A Comprehensive Bibliometric Review of Autonomous Vehicle Research: Trends, Disciplines, and Future Directions

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Abstract: A comprehensive bibliometric analysis was conducted to evaluate the evolution, thematic structure, and emerging trends in autonomous vehicle (AV) research. Scientific literature published up to 3 January 2025 was retrieved from the Web of Science (WoS), resulting in a corpus of 11,069 publications spanning 60 countries. Using VOSviewer software, a detailed examination was performed to map the intellectual structure of the field, including co-authorship patterns, citation networks, keyword co-occurrence, and institutional contributions. The findings revealed a marked increase in the volume of AV-related publications over time, indicating growing scholarly interest and investment in the domain. A total of 157 distinct scientific disciplines were identified, underscoring the inherently multidisciplinary nature of AV research, which encompasses fields such as computer science, robotics, transportation engineering, artificial intelligence, and socio-economic policy. The most prolific countries, institutions, and authors were visualised through citation and collaboration networks, revealing key contributors and international linkages. Particular emphasis was placed on the use of reinforcement learning and other machine learning methodologies in AV development, as reflected by keyword trends and thematic clustering. Additionally, attention was given to the broader socio-economic and managerial dimensions of AV adoption, including market dynamics, regulatory frameworks, and public acceptance. This analysis provides a rigorous and systematic overview of the current state of AV research and highlights potential avenues for future exploration. By synthesising large-scale bibliometric data, this study offers valuable insights for academics, policymakers, and industry stakeholders engaged in the evolving landscape of autonomous transportation systems.

Keywords: Bibliometric analysis; AV; VOSviewer; Scientific mapping; Reinforcement learning; Multidisciplinary research; Intelligent transportation systems

1 Introduction

Unlike a systematic literature review, a bibliometric analysis is an analytical method that provides formal, quantitative data on the current state of a field, facilitating the monitoring of academic trends through visualisation software. For this reason, there are many bibliometric analyses in the field of transport.

The most important goals of transport research have always centred on safety, efficiency, and environmental sustainability [1]. There is a strong expectation that AVs can provide accessibility for those in need, reduce transport system costs and journey times, and offer a comfortable alternative for non-drivers [2]. However, autonomous driving technology is changing rapidly due to concerns about road safety, potential cost savings, and technological innovations [3]. Consequently, public acceptance of AVs continues to receive serious attention from various sectors, with an increasing trend in related research. The integration of AVs into traffic systems has been a focal point of recent research, particularly concerning their impact on traffic flow dynamics. Existing studies are highlighting the multifaceted effects of AVs on traffic efficiency, safety, and infrastructure. The coexistence of AVs and human-driven vehicles (HDVs) presents unique challenges. A study by Bamdad Mehrabani et al. [4] introduced a multiclass simulation-based dynamic traffic assignment model, revealing that increased AV penetration can reduce overall travel time, but benefits are contingent on AV behavior and network conditions. Similarly, research by Chen et al. [5] demonstrated that higher levels of Level 4-5 AVs improved fuel efficiency and mobility, though the extent varied across urban and freeway scenarios.

Efficient intersection management is crucial for traffic flow. Wang et al. [6] developed the OSaaS system, leveraging connected vehicle data to optimize traffic signals in real-time, resulting in reduced congestion and improved fuel efficiency. Vieira et al. [7] proposed a novel traffic signal optimization approach that combines Visible Light Communication (VLC) with machine learning to improve urban intersection efficiency. Their system enables real-time communication between traffic lights and vehicles, resulting in better vehicle coordination, reduced delays, and enhanced overall traffic flow. Similarly, Daglı et al. [8] investigated the operational efficiency of the Cosandere intersection in Selçuklu, Konya, Türkiye. The study suggests that implementing adaptive signal control and making minor geometric improvements could enhance traffic flow and reduce delays at this critical urban junction for classical and AVs.

Stabilizing traffic flow is a key benefit of AVs. Research by Xie et al. [9] proposed a theoretical framework for traffic platoon control, demonstrating that AVs can enhance flow stability through coordinated movements. Conversely, studies have shown that AVs operating without connectivity may drive conservatively, potentially slowing down traffic at intersections. The impact of AVs varies between urban and rural settings. A simulation study in Japan indicated that initial AV integration might increase delays in urban areas, but as AV penetration exceeds 50%, delays decrease, suggesting a threshold effect [10].

Effective AV integration requires supportive policies and infrastructure. Wei and Shao [11] explored hybrid traffic laws for mixed traffic, finding that dynamic lane access policies can improve flow and encourage AV adoption. Additionally, the SURTRAC system, developed by Carnegie Mellon University, exemplifies adaptive traffic control that can accommodate AVs, enhancing urban traffic management [12]. Chen et al. [13] provided a comprehensive review of data-driven traffic simulation methods, emphasizing their importance in evaluating AV performance and informing traffic management strategies. Despite technological progress, real-world AV deployment faces challenges. In San Francisco, incidents of AVs causing traffic disruptions highlight the need for robust operational protocols and regulatory frameworks. Ongoing research is essential to address the complexities of AV integration. Key areas include refining AV algorithms for diverse traffic conditions, developing adaptive infrastructure, and formulating policies that balance innovation with public interest [14].

This study uses bibliometrics to obtain quantitative findings on the productivity of countries, authors, universities and journals, as well as identifying weak and strong research areas, literature gaps, collaboration networks and potential opportunities, and assessing the widespread impact of outputs produced in a field. Despite its limitations, bibliometrics can be used as a preliminary step in a systematic literature review, which is one of the reasons for its widespread interest today.

In this study, the term 'impacts' refers to the 'ripple effect', in which AVs are at the centre, surrounded by a first layer of impacts such as traffic, travel costs and choices. The second layer refers to changes in car ownership and sharing, location choices, land use and transport infrastructure. The third layer refers to the broader societal impacts of the introduction of AVs, such as energy consumption, air pollution, safety, social equity, the economy and public health.

2 Analysis Methodologies and Data Sources

2.1 Research Design and Data Sources

This study aims to investigate AV research from an international and broader perspective. Bibliometric analysis was used to identify trends in the field of study and show the current status of authors, publications, journals, countries and citations. To this end, the WoS database was employed. It is one of the most widely used and reliable databases for academic and conference papers. In this research:

•WoS Core Collection is used.

•Time period covered by the study: 1984 - 03.01.2025 (all times).

•Citation Indexes: Science Citation Index (SCI), Science Citation Index Expanded (SCIE), Social Science Citation Index (SSCI), Social Science Citation Index Expanded (SSCI-E), Emerging Science Citation Index (E-SCI).

As mentioned above, the number of records is increasing day by day, so 03/01/2025 was chosen as the deadline. Studies conducted before this date were considered in detail. The VOSviewer programme was chosen for this study due to its functionality. It is considered an important programme that offers researchers convenience in discovering evolutions, relationships and new concepts in literature. It also enables in-depth analysis of data sets by providing visualisation, mapping and multidimensional analysis. The WoS database was used in the present study. Using the WoS database for various analyses, including bibliometric analyses, is an important factor in ensuring the reliability of the research. The WoS database offers advanced search indicators for data analysis and employs various control mechanisms. It includes studies that are both qualified and reliable in terms of publication ethics. It also provides access to a comprehensive collection of data from various disciplines. On 3 January 2025, a search in WoS using the keyword 'AV' and selecting 'all fields' yielded 11,069 results. Of these, 5,755 were journal articles, 5,147 were papers, 192 were review articles, 180 were early access, 36 were editorial content, 38 were book chapters and nine were corrections. The results came from different disciplines and spanned the years 1984 to 2025. The majority

of the studies seem to belong to the fields of transport science technology (2,546), computer science of artificial intelligence (2,218), automation control systems (2,145), robotics (1,586), computer science of information systems (1,207), telecommunications (1,058), computer science theory methods (991), civil engineering (731), and public transport (711). The majority of the studies are in the field of electrical and electronics engineering (4,087).

2.2 Research Methodologies

The study identified the impact factor, number of publications, most-cited articles and keywords in order to analyse the impact of journals, authors, institutions and countries. This descriptive study uses a quantitative approach to identify the key characteristics of the AV field and highlight potential trends for future studies. The study is a bibliometric survey based on articles indexed in the WoS database from Thomson Reuters. The current study aims to use document co-citation and keyword co-occurrence to create a knowledge map. Co-citation occurs when two documents are cited simultaneously by another document. Document co-citation analysis aims to identify intellectual relationships between documents based on co-citation frequency [15]. Consequently, a co-citation network can be constructed to identify clusters of scientific knowledge and influential articles in the field of AVs. It can identify important research perspectives, as well as potential collaborators or competitors. Furthermore, keyword co-occurrence refers to the appearance of two or more keywords in the same document. Creating mapping networks based on keyword co-occurrence can reveal significant concepts and research directions within the AV field. These analyses were visualised using VOSviewer, a free visualisation programme, to make them more understandable.

The bibliometric analysis was systematically designed and comprised primary studies only. It includes clearly articulated objectives and materials and methods, and was conducted using a clear, reproducible methodology [16]. In this sense, the results of bibliometric analysis are as follows:

•To measure and understand a particular subject's field of study.

•To provide a solid perspective on the historical evolution of the field.

•To provide thematic and technological analyses.

It is also useful in providing evidence and a basis for future research. Based on these methodological procedures, the present study proposes the four steps described and illustrated below.

Step 1. Limiting the scope of the analysis and article selection

A single search of the WoS Core Collection database was conducted for articles from 1984 to 2025. Due to the multiple definitions still in use in this field, articles containing the term 'AV' in the title, abstract or keyword fields were selected. This search yielded 11,069 results, forming the basis of the present study.

Step 2. Descriptive analysis of articles

The following analyses were performed:

•Overview of general statistics and number of articles per year.

•Publication types and research areas.

•Most published authors.

•Most productive countries.

•Citation distribution of studies on AVs by country.

Step 3. In-depth analysis of articles

The following in-depth analyses of 11,069 articles were performed in VOSviewer.

•Co-authorship of authors.

•Citation of authors.

•Citation analysis of countries.

•Citation analysis of organisations.

•Co-occurrence of author keywords analysis.

•Bibliographic coupling of documents.

Step 4. Interpretation and discussion of results

A joint interpretation and discussion of the results from steps two and three were carried out to identify key research trends and gaps in the study areas.

3 Analyses and Findings

This section presents the findings obtained in the study. Studies on AVs were analysed. To this end, the WoS Core Collection was used to identify relevant studies.

3.1 Statistics Overview

Figure 1 shows the distribution of publications on AVs, which is the subject of this study. This figure shows that the number of publications was stagnant until 2012, when it started to increase, gaining tremendous momentum after 2017. This significant increase can be attributed to the surge in artificial intelligence studies in recent years and the growing interest in autonomous technologies.
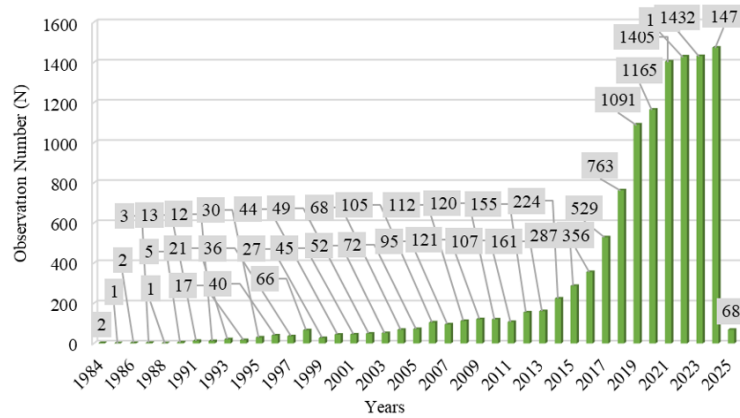
Figure 1. Distribution of publications on AVs by year

3.2 Publication Types and Research Areas

Figure 2 shows the publications indexed in WoS from 1984 to 3 January 2025. For the bibliometric analysis in this study, the following article types were considered: original articles, proceedings articles, early access articles and review articles. Book chapters are excluded from the analysis due to insufficient scientific data. Therefore, 60% of all publications are original articles, followed by 35% of conference proceedings. Only 3% of publications are review articles. Review articles are of great value to the academic community, consolidating existing research findings, providing essential guidance for future research, and reinforcing established theories.

Figure 2 shows the distribution of research areas among the 647 publications. As can be seen, studies in the field of engineering account for around 65% of all studies. This indicates that the majority of studies focus on solving engineering problems. Furthermore, computer science and transport account for approximately 35% and 20% of studies, respectively. This indicates the significant impact of artificial intelligence and sensor technology development on engineering, computer science, and transport technologies.
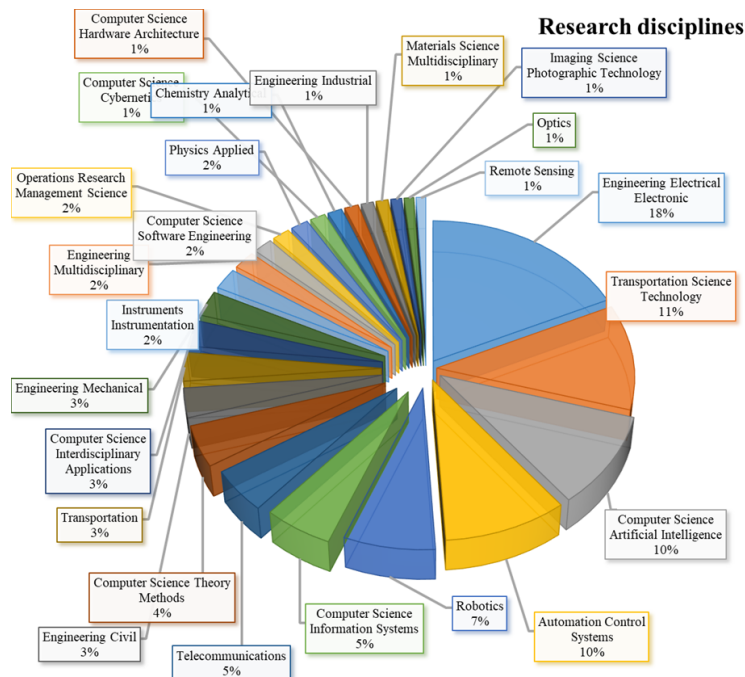

Figure 2. Publication trends of studies on AVs, categorised by discipline

3.3 Most Published Authors

This analysis looks at the authors who have published the most academic work on AVs, and their contributions to the field. The number of publications indicates the authors' influence and their contribution to research in this area (refer to Figure 3).
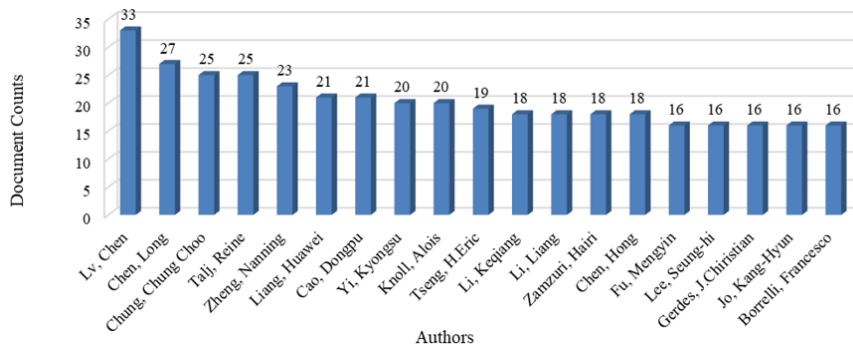
107

Figure 3. Authors with the most publications on AVs

With 33 documents, author Lv Chen is in the leading position. This demonstrates his extensive research into AVs and significant contributions to the field. He is followed by Chen Long with 27 documents. Chung, Chung Choo, and Talj, Reine are joint third with 25 documents each, and are among the most important researchers in this field. Zheng Nanning and Liang Huawei follow with 23 and 21 documents, respectively. Cao Dongpu, Yi Kyongsu and Knoll Alois are among the other influential researchers in this field, they have published 20 documents each. Tseng, H. Eric, draws attention with 19 documents. Additionally, Li Keqiang, Li Liang, Zamzuri Hairi and Chen Hong continue to contribute to this field, with 18 papers each. These authors have made significant contributions to the development of AV technology. Finally, Fu Mengyin, Lee Seung-hi, Gerdes J. Christian, Jo Kang-hyun and Borrelli Francesco are actively publishing in this field, having each published 16 papers.

This data reveals that a wide range of authors are working in the field of AVs and contributing to technological development in various ways.

3.4 Most Productive Countries

This analysis examines the distribution of academic publications on AVs by country. The number of publications reflects the research intensity and contribution of a given country in this field (refer to Figure 4).
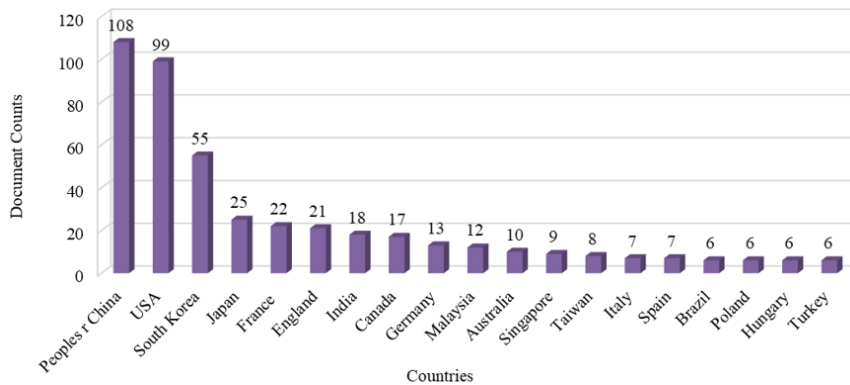

Figure 4. Distribution of academic publications on AVs according to countries

With 108 documents, China is the leader, indicating that it has become an important centre for AV research. The USA ranks second with 99 documents, demonstrating the country's ongoing commitment to research in this field. South Korea is in third place with 55 documents, which demonstrates Asia's high research potential in this area. Other significant contributors include Japan (25 documents) and France (22 documents).

3.5 Citation Distribution of Studies on AVs by Country

This analysis analyses the citations of studies on AVs from various countries. Citation counts indicate the research impact and contribution of a particular country in this field (refer to Figure 5).

According to the data, China is in the lead with 2,045 citations, which indicates that the country is making a significant contribution to AV research. The US is a close second with 1,886 citations, also playing a critical role in this field's development. South Korea ranks third with 1,231 citations, demonstrating its strong research potential in Asia. The UK and Germany are also major players in AV research in Europe, with 493 and 415 citations, respectively. Countries with lower citation numbers, such as Malaysia (251), Italy (240), France (236) and Saudi Arabia (171),

are also making active contributions to this field. These citation numbers demonstrate the wide global impact of AV technologies as a research area. Other countries, such as Singapore (152), Australia (139), Japan (131) and Türkiye (129), are also making their presence felt in this field with their notable citation numbers. Countries such as India (99 citations) and the Netherlands (67 citations) have the potential to contribute more in the future.
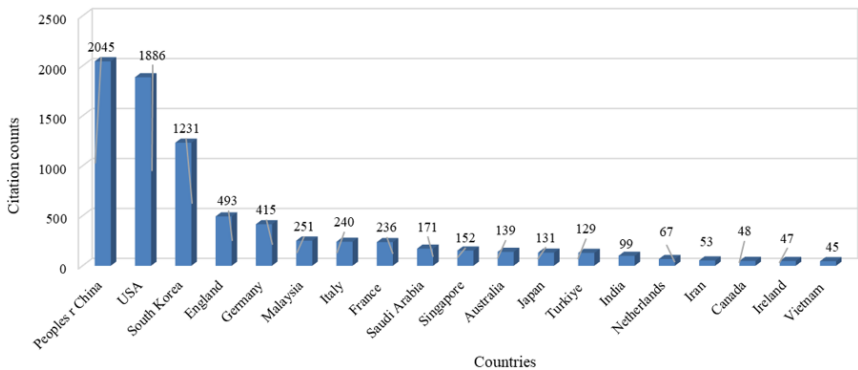

Figure 5. Comparison of citations to studies on AVs by country

3.6 Co-author Analysis

A network map was created based on a co-authorship analysis, identifying the most connected and collaborating authors by determining at least one publication and one citation. The analysis of the names with the highest number of connections revealed 17 names and a total of 136 connections within a single cluster. Each of the 17 most connected authors in the cluster has 16 connections. It can also be seen that the most cited authors (Yong Gu Ji with 695 citations, Constantinos Antoniou with 379 citations and Santhanakrishnan Narayanan and Emmanoil Chaniotakis with 379 citations) are not the most connected. Nor do the authors who produced the most works appear among the most connected authors (Chen Lv, Long Chen and Chung Choo Cung, respectively) (refer to Figure 6).
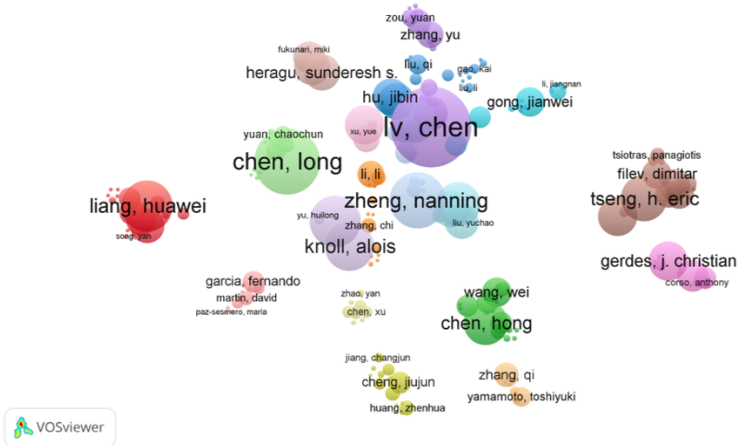

Figure 6. Co-author links indicating co-operation between authors

3.7 Citation Analysis of Authors

To determine citation networks, a network map of author citation analysis was created, based on the criterion of at least one publication and one citation. Of the 283 units found to be connected to each other, the analysis determined 24 clusters and 941 connections, with a total connection strength of 1,079. The most frequently cited authors were Yong Gu Ji (695 citations), Jong Kyu Choi (675 citations), and Constantinos Antonio (379 citations) (refer to Figure 7).

3.8 Citation Analysis of Countries

To create a network map of citations received by publications according to their country of origin, 49 observation units were analysed within the scope of the following criteria: publishing at least one work by a country and receiving at least one citation. Thirty-five clusters, forty links and a total of one hundred and four link strengths were identified.

The countries with the most citations were China (2,045), the USA (1,886) and South Korea (1,231). In terms of total link strength, China and the USA were ranked first and second, respectively. The ranking in terms of the number of publications is as follows: China (108 publications), the USA (99 publications) and South Korea (55 publications) (refer to Figure 8).
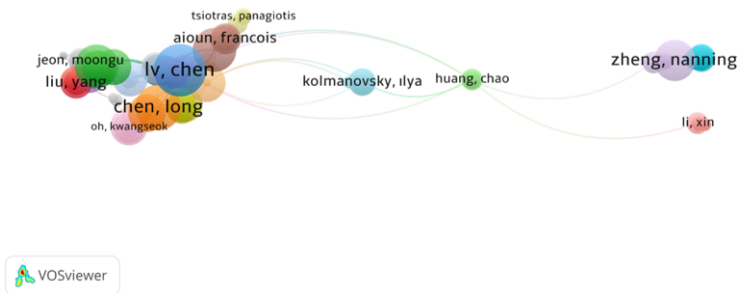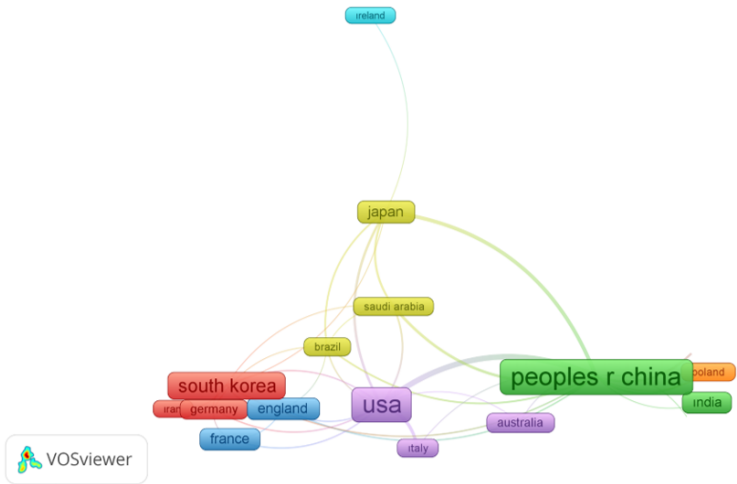

Figure 7. Authors' citation links

Figure 8. Citation links of countries

3.9 Citation Analysis of Institutions

To create a network map of inter-institutional citations, 62 observation units were analysed within the scope of the following criteria: publishing at least one work and receiving at least one citation from another institution. The Beijing Institute of Technology (13 works), Tsinghua University (12 works) and Tongji University (12 works) were represented, while the institutions at which the most-cited publications were produced were Tsinghua University (1,007 citations), Yonsei University (707 citations) and the Chinese Academy of Sciences (520 citations). A total of eight clusters and 141 links were identified, with a total link strength of 220 (refer to Figure 9).
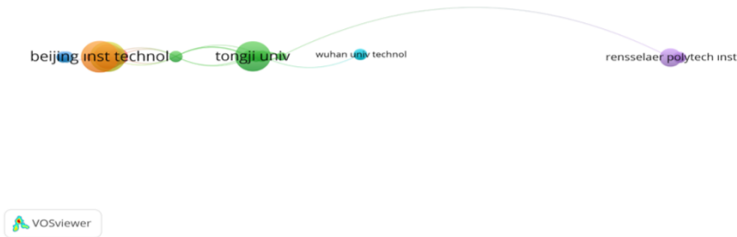

Figure 9. Citation links of institutions

3.10 Co-occurrence of Author Keywords Analysis

The most frequently used keywords in publications related to AVs were 'autonomous vehicle' (190 repetitions), 'autonomous vehicles' (40 repetitions), 'path planning' (16 repetitions) and 'path tracking' (10 repetitions). The

strongest expressions in terms of total connection strength were 'autonomous vehicle', 'autonomous vehicles' and 'vehicle dynamics'. The analysis of 61 observation units that appeared at least three times and were connected revealed a total of 12 clusters, 209 connections, and a total connection strength of 411 (refer to Figure 10).
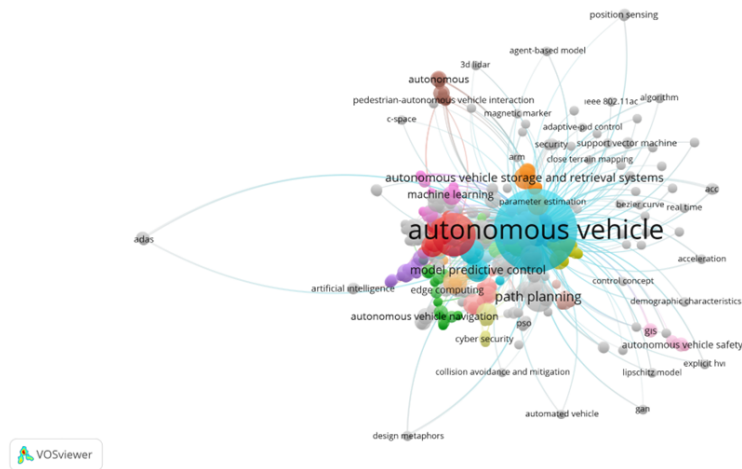

Figure 10. Most frequently used keyword links

3.11 Bibliographic Match Analysis of Texts

Bibliographic matching refers to the citation of a work that is cited by two independent sources. An analysis of 223 unit works, selected on the basis of having at least one citation and a link between them, revealed 19 clusters, 1,037 links and a total link strength of 1,398. The publications with the highest number of bibliographic matches were Choi (2015) with 675 citations, Narayanan (2020) with 379 citations, and Gao (2018b) with 341 citations. The works with the highest total link strength were those by Adnan (2018), Chen (2020) and Adnan (2019) (refer to Figure 11).
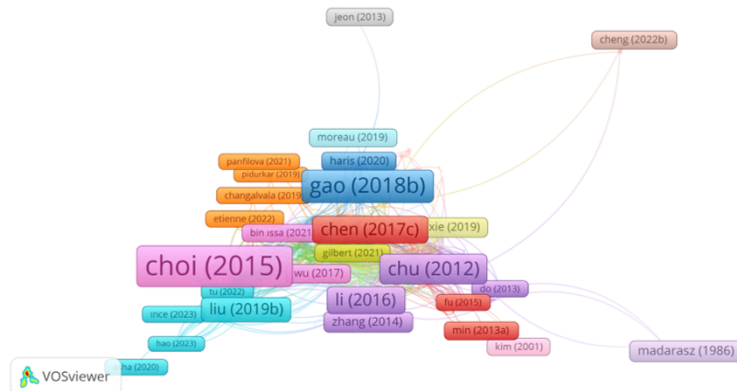

Figure 11. Bibliographic matching links of the works

4 Conclusions and Suggestions

This study provides a scientific and bibliometric analysis of research into AVs, evaluating the development of the field and its future trends. A total of 11,069 publications from 60 countries were examined and analysed using VOSviewer software. While the USA ranks second with 99 publications, China stands out as the country with the largest number of publications, at 108. Other countries, such as South Korea (55 publications), Japan (25 publications) and France (22 publications), also have a presence in this field. These data demonstrate that research into AVs is geographically diverse and attracts global interest.

The results of the study clearly show that AVs should be developed by drawing on many different disciplines, including engineering, computer science, the social sciences and economics. Issues such as road safety, cost savings and public acceptance are particularly important areas of research. However, existing studies also take into account social aspects such as energy consumption, environmental impacts and social equality.

The results show that AV research is multifaceted and dynamic, and that the number of studies in this field continues to grow. Interdisciplinary collaborations will facilitate important advances in the safe and sustainable application of the technology. In this context, research led by China and the US provides a solid basis for technical and social innovation. In the future, increased cooperation and research in this field are needed for wider acceptance and implementation of AVs.

The study results provide a comprehensive review of AV research and highlight key areas of focus, offering researchers and policymakers valuable predictive information for future work. Technological development will continue to create far-reaching changes at scientific and societal levels. Therefore, the scope of research should be broadened, and the integration of different disciplines into this field, along with their cooperation, should be encouraged.

Data Availability

Not applicable.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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