keywords occurrences (i.e., keywords listed by the author). Keywords with minimum occurrences of 25 times were shown in the map. Keywords with the same color were commonly listed together. So, for example, energy management, plug, electric vehicles and hybrid vehicles have similar colour suggestive that these keywords have close relation and usually co-occur together (Singh and Gochhait , 2020).

Conclusion:

This paper has analyzed the progress and various trends of Electric vehicles from 1980 to 2020. According to the analysis, most of the records collected were from the Engineering Sector which accounted for 53.62 %. Since 2016, there has been a large trend in publishing of papers in electric vehicles field. Around 5673 papers have been published within the years 2016-2020.This shows that the concept of electric vehicles has become more popular during these years and will grow in the future. Several records that were analysed were the study of different energy management models, development of new sustaining batteries and applications of electric vehicles, while others describe the environmental benefits of using electric vehicles equipped with other latest technologies.

A country wise analysis was also done which showed that China had the highest number of records published with a high-count of 2908 publications with USA being the second with 2017 publications. A

lot of research and amount is spent from these countries in developing new innovative and energy efficient technologies in the field of electric vehicles. The records analysed for this paper were published in more than 15 languages. English was the most used language (9490 records), and it was followed by German (38 records) and Spanish (24 records). The most cited paper was 'A review on the key issues for lithium-ion battery management in electric vehicles' which had a citation count of 1700 and was published in China in 2013.

In order to facilitate the implementation of electric vehicles, it is crucial to focus on the sustainable business models for the following parameters in electric cars: Electricity management, charging technologies, location and services. Creating a common framework within different organisations can show positive results for environment, automobile manufacturers and customers as well. Further analysis in this field could also identify why research was conducted extensively by just few countries and how business model related to electric cars affects highly populated countries. With advancement in technology, new sustainable energy management models can be developed for electric vehicles which reduces the cost and the negative impact towards environment and improve the energy efficiency.

References:

1. Arat, B.T., Turan, H.,and Ertugrul,B.(2019), Overview of the next quarter century vision of hydrogen fuel cell electric vehicles. International Journal of Hydrogen Energy, Volume 44, Issue 20, Pages 10120-10128.https://doi.org/10.1016/j.ijhydene.2018.10.112
2. Molin,E.,and Bert, W.V. (2017), Consumer preferences for electric vehicles: a literature review, 252-275. https://doi.org/10.1080/01441647.2016.1230794
3. Leena, H., and Gochhait,S. (2020). A Bibliometric Analysis of Telemedicine: Remote Healthcare Delivery over the Years, International Journal of Psychosocial Rehabilitation , ISSN: 1475-7192., Vol: 24, Issue 2.
4. Yue , M., Samir Jemei, S.,Gouriveau, R., and Zerhouni, N. (2019). Review on health-conscious energy management strategies for fuel cell hybrid electric vehicles: Degradation models and strategies. International Journal of Hydrogen Energy 44(13).
5. Secinaro, S., Brescia, V., Calandra, D., and Biancone, P. (2019). Employing bibliometric analysis to identify suitable business models for electric cars. Journal of Cleaner Production, Volume 264. https://doi.org/10.1016/j.jclepro.2020.121503.
6. Singh, T., and Gochhait,S. (2020). Electronic Voting Research Papers in Web of Science: A Bibliometric Analysis, International Journal of Psychosocial Rehabilitation, ISSN: 1475-7192., Vol: 24, Issue 2.
7. Athanasopoulou,A., Reuver,M,D, Nikou, and S., Bouwman,H. (2019). What technology enabled services impact business models in the automotive industry? An exploratory study Futures, 109, pp. 73-83.
8. Kley,F., Lerch, and C., Dallinger,D. (2011). New business models for electric cars-A holistic approach Energy Pol., 39 (6), pp. 3392-3403.
9. Nieuwenhuis,P. (2018), Alternative business models and entrepreneurship: the case of electric vehicles, Int. J. Enterpren. Innovat., 19 (1), pp. 33-45.
10. Robinson,J., Brase,G., Griswold,W., Jackson,C., and Erickson,L. (2014). Business models for solar powered charging stations to develop infrastructure for electric vehicles Sustainability, 6 (10), pp. 7358-7387.