World Electric Vehicle Journal

MDPI

Systematic Review

Managing Transitions to Autonomous and Electric Vehicles: Scientometric and Bibliometric Review

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Abstract: This paper presents a scientometric and bibliometric literature review of the research on transitions to autonomous and electric vehicles. We discuss the main characteristics, evolution, and various transitional issues, identifying potential trends for future research. The Scopus and WoS search for relevant research articles generated a corpus of 4693 articles, which we analyzed using VOSviewer visualization software. This result shows that the transition research is interdisciplinary, with 54 scientific areas identified. Analysis requires an understanding of the broader aspects of the automotive industry, trends related to sustainability, environment protection, road safety, public policies, market factors and other business, and legal and management issues. This study highlights the need for more research to address the challenges of this global transition in the automotive industry. Topics for future research are constant improvements in AI algorithms used in AVs, innovations in green energy sources, and storage solutions for EVs. This is leading to new innovative business models and platforms. Further to that, the conclusion is that the impact of the transition to a shared economy, the emergency of mobility as a service, and public acceptance of the technology have to be comprehensively considered. The vehicle of the future is seen as a smart electric car, running on green energy, and utilizing various levels of automation up to full autonomy.

Keywords: transition; electric; autonomous; vehicle; scientometric; bibliometric; review

Citation: Todorovic, M.; Aldakkhelallah, A.; Simic, M. Managing Transitions to Autonomous and Electric Vehicles: Scientometric and Bibliometric Review. *World Electr. Veh. J.* **2023**, *14*, 314. https://doi.org/10.3390/wevj14110314

Academic Editor: Joeri Van Mierlo

Received: 4 September 2023
Revised: 16 October 2023
Accepted: 11 November 2023
Published: 20 November 2023

1. Introduction

This literature review presents research related to the transition to autonomous vehicles (AVs) and electric vehicles (EVs), particularly on the work published in the last six years, from 2016 to 2022. Concurrent transitions in the automotive sector to AVs and EVs have already been critically reviewed by many readers and subject matter experts. The most cited works are included in the synopsis.

Our intention was to select the most influential works which can guide further research. We analyze the publication statistics of the most cited and influential works on the topic of technology transitions. Autonomous and electric vehicles have already become common on our roads. However, there are still issues that need to be solved to make the full transition to new technologies. In the following decades, there will be a coexistence of previous and new technologies: cars with and without human drivers, ICE vehicles, hybrids, and EVs. We are moving to Connected, Autonomous, Shared, and Electric (CASE) mobility.

Self-driving cars, also known as autonomous, driverless, or mobile robots, have integrated vehicle automation. AVs can sense their surroundings and move safely with little or no human intervention. Self-driving cars use various sensors, including infrared cameras, radar, lidar, sonar, GPS, odometry, and inertial measurement units to observe their surroundings. Control systems interpret sensory information to identify appropriate navigation paths and detect obstacles and road signs. Artificial intelligence (AI) algorithms perform real-time data processing for motion control. Motion is generated using ICEs, electric motors (EMs), or both in hybrid vehicles.

A wide range of hybrid vehicles combine various energy sources [1]. Referring to EVs only, with AC or DC electrical engines, we have the following classification:

- Battery Electric Vehicles (BEVs);
- Hybrid Electric Vehicles (HEVs);
- Plug-in Hybrid Electric Vehicles (PHEVs);
- Fuel Cell Vehicles, or Fuel Cell Electric Vehicles (FCVs or FCEVs).

TESLA EVs are BEVs using just battery systems, DC to AC inverters, and AC engines. Nikola Tesla's AC induction motor, patented 127 years ago, in 1896 [2] is more powerful and more efficient than any modern ICE. HEVs are using electric motors (EMs) and ICEs for the drive train. ICEs generate electricity to charge batteries and power EMs. Drive trains can also be powered by ICEs supported by EMs. A PHEV is a HEV with an onboard battery charger. FCVs or FCEVs are BEVs with fuel cells used to produce electricity from hydrogen. There is also research on solar-powered vehicles [3,4].

Compared to internal combustion engines (ICE), an EM does not cause environmental pollution [5], but they are more expensive to buy. In America and the EU, from 2020, the total cost of possession of the latest EVs is less than that of ICE vehicles thanks to the decrease in fueling and maintenance costs [6]. Charging stations for EVs may be set up in each home and public spaces. Worldwide, 6.6 million plug-in electric-powered motors were bought in 2021, surpassing the 2020 sales income and reaching a marketplace percentage of 9% of the worldwide new automobile marketplace [7]. BEV-powered cars represented 71% of the total plug-in automobile income in 2021, while plug-in hybrid EVs (PHEVs) brought the remaining 29% [8]. From December 2021, sixteen million plug-in electric vehicles (PEVs) have been on the roads worldwide. Many countries give incentives for PEVs, tax credits, subsidies, and different non-economic supports.

Several taxonomies were proposed to cover a wide range of technical discussions related to EVs and AVs. One such suggestion is to classify vehicles based on the following categories: green powertrain, automated navigation, route planning, environment awareness, and autopilot. In the 2020s, it became clear that these technologies were much more complex than initially thought. Following that, in 2021, the Society of Automotive Engineering (SAE) internationally defined the six levels of automation [9]. Level 0 refers to no automation. Level 1 utilizes applications where the driver has his or her feet off (like when using adaptive cruise control, or having line-keeping assistance). Level 2 is partial automation where the car navigates, keeps line, accelerates, and brakes. Level 3 is conditional automation when the vehicle has full control and is driving at some segments of a path under certain operating conditions. At level 4, the driver is just present and can take control if needed. At level 5, the vehicle is an autonomous robot and all humans are just passengers.

A possible technological obstacle to automated cars' widespread deployment is that AI still does not function reliably in chaotic, inner-city environments. Vehicles' computer control and communication could potentially be compromised. Their sensing and navigation systems are susceptible to weather or deliberate interference, including jamming and spoofing. AV and pedestrian interaction must always be safe [10]. Behavior models of pedestrians, cyclists, and animals are programmed into AI driving algorithms. Safety performance evaluations are conducted for various road scenarios [11].

Autonomous taxis used in the cities are changing the behaviors of the experienced users [12]. Automating trucks and driving in a group (platooning) brings fuel savings, fewer traffic collisions, and the possibility of vehicle-to-vehicle charging. Autonomous vans are being developed for use by online grocers. The goods distribution on the macro (urban distribution) and micro level (last mile delivery) could be made more efficient with the use of AVs. In all scenarios, customer expectations and satisfaction are key factors [12].

Surveys were conducted where consumers expressed their interest in purchasing AVs. Safety, comfort, cybersecurity, privacy, as well as the cost of the new technology are the main issues. AV technology acceptance was investigated in our longitudinal surveys with participants from KSA and Australia. It appears that the public, i.e., ordinary customers, needs to be better informed about the transition.

Given the complexity of the transition to autonomous and electric vehicles and the growing demand for a new concept that emphasizes sustainability, this paper aims to address the need for electric vehicles in determining new transportation paradigms and beyond. We have conducted a literature bibliometric analysis of the impact of self-driving cars on various social issues. Therefore, this paper engaged science mapping to elicit essential bibliometrics details of the most cited articles by addressing the following questions:

- What is the pattern of publications, and areas covered, in the most cited publications on the transition to the new AV/EV technology?
- What is the pattern of citation of the most cited papers?
- What is the pattern of collaboration and contribution of the most cited educational research publications?
- What are the most recurrently used keywords and terms, among the most cited publications?
- What are the challenges in transitioning to autonomous and electric vehicles?

It is possible to determine that there is a greater interest in topics relating to autonomous and electric vehicles by looking at the number of articles published, particularly during the transition process that has already started. In addition, the number of publications can also attest to the rise in academic interest in studying related subjects.

This paper presents the current knowledge and the stage of electric and autonomous vehicle deployment. The organization of this study is as follows. First, after providing an overview of autonomous and electric vehicles, we present the study design and describe the data collection and analysis methods. Second, the findings are discussed, which includes descriptive evidence about the research sample and detailed findings on bibliographic links. Third, the results are linked and compared with the broader field of the research. The final section concludes by proposing methods for future research highlighting important implications.

2. Materials and Methods

Elsevier's Scopus database was chosen as the primary source to search for publications on the topic of research as it covers a broad range of material. Scopus covers about 70% more sources than WoS [13]. Databases are in continuous development and that may change. The literature review was conducted in 2022. It is descriptive and uses a quantitative approach to identify potential trends for future research. With numerous research papers published in various journals, it is difficult to identify the most influential publications in the field. However, the advanced quantitative literature mapping and clustering techniques make it possible to visualize and structure complex research literature. Furthermore, through bibliographic analysis, scholars can identify and classify research hotspots and examine the latest developments in a particular field.

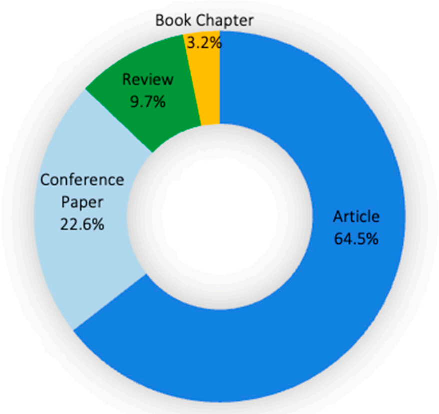
Visualized representations of econometric bibliographic maps and clustering methods that provide an overview of various aspects of transition have just begun to be used in this research area. Therefore, the current study aims to assess the number of scholarly publications relevant to the transition in general and perform scientometric and literature analyses to characterize the most cited studies in the field.

Scientometric techniques are methods related to the visualization or mapping of knowledge domains. Quantitative and quantitative techniques apply literature metrics to the published literature, to map the structure. Numerous themes were developed based on extensive scientific datasets, through network modeling and visualization. Scientometrics research aims to analyze the intellectual landscape of the field of knowledge and identify the questions researchers have sought to answer and the methods they have developed to achieve their research goals.

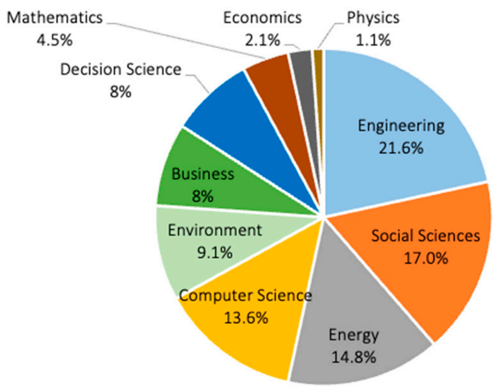
Bibliometric analysis must be systematic and stem from primary studies. It must be conducted through a transparent and reproducible methodology. In this sense, the results of the bibliometric analysis are helpful for the following reasons:

1. Bringing clarity and focus to the research problem;
2. Measuring and understanding the study field;
3. Providing a solid view of the field's historical evolution;
4. Improving the research methodology;
5. Broadening the knowledge base;
6. Presenting thematic and technological analysis;
7. Contextualizing the findings;
8. Providing evidence and a basis for future research.

The first step in our investigation was to determine the scope of analysis and article selection by identifying the relevant literature. The intention was to select literature that contains research on transitioning from traditional vehicles with ICEs to electric and autonomous vehicles. The primary focus was on the transition process, and the secondary one on autonomous and electric vehicles. We have initially used three databases: Scopus, WoS, and PubMed. The literature selection process was based on the guidelines defined in *'The PRISMA 2020 statement: an updated guideline for reporting systematic'* reviews [14]. Figure 1 presents the Scopus generated breakdown of papers, researching the transition to the autonomous and electric vehicle, by the type of the publications and by the research area. Figure 1a) shows that the most valuable and quality publications considered in this study, are peer reviewed journal articles, with 64.5% following by peer reviewed conference publications with 22.6%, making 87.1%. Figure 1b) is even more interesting. We can see multidisciplinary character of those two transitions in automotive sector. First, we should have all technology problems solved. This is expressed through number of publications in engineering, computer science (AI, motion control, engine control, and many other), physics and mathematics. In total 40.8% of all publications are covering this key aspect of new technology. Another extremely important aspect is care for the environment and the use of green energy for the future transport. Here we have publications in environmental and energy domains, in total of 23.9%. Finally, any new technology should have public, i.e., customer acceptance, or social side, as well as business decisions and economics of the change. Those sectors make 35.3% of total publications. In summary, we could say that Figure 1b) gives as big picture about relationships and involvement of each discipline in the multidisciplinary efforts to introduce new technologies.



(**a**)



(**b**)

Figure 1. Analysis of the papers by the type and the research area. (**a**) Documents by the type of publication show that the most of the publications are journal articles covering 64.5% of all; (**b**) Documents by subject area show that engineering publications are dominant covering 21.6% of all publications.

In identifying potential candidates, we have searched terms in titles, abstracts and author keywords, and keywords defined by publishers who use them for their categorization. The articles were searched on the Scopus and WoS databases using the Boolean operators "OR" and "AND". That has ensured that we have all potential candidates that fully or partially meet our search criteria.

Keywords used to search databases were "transition", "electric vehicle", and "autonomous vehicle". For example, a preliminary search of the WoS database identified 561 articles ("electric vehicle" AND "autonomous vehicle"), 2615 articles ("transition" AND "electric vehicle"), and 480 articles ("transition" AND "autonomous vehicle"). A similar search in Scopus gave 3180 articles for (("electric vehicle" OR "electric car") AND transition), 601 articles for ("autonomous vehicle" AND transition), and 912 articles for (("electric vehicle" OR "electric car") AND "autonomous vehicle").

In the screening phase, we narrowed our initial results to those that meet the criterion of considering only the literature that mentions all four keywords from our search—transition AND autonomous AND electric AND vehicle. Examination of the WoS database using all keywords returned 114 articles. A similar search of all keywords in Scopus gave 191 articles, while PubMed gave 10 articles. This bibliographic summary includes only scholarly peer-reviewed articles and reviews, excluding books and book chapters.

We see that the best and most complete results were obtained by searching Scopus. This approach gives us results that mostly satisfy our search criteria. These are all candidates who are eligible to be included in our study. After filtering, the total number of articles included in the studies was 191. It means that Scopus returned 68% more results in our search than WoS.

Considering that the primary focus of this review was on the transition process, which includes both autonomous vehicles and electric vehicles, we narrowed our search to ensure getting results where these keywords appeared together in pairs. Using exact keywords ("autonomous vehicle" AND "electric vehicle" AND transition), our search returned 32 focused results. The expanded list of 191 articles and the focused list of articles show that the best and most complete data were obtained from Scopus. Bibliometric analysis was performed on both researched segments, broadened (191 articles) and narrower, more focused (32 articles). Contributions of the 10 most cited and the 10 most relevant articles from a more focused result list of 32 articles are presented in more detail in this review.

The synonyms for autonomous vehicles were also used in the search. Because of the multiple definitions historically used in this field, the papers were selected using various synonyms for autonomous vehicles in the title, abstract, or keyword fields. These terms slightly increased the number of results obtained. More precisely, the resulting number in WoS was 115, i.e., it increased by only 1. It means that when the concept of transitioning to autonomous and electric vehicles began to be researched in the literature, the terminology had already been standardized. So, researchers who investigate the recent period (for example, the last five years) need only to use the term autonomous vehicles without other synonyms.

The following descriptive analysis of the work was performed next: number of published articles per search term; annual number of papers; most published authors; most public sources; and countries analyzed.

In the next stage, an in-depth analysis of 191 (or 32) articles was performed based on the literature search conducted using the VOSviewer bibliometric visualization software for the dual-map overlay; analysis of the main Scopus categories in which the articles were published; and analysis of the most relevant keywords and terms. VOSviewer software (version 1.6.18) has been developed by Nees Jan van Eck and Ludo Waltman at Leiden University's Centre for Science and Technology Studies (CWTS), Leiden, The Netherlands. Its online version was sourced from https://www.vosviewer.com/ (accessed on 12 October 2023).

The parameters of the bibliographic literature review were institutional productivity, author productivity, corresponding author analysis, top citation analysis, and co-citation analysis. Productivity analysis of institutions was performed by analyzing the absolute number of papers produced by an institution during the observation period.

The parameters considered, when analyzing authors' contributions were the total number of papers produced, the country of origin of the authors, the articles, the partial articles associated with one author's contribution, and the published series.

Interpretation and discussion of results was the final step. Articles were analyzed based on citation counts and on the most relevant ranking. We have selected the essential tasks and analyzed their purpose, types, and methods to evaluate their contributions. Co-citation analysis refers to the analysis of cross-citations between authors. A bibliometric visualization software, VOSviewer, using the outputs from Scopus, assisted in the interpretation and discussion of results. This software divided the authors into clusters and connected them by lines. The thickness of the line indicates the number of citations, and the size of the circle indicates the author's importance and influence. The interpretation and discussion of the results were conducted to identify the main research trends and gaps. Results are displayed graphically and tabularly.

3. Results

This section provides a comprehensive description of the obtained results, their interpretation, as well as the conclusions that can be drawn. Regarding general survey data, we found that the papers researching the simultaneous transition to autonomous and electric vehicles (focused group) started to be published in 2017, but only in the last three years, their numbers increased from 3 (2019, 2020) to 8 (2021) and 6 (2022). In the broadened group this increase was from 10 (2017) to 21 (2019), 24 (2020), 40 (2021), and 30 (November 2022).

3.1. Analysis of Publications

This review analyzes some of the leading publications which have the highest number of citations. The work of Sovacool, B.K. and Axsen, J. "Functional, symbolic and societal frames for automobility: Implications for sustainability transitions", [15] has been cited 54 times, making it the most cited paper of the transition to autonomous and electric vehicle research. Authors have developed a conceptual framework that explores driving through categorizing frames. They illustrate this framework with eight frames and discuss transportation innovations considering that approach.

The second most cited work is by Wu, J. et al., "Analysis of consumer attitudes towards autonomous, connected, and electric vehicles: A survey in China", [16] with a total of 37 citations. The authors aim to understand consumer attitudes toward autonomous, connected, and electric vehicles, using data collected through a survey in China. They found the potential for environmentally friendly transport, increased accessibility of travel for non-drivers, and reduced driving fatigue as the most attractive aspects. At the same time, the biggest concern is related to vehicle safety, legal liability, and charging issues.

The third most cited publication is Müller, J.M. et al., "Comparing technology acceptance for autonomous vehicles, battery electric vehicles, and car sharing—A study across Europe, China, and North America", with 30 citations [17]. In this paper, the authors surveyed more than 1000 participants to establish their acceptance of autonomous/electric technology and car sharing and the significance of these findings to industry, society, and policymakers.

Finally, the work by Weiss, J. et al., "The electrification accelerator: Understanding the implications of autonomous vehicles for electric utilities", has 25 citations. The authors analyze how the development of shared autonomous electric vehicles may make electrified transportation more likely and how these trends may affect utilities. They suggest what could be done to prepare for the transition [18].

In addition to this citation analysis, Table 1 presents the most relevant works according to the Scopus database. The top ten articles included in the analysis were selected, and each work's contribution was presented. These papers primarily review existing research, analyze how the authors attempt to envisage future scenarios through simulations, and how various issues may affect both transitions to EVs and to AVs.

Table 1. Analysis of the most important papers (Scopus).

Reference	Goal of Paper	Type of Paper/Method	Contribution of the Paper
[19]	Answering the question if autonomous electric vehicles represent one of the mechanisms that will be used to increase the sustainability of urban mobility.	Review	The paper emphasizes the growing relevance of the sustainability of urban mobility in replacing traditional forms of transportation. It tries to answer the question if autonomous electric vehicles are one of the mechanisms that will be used to increase the sustainability of urban mobility. It was found that many researchers focus on the advantages and disadvantages of autonomous electric vehicles, but only a few of them research the planning process for this transition. It is also concluded that an insufficient number of papers investigate the application of autonomous electric vehicles in distribution logistics.
[20]	Investigates the application of fuzzy logic in a decision-making transition process considering the crisp and fuzzy information, outcomes, and actions and compares the values of additional information.	Article/conceptual method	This paper describes complex transitions in the automotive industry where decisions on the optimal pathways depend on the incomplete and inconsistent knowledge and expectations. Considering the fuzziness of the global business, social, ethical, and other domains, presented are the results of the investigation and the application of fuzzy logic in the decision-making process of the transition to autonomous vehicles. It considers the crisp and fuzzy information, outcomes, and actions and compares additional information values. Illustrated is a decision made by a car manufacturer based on the Bayesian framework.
[16]	Aims to understand consumer attitudes towards autonomous, connected, and electric vehicles using data collected through a survey in China. [1]	Article	The aim of this paper is to apprehend consumer attitudes towards autonomous, connected, and electric vehicles based on data collected in a survey in China. The results indicate that the most attractive aspects are the potential for environmentally friendly transport, increased accessibility of travel for non-drivers, and reduced driving fatigue, while the most concern is about vehicle safety, legal liability, and charging issues. On the other hand, the battery service life, driving mileage, and charging are prominent barriers to the adoption, while concerns and cost reduce their appeal.
[18]	Analyzes how the development of shared autonomous electric vehicles may make electrified transportation more likely and how they may impact utilities.	Article	This paper analyzes how the development of shared autonomous electric vehicles may make electrified transportation more likely and why this may lead to a more rapid than expected shift in the current transportation paradigm. It also discusses how these trends may affect utilities and suggests what they can do to prepare for the transition.
[21]	Estimates the potential for the full transitions in China, under different policy scenarios, using a bottom-up national transport model and an electricity model based on publicly available data.	Article	The paper estimates the potential for full transitions to autonomous and electric vehicles in China under different policy scenarios. The conclusion is that under the current policy scenario, the country can achieve emission reduction targets by 2035. Still, the goal of achieving net zero emissions by 2060 may not be fully achieved due to bottlenecks in the electrification of heavy-duty trucks and the treatment of battery systems and vehicles at the end-of-life cycle. The estimates are that in 2030, the AV technology introduction will be at Level 3. After 2035, autonomous driving technology will be fully introduced and able to offer advantages for sustainable transport.

Table 1. *Cont.*

Reference	Goal of Paper	Type of Paper/Method	Contribution of the Paper
[22]	Trying to find the best operation strategy for electric vehicles' energy storage and power supply in interdisciplinary problems such as electronics, machinery, control, and artificial intelligence.	Article/case study	In this paper, the authors present project-based learning in China's competition for energy-harvesting electric vehicles. As an option for zero-emission vehicles, making the battery of electric vehicles more sustainable has become an important topic. The competition's key challenge is to find the best operation strategy for electric vehicles' energy storage and power supply in interdisciplinary problems such as electronics, machinery, control, and artificial intelligence. Through project-based learning, participants from different professional backgrounds optimized the design of electric vehicles.
[23]	Explores the various aspects of the paradigm shift, highlighting potential benefits, technological changes, and policy recommendations.	Article	The main objective of the investigation presented in this paper was to explore various aspects of this paradigm shift, highlight potential benefits, technological changes, and policy recommendations. It establishes the feasibility of the widespread deployment which could provide significant social benefits by improving safety and saving lives; reducing fuel consumption, congestion, and pollution; and improving mobility and land utilization, which is driven by convergence of connectivity, electrification, and changing customer needs.
[24]	Develops the planning model for optimal transition to electric vehicle in the deep decarbonization pathway project considering electricity grid constraints.	Article/ modeling	This paper develops a decomposed planning model for optimal transition to electric vehicles in the deep decarbonization pathway project considering electricity grid constraints. A bi-level charging/discharging control is proposed for plug-in electric vehicles to increase their penetration. An integrated model of electricity and transportation sectors is developed to investigate the impact of autonomous electric vehicles as a clean disruptive technology for electric vehicles which can determine whether the existing and future City's electricity grid infrastructure can meet the growing electrified transportation load in the near future.
[25]	Demonstrating the contribution of decision support systems that combine data-driven analytics and simulation techniques in the understanding of urban transport.	Article/case study/simulation	This paper demonstrates the valuable contribution of decision support systems that combine data-driven analytics and simulation techniques in understanding urban transportation. The city of Berlin is used as a case study to prove that shared, autonomous electric vehicles can substantially reduce resource investments while keeping service levels stable. Furthermore, a trade-off between economic and sustainability-related considerations was discovered when fostering the transition to sustainable urban mobility.
[26]	Investigated the longitudinal control for an autonomous electric vehicle with a tracking differentiator modeled for model predictive control.	Article	In this paper, the autonomous electric vehicle is modeled as a longitudinal system for dual-mode model predictive control. The tracking differentiator is proposed to obtain the transition profile and acceleration information. The controller is designed to find the optimal control input, which is restricted by some constraints on the desired acceleration and its increment. Both iterative feasibility and stability issues are analyzed, and experimental results present the effectiveness of the proposed strategy.

Figure 1 presents the breakdown of papers investigating the transition to autonomous and electric vehicles by type and by research area.

3.2. Citation Analysis

A bibliometric literature analysis is a standard and rigorous method for investigating and analyzing large amounts of scientific data. It allows us to uncover the nuances of a particular field's evolution while shedding light on new areas in that field. Bibliometric methods employ a quantitative approach for describing, evaluating, and monitoring published research. These methods have the potential to introduce a systematic, transparent, and reproducible review process and thus improve the quality of reviews. Bibliometrics is the quantifiable analysis of scientific publications and a collection of numerical and statistical methods that provide a variety of ways to support research.

The bibliometric literature analysis uses scientific publications as a data source to provide a better understanding of how research is created, organized, and linked. It is a scholarly, computer-aided verification method that can identify core research, authors, and their relationships by covering all publications on a particular topic or field. Bibliometric analysis was undertaken to understand research trends and to assess citations as a measure of impact. For example, metric literature mapping visualizes scholarly outputs as publications and citation information in parameters of a particular subject.

In the citation analysis, we were looking at aspects that best express research in the transition to EV and AV technology. First, the citation of articles can be observed by visualization. In this analysis, we used VOSviewer software. The number of citations of papers tells us about the influence that the most cited papers had on later published papers. In other words, we must check the size of the circles to identify them.

Figure 2 presents the co-citation analysis. It shows one author and the impact of his or her research on other authors and their studies. Circles indicate authors and their works. Larger circles indicate more citations or significant influence of the author and his or her work. All circles, i.e., all authors and their articles, are connected by lines. The greater the number of lines and their thickness, the greater the influence of the paper and author. Authors are split into several clusters, defined by the similarity of the research areas in which the author works.

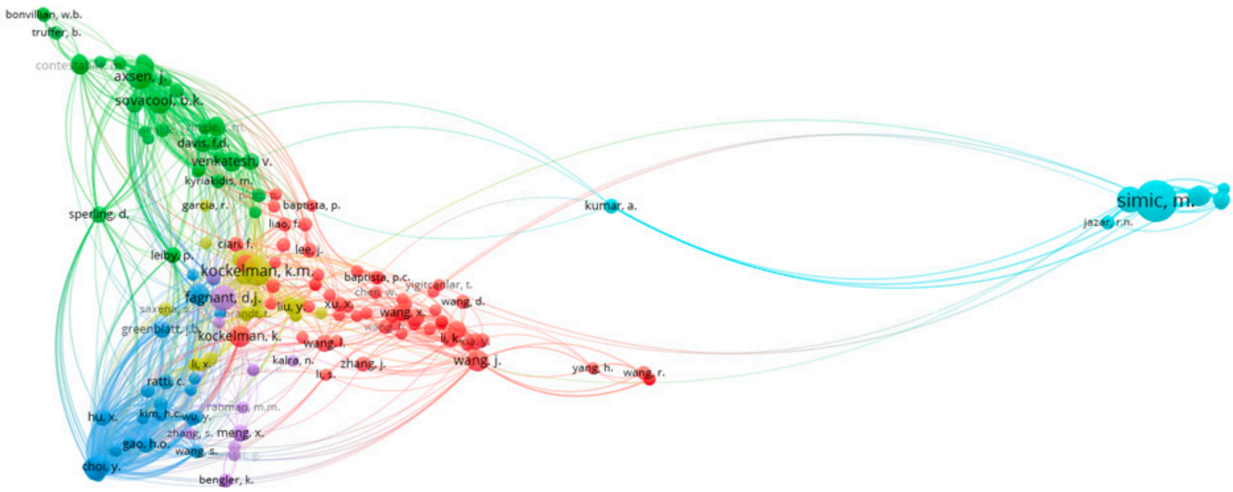


Figure 2. Co-citations analysis with network visualization of minimum three co-citations.

Figure 3 shows the citations of the broadened group of papers for 191 articles with at least 1 citation. The first authors are presented in circles.

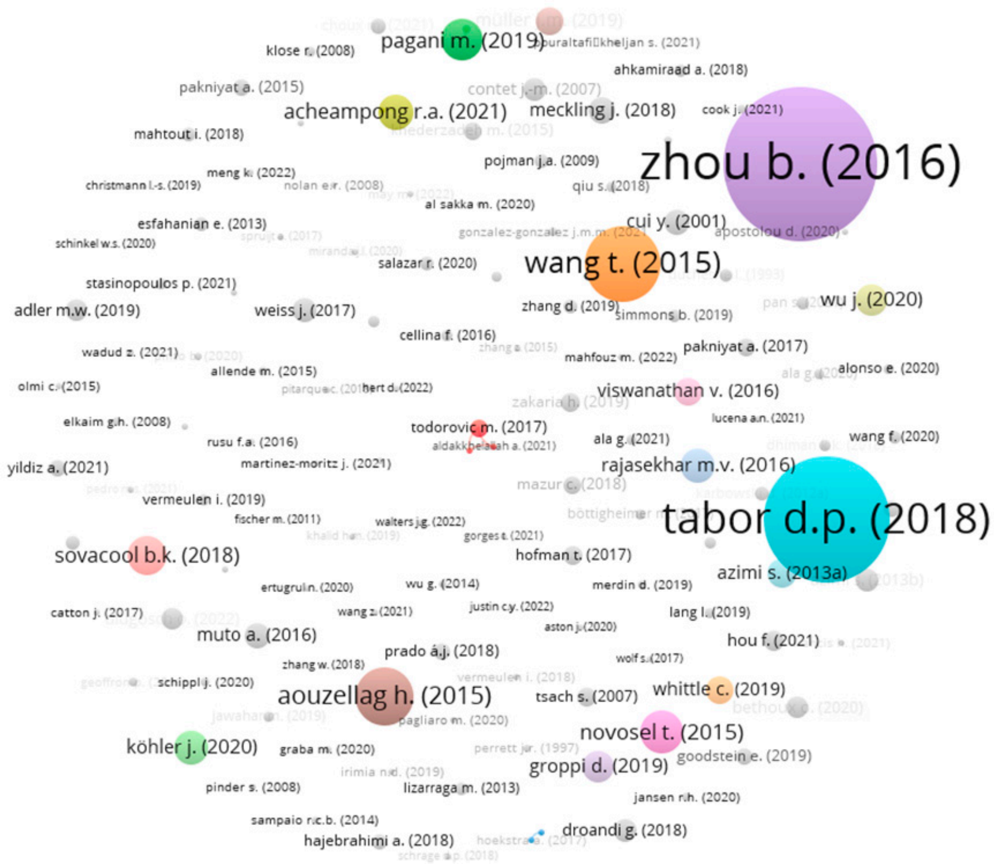


Figure 3. Citation analysis for 191 articles. The first author is in the circle.

Another bibliographic analysis of the most cited works also shows the research content in the area. It is a co-occurrence analysis, which is a more useful common concept between the most cited papers. These data show us the areas where the research was conducted. Moreover, we can follow Figure 4 to see when certain concepts were first mentioned and when they started to be used. Common co-occurrence terms extended lists of authors and keywords and terms used by publishers. Overlay visualizations of the VOSviewer can be used to show developments over time. A higher numerical value of link strength shows a stronger link between items. The link strength means the number of cited references that two items have in common. Also, when interpreting co-occurrence links, the link strength represents the counts of publications in which two terms co-occur.

Figure 4 presents the network visualization of co-occurring terms in the broadened group of 191 articles. The terms are grouped in clusters depicted in different colors.

A desired number of terms could be chosen to be represented on the diagram. In our analysis, we have shown this only for the case of one common term. The data we receive are the number of terms' occurrences. In this overlay diagram, we can see the timeline of terms that have appeared in the research papers. These terms are attached to the keywords autonomous vehicles and electric vehicles and presented in yellow color. We can see that the latest terms attached to electric vehicles are urban transport, economics, life cycle, and green gases. The latest terms attached to autonomous vehicles are the same as in the previous case, with the addition of energy transition.

Terms attached further to economics are transportation system, economic and social effects, and sustainability. Terms attached to energy transitions are life_cycle and greenhouse gases, while for life_cycle are attached the terms energy transition, greenhouse gases, electrical utilities, and carbon omission. Finally, we can check the co-occurrence terms for the broadened group of 191 papers which also comprise earlier papers. In that case, we can find economic and social effects, urban transport, air quality, and decision making.

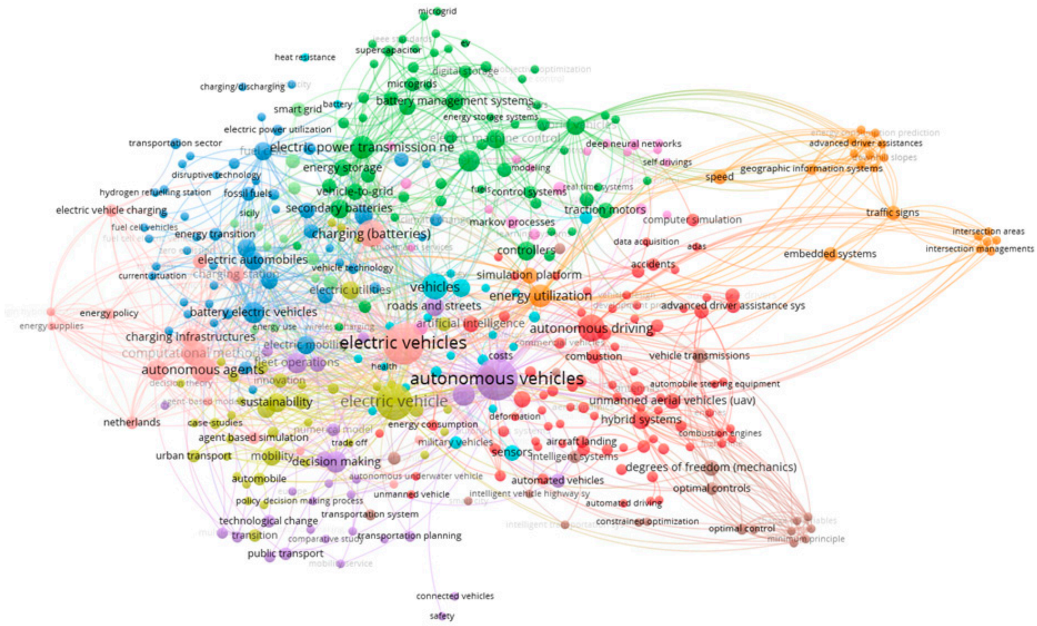


Figure 4. Papers analysis by terms co-occurrence for the set of 191 articles.

Previous information can be used to construct diagrams and analyze research categories, research fields, and specific research sub-categories of work related to the transition to autonomous and electric vehicles.

4. Discussion

As mentioned earlier, we have focused primarily on technology transition. The central gap observed in this review is the need for a comprehensive discussion and research of the various aspects of the transition to autonomous and electric vehicles.

Firstly, the discussion revolves around standardizing technology and infrastructure. While there has been extensive research on the technological aspect, as the deadline for complete transition approaches, new issues are coming to the forefront. One notable concern is the focus on infrastructure as support for both transitions. Although electric vehicles are already in use, there are notable variations in infrastructure standards across different regions. Vehicles themselves and the associated infrastructure still require complete standardization. Manufacturers are racing to introduce their products quickly, attempting to establish their standards as the norm in the market.

Secondly, there is a need for greater clarity concerning legal matters, inconsistent regulations, and liabilities associated with autonomous and electric vehicles. Many aspects remain undefined. For instance, issues such as insurance coverage and responsibilities in various incidents, including those involving the loss of human lives, lack clear definitions. Clarifying the intricate responsibilities among central authorities, city, and regional administrations, companies involved in infrastructure design, production, and installation, as well as automobile manufacturers, presents a significant challenge.

Third, we need more research regarding logistics, especially the first and last mile. All issues regarding the connections of vehicles in platoons still need to be defined. These problems are approached partially, but it is necessary to consider all aspects simultaneously when planning the transition. During that time, there will be mixed traffic with traditional and new technologies. It has not been globally determined for how long ICE vehicles will be on the roads and whether the corresponding regulation will exclude them before their useful life expires [27].

Fourth, the economic aspect includes significant investments in infrastructure, car production, changes in the type of employment and business operations, and personal expenses for purchasing new vehicles. All technology innovations bring needs for business models' innovations. In our case, we have a synergy of innovations in the automotive industry sector: driving automation, electrical powertrain, connectivity, and the IoT. This brings new business models and business model innovations [28] into the sector and they are based on big data and data intelligence, digitalization of all subsectors online with Industry 4.0, and shared economy and services.

Related issues are: What kind of transport and ownership can be expected in the future? How to use AI or fuzzy logic to make right decisions [29]? What will the future cities look like and how will the new road usage charging policy be defined? A significant issue that needs to be covered in the studies is the economy of environmental protection and respective legal and infrastructural regulations, production, and provision of clean and renewable energy. How to fuel sustainable future [30].

Fifth: Many of these decisions that need to be made will have to follow communities' needs and requirements. It is necessary to investigate how people accept new technology and regulations through the technology acceptance model, where they see future benefits, what they consider as risks, whether they feel safe, whether their privacy is threatened, and their economic capabilities.

Sixth: planning new areas where the most inhabitants will live, creating smart cities where a synergy of mobility and more abundant energy storage and generation will be achieved [31,32].

Seventh: Many decisions are to be made that often need to be revised. Available information is often lacking to predict future developments or possible changes in user expectations that need to be periodically updated with new findings. That is why decision-making models based on fuzzy logic could be applied, including all possible scenarios. Models with fuzzy logic can also be applied to streamline technological decisions.

Transitions to autonomous and electric vehicles are already underway. In the past twenty years, academic work has been dedicated to specific problems, mostly focused on research and development in automotive technology. Problems of a technological nature were identified, and solutions were sought and proposed. We already have electric vehicles on our streets. In the meantime, autonomous vehicles have reached the level that further testing and verification of technological readiness must be conducted on the road.

Many questions arose related to powering the vehicle with electricity, the number and arrangement of power points, and the sources of green electricity. Currently, if we use fuel cell electric vehicles (FCEVs) powered by hydrogen, the electricity is green [33]. If we charge our EVs at home, using electric power generated by our own solar panels, or charge at solar-powered charging stations, we use green electricity. In all other cases, it is green as much as sources of grid-supplied power are green.

The sources of green electricity are hydroelectric power plants, wind farms, solar farms, tidal wave energy power stations, geothermal energy sources, solar ponds, and solar panels in households and businesses. All those sources do not produce CO_2 and other greenhouse gas emissions. Nuclear power plants do not generate CO_2 pollution in the same amount as thermal power stations, but authors' opinions on those sources is the same as for those that causes environment degradation. Safe disposal of nuclear waste is still a big research question, although there are methods being developed for radioactive waste management [34].

As a good example of the current state of green electricity, we could look at the state of Victoria in Australia. In 2023, Victoria has 43 wind farms and a large number of solar panels installed. Victoria's renewable energy targets are 25% by 2020 (achieved) [35], 40% by 2025, and 50% by 2030. At the same time, the Victorian government's greenhouse emission report, available for the year 2020 [36], shows that the electricity generation share in CO_2 emissions is 50.1%. Regardless of that, Victoria has cut emissions by nearly 30% from 2005 and in 2020 was 10–20% below 2005. The aim is to achieve net zero emission by 2050. Then, we will have a truly green economy and transport as well.

The main reasons for introducing electric vehicles were environmental factors, i.e., greenhouse gas emissions reduction and targeting net zero emission. There was also the fear that fossil fuels would be exhausted and vehicles would run out of fuel. Therefore, the concepts of sustainability and renewable energy have become closely linked. The idea was to use renewable sources to power vehicles with electricity because otherwise, classically producing electricity would only increase pollution.

In the meantime, the development of autonomous vehicles took place. AVs also contribute to pollution reduction, to some extent, by bringing more efficient transport. It is possible to implement this technology in conventional ICE vehicles, but over time, it became clear that they would most likely be implemented mainly in electric vehicles. Autonomous vehicles have opened many new questions, including testing in real-world conditions. That development implied the applications of many new technologies, artificial intelligence, sensors, communications, and computer vision. It became clear that the transition to autonomous and electric technologies cannot be approached partially with only one set of problems in mind. The first academic works were devoted to technological progress and solving the problems that arose with the progress of technology. Over time, awareness has matured that introducing these technologies must be approached holistically, considering all possible problems, not only technological ones. Many solutions have yet to be adopted, especially in regulation, insurance, liability, and public policy.

In reference to the management of the transition to autonomous vehicles, our team has conducted three surveys during 2021 and 2022: two in Saudi Arabia and one in Australia. According to our findings, new technology is ready to be introduced to the public when the following parallel processing stages are finalized:

- Engineering: all problems and issues should be solved using safe and reliable technology.
- Legal: regulations should be given covering all possible issues and scenarios.
- Moral: all community moral views should be considered and implemented into AI motion control algorithms developed for the local market.
- Ethical: all community ethical views should be considered and implemented into AI motion control algorithms developed for the local market.

The engineering stage is very much the same in any country in the world. The other three show high diversity depending on the country, i.e., society. This appears to be a larger problem than engineering optimizations. There are no debates and disagreements, just local differences coming from the diversity of cultures, ethics, morals, and traditions. The areas of knowledge that remain unexplored, i.e., not exactly presented enough, are moral and legal views and they are different from country to country. The hypothesis is that, in those domains, there are much more discussions and published documents in local languages.

The transition to EVs has different fundamental questions and frameworks, which involve the following:

- Development of new road infrastructure, which can take up to ten years;
- Research and development of new, more efficient electrical energy storage systems, which can also take up to ten years;
- Development and production of new vehicles, which could take between three to ten years, usually five years;
- The use of green energy.

Our vision of an optimal EV introduction timeline is shown in Figure 5. Unfortunately, no country in the world has followed that scenario. The introduction of electric vehicles was performed by car manufacturers stochastically worldwide, while the road infrastructure setup was not ready for the transition. With the EV transition, we have no ethical and moral issues. To support the transition, governments often come with subsidies, new regulations, and bans on the use of ICE vehicles, from 2030, 2035, or other, depending on the country. At the same time, five EU countries want the ICE ban delayed from 2035 to 2040 [37].

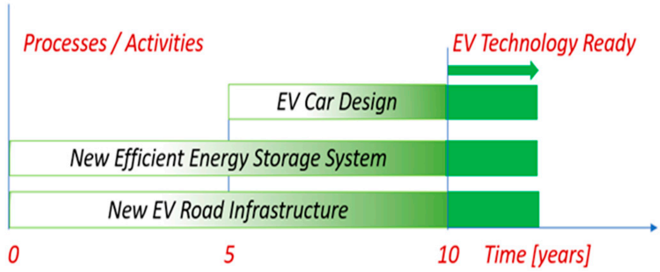


Figure 5. Optimal EV research, development, and production timeline.

Thus, in the past six years, we have had research focusing on the problem of transitions in all domains and not only in the technological domain. It can be noticed that there are still few of these studies and that a particular scientific discipline could be constituted. This discipline, which could be seen as part of global management, would consider all transition problems, globally, in a multidisciplinary manner, starting from powertrain technology, ecological limitations, sustainability of the entire project, current regulations, public policies, harmonization of international regulations, and others.

Every new technology must be accepted by customers. We have academic papers based on market research to determine what users see as a benefit, an increase in comfort and flexibility, as well as the risks they face, starting from participation in traffic itself, the reliability of technology, privacy, and Internet security. There is also the question of the price of the new technology and the business model that would be satisfactory for producers and users.

5. Conclusions

We have presented a systematic literature review obtained from the Scopus and WoS databases, based on the most relevant keywords used in the transition to autonomous and electric vehicles. A review was conducted to identify the main characteristics of the transition, to follow the evolution of this process, and to augment potential trends for future research. Globally, we have a synergy of four technology innovations in the automotive sector: electrical power train with EVs, automation with AVs, connectivity, and the IoT. Synergy brings complexity presented with 54 Scopus research categories. Although there is a dominance of areas related to the technical evolution of AVs and EVs, a growing presence of various fields of research, including AI, is evident.

Referring to the transition to EVs, we have a wide range of hybrid technologies. That variety will stay for a long period of time, but according to our conclusions, hydrogen and solar sources of energy will play a more important role, on board, not just stored energy like in BEVs. FCEVs and solar-powered EVs are also coming.

Talking about other transitions, a report implies that the introduction of AVs to the market is locally dependent, indicating that improvements in AI technology, business models' innovations, and regulations have to be addressed. The results of this study could contribute valuable insights and inputs to public policies and laws, government incentives, liabilities, cyber-security, data privacy, and security. Car safety issues, analyses of crashes and accidents, and the probability of accidents with vehicles using different automation levels are extremely important topics for research and regulatory framework setup. The development of new AI algorithms is more safe and reliable, for real-time operations are a continuous process. Therefore, constant, comprehensive integrative studies are suggested to investigate the progress of developments in these areas.

Conducting surveys, and through this review, we have found that there are public concerns about safety, sustainability, environmental impact, and ecological footprint. We need more research on different fuel types, battery storage solutions, and powertrains. In addition to research in technology, particularly AI, topics for future investigations are new innovative business models and platforms, regulatory frameworks, and full implementation of ethical and moral views of the customers. More generally, we should monitor the impact of the shared economy, the emergency of Mobility as a Service, new ways businesses are operating in the Industry 4.0 environment, and of course, consumer acceptance of new technologies.

Author Contributions: Conceptualization, M.T., M.S. and A.A.; methodology, M.T. and M.S.; validation, M.T. and M.S.; formal analysis, M.T., A.A. and M.S.; investigation, M.T. and A.A.; conducting reviews A.A. and M.T.; data curation, M.T. and A.A.; writing—original draft preparation, M.T.; writing—review and editing, M.S.; supervision, M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All data is available online on Scopus and Web of Science. VOSviewer visualization software tool was applied on the outcomes of the searched. Research is related to the transition to AVs and EVs, particularly on the work published in the six years, from 2016 to 2022. Data and methods used in the research are presented in sufficient detail in the paper, so other researchers can replicate the work. Scopus, WoS and VOSviewer are readily available, but the data in any moment of time is different and the finding will be different. That could be subject of another publication.

Acknowledgments: The first author, Milan Todorovic, acknowledges The Australian Postgraduate Awards (APA) scholarship, funded by the Australian Federal Government, for the support in the study and research in the management of transitions to autonomous and electrical vehicles. The second author, Abdulaziz Ayedh A Aldakkhelallah, acknowledges the financial support of the Saudi Arabia government under the Custodian of Two Holy Mosques King Salman Scholarship Program. Research is conducted on the topic of management of the transition to autonomous vehicles.

Conflicts of Interest: The authors declare no conflict of interest.

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