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"A Biblioshiny Analysis of Research Trend and Innovations in Autonomous Vehicle Technology"

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Abstract

Since its initial proposal in 1918, the idea of autonomous vehicles (AVs) has gained significant attention due to its potential to transform transportation through increased efficiency, safety, and mobility. AVs research hasn't been systematically analyzed, though. Data were gathered from 625 legitimate documents from WoS and bibliometric analysis was performed using Biblioshiny visualization program and Scopus database, from 1986-2024. The results says that there was no growth on research till 2015, but it started getting momentum in 2016 till 2022 and the reasons for lack in research were technology limitation, lack of data, high cost, regulatory and legal challenges, Public acceptance, limited govt and private funding etc. The largest country collaboration found between USA with Bangladesh and Canada. Further, the top most 5 cited countriesin terms of research are UK, USA, China, Germany, Spain, Netherland. As per three-field plot China has the highest thickness, followed by Korea and USA connecting to authors belong to China (majority) andin terms of keyword Autonomous vehicle has the most thickness. The highest number of documents published in the "Journal of advanced transformation" with 125 number of documents, followed by "Transportation research Part A: policy and practice". There are only 5 major productive journals which consist of 216 articles (35% of the all articles). The Trending topics of 2024 are "Model predictive control" and "Artificial intelligence technologies". The highest co-occurred (occurring simultaneously in different papers) terms in Network and Overlay mode is "Autonomous vehicle" is making a network with its own Group and other groups as well. The historical development, and trends in AVs research are revealed in this study, which helps researchers gain a thorough grasp of the topic and provide a more objective and scientific foundation for future quantitative research.

Keywords-Autonomous vehicles; Bibliometric analysis; Biblioshiny; R-Square; Quantitative research.

Introduction

By reducing human error, autonomous vehicles can significantly lower the number of accidents, saving lives and reducing injuries. They offer increased mobility and can help alleviate traffic congestion through optimized driving patterns. Additionally, autonomous vehicles contribute to environmental sustainability by reducing fuel consumption and emissions. The development of this technology also drives economic growth, creating new industries and job opportunities. Moreover, research is crucial for addressing ethical, regulatory, and security challenges, ensuring that autonomous vehicles are safe, reliable, and beneficial for society. For more than 50 years, the robotics sector has influenced many facets of daily life. Further, the fourth industrial revolution, is causing a number of IT-related enterprises based on mobile IT to emerge (Rifkin, 2011; Schwab, 2017). The Navlab 5, the first automobile with an autonomous driving system, debuted at Carnegie Mellon University in the middle of the 1980s (Pomerleau & Jochem, 1996). Since then, this field has seen a number of developments, and many significant businesses and research institutions have created AV prototypes. It is highly anticipated that this will increase accessibility for those in need, cut down on the time and expense of transportation and bring comfort (Mutz et al., 2016). Even while AVs may appear far off, it is becoming more and more clear that they are developing and will probably arrive soon (Attias, 2017). Road safety concerns, possible cost savings, and technological advancements are all contributing to the rapid changes in automated driving technology (McKinsey & Company, 2016). Given the state of technology today, anticipated advancements, and the plans previously revealed by a number of major Original Equipment Manufacturers, it is possible that AVs will be accessible by the middle of the 2020s. AVs have been receiving more and more attention in the corporate world. Despite the establishment of the AV theoretical discipline, its key features, conceptual foundation, trends, and traits have not yet been thoroughly determined. The format of our paper is as follows: An introduction of AVs is given in Section 1 along with information on their idea and terminology, presumed advantages and ramifications, and the initiatives taken by various stakeholders to promote them automobiles. The study methodology is presented in Section 2, outlining the steps required to apply the scientometric technique. Through a thorough examination of the conceptual underpinnings, trends, orientations, and developments impacting this research area, Section 3 summarizes the findings in an effort to define the field of study and to provide insights. Section 4 concludes with the key findings, a discussion of potential directions for further research, a discussion of its limits, and some practical consequences.

Objectives

Working on autonomous vehicles in research involves pursuing several key objectives to advance thefield. One of the primary goals is to enhance the perception and decision-making capabilities of autonomous systems, enabling them to accurately interpret and respond to complex, dynamic environments. Another critical objective is to refine path planning and control algorithms, allowing in diverse conditions, from urban settings to highways. Addressing the ethical and regulatory challenges associated with autonomous vehicles is another important objective. The principal objectives of this investigation are as follows:

- To see the development and trend in the topic, since from the period of publication.
- To see the most relevant sources, Countries collaboration (MCP-SCP) and Affiliations.
- To see the keyword analysis (Network-Overlay-Thematic) and identify Trending topics.

After searching the term “Autonomous Vehicle” in Scopus database some 48,545 papers appeared. Limiting it to conference and articles with language English only, the papers filtered out to 13,515 further limiting it to business,

management, accounting and humanities, 496 papers were the final output with 33 variables (R square results). Same term was searched in WOS database, some 5,123 papers appeared again limiting it to open access and reviewed articles and going through the same process as Scopus the final result were 133 papers with 58 variables (R- square results). Merging the data with the help of R-square, 4 duplicates were found and after removing them 625 papers were thefinal output to extract data (Publication year 1986-2024).

While section 1 covers the introduction bout the topic, objectives and gaps. Section 2 of this article covers some of the literature which is available on “Autonomous Vehicle” to assess the present condition in this area, Section 1 of this paper provides an outline of this study. methodology used is discussed in Section 3, which use "Biblioshiny” etc to assess the records, Section 5 talks about the results and a conclusion based on the results is provided in Section 4.

Literature Review

Autonomous vehicles (AVs) are vehicles that may move and act without the support like a conductor (driver) or teleoperation (Frazzoli, Dahleh, & Feron, 2002). In order to avoid having several definitions with unclear meanings, SAE, 2016 has suggested using the term "automated driving systems (ADS)" to refer to cars with varying degrees of automation. Several phrases that are frequently used including autonomous vehicles/cars, self-driving cars, car-like robots, intelligent vehicles, and driverless cars, are intended to be covered by this vocabulary. Since automated driving may have a number of interconnected implications on mobility and society. (Arem & Wee, 2017) noted that AVs represent a potentially disruptive and favorable change to the economic paradigm of intelligent transportation networks. AVs are positioned at the middle of a first layer of consequences, which include traffic, travel expenses, and travel choices. The authors call this second layer of consequences the "ripple effect," which suggests changes in land use and location choices, transportation infrastructure, and vehicle ownership and sharing. Lastly, the third layer addresses the wider societal implications of AV adoption, such as public health, energy use, air pollution, safety, social justice, and the economics. But there's no guarantee that AV will spread. "Complex questions related to legal aspects, liability, privacy, licensing, security, and insurance regulation still remain to be solved," write Fagnant and Kockelman (2015, p. 168). Additionally, because AVs are controlled by a central unit system and connected to the cloud, they may present additional risks, that could reduce their safety in specific circumstances. This raises security and privacy issues. Hucko (2017) further emphasizes how passengers' privacy may be violated by the misuse of sensitive data, tracking, and data sharing, and how such vehicles may be exploited for terrorist purposes. Large-scale manufacture would be hampered by the significant costs associated with additional auto equipment services (Grau, 2012; Hickey, 2012). Large automakers, including California tech behemoths like Google and Uber, as well as European automakers Audi, Mercedes, and Volvo, as well as American automakers Ford, GM, and Tesla, have made autonomous technology their best shot (Nascimento, Salvador, & Vilicic, 2017). AVs are currently being tested by a number of automakers, including Mercedes-Benz, Nissan, Audi, BMW, Cadillac, Ford, GM, Volkswagen, and Volvo.

(Fagnant & Kockelman, 2015), In addition, cars with semi-autonomous features at the level 2 and 3 of automation set by the the Tesla Roadster, which Nascimento et al. (2017) claim is the first mass-produced vehicle are among the vehicles that are already available on the market according to the Society of Automotive Engineers, 2016. Business partnerships are particularly significant because they have been a common tactic for the development and progress of new AV technologies (like BMW's partnership with Mobileye and Intel) and even for the training of new specialists in the field. To train local technological workers, for example, Mercedes-Benz, McLaren, Otto, Nvidia, and Udacity

(University of the Silicon Valley) have collaborated to create an online course. Many governments have also expressed interest in the potential benefits of vehicle automation. The United States was the first country to pass legislation allowing AV testing on public streets and roadways. The development and testing of autonomous vehicles (AV) on European roads has already received approval from lawmakers in several countries (Patel, 2018). Similar to this, Asian nations including China, South Korea, Japan, and Singapore are eager to see international laws changed to permit the advancement of automated car technology (Schoitsch, 2016; U.K. Department for Transport, 2015). In order to consolidate autonomous vehicles, research institutes and universities worldwide are advancing studies on technology mobility, vehicle-infrastructure interaction, and management and business-related concerns. As noted by Cavazza et al. (2017), Lima (2015), and Weick and Jain (2014), significant advancements are also being made within academia. Yun et al. (2016) state that the dynamic interaction that has been developed includes the progress of technological breakthroughs in the AV area.

It is clear from this that adjustments to the dynamic relationships between these three components may be necessary to get the desired outcomes. This modification can be a natural progression of an undefined business model. More detailed simulation studies on political leverage, including the market's growth pattern and the effects it will have on other sectors, will be required in the future, though, as well as the development of dynamic system models. Numerous articles have been written about the topic, and there are still many unknowns regarding the fundamental elements of technology, business models, the market, and regulations surrounding the shift from the long-standing automobile sector to the new configuration known as the mobility eco-system.

Research Gaps and Research Novelty

- There is a notable scarcity of in-depth microlevel literature assessments on the topic of “Autonomous Vehicle,”
- No comprehensive scientific study has been encountered thus far.
- While there have been a limited number of prior research and reviews, they have primarily employed manual review methods and have been narrowly focused, lacking a broader perspective.
- Consequently, a significant research gap exists because there is a lack of comprehensive reviews on studies within this field.

This study stands out from prior research in several key ways:

1. It undertakes a comprehensive literature review on the subject of “Autonomous Vehicle”.
2. Instead of relying on conventional literature review methods, this paper employs techniquessuch as Countries Collaboration, Three-Field Plot, Keywords analysis, yearly trends, and the Identification of the most-cited countries.

Research methodology

Despite significant advancements in autonomous vehicle research, there remain crucial gaps that continue to challenge the field. Researchers have already work on topics like Transportation, Vehicles,Automation, Fleet operation etc. but no study was done to see the overall analysis on this topic sinceit’s momentum. Another gap lies in the integration of ethical decision-making within autonomous systems. While researchers have made strides in developing algorithms that optimize for safety and efficiency, the ability of these systems to make morally sound decisions in scenarios where human lives are at stake remains underexplored. Additionally, there is a need for more comprehensive and

standardized frameworks for the validation and verification of autonomous vehicles, which can consistently ensure safety and reliability across different models and environments.

A critical research gap in the field of Autonomous Vehicles that has yet to be fully addressed is the comprehensive understanding and management of the long-tail distribution of rare and unpredictabledriving scenarios, often referred to as edge cases. Despite advances in machine learning and sensor technologies, current autonomous systems struggle to reliably predict and respond to these edge cases, which limits their real-world applicability.

- To fill these gaps, conducting a bibliometric analysis could be invaluable.
- By systematically reviewing the existing literature, identifying trends, and mapping out under-researched areas.
- Researchers can gain insights into where the field is lacking and propose targeted studies to address these deficiencies.
- This approach would not only highlight existing knowledge but also provide a roadmap for future research, ensuring that critical gaps are filled, and the transition to fully autonomous vehicles is both safe and socially responsible.

By using a quantitative approach and bibliometric analysis, this study seeks to comprehend the general state of AVs' academic research. This study performed a bibliometric analysis using visual analysis tools. Furthermore, research is essential to solving security, ethical, and legal issues and guaranteeing that autonomous cars are dependable, safe, and advantageous to society.

The current study suggests four phases based on these methodological approaches, which are explained below and shown in Figure 1.

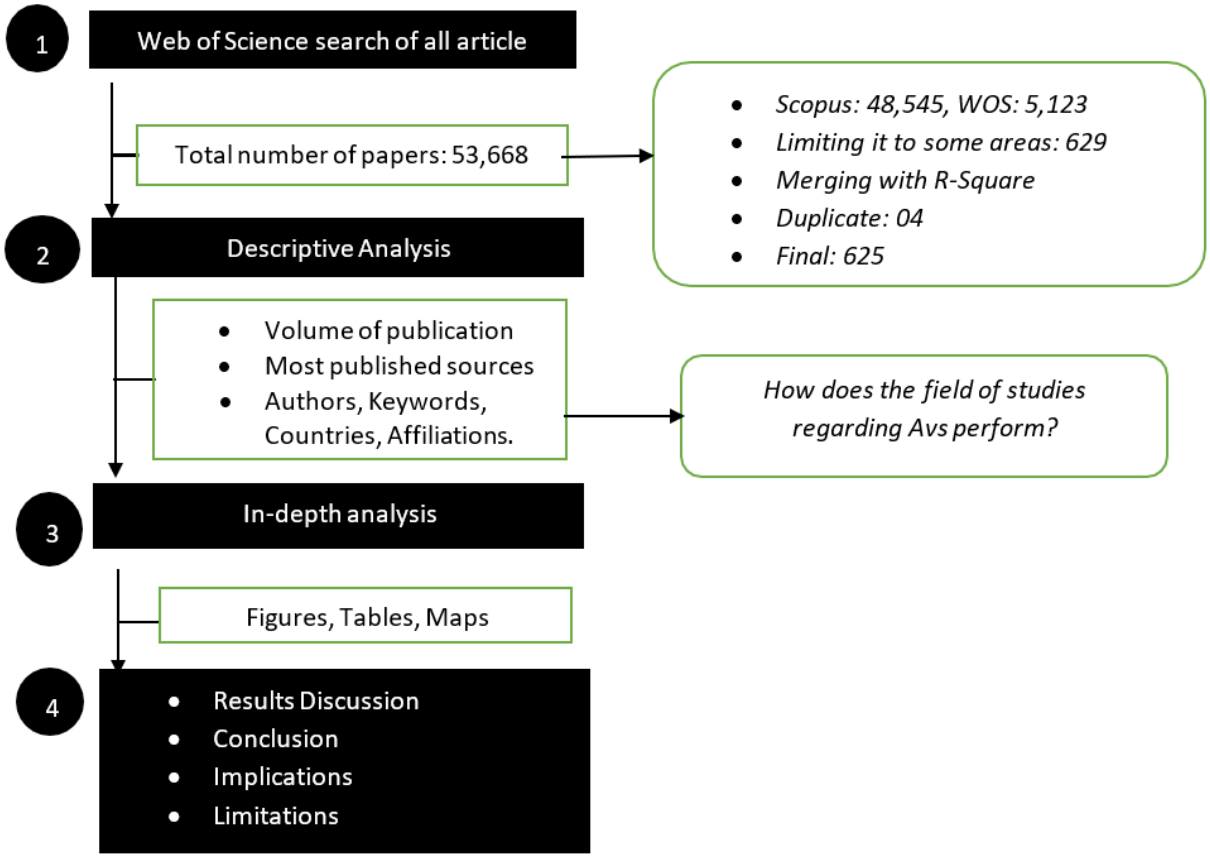

Figure 1: Methodology followed, Source: Authors composition

Materials and Methods

Data Collection

The study was carried out between 1986 and 2024. In addition to being descriptive, it uses a quantitative method to pinpoint the key features of the AV sector and its development, highlighting possible directions for further research. Based on papers indexed in the Thomson Reuters Web of Science (WoS) and Scopus databases, the study is described as "scientometric" and bibliometric. Through network modeling and visualisation, the technique—which is a quantitative approach.

According to Greenhalgh (1997), bibliometric analysis must be methodical, originate from primary studies, and be carried out using a clear and repeatable methodology. It must also include the objectives and clearly stated materials and techniques. Accordingly, the findings of bibliometric analysis are helpful for

1. Determining and comprehending the field of study for a particular subject.
2. Offering a comprehensive perspective on the historical development of the field.
3. Outlining a technological and thematic analysis; and 4. Offering proof and a foundation for further study.

Results

Trend on Autonomous Vehicle Worldwide

Table 1, represents the summarized statistics of data merged with the help of R-Square and analyzedwith “Biblioshiny” software from 219 sources. The main information extracted from data was that the publication started on this topic was 1988 till 2024, total documents generated from two major database was 625 with annual growth rate 13.13%. Total of 1899 authors worked on this single topic, some 1746 keywords were extracted with average citation 23.16. further we can analyze from figure 2that the highest number of papers published in 2022 (125 in number), which was initially started in 1988 with 1 published document. Publications were not so impressive till 2015 but it started getting momentum in 2016 till 2022 and the reasons were technology limitation, lack of data, high cost, regulatory and legal challenges, Public acceptance, limited govt and private funding etc.

Table-1: Trend on Autonomous Vehicle, Source: Authors Composition

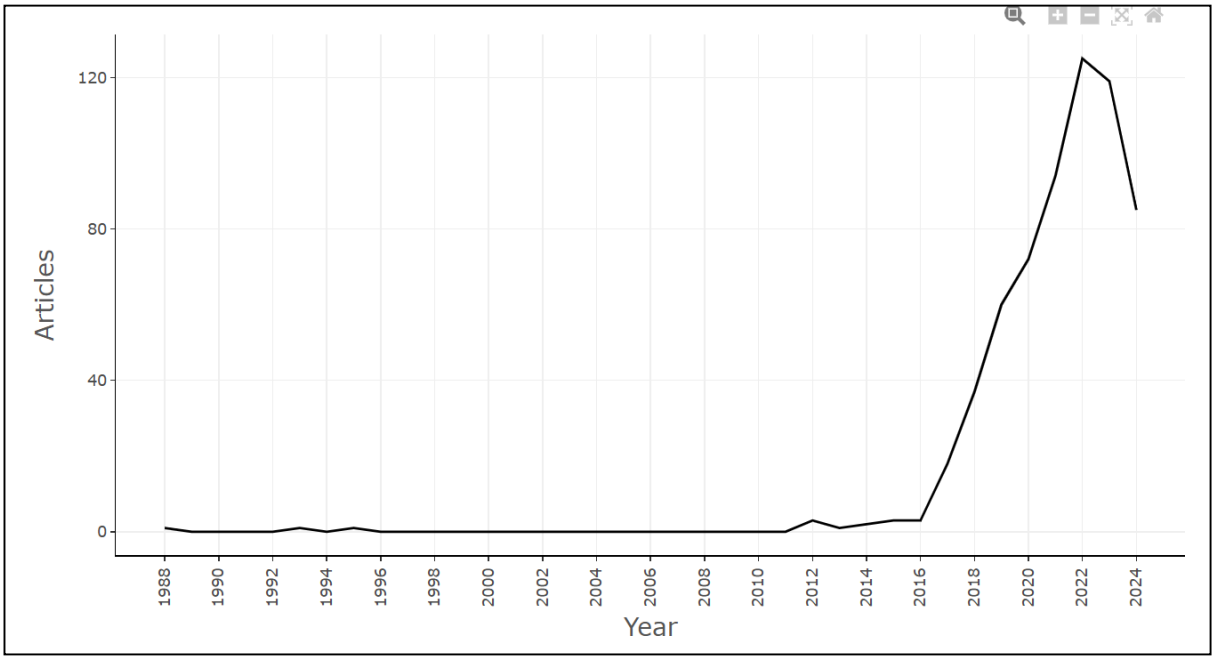

Figure-2: Annual Scientific Production, Source: Authors Composition

Countries Collaboration

As shown in Figure-3, The largest collaboration (hoe different countries are working together) found between USA with Bangladesh and Canada. Further the highest collaborating countries are China, USAand Canada. The top most 5 cited countries are UK, USA, China, Germany, Spain, Netherland.

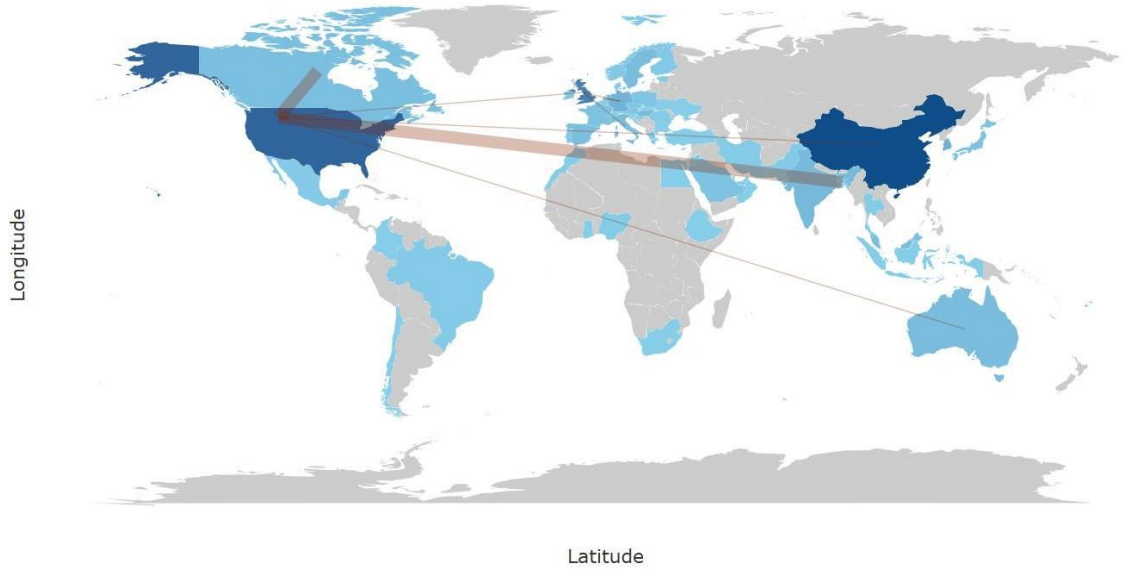

Figure-3: Collaborating Countries, Source: Authors Composition

Country	TC	Average Article Citations
UNITED KINGDOM	2914	44.80
USA	1576	25.00
CHINA	1341	10.40
GERMANY	1233	51.40
SPAIN	500	29.40
NETHERLANDS	452	34.80
AUSTRALIA	429	26.80
ITALY	380	29.20
GEORGIA	371	46.40
KOREA	355	12.70

Table-2: Most cited countries, Source: Authors Composition

Three-Field Plot

A three-field plot is a Sankey diagram that shows the connection between three relevant information,here we showed two types of three- field plot in the first figure countries lying on the left side, authorson the centre and keywords are on the left of the diagram, similarly, in the second figure we tried to find out the universities associated, so we again run the software keeping universities on the right. Note the height of the boxes and thickness (shows the amount of work) of the connecting lines, whichis known as field. As we can see in figure 4 China has the highest thickness, followed by Korea and USAconnecting to majority authors belong to China and keyword Autonomous vehicle. Whereas, in next figure, figure 5 we can see the highest thickness of Chinese universities itself.

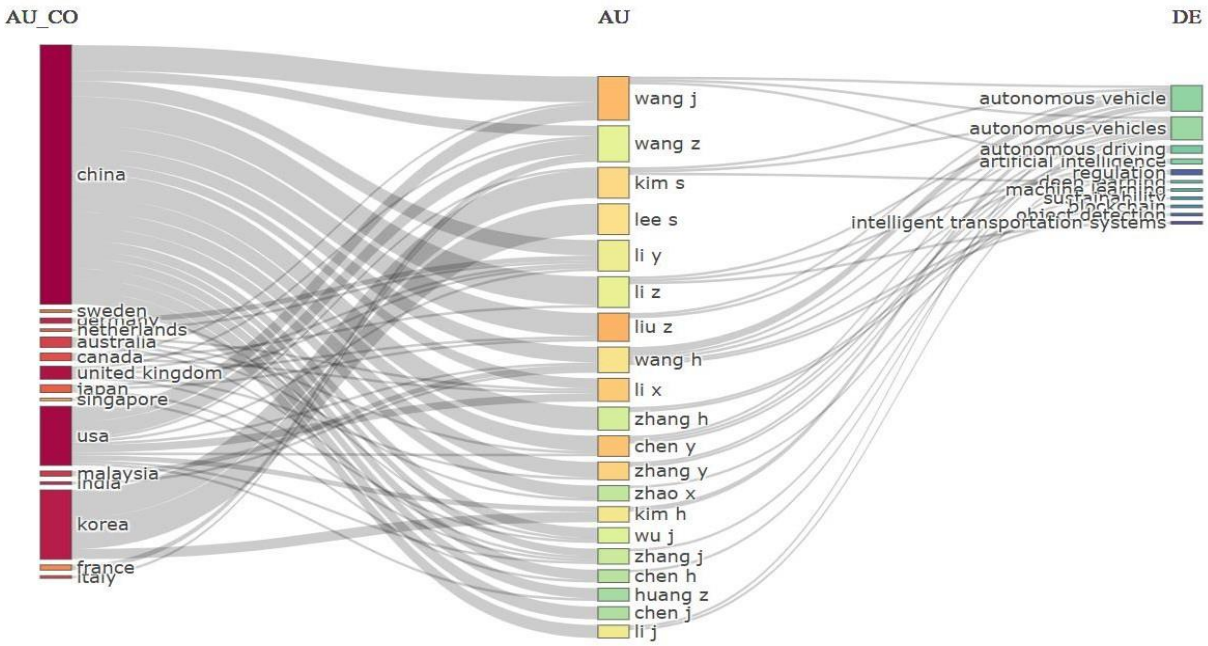

Figure-4: Three-Field Plot with Countries, Authors and Keywords, Source: Authors

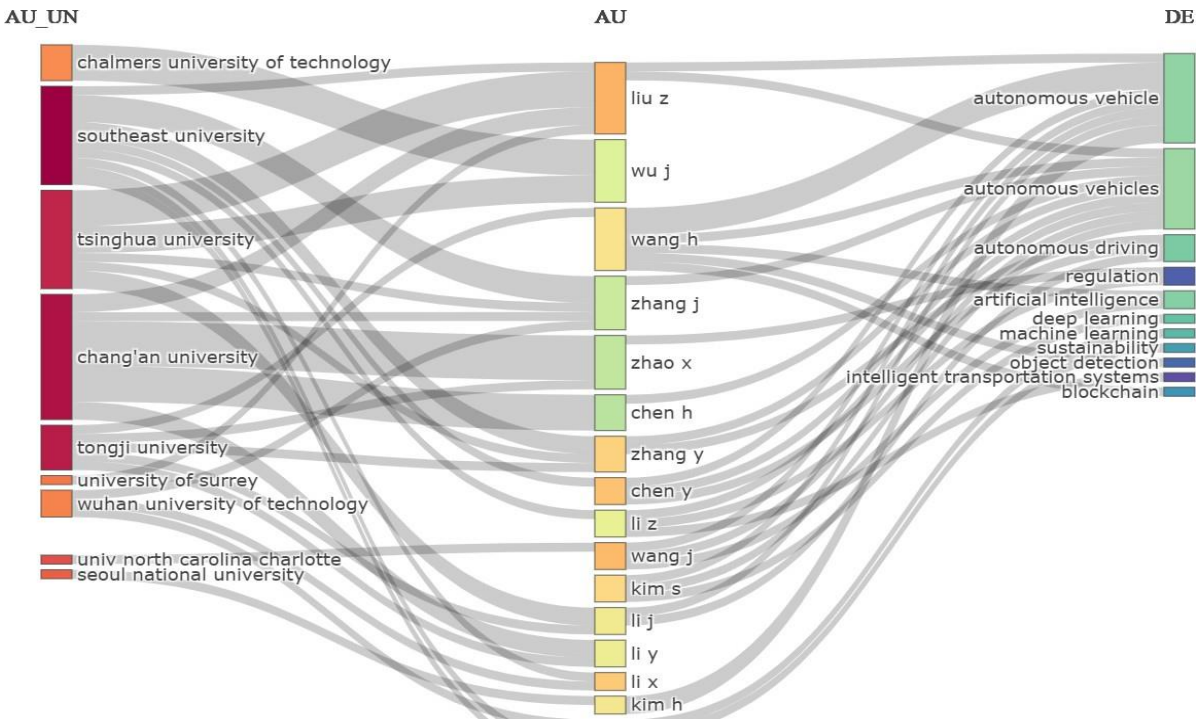

Figure-5: Three-Field Plot with Affiliations, Authors and Keywords, Source: Authors

Top Most Relevant Sources

The highest number of documents published in the "Journal of advanced transformation" with 125 number of documents, followed by "Transportation research Part A: policy and practice" with numberof documents published 37), "Advances in Transdisciplinary Engineering" (20), "Technological forecasting and social change (18) and "Sensor" (number of documents=16). Under Most relevant documents there is one more method to know the most productive journals that is "Brandford's Law".Which describes how articles are distributed across journals. As we can see in the below figure that there are only 5 major productive journals which consist of 216 articles (35% of the all articles).

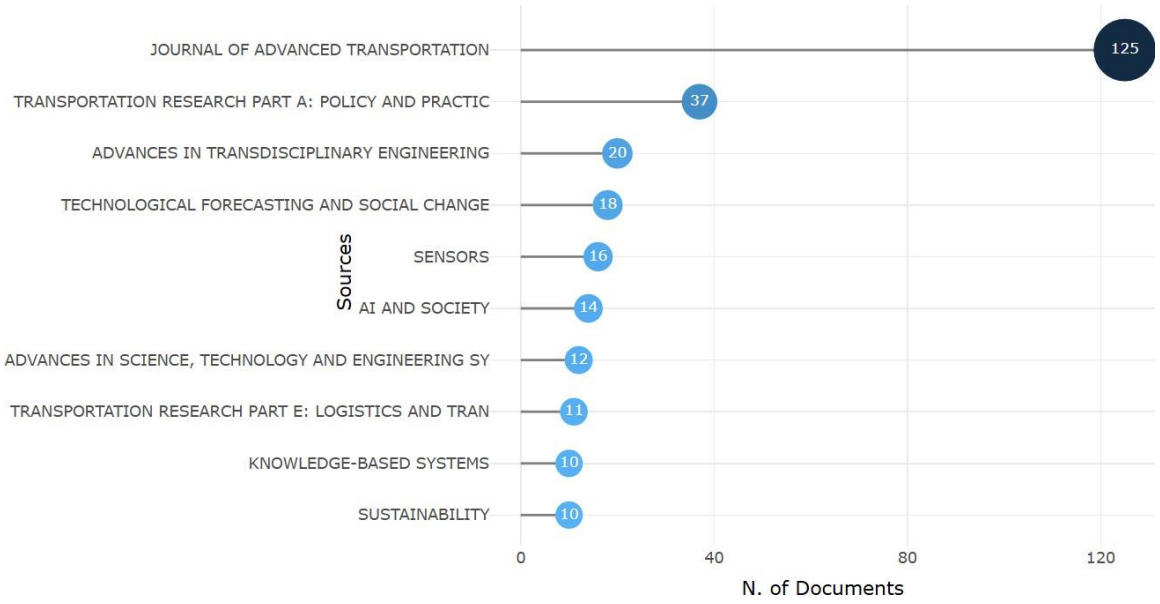

Table 3: Most relevant sources, Source: Author

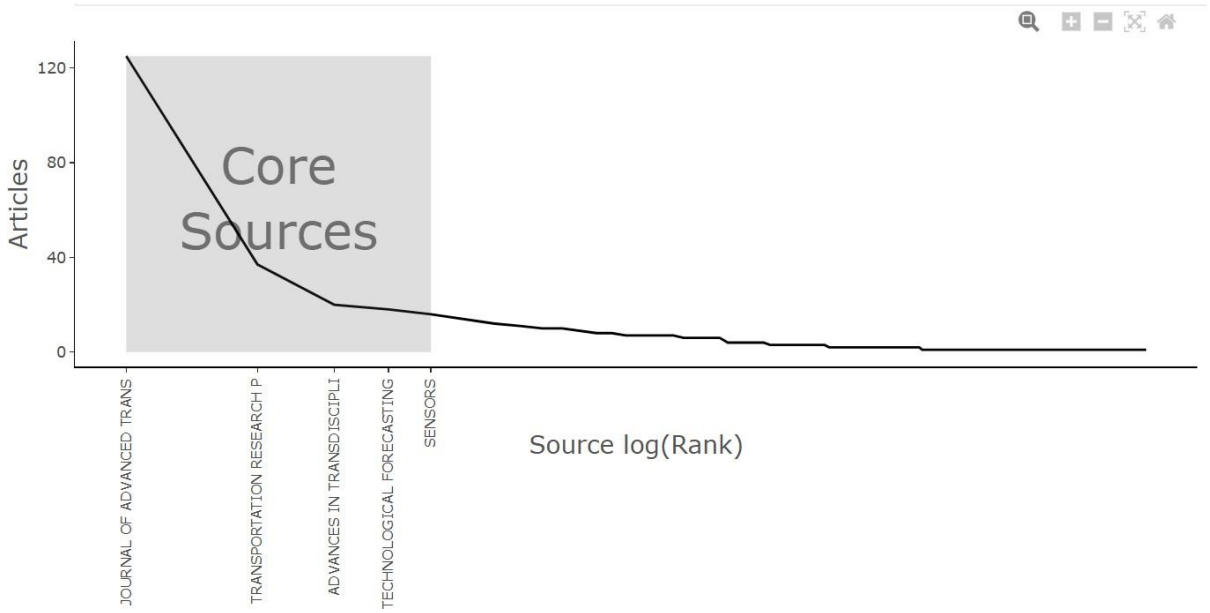

Figure 6: Brandford's Law, Source: Author

Corresponding Authors Countries

China, UK, USA, Korea and Germany are the highest Intra or Inter collaborating countries. Here, SCP means Intra-country collaboration and MCP means Inter-country collaboration. table 4 shows the division of total Articles into MCP and SCP, which means how frequently one country is collaborating within its own country and with different countries. China which has the highest number of articles. Below are few countries with inter and intra country collaboration.

Countries	Articles	SCP	MCP
CHINA	129	123	6
UNITED KINGDOM	65	60	5
USA	63	56	7
KOREA	28	25	3
GERMANY	24	22	2
HUNGARY	19	19	0
SPAIN	17	17	0
AUSTRALIA	16	16	0
ITALY	13	12	1

Table 4: Corresponding Countries, Source: Authors Composition

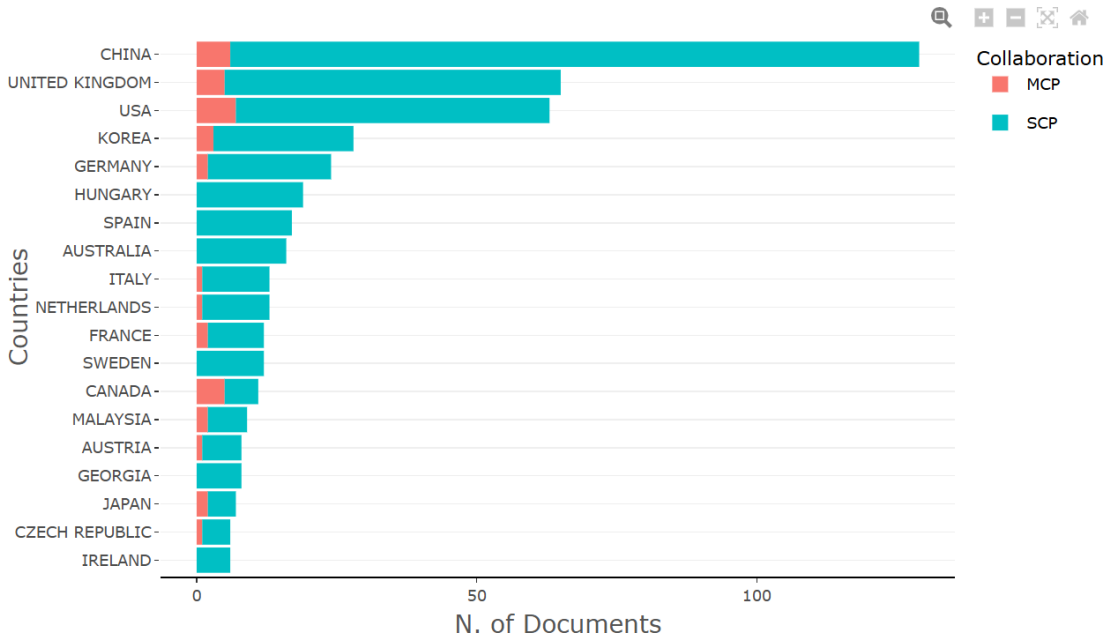

Figure 7: Corresponding Countries, Source: Authors composition

Trending Topics

The trending topics of 2024 are Model predictive control and Artificial intelligence technologies (frequency= 5 times) autonomous vehicle, autonomous driving, decision making, automated vehicle are the highest frequent words of 2021. Throughout the period after 2015 is Autonomous vehicle, occurred 412 times as denoted by green line in below figure as well.

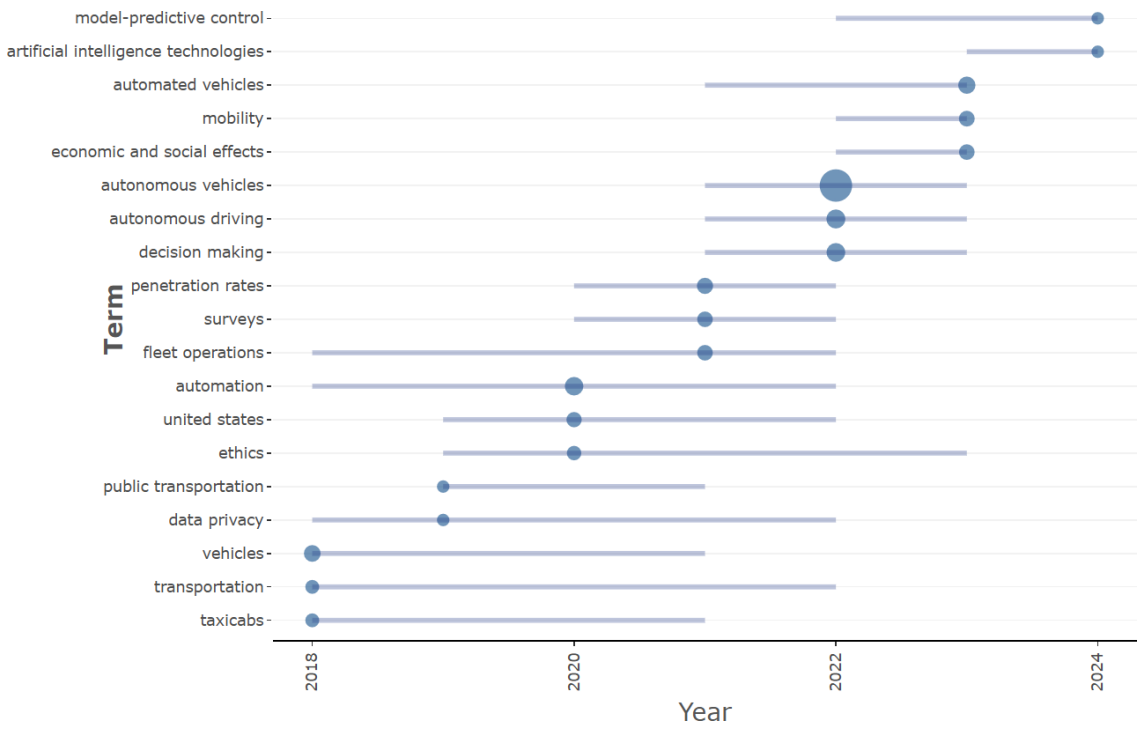

Figure 8: Trending Topics, Source: Authors Composition

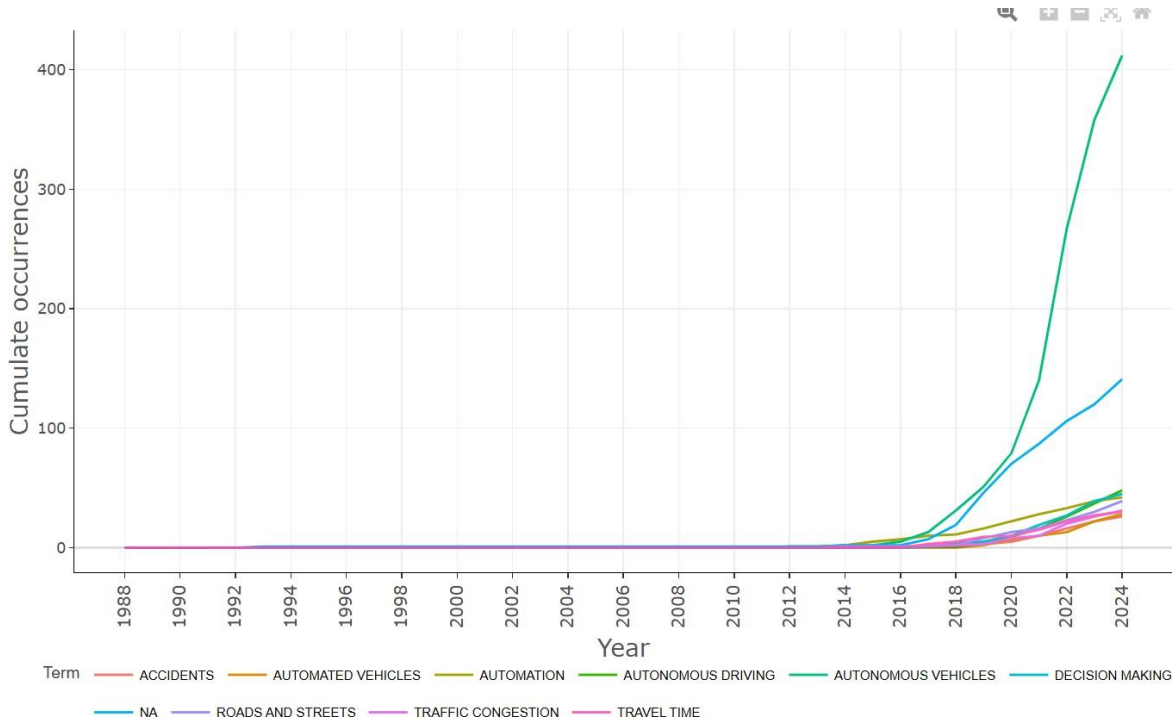

Figure 9: Most occurring terms, Source: Authors Composition

Co-Occurrence of Keywords

This diagram shows the highest co-occurred (occurring simultaneously in different papers) terms inNetwork and Overlay mode. As per these, Autonomous vehicle is the most occurred keyword and making a network with its own Group and other groups as well. There are four groups in different colours showing interrelationship. Overlay diagram is also used to show prominent areas of work, highlighted by dark red colour. Further, thematic map showing clusters of keywords, where X-axis represents the degree of interaction of a network cluster in comparison with other clusters and Y-axissymbolizes the density. The map is further bifurcated into four quadrants, the first one is motor theme, well developed and important theme, second quadrant (Niche Theme) plotted highly developed and

isolated themes, third quadrant contains weakly developed and fourth quadrant fall basic or general topics.

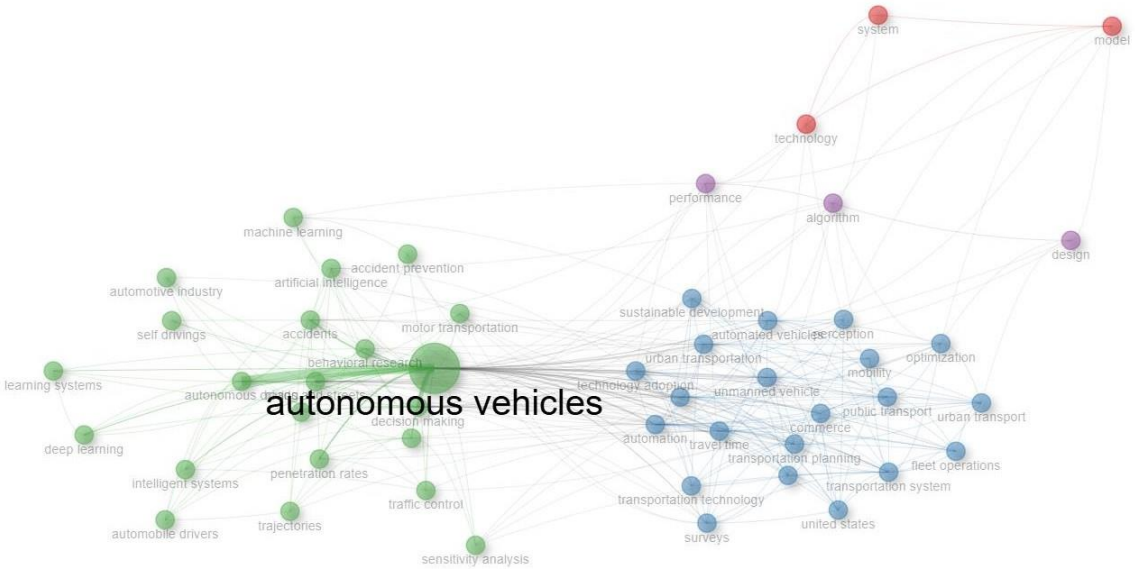

Figure 10: Co-Occurance keyword (Network), Source: Authors Composition

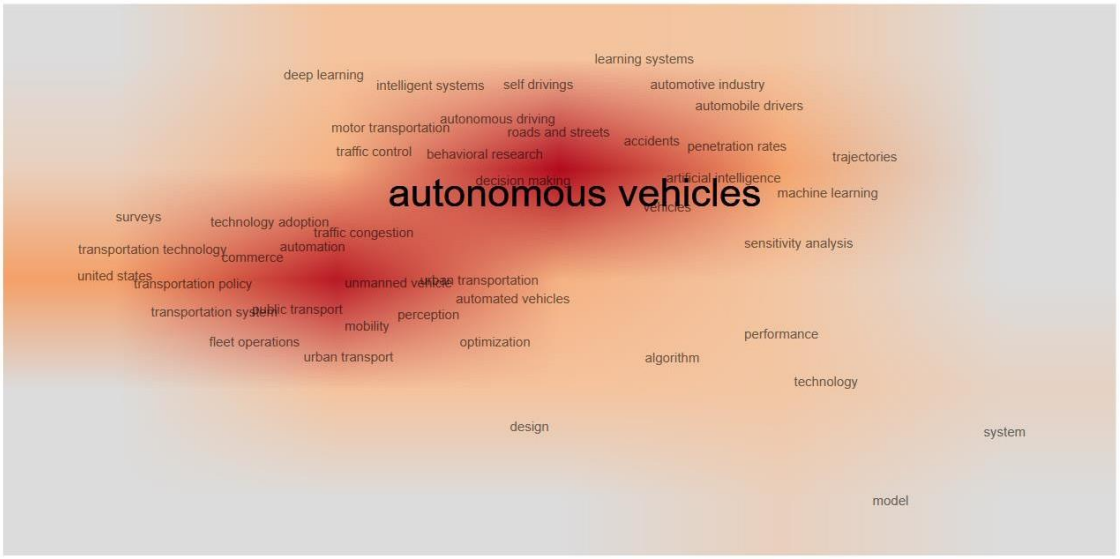

Figure 11: Co-occurance keyword (overlay), Source: Authors Composition

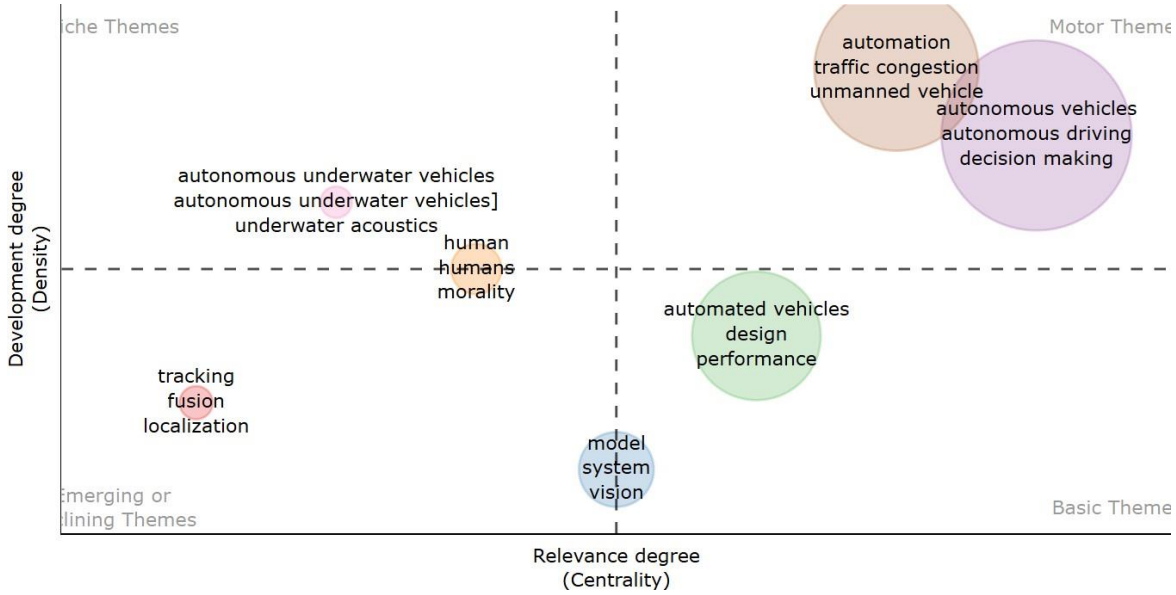

Figure 12: Trending Topics, Source: Authors Composition

Conclusion

The summarized statistics of data merged with the help of R-Square and analyzed with "Biblioshiny" software from 219 sources. The main information extracted from data was that the publication started on this topic was 1988 till 2024, total documents generated from two major database was 625 with annual growth rate 13.13%. Total of 1899 authors worked on this single topic, some 1746 keywords were extracted with average citation 23.16. additionally By examining ,AVs research during the previous forty years, this study demonstrates the historical evolution and trends. The number of articles that AVs research has produced the results says that there was no growth on research till 2015, but it started getting momentum in 2016 till 2022 and the reasons for lack in research were technology limitation, lack of data, high cost, regulatory and legal challenges, Public acceptance, limited govt and private funding etc. According to major distribution, there is very less study on other disciplines in AVs, with the majority of the concentration being on engineering and computer science (scopus database) and engineering and transportation (WOS database). Further research on additional fields can be conducted in the future. Based on the co-occurrence of authors, writers' collaboration in AVs research is more focused but still fairly close. to limited.geographical location like China. The cross-research shows that China, UK, USA, Korea and Germany are the highest Intra or Inter collaborating countries. AVs' primary research institutes include Tongji University, Tsinghua University, and others. Future research can increase collaboration across institutions with diverse disciplinary backgrounds, and the close ties between institutions enhance the legitimacy of AVs research. Over the years, researchers have focused their attention on a number of topics, including autonomous vehicles, automation, commerce, and decision-making. Meanwhile,

The trending topics of 2024 are Model predictive control and Artificial intelligence technologies (frequency= 5 times), autonomous vehicle, autonomous driving, decision making, automated vehicle are the highest frequent words of 2021, which can provide a reference forfuture research. The highest number of documents published in the "Journal of advanced transformation", "Transportation research Part A: policy and practice", "Advances in Transdisciplinary Engineering", "Technological forecasting and social change" and "Sensor". Under Most relevant documents there is one more method to know the most productive journals that is "Brandford's Law" which describe how articles are distributed across journals, and there are only 5 major productive journals which consist of 216 articles (35% of the all articles). As

per three-field plot China has the highest thickness (shows the amount of work), followed by Korea and USA connecting to majority authors belong to China and Chinese universities with the most worked keyword Autonomous vehicle.The final output is the largest collaboration found between USA with Bangladesh and Canada. Further the highest collaborating countries are China, USA and Canada and the top most 5 cited countries are UK, USA, China, Germany, Spain, Netherland.

In conclusion, the study helps researchers gain a thorough grasp of the subject of AV expertise and provides a more objective and scientific foundation for future quantitative research on AVs.

Research Implications

- The implications of autonomous vehicle research are far-reaching and impact various aspectsof technology, society, and the economy.
- Technologically, the research drives advancements in artificial intelligence, machine learning,and robotics, leading to more sophisticated systems capable of perceiving, analyzing, and making decisions in real-time.
- These innovations not only improve the performance of autonomous vehicles but also accelerate developments in related fields like smart cities, where vehicles could seamlessly integrate with infrastructure to optimize traffic flow and energy use.
- Socially, autonomous vehicles promise to revolutionize transportation by increasingaccessibility
- Economically, the widespread adoption of autonomous vehicles could lead to significant shiftsin employment, particularly in sectors like logistics, public transportation, and ride-sharing services.
- Environmental implications are also significant, as autonomous vehicles could lead to more efficient. However, there is also the potential for increased vehicle usage, which could offset these benefits unless managed through careful planning and policy.

Limitations

It is also important to highlight the flaws of the paper:

1. The study primarily relied on data from the WoS and Scopus core collections, potentiallyexcluding relevant articles not covered by these databases.
2. While the WoS and Scopus databases are commonly used in academia, thecomprehensiveness of their coverage is not guaranteed.
3. The data collection process was confined to academic journals, possibly overlooking pertinentresearch on Metro Urban Transit from other sources.
4. Paucity of Time and Funds.

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