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Research Article

Exploring the Landscape of Autonomous Vehicles Research: A Scientometric Analysis in the Context of Urban Transportation Planning

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ABSTRACT
Autonomous Vehicles (AVs) have the potential to (re)shape the urban transportation network drastically. The significant investment by the automotive industry and leading technology companies in AVs has resulted in a substantial surge in the number of published documents in this domain. Therefore, this study aims to analyze the current state and trajectory of AVs research by conducting a comprehensive review of the available literature. The study employs scientometric methods to examine the scientific landscape of AVs and assess the position of Urban Transportation Planning (UTP) within this context. The analysis encompasses both a macro-level perspective and a meso-level focus on UTP, utilizing datasets of journal articles published up to January 2023. The study addresses various questions such as identifying the main research trends, evaluating the impact and influence of countries and sources, determining the collaboration level among different countries, and assessing the maturity of AVs domain in the field of UTP. To accomplish this, the study analyzes the conceptual, intellectual, and social landscapes of AVs from both a holistic and macro-level perspective, as well as from the UTP perspective in a meso-level. The findings highlight a significant disparity between attention on AVs' UTP aspect and their technical advancement, emphasizing the need for more comprehensive research to fully comprehend the implications of AVs deployment from the UTP perspective. The comprehensive understanding of the literature gained from this study will enable scholars to identify research gaps, necessities, and potential avenues for future research.

Keywords: Autonomous vehicles, Automated vehicles, Urban transport, Transportation planning, Urban mobility, Urban form, Scientometrics, Bibliometrics, Literature review.

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INTRODUCTION

Technological advancements are profoundly influencing various facets of our daily lives, from healthcare and education to transportation and business. Although these advancements present promising possibilities, without well-designed and timely policies along with proper regulations in place, many of them could lead to disruptions and significant challenges. Autonomous Vehicles (AVs) are among the pioneering technological advancements that aim to enhance safety, convenience, sustainability, and the overall effectiveness of urban mobility.[1,2]

AVs as a rapidly growing trend in both research and industry worlds, have the high potential to revolutionize the automotive industry, transportation systems, and the way we live our daily lives. The roots of AVs can be traced back to the early 1920s,[3] gaining momentum in the 1980s when researchers successfully developed automated highway systems.[4] Subsequently, after 2004, the remarkable progress of AVs can be attributed to the extensive research on unmanned equipment conducted by the U.S. Defense Advanced Research Projects Agency, commonly known as DARPA.[5,6] As a result, legislative strides in some U.S. states marked a turning point, establishing a framework for the integration of AVs.[7]

The benefits of AVs extend beyond mere convenience, as they hold the potential to address critical issues associated with traditional transportation. From the reduction of crashes through advanced safety features[8,9] to the positive impact on traffic congestion and environmental concerns,[10] AVs promise transformative benefits. Additionally, the prospect of driverless taxis,[11] changes in car ownership dynamics,[12] and the synergy between AVs and electric vehicles[13] underscore the multifaceted advantages.

The interdisciplinary nature of the AVs' subject, coupled with enormous investments by automakers and technology leading

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companies, has resulted in an exponential increase in the number of research papers published on various aspects of this emerging technology. A simple search using the query "autonomous/automated vehicle/car" in the ScienceDirect database (as of January 2023) yielded nearly 20,500 published journal articles, conference papers, book chapters, reports, and other materials, demonstrating the booming interest in recent years.

Considering the volume of research studies on AVs, it becomes imperative to periodically monitor the trajectory, synthesize and summarize these materials to map the domain's landscape, identify its evolutions and key characteristics, pinpoint gaps, and develop a roadmap to detect potential trends. This undertaking aids planners, engineers, academics and other associates to form an efficient road for the future studies. Furthermore, it remains essential to consistently monitor the progress of the field and take proactive and visionary steps to maximize benefits while mitigating adverse impacts. Accordingly, the current study employs scientometrics analyses to depict a comprehensive review of the literature on AVs. This has been achieved by visualizing and mapping the scientific landscape of the domain at a holistic macro-level, along with the analysis of the literature from the perspective of Urban Transportation Planning (UTP) at a meso-level.

In the dynamic landscape of UTP, the emergence of AVs sparks a multifaceted discourse. While some foresee the potential for AVs to revolutionize urban mobility,[14] others raise concerns about the lack of comprehensive planning and regulatory frameworks.[15] The integration of AVs into urban environments necessitates a delicate balance, requiring collaboration between local authorities, researchers, and industries. Questions around safety, infrastructure adaptation, and societal acceptance loom large. Yet, amongst these challenges, the promise of reduced traffic accidents, optimized travel efficiency, and environmental benefits adds momentum to the ongoing conversation. Research continues to explore avenues such as the value of time, impacts on land use patterns, and the unique challenges and opportunities presented in developing countries.[16] As cities navigate the uncharted territory of AVs, the need for proactive, interdisciplinary approaches becomes increasingly evident.

Scientometrics analyses provide the opportunity of evaluating the conceptual, intellectual and social structures of the scientific domain from a statistical viewpoint, by making the scientific literature itself the subject of the study.[17] Numerous disciplines have employed scientometric-based methodologies to systematically analyze their own research fields. Notably, these include operations management,[18] environment and climate change,[19] medicine and health,[20] social science,[21] urban planning and smart cities,[22,23] and transport domain,[24-26] among others. Despite the tremendously increasing number of research studies related to AVs, there are relatively few available studies that have utilized scientometric analyses to scan the trajectory and evolutions of the domain.

Employing bibliometric analysis of 374 documents belong to 1999-2021 time-span, Azam *et al*.[27] mapped the scientific production of AVs in mixed traffic conditions. Shams Esfandabadi *et al*.[28] conducted a systematic bibliometric analysis using 729 peer-reviewed journal articles in the carsharing research field, considering both the conventional carsharing and the impact of AVs on the field.

Gandia *et al*.[29] deployed a combination of descriptive analysis and bibliometric analysis to determine the historical evolution of the AVs domain and main research trends by using a dataset of published documents up to 2018. This resulted in the observation of a non-fully constructed science in the field, as indicated by the dispersion of authorship. Furthermore, the absence of a consolidated state-of-the-art on this subject was identified. They also observed a slight evolution of business, economic, and management domains related to AVs. In the same vein, Faisal *et al*.[30] applied scientometric analysis to investigate the patterns, trends and interconnections among 4,645 published documents including journal articles, conference papers, book chapters, editorials, and other grey literature between 1998 and 2017. While they observed that only a limited portion of their dataset was published in peer-reviewed journals (28%), their results revealed a relatively limited collaboration and knowledge sharing between academia and industry.

In another review study of the literature on AVs, Rashidi *et al*.[31] employed bibliometric methodologies to elaborate on the evolution of disciplines related to AVs, along with utilizing qualitative analysis to provide insights into potential future scenarios involving AVs. For this purpose, they analyzed bibliometric records of 6,206 published articles and book chapters on Scopus within the time span of 1999-2018. The results of the bibliometric analysis led them to conclude that the focus of AVs studies should shift from a heavy emphasis on technological aspects, as the core of the literature, toward studying safety and behavioral aspects related to AVs.

Bearing in mind that the AVs' technology is intended to be implemented in urban environments, which will ultimately be the end destination of this giant technology, mapping the overall literature on AVs by evaluating the position and relevance of the UTP-related research within this domain arises as a crucial necessity. Meanwhile, the conducted literature review reveals a lack of studies specifically focusing on the UTP aspect of the AVs domain. To address this gap and enrich the existing literature, the present study has deployed a comprehensive and thorough dataset of published peer-reviewed journal articles up util January-2023. These articles have been analyzed at an aggregate level from a holistic perspective, along with an additional set of analyses concentrated on the UTP niche of the field.

Aligned with the primary objective of this study, which is to map the scientific structure of the AVs field and evaluate the place of the UTP in this domain, a variety of key questions have been raised to achieve these objectives: what are the primary research trends and the progress directions within the AVs domain in recent years? What are the future directions of research? Which topics, sources, or countries have the most impact and influence on the domain? How is the collaboration level between different countries on a global scale? Is there an adequate amount of research within the UTP domain to prepare end-users and responsible authorities for the impending technology? Finally, to what extent has the AVs domain matured in the context of UTP?

The remainder of the article is structured as follows: In Section 2, a comprehensive explanation of the deployed methodology is provided, followed by a detailed description of the utilized data in Section 3. Section 4 is dedicated to the analysis of the data and presentation of the results. Following this, Section 5 discusses the findings of the study. The conclusion is presented in Section 6, and recommendations for future research are outlined.

METHODOLOGY

Automated vehicles are a topic of significant interest in today's world, encompassing various disciplines from engineering and physics to astronomy and even psychology.[32-35] The wide scope of this field has resulted in a substantial increase in the number and depth of published research on various aspects of this emerging technology. A straightforward search on reputable science databases will yield a vast number of published materials, including journal articles, conference papers, book chapters, review papers, reports, and other forms of scholarly works, spanning a broad range of disciplines and categories. Therefore, it is crucial to regularly synthesize and compile these multifaceted research outputs within specific areas of expertise in order to advance the domain and efficiently direct the progress toward its desired future. To achieve this, scientometric analysis methods are powerful quantitative techniques that can be used to map the scientific landscape of different fields and review existing literature in a structured manner.[17]

Scientometrics and bibliometrics are systematic methodologies that utilize the scientific literature as the object of study to examine the characteristics and patterns of scientific research and its corresponding literature. Within the literature, the terms "scientometrics" and "bibliometrics" are often used interchangeably to describe similar and overlapping methodologies. Bibliometrics focuses on the relationship of numbers and patterns in bibliographic data and use, for instance, titles, abstracts, authors information, keywords, and references in the given field.[31] It aims to measure the impact and productivity of individuals, institutions, and countries in science and technology. In contrast, scientometrics is a broader field that encompasses bibliometrics and can also be used to evaluate the structure and dynamics of science, technology and innovation. Scientometrics involves a systematic analysis of the numerical aspects of the production, dissemination, and utilization of scientific data, with the aim of gaining a more comprehensive understanding of the mechanisms of scientific research.[36] Both methodologies (a.k.a. science mapping) are employed to guide policy decisions and evaluate the effectiveness of research funding.

Five main methods have been used in science mapping analysis:[37] (i) Co-occurrence analysis, to assess the studied concepts and aspects of the domain and estimate their connections based on the occurrences of common words in the title/abstract/keywords of the documents, (ii) Co-author analysis, to analyze the social structure of the domain and evaluate the collaboration of authors based on co-authorship data such as authors' name, their organizations or countries, (iii) Direct-Citation analysis, to quantify the impact and influence of the publications, authors, sources, organizations or even countries, based on the assumption that the more citation a document receives, the more important it is,[38] (iv) Co-citation analysis, to evaluate the similarity between authors, documents, and sources, that utilizes the frequency of common citations shared between two items as cited by a third document, as a means of determining the similarity,[39] and (v) Bibliographical coupling, to measure the similarity between authors, documents, sources, organizations and countries based on the frequency count of common references that two items, have cited a third document simultaneously.[40]

The evaluation of the domain's intellectual structure, as has been clarified in Figure 1, is the focus of the last two methods. The co-citation method assumes that as the frequency of concurrent citations of two items by third documents increases, the likelihood of their contents being similar increases. The bibliographic coupling method, on the other hand, is based on the assumption that when the count of shared references between two items increases, they are likely to have significant similarity in their contents.[39,41]

The proposed workflow for conducting scientometric analyses within this study comprises a five-step process. Initially, the

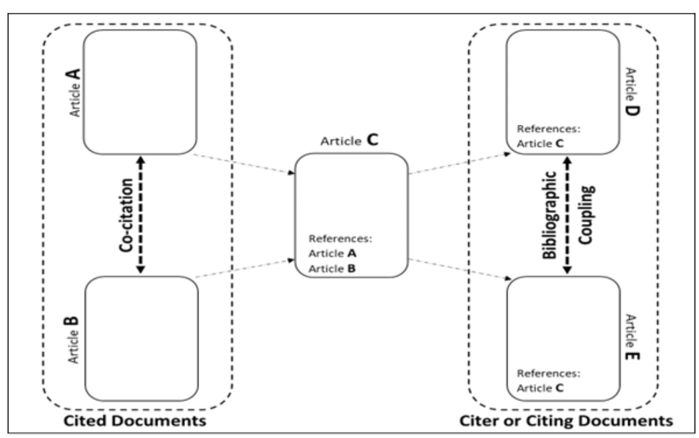


Figure 1: Co-citation and bibliographic coupling methods for references.

whys and wherefores for utilizing these analyses within the domain under consideration have discussed and elucidated in the Introduction section. Subsequently, to compile the required datasets, a suitable database will be selected and, in accordance with the analyses requirements outlined in the initial step, the data will be filtered and extracted. Furthermore, based on the analysis objectives and the obtained data, the most appropriate scientometric analysis software will be employed. Depending on the requirements, multiple software tools may be utilized for different types of analyses. The following step involves the analyses of the data and the visualization of the results in a comprehensive manner. Finally, the analyses results and visualizations will be interpreted and conclusions will be drawn.

DATA ACQUISITION

In order to obtain accurate and dependable answers for the research questions raised in the introduction part, it is essential to choose a precise database with maximum comprehensiveness and precision. Some of the most widely recognized sources include Google Scholar, ScienceDirect, Web of Science, and Scopus. Google Scholar has one of the broadest ranges of publications, and with ScienceDirect, they are more common databases among researchers and academics. However, it should be noted that none of these databases provide the capability of automatically exporting bibliometric data. In contrast, both Scopus and Web of Science are widely used databases that comprise a wide range of high-quality scholarly literature and possess the feature of automatically exporting bibliometric data. For the present study, Web of Science[1] (WoS) was selected as the database to export the required bibliometric data, as most scientometric software tools are more compatible with its data, as per the instructions in their manuals.

In light of the highly multidisciplinary nature of the AVs domain, an initial search query was conducted to analyze the literature at a holistic and macro-level. The search query included all available designations for AVs in titles, abstracts, and keywords of documents, such as "autonomous/automated vehicle(s)/car(s)", "autonomous/automated driving", "driver(-)less vehicle(s)/car(s)", "self(-)driving vehicle(s)/car(s)", "robotaxi", and "autopilot vehicle(s)/car(s)". To minimize the false positive results, a number of unrelated categories (such as "medical informatics", "surgery", "cell biology", "chemistry organics", or "mineralogy") were individually and manually checked and excluded. The full list of excluded categories, as well as the detailed version of the final search query can be found in Appendix A. By selecting the document type as "articles", the language as "English", and without any time limitations, the final dataset for the macro-level analyses was formed and retrieved. The last update of the macro-level dataset was on January 2023, and it includes 14,722 peer-reviewed journal articles. The macro-level dataset will be referred as D_{Macro} hereupon.

The second primary objective of this study is to conduct a meso-level analysis of the literature on AVs from UTP perspective. To achieve this objective, it is necessary to acquire an additional dataset. To this end, a list of keywords (comprising both authors' keywords and indexed keywords) was retrieved from D_{Macro} and carefully examined, meanwhile the titles and abstracts of 20% of the randomly selected papers from D_{Macro} were examined individually and separately. These examinations resulted in the extraction of a comprehensive set of UTP-related words and terms, which were subsequently categorized into seven distinct groups, as follows:[2]

(I) acceptance, adoption, attitude, preference, purchase, consumer, opinion, willing*, "public perception$", "consumer perception$", "user perception$", "public concern$", "public interest", "public awareness", "intention to use"

(II) "travel behavio$r", "travel pattern$", "travel demand$", "transport* demand$", "induced demand$", "transport* planning"

(III) "Land use", "residential location$", "residential relocation$", "location choice$", "urban sprawl", suburbanization, "urban form", "urban growth", "urban development", "urban characteristics", "urban planning", "urban design"

(IV) "Mode choice$", "discrete choice$", "choice model*", "stated choice", probit, logit, questionnaire, survey, gender, age, household, "focus group$", "value of time", "value of travel time"

(V) Sustainable*, "smart cit*", "urban mobility", "built environment"

(VI) Equity, "social exclusion", "socio technical", governance, "liability", legal*, justice, trolley, moral, "law", regulation", policy, policies, ethic*, incentive, legislat*

(VII) Maas, "mobility as a service", "car sharing", car$sharing, "ride hailing", ride$hailing, "ride sharing", ride$sharing, "ride sourcing", ride$sourcing, "sharing economy", "on demand", "demand responsive", pooling, "sharing mobility", "park and ride", "last mile", "first mile", "first last", ownership, parking

Since the AVs literature is highly interdisciplinary in nature, using any of the above-mentioned words or terms as a search query to titles, abstracts, and keywords of the articles indexed by WoS will yield in results from a wide range of categories, many of which may not be relevant to the domain of UTP. For instance, using the query of "policy" alone, could lead to irrelevant results, such as a paper with title of "Obstacle Avoidance for Self-Driving Vehicle with Reinforcement Learning".[42] The paper's abstract focuses on employing reinforcement learning for obstacle avoidance in self-driving vehicles, which has no relation to UTP and does not align with the objectives of the current study, although it has used

1 Clarivate Analytics Web of Science (http://www.webofknowledge.com)

2 For further information on wildcard definitions in the WoS core collection, please refer to the link below: https://images.webofknowledge.com/images/help/WOS/hs_wildcards.html

the word "policy" in the context of "Deep Deterministic Policy Gradients (DDPG) algorithm". Hence, to ensure the accuracy of the data and minimize false positive results, it is essential to establish an additional set of query strings to work as a filtering set. This was achieved by individually reviewing the results obtained from adding each one of the aforementioned words/terms to the search query, and verifying whether their results align with the objective of the meso-level analysis and pertain to the domain of UTP. In instances where the results were not relevant, efforts were taken to extract one or a few keywords to form a set of filtering query string. Each component of the filtering query string was then independently reviewed and manually controlled to prevent any false negatives. Creating this filtering query set was quite a challenge, given its complexity and non-straightforward nature. At the end, a comprehensive list of filtering query string, categorized in eight distinct groups was provided, as presented in Appendix B.

By implementing the established filtering query string and adding the set of UTP-related words/terms to the D_{Macro}, the data set required for the meso-level analyses of the study (i.e., D_{Meso}) has been retrieved. D_{Meso} was last updated in January 2023, containing 1,870 items. The full bibliographic information of both datasets was extracted from the Web of Science database and stored as text files. This information includes various elements such as the title of the document, author details, publication year, source journal, citation frequency, document categorization, abstracts, author-generated keywords, indexed keywords, and a list of references for each item.

DATA ANALYSIS AND RESULTS

There are several software tools that are able to carry out scientometric and bibliometric analysis methods. VOSviewer,[43] Bibliometrix,[17] SciMAT,[44] CiteSpace,[45] and BibExcel[46] could be named as the prominent science mapping tools. As each tool has its own strengths and limitations and based on the specific requirements, research questions, and the objectives of the studies, it is important to select the appropriate tool(s). Taking this into account, in the present study, VOSviewer (version 1.6.17), Bibliometrix R (version 4.1.3), and CiteSpace (version 6.1. R6) were utilized to analyze, visualize and map the scientific landscape of AVs literature.

VOSviewer is a free software developed using the Java programming language by van Eck and Waltman[43] at the University of Leiden (The Netherlands). It has strong visualization capabilities and supports all bibliometric analysis methods. Bibliometrix, on the other hand, is an open-source tool developed as an R package by Aria and Cuccurullo[17] at the University of Naples and the University of Campania Luigi Vanvitelli (Italy), with the capability of performing extensive science mapping analysis. The tool can be operated in RStudio or its web-interface, Biblioshiny, can be used. Lastly, CiteSpace is a software tool for visualizing and analyzing scientific literature developed by Chaomei Chen[47] at Drexel University (US), using the Java programming language. CiteSpace has been applied in various fields, including bibliometrics, scientometrics, and intellectual structures.

The distribution and soaring interest in AVs-related topics, both holistically and from the UTP perspective, are depicted in Figure 2. As can be seen, interest in the AVs domain began to arise between 2010 and 2012, and has experienced a sharp increase since around 2014. In the same vein, UTP aspect of the domain began to receive attention from scholars around 2014-2015, and began to expand since around 2017. Key bibliometric information of the extracted datasets is provided in Table 1. As is evident from this table, the earliest published articles of the macro- and meso-datasets date back to 1974 and 1991, respectively. However, it is worth mentioning that the macro-dataset experienced its first year in which over 100 articles were published annually in 2012, while the meso-dataset experienced its first year in which double-digit total yearly articles were published in 2015.

The following subsections of the study examine the conceptual, intellectual and social structures of the AVs literature at a holistic level, as well as the UTP-related literature.

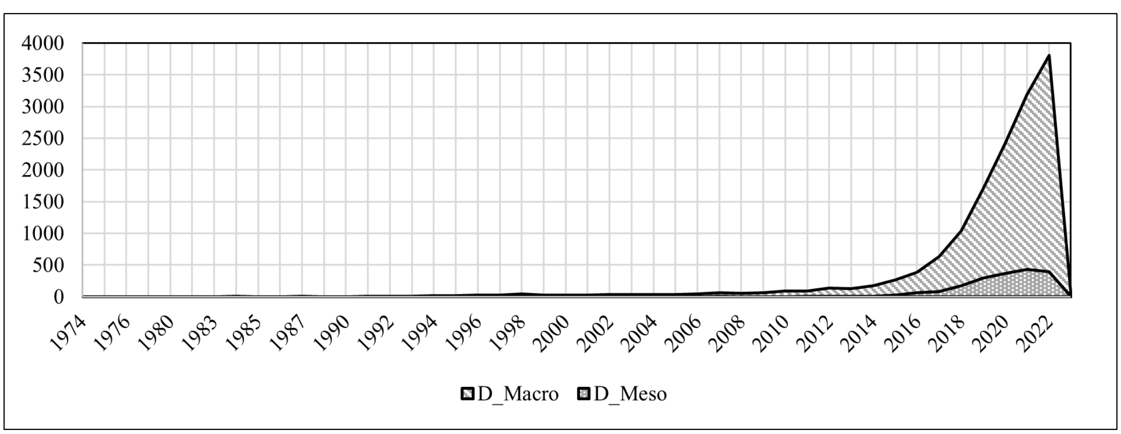


Figure 2: Soaring number of AVs-related published articles over years.

Conceptual Landscape

Co-occurrence analysis of keywords occurring in published documents within a particular field allows for the visualization of the conceptual structure of that research field. In this study, this is achieved using of the VOSviewer software, which utilizes a similarity matrix as input and subsequently calculates association strengths as similarity indexes.[43]

A total of 33,856 keywords, comprising an aggregation of author keywords and indexed keywords, with overlapped keywords being counted only once, were extracted from the macro-level dataset, D_{Macro}. By implementing the criterion of minimum of 5 occurrences per keyword, of these keywords, 3,013 pass the threshold, and the top 1,000 most frequently occurred keywords are shown in the visualization presented in Figure 3. The size of the bubbles indicates the frequency of occurrence of the corresponding keyword in the examined dataset; the more a keyword is repeated in, the bigger its corresponding bubble is. Additionally, the proximity of the labels in the visualization serves as an indicator of conceptual similarity, with closer labels indicating a higher degree of similarity.

In spite of the spatial overlap that exists among keywords of D_{Macro} , they can be classified into six distinct clusters, as demonstrated in Figure 3. These clusters depict the conceptual structure of the AVs research domain at the macro-level, thereby indicating the presence of six major subdisciplines within the field. The clusters, as inferred from the most frequently occurring keywords in each cluster, can be labeled as (i) Sensor technology and navigation (ii) Vehicle dynamics and motion planning (iii) Intelligent transportation, connectivity and IoT (iv) Human factors in AVs and driver-vehicle interaction (v) AVs adoption, attitudes, acceptance, and demand for AVs (vi) Traffic flow management and control. The conceptual analysis map demonstrates that keywords pertaining to UTP are categorized within cluster five, which is depicted in purple. When compared to the size of bubbles, the bubbles representing this cluster are noticeably smaller, indicating a limited extent of this branch within the entire domain. The hybrid map Figure 3, right side) portrays the average citation of keywords across all clusters. Keywords with higher average citations are depicted in a redder shade, indicating their trending nature and their significance within the AVs domain. As the hybrid map indicates, all clusters possess at least a few red bubbles, implying that the AVs domain, in all of its subfields, remains a non-exhausted and not-yet-matured field. Table 2 presents the most prominent keywords that are characteristic of each cluster, and highlights the keywords within each cluster that have, on average, been cited most frequently.

An identical methodology was implemented in the analysis of the meso-level dataset, D_{Meso}, which comprised a total of 6,262 keywords. These keywords were derived from an amalgamation of author keywords and indexed keywords, with duplicated keywords being counted only once. Of the extracted keywords, those that met the criterion of a minimum of 5 occurrences, 488 in total, were included in the representations illustrated in Figure 4.

Similar to the macro-level dataset, regardless of the spatially overlapping of the keywords, the meso-level dataset can be conceptualized under four distinct clusters. Based on the most frequently occurred keyword in each cluster, these clusters can be named as (i) User acceptance, adoption, and trust, (ii) Demand

Table 1: Key bibliometric information about the extracted datasets.

	Description	D_{Macro}	D_{Meso}
Main Information	Timespan	1974 - 2023	1991 - 2023
	Sources (Journals)	1,680	550
	Documents	14,722	1,870
	Average years from publication	3.92	3.30
	Average citations per documents	16.45	19.94
	References	336,146	66,386
Document Type	Journal Article	14,722	1,870
Document Contents	Author’s Keywords	28,978	4,682
	Indexed Keywords	7,355	2,128
Authors	Authors	30,365	4,642
	Authors of single-authored documents	672	216
	Authors of multi-authored documents	29,693	4,426
Authors Collaboration	Single-authored documents	793	238
	Documents per Author	0.49	0.40
	Authors per Document	2.06	2.48
	Co-Authors per Documents	3.98	3.42

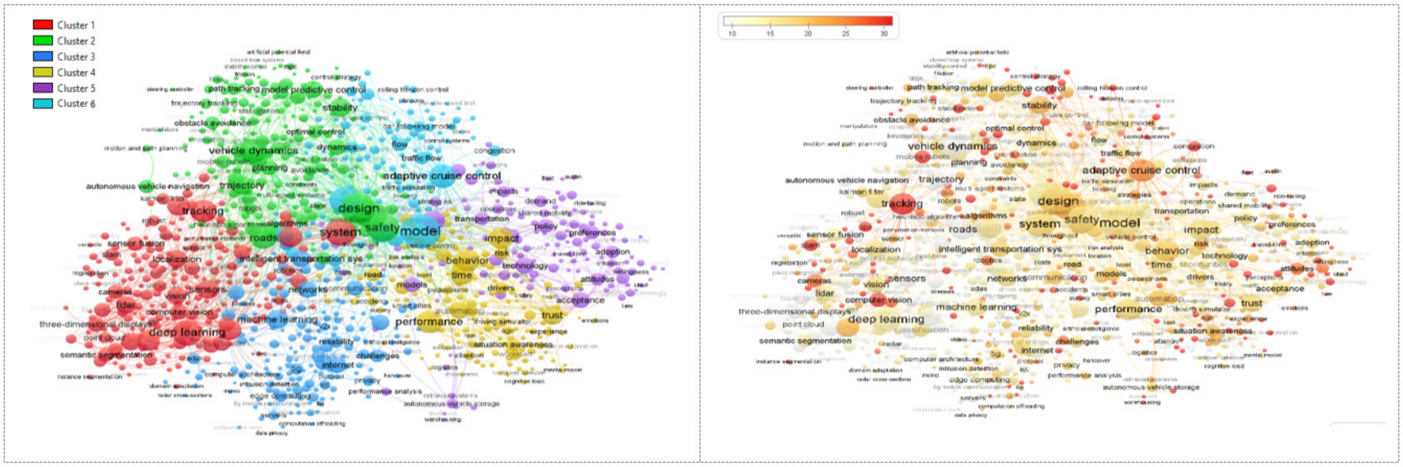


Figure 3: Conceptual analyses of macro-level dataset, D_{Macro}, based on co-occurrence analysis of keywords (left), as well as hybrid map of the average citation (right).

estimation, mode choice, and shared modes, (iii) Sustainability, built environment, and policies, and (iv) Ethical problems of AVs deployment. The analysis illustrates that clusters three and four (depicts in green and yellow respectively), representing policy-related and ethical topics, received comparatively less attention from the transportation planning academic community compared to the two major clusters (i) and (ii). However, it is important to note that the nature of these clusters is interrelated, with some keywords lying on the boundary between multiple clusters, such as “policy” connecting all four clusters, or “preferences” bridging clusters two, three, and four.

Intellectual Landscape

The literature’s intellectual structure endeavors to comprehend the impact of the internal intellectual research tradition, research program, and community on the shaping, influence, and evolution of the science domain.[48] Different citation-based methods of the scientometric analysis (as explained in Methodology section) can be used to map the intellectual structure of a field and highlight the research fronts.[49] Depending on the unit of the analysis, i.e., authors, documents, sources, organizations or countries, any of the co-citation, bibliographic coupling, or direct-citation analysis methods can be employed to obtain and visualize the required results. However, co-citation and bibliographic coupling are the two dominant methods in the scientific mapping of literature. Although the two methods look similar, their analytical scopes are totally different: the latter utilizes a static approach, while the former employs a dynamic approach. In other words, a co-citation indicates a relationship extrinsic to the documents involved, as it is based on papers aside from those it links. In contrast, bibliographic coupling is based on the involved documents references and is intrinsic to those documents.[18] Few research studies have investigated the accuracy of different citation-based analysis approaches to represent the research frontiers. As one of the most comprehensive studies, Boyack and Klavans[49] after comparing the accuracy of the three citation-based methods with a database of 2,153,769 articles from biomedical literature (2004-2008) have concluded that bibliographic coupling slightly outperforms co-citation analysis, while direct citation has been found as the least accurate method.

In the present study, to perform a more precise analysis, and based on the above explanations, the coupling technique is used to delineate the most productive and influential sources, along with dual-map overlays, and analysis of temporal patterns to map the intellectual landscape of AVs at a full-scope macro-level, in addition to its transportation planning branch.

The most productive and most influential sources

The bibliographic coupling analysis method was employed to analyze 1,680 sources within the macro-level dataset, D_{Macro}. Out of these sources, 431 met the established criterion of a minimum of 5 documents per sources. A density map, presented in Figure 5, was generated through normalization of data using the association strength method, and assigning similarity weights for mapping based on the number of published articles per source.[50] The results of the analysis demonstrate that sources located in the hot spots of the map are the most productive in the AVs research field, while the distance between labels indicates the conceptual similarity of these sources as determined by mutual citations they have received in total. The closer the sources’ labels, the greater the degree of conceptual similarity. As can be seen for the density map of D_{Macro}, the hottest spots of the map, are mainly concentrated on the left part of the map, whereas “IEEE Transactions on Intelligent Transportation Systems”, “IEEE Access”, and “IEEE Transactions on Vehicular Technology” are examples of the most dominant ones. Meanwhile, the majority of sources which mainly publish the transportation-related articles are concentrated on the right part of the map, with “Transportation Research Part C-Emerging Technologies” and “Sustainability” being the hottest spots.

The same methodology was utilized for the meso-level dataset of transportation planning, D_{Meso}, in which out of the 550 sources, 64 met the threshold of minimum 5 documents per sources. Its result is also depicted on Figure 5 with a comparison provided in Table 3 showing the top ten most productive sources along with their citation numbers. From the sources of the transportation planning subfield, two sources (i.e., Transportation Research Part C-Emerging Technologies, and Sustainability) are common among the top ten sources of the macro-level dataset, whereas only 23% and 47% of their whole published articles are belong to the transportation planning-related domain. This highlights a heavy concentration of the AVs research field on technological aspect, as well as the eventually increasing attention and focus towards this crucial sub-field of AVs by scholars and researchers.

Furthermore, to determine the most influential sources, the citation per document for all sources was calculated, and the list of top ten most influential sources for both macro and meso datasets have been provided in Appendix C. For the macro-level dataset, the "Nature" journal with ten documents and an average of 204.5 citations per document holds the top rank for most influential source. No sources related to transportation planning are among the top ten influential sources in the macro-level dataset. For the meso-level dataset, the journal "Transportation Research Part A-Policy and Practice" holds the top rank, with 91 published articles and an average of nearly 60 citation per document. This highlights a growing focus and attention on policy and planning aspects within the AVs domain.

Dual-map overlays

The dual-map overlays, have designed by Chen and Leydesdorff[51] as a means of illustrating patterns within a scientific portfolio in relation to a global map of scientific literature. In other words, dual-map overlay analysis is a useful tool to gain a comprehensive understanding of the field's evolution. It depicts the dataset within the framework of a global map of science, which has been constructed utilizing a corpus of over 10,000 journals indexed in the Web of Science. These journals have been grouped into regions that reflect publication and citation activity at a disciplinary level. The term "dual-map" pertains to the citing and cited component maps included within the overall visualization. Through the overlay of a set of articles, it is possible to discern disciplinary concentrations and the connections between various regions on the global map through citation links.[20] Figure 6 and Figure 7 show the dual-map overlays of the holistic literature of AVs (D_{Macro}) and the transport planning-related literature of AVs (D_{Meso}), respectively.

The graphical representation of the colored curves symbolizes the citation links; originate from the map of citing journals situated on the left-hand side and point towards the map of cited journals located on the right-hand side. The presence of dots on the map symbolizes individual journals. The positioning of the starting and ending points of these curves provides insights into the structure of an article in relation to prior research. Both the citing and cited journals maps are divided into multiple thematic regions, with each location on the map assigned to one of these regions. The determination of each region is based on a set of journals that belong to the same region or cluster. The labels assigned to each region are derived from the lexical frequencies of the most prevalent terms within the titles of the journals associated with the region.[20]

The drawn dual-map overlays for the holistic literature of AVs (i.e., D_{Macro}) on Figure 6, clearly shows the truly interdisciplinarity nature of the AVs research domain. On the citing map, the overwhelming proportion of the literature falls under the field of "Mathematics, Systems, and Mathematical" (MSM; represented in red). Meanwhile, there are curves have been originated from

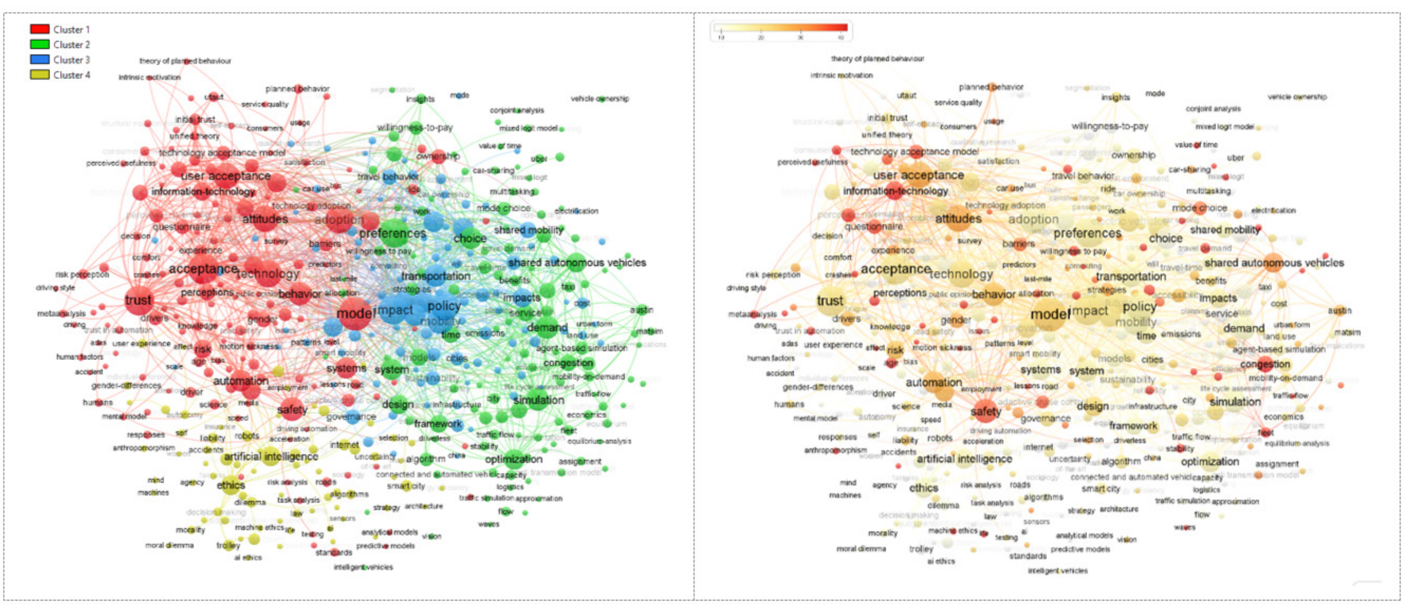


Figure 4: Conceptual structure of meso-level dataset, D_{Meso}, based on co-occurrence analysis of keywords (left), as well as hybrid map of the average citation (right).

Table 2: Representative keywords of each cluster, as well as the most cited keywords.

	D_{Macro}		D_{Meso}	
	Representative (most frequent) keywords	**Most cited keywords**	**Representative (most frequent) keywords**	**Most cited keywords**
Cluster 1	Tracking, sensors, computer vision, object detection, lidar, cameras.	Tracking, computer vision, cameras, slam.	Acceptance, adoption, trust, public opinion.	Acceptance, questionnaire, attitudes.
Cluster 2	Vehicle dynamics, trajectory, path planning, motion control, obstacle avoidance.	Mobile robots, stabilization, control strategy.	Demand, mode choice, willingness to pay, shared vehicles.	Shared vehicles, mode choice, congestions, fleet.
Cluster 3	Intelligent transportation, internet of things, cybersecurity, edge computing, communication.	Big data, 5G	Future, mobility, electric vehicles, policy, built environment.	Policy
Cluster 4	Driver behavior, human factors, performance, driving simulator, situation awareness.	Driver behavior, visual attention, assistance.	Ethics, dilemma, trolley problem.	Ethics
Cluster 5	Acceptance, preferences, adoption, attitudes, demand, gender, policy.	Shared autonomous vehicles, mode choice, attitudes, acceptance	-	
Cluster 6	Traffic flow, signal control, car-following model, congestion, traffic simulation, optimization.	Congestion, intersection control.	-	

almost all other regions of the map, particularly from the areas with labels of "physics, materials, and chemistry" (links in purple, near the top-left) and "Economics, Economic, and Political" (EEP; links in cyan, near bottom-left). The predominant field of MSM strongly evolves in terms of cited references, from four major areas. In other words, citation links in red have been split into four major streams, indicating that published articles in AVs literature cite four distinct groups of journals. Major destination regions for citations in the MSM include "Systems, Computing, and Computer" (SCC), "chemistry, materials, and physics", "Psychology, Education, and Social" (PES), and "economics, economic, and political".

In the same vein, the dual-map overlays of the UTP branch of AVs literature (i.e., D_{Meso}) have been presented in Figure 7. It can be seen that transport planning-related articles, have appeared in three broad regions: MSM, that still is the predominant region of the published articles, next to two other fields of "psychology, education, and health" (in cyan), and EEP (in blue). The destination regions of the curves shows that this dataset has influenced heavily from three research areas of PES and EEP, while the MSM area has also partly evolved from SCC.

Temporal patterns

The examination of the temporal patterns provides a comprehensive evaluation of the areas in which research within the field has been the most intense throughout different time periods. Additionally, it gives insights that can aid in forecasting the regions likely to exhibit similar characteristics in the future.[52] Thus, the thematic evolution analysis of both datasets has been carried out to better comprehend the progression of subfields over time. This analysis uses co-word network analysis and clustering and is based on the proposal of Cobo *et al.*[41] The main aim of this analytical method is to identify the prominent themes in the literature during a given time frame.

Using authors' keywords (with a minimum cluster frequency of 10 per thousand documents) and by applying five cutting points, as illustrated in Figure 8, it can be observed that all the predominant themes throughout all years are exclusively technical aspects of AVs, while transportation planning-related themes are absent at any point in time. Furthermore, a notable outcome from the macro-level literature is the domination of "deep learning" and "machine learning" themes in recent years, signaling a rapid advancement of AV technology and a significant shift in AV-related research in the coming years.

Figure 9 depicts the thematic evolution of AVs literature pertaining to UTP. This illustration highlights the prominence of the theme "shared AVs" across most time periods. The high frequency of "shared AVs" can be attributed to the availability of shared cars in today's world, which facilitates scholars in conducting their research studies with the help of existing conventional shared cars and modes. This trend may result in underestimating the implications of non-shared AVs, especially during the transition phase and in societies where car ownership symbolizes prestige rather than merely serving as a mode of transportation. Additionally, the themes of "safety", "trust", and "acceptance" are notable and play a significant role in shaping the future trajectory of AVs in UTP. These themes, in conjunction with the dominant theme of shared AVs, are crucial indicators of the research priorities and overall direction within this domain. It also has to be underlined that the AVs literature from the UTP perspective, lacks studies regarding the potential impacts of AVs on urban form and land use. This research gap could hinder a comprehensive understanding of the broader implications of AVs integration into urban environments. By comprehending the thematic evolution of AVs in UTP, researchers and practitioners can make informed decisions about future advancements and developments.

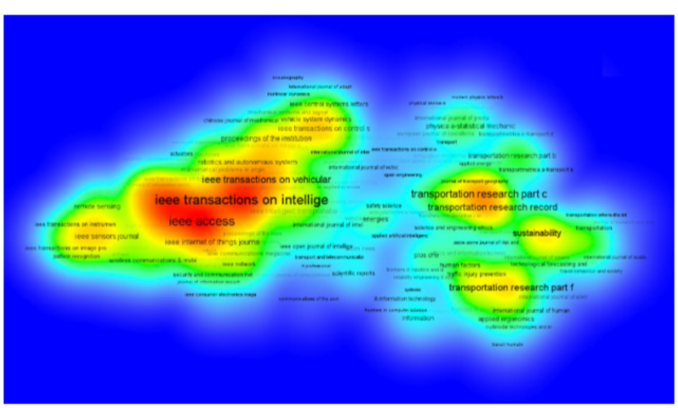
Social Landscape

Social structure analysis can be used as a basis for identifying pertinent expertise and promoting future partnership and collaborations within the field. In order to understand the social landscape of the AVs literature, two distinct methods of analysis have been employed: (i) bibliographic coupling analysis of countries, and (ii) co-authorship analysis of countries and organizations. The primary objective of the first method is to identify the most productive and the most impactful countries within the field, whereas the second method is utilized to uncover the structure of connections among authors from different countries and organizations. Figure 10 depicts the bibliographic coupling analysis of countries (which have minimum of 15 published articles per country) for both macro and meso datasets. The size of the bubbles represents the total number of published articles per country, while the spatial proximity of the bubbles indicates the level of connectivity and collaboration between countries. The closer the countries are, the more collaboration they have, and the thickness of the link connecting the bubbles represents the strength of collaboration.

As depicted in the Figure 10, the United States and China occupy central positions and dominate the AVs literature domain in both datasets. These two countries have connections with almost all other countries on the map, meaning that their publications significantly impact the entire field of AVs literature. In the macro-level dataset, Germany, England, South Korea, Australia, Canada, the Netherlands, France, and Japan respectively occupy the next ranks among the top-ten most impactful countries with strong bibliographic coupling links. In terms of productivity, after the US and China, the next most productive countries, in order, are Germany, South Korea, England, Canada, Australia, Japan, Spain, and Italy.

Similarly, in the meso-dataset related to UTP aspects of the literature, the United States and China remain the central and dominant countries, with Germany, Australia, England, the Netherlands, Singapore, South Korea, Canada, and Sweden following as the next top-ten most impactful countries. The most productive countries, in order, are Germany, England, Australia, the Netherlands, South Korea, Canada, and Singapore, following the US and China.

Figure 11 depicts the co-authorship map of macro- and meso-datasets (which have minimum of 15 published articles per country). As can be seen in the left-hand map, the analysis result for the macro-level dataset, the United States and China are the dominant countries, while they are also closely connected to each other. European countries such as Germany, the Netherlands, France, and England are concentrated on the left side of the map, indicating their close collaborations among each other. Conversely, only a few Asian countries are concentrated on the bottom right side of the map. Similarly, for the meso-level dataset, only 26 out of 83 countries fulfilled the criterion of minimum 15 publications, with Singapore, South Korea, and India (with total of 17 published articles) being the only Asian countries in the map, indicating a dramatically weak position for Asian and developing countries in this field.



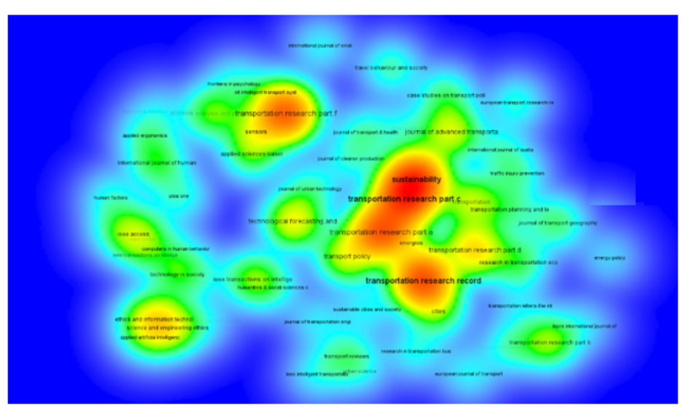


Figure 5: Sources density map of D_{Macro} (left) and D_{Meso} (right).

Table 3: The most productive sources.

D_{Macro}			
Sources	**#Documents**	**#Citations**	**Citation/Document**
IEEE Transactions on Intelligent Transportation Systems.	944	21226	22.49
IEEE Access	736	8144	11.07
Sensors	702	5494	7.83
Transportation Research Part C-Emerging Technologies.	392	15647	39.92
IEEE Transactions on Vehicular Technology.	333	7050	21.17
IEEE Robotics and Automation Letters.	327	3167	9.69
Transportation Research Record.	309	4467	14.46
Applied Sciences-Basel.	299	1396	4.67
Transportation Research Part F-Traffic Psychology and Behaviour.	280	5961	21.29
Sustainability	204	1034	5.07
D_{Meso}			
Transportation Research Record.	100	1689	16.89
Sustainability	97	587	6.05
Transportation Research Part C-Emerging Technologies.	92	4537	49.32
Transportation Research Part A-Policy and Practice.	91	5091	55.95
Transportation Research Part F-Traffic Psychology and Behaviour.	89	2666	29.96
Transportation Research Part D-Transport and Environment.	42	756	18.00
Technological Forecasting and Social Change.	33	982	29.76
Journal of Advanced Transportation.	29	333	11.48
Transport Policy	29	767	26.45
Transportation	26	923	35.50

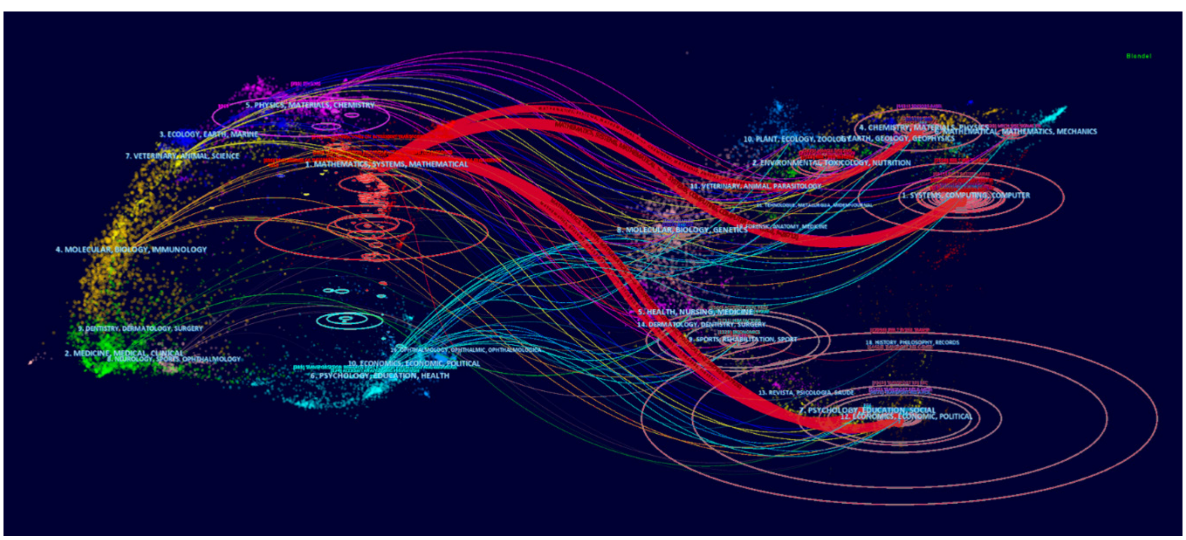


Figure 6: Dual-map overlay of dataset D_{Macro}.

DISCUSSION

Discussing Autonomous Vehicles (AVs) was far from reality until just a few years ago. However, in the present day, due to the massive investments made by technology leading and automotive companies, AVs are rapidly moving closer to become an integral part of our daily lives. This investment increase has also led to a surge in the number of published documents, including journal articles, conference papers, books, book chapters, and reports produced by different stakeholders from both the industry and academia. Consequently, it becomes imperative to periodically and consistently analyze this extensive collection of published documents. Doing so would not only help to identify emerging trends and revolutions, but also will highlight existing gaps. Additionally, such an analytical process can effectively map the path toward the envisioned sustainable future in the light of AVs.

To achieve this, the present study utilized scientometrics (a.k.a., science mapping) analysis. The utilization of science mapping is becoming increasingly important for academic researchers across a multitude of scientific fields due to the exponential growth in the volume of scholarly publications, which has resulted in a fragmented body of knowledge. In this context, it is crucial for both academic inquiry and policy formation to determine the intellectual framework and current state of research within specific scientific domains. Scientometrics analysis methods offer the opportunity to evaluate the conceptual, intellectual and social structures of the scientific domain from a statistical viewpoint by making the scientific literature itself the subject of the study.

Despite the exponential increase in the published scholarly documents related to different aspects of AVs, very few studies have utilized scientometrics methods to analyze the existing literature on AVs. Therefore, to enrich the literature in this regard, the present study deployed a comprehensive dataset of 14,722 peer-reviewed journal articles up to January 2023 (referred to as D_{Macro}), to depict the current state of AVs literature in a holistic and macro-scale manner. Meanwhile, the study has placed extra attention on evaluating and assessing the place and position of the Urban Transportation Planning (UTP) within the D_{Macro}. By implementing precisely designed additional search queries pertaining to UTP on D_{Macro}, the study has extracted a secondary dataset of 1,870 journal articles to delve more deeply into the subject in a meso-level, and comprehensively evaluate the position of the UTP in greater detail.

In terms of the conceptual analysis results at the macro-level, patterns of term co-occurrences demonstrate the presence of six major divisions. Meanwhile, among these six clusters, the UTP-related cluster constitutes the smallest, at the meso-level analysis from the UTP perspective itself, the obtained patterns indicate four distinct streams, including (i) User acceptance,

Figure 7: Dual-map overlay of dataset D_{Meso}.

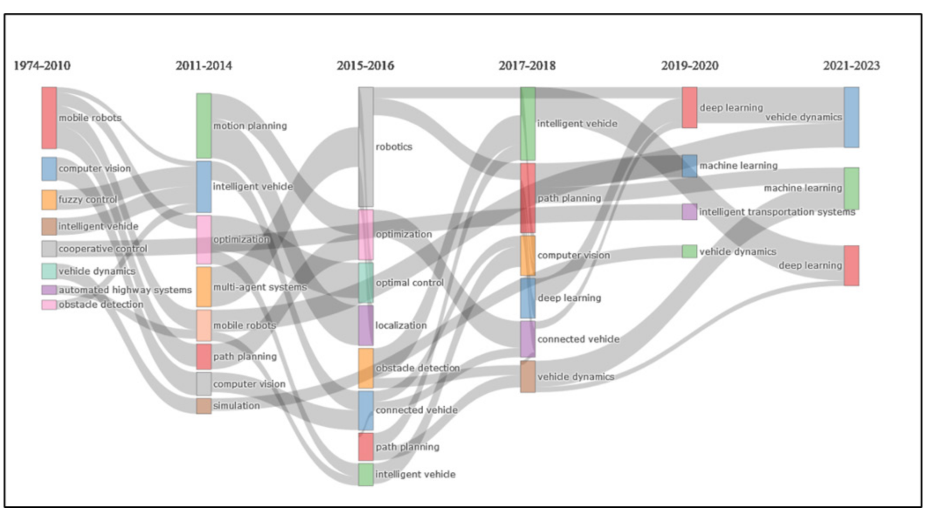


Figure 8: Thematic evolution of AVs literature in the macro-level.

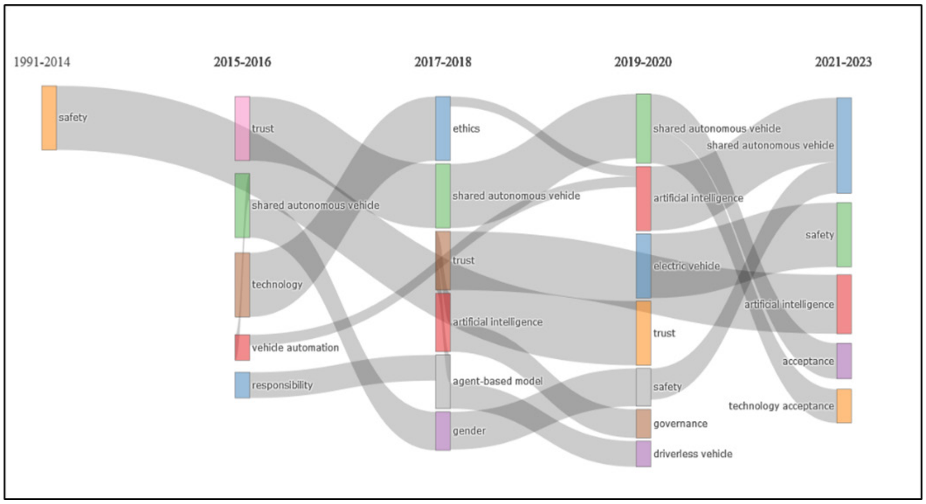


Figure 9: Thematic evolution of AVs literature pertain to UTP.

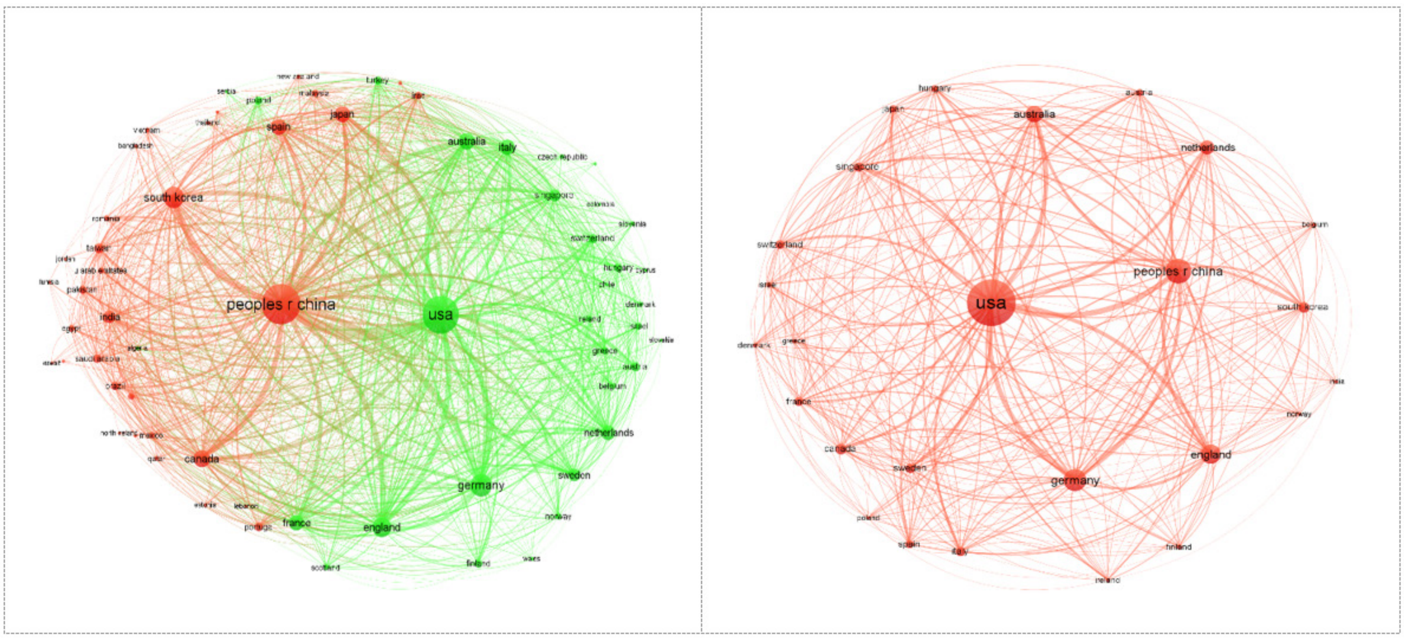


Figure 10: Bibliographic coupling analysis of countries for D_{Macro} (left), and D_{Meso} (right).

adoption, and trust, (ii) Demand estimation, mode choice, and shared modes, (iii) Sustainability, built environment, and policies, and (iv) Ethical problems of AVs deployment. The average citation analysis of macro-level clusters revealed that all clusters possess at least a few highly cited topics, implying that the AVs domain remains an underexplored and immature field in almost all of its subfields. With regard to the UTP-related dataset, although it constituted the smallest share of the macro-level analysis, its internal clusters representing policy-related and ethical topics have received comparatively less attention from researchers and the academic community compared to other clusters. Moreover, subjects concerning long-term impacts of AVs, such as their effects on urban form and land use, are notably absent from these clusters. Furthermore, the analysis of the average citations per frequency for meso-level data demonstrated that the UTP aspect of AVs is still in its embryonic stage and requires further investigation. This is indicated by the lower average citation value compared to the technological clusters in the macro-level dataset. These findings highlight the need for more comprehensive research to fully comprehend the implications of AVs deployment from the UTP perspective.

The analysis of the intellectual landscape involved examining the most productive and impactful sources, as well as the dual-map overlay analysis, and exploring temporal patterns within the field. The dominance of technical studies in the AV field during different time periods was once again highlighted in the analysis of the temporal landscape. Meanwhile topics such as "machine learning", and "deep learning" have emerged in the recent years' studies and should be expected to dominate the field in the

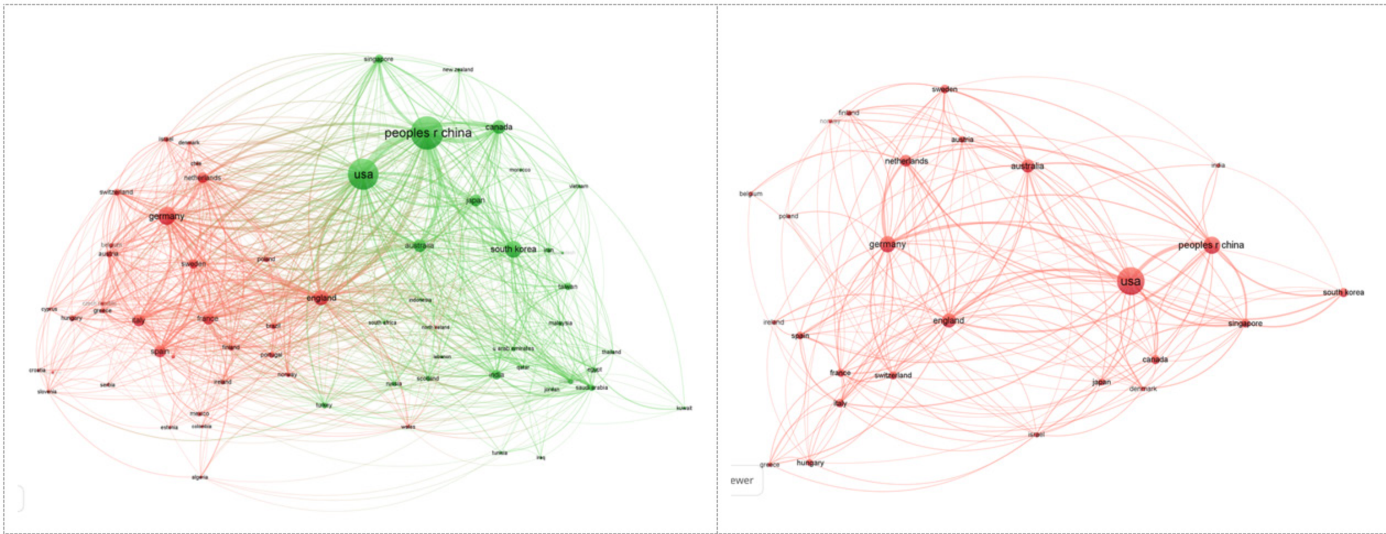


Figure 11: Co-authorship analysis of countries for D_{Macro} (left), and D_{Meso} (right).

upcoming years, especially from the technical perspectives. However, the meso-level dataset revealed that the dominance of shared AVs was obvious in all time periods. This dominance could lead to underestimating the implications of non-shared AV modes, especially during the transition phase and in societies where car ownership is a symbol of prestige rather than just a mean of transportation. Moreover, keywords related to AVs impacts on urban form, land use and built environment were noticeably absent across all time spans. By understanding the thematic evolution of AVs, particularly from the UTP perspective, researchers and practitioners can make informed decisions about future advancements and developments.

Finally, the analysis of the social landscape mapped the most productive and impactful countries in the field. The analyses consistently placed the US and China at the forefront across all types of assessments. In contrast, there is a notably limited presence of developing countries in the findings of both macro- and meso-level datasets. This emphasizes the necessity for developing countries to prioritize, at least the UTP aspects of these technologies, to be able to leverage the benefits and mitigate adverse effects before widespread deployment.

CONCLUSION

In summary, this research aimed to advance the field by creating a visual representation of the content, structure, and connections in the existing literature on AVs, particularly by giving an extra effort on UTP aspect of the field, because considering the fact that ultimately AVs will be integrated into urban transportation networks as an integral part of daily life, it is crucial to emphasize the UTP aspect. By doing so, it provides a comprehensive understanding of the knowledge contained within for scholars, enabling them to identify research gaps and formulate directions for future study.

The overall outcomes the study highlighted a notable contrast between attention on AVs' UTP aspect and their technical growth. Although there are some emerging signs of growing interest in UTP, still it is very limited, and a distinct research gap persists, particularly in developing countries. It's important to mention that developing countries tend to be more inclined toward adopting technology rather than producing it. Although UTP related subfield of the AVs research has smoothly begun to evolve in recent years, but there is still a great need to focus on this aspect of the field to be able to fully realize its benefits and minimize any probable negative impacts.

Developing countries, with their potential as key markets for technological products, including AVs, particularly need to increase their efforts in areas such as estimating adoption rates, assessing the impact of AVs on urban mobility and urban form, establishing necessary regulations and policies, and enhancing their readiness with the involvement of researchers, academics, and stakeholders.

It must be acknowledged that the limitations of this study include reliance on the WoS as the sole source for data collection, and the future studies might use different data sources at the same time to extend the deployed dataset.

Scientometric techniques provide a different depiction of the field's structure compared to conventional literary assessments, but it is more reasonable to be considered as the complementary of the manually research and examination of the field in the micro-level. As an agenda for future studies, it is recommended to undertake a thorough examination of the individual publications pertaining to the searched terms, as well as an in-depth examination of the sub-disciplines that have been recognized as potential gaps and prevalent tendencies in the current paper.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ABBREVIATIONS

AV: Autonomous Vehicle; **UTP:** Urban Transportation Planning; **MSM:** Mathematics, Systems, and Mathematical; **EEP:** Economics, Economic, and Political; **SCC:** Systems, Computing, and Computer; **PES:** Psychology, Education, and Social.

APPENDIX A

The detailed version of the used search query to retrieve the required data sets:

TS=("autonomous vehicle$" OR "autonomous car" OR "autonomous cars" OR "automated vehicle$" OR "automated car" OR "automated cars" OR "autonomous driving" OR "automated driving" OR "driver less vehicle$" OR "driverless vehicle$" OR "driver less car$" OR "driverless car$" OR "self driving vehicle$" OR "selfdriving vehicle$" OR "self driving car$" OR "selfdriving car$" OR "robo$taxi" OR "robo taxi" OR "autopilot vehicle$" OR "autopilot cars")

AND TS=(acceptance OR adoption OR attitude OR preference OR purchase OR consumer OR opinion OR willing* OR "public perception$" OR "consumer perception$" OR "user perception$" OR "public concern$" OR "public interest" OR "public awareness" OR "intention to use"

OR "travel behavio$r" OR "travel pattern$" OR "travel demand$" OR "transport* demand$" OR "induced demand$" OR "transport* planning"

OR "land use" OR "residential location$" OR "residential relocation$" OR "location choice$" OR "urban sprawl" OR suburbanization OR "urban form" OR "urban growth" OR "urban development" OR "urban characteristics" OR "urban planning" OR "urban design"

OR "mode choice$" OR "discrete choice$" OR "choice model*" OR "stated choice" OR probit OR logit OR questionnaire OR survey OR gender OR age OR household OR "focus group$" OR "value of time" OR "value of travel time"

OR sustainabl* OR "smart cit*" OR "urban mobility" OR "built environment"

OR equity OR "social exclusion" OR "socio technical" OR governance OR "liability" OR legal* OR justice OR trolley OR moral OR "law" OR regulation OR policy OR policies OR ethic* OR incentive OR legislat*

OR maas, "mobility as a service" OR "car sharing" OR car$sharing OR "ride hailing" OR ride$hailing OR "ride sharing" OR ride$sharing OR "ride sourcing" OR ride$sourcing OR "sharing economy" OR "on demand" OR "demand responsive" OR pooling OR "sharing mobility" OR "park and ride" OR "last mile" OR "first mile" OR ownership OR parking)

NOT TS=(warehous* OR maritime OR marine OR military OR ocean* OR *water OR vessel OR crane OR farm* OR agricultu* OR vegetation OR boat OR flight OR aerospace OR aerial OR *craft$ OR container

OR "lane management" OR "lane detection" OR "lane chang*" OR "managed lane$" OR "lane following" OR "lane keeping" OR "path planning" OR "route planning" OR "path following" OR "path tracking" OR "target tracking" OR "object tracking" OR "motion planning" OR "motion control" OR "motion prediction$" OR "eye tracking" OR "tracking control" OR "car following" OR "vehicle following" OR trajector* OR kinematic* OR *slip

OR "obstacle avoidance" OR detection OR camera OR "sign recognition" OR "emotion recognition" OR "fac* recognition" OR "object recognition" OR "speech recognition" OR "image recognition" OR "injury severit*" OR collision OR "pedestrian crossing" OR "human machine interaction$" OR "human machine interface$" OR "human robot interaction$" OR "visual odometry" OR "image segmentation$" OR "image process*" OR locali$ation OR optic$

OR "reinforcement learning" OR "deep learning" OR *attack* OR cloud OR "sensor fusion" OR "fog computing" OR "edge computing" OR "software engineering" OR "software testing"

OR "longitudinal dynamic$" OR "longitudinal driv*" OR "longitudinal vehicle" OR "lateral vehicle" OR "lateral offset" OR "lateral dynamic$" OR "lateral acceleration" OR "vehicle dynamic$" OR "steering control*" OR "vehic* navigation" OR "vehicl* control*" OR velocity OR "situation* awareness"

OR Platoon* OR "routing problem" OR "fleet management" OR "vehicle routing" OR "route choice$" OR "vehicle relocation$" OR "vehic* operation$" OR "operational design" OR "vehicl* network$" OR "performance evaluation" OR radar$

OR "*signalized intersection$" OR "intersection management" OR "signal control" OR "intersection control*" OR "flow dynamics" OR "traffic sign*" OR "driv* behavio$r" OR ramp OR take$over OR "take over"

OR storage OR torque OR voltage OR "GHz" OR 6G OR 5G OR "power transfer" OR "vehicul* communication$" OR "wireless communication$" OR "ad hoc network$")

AND English (LANGUAGES)

AND Urology Nephrology OR Obstetrics Gynecology OR Medical Ethics OR Immunology OR Cell Biology or Endocrinology Metabolism or Genetics Heredity or Biochemistry Molecular Biology OR Surgery OR Physics Nuclear OR Oncology OR Clinical Neurology OR Pharmacology Pharmacy or Entomology or Soil Science or Forestry or Mineralogy or Materials Science Composites OR Materials Science Ceramics OR Chemistry Organic OR Astronomy Astrophysics OR Mining Mineral Processing OR Nuclear Science Technology OR Chemistry Applied or Fisheries OR Limnology OR Plant Sciences OR Marine Freshwater Biology OR Radiology Nuclear Medicine Medical Imaging OR Agronomy OR Engineering Ocean OR Agriculture Multidisciplinary OR Agricultural Engineering OR Medical Informatics OR Nanoscience Nanotechnology (EXCLUDE - Web of Science Categories)

AND Proceeding Paper OR Early Access or Review Article OR Editorial Material OR Book Chapters OR Data Paper OR Book Review OR Correction OR Meeting Abstract OR News Item OR Letter OR Expression of Concern OR Biographical-Item OR Correction, Addition OR Note OR Retracted Publication OR Book (EXCLUDE - Document Types)

APPENDIX B

Set of words/terms, used as filtering query string, categorized in eight distinct groups:

(I) warehous*, maritime, marine, military, ocean*, *water, vessel, crane, farm*, agricultu*, vegetation, boat, flight, aerospace, aerial, *craft$, container

(II) "lane management", "lane detection", "lane chang*", "managed lane$", "lane following", "lane keeping", "path planning", "route planning", "path following", "path tracking", "target tracking", "object tracking", "motion planning", "motion control", "motion prediction$", "eye tracking", "tracking control", "car following", "vehicle following", trajector*, kinematic*, *slip

(III) "obstacle avoidance", detection, camera, "sign recognition", "emotion recognition", "fac* recognition", "object recognition", "speech recognition", "image recognition", "injury severit*", collision, "pedestrian crossing", "human machine interaction$", "human machine interface$", "human robot interaction$", "visual odometry", "image segmentation$", "image process*", locali$ation, optic$

(IV) "reinforcement learning", "deep learning", *attack*, cloud, "sensor fusion", "fog computing", "edge computing", "software engineering", "software testing"

(V) "longitudinal dynamic$", "longitudinal driv*", "longitudinal vehicle", "lateral vehicle", "lateral offset", "lateral dynamic$", "lateral acceleration", "vehicle dynamic$", "steering control*", "vehic* navigation", "vehicl* control*", velocity, "situation* awareness"

(VI) Platoon*, "routing problem", "fleet management", "vehicle routing", "route choice$", "vehicle relocation$", "vehic* operation$", "operational design", "vehicl* network$", "performance evaluation", radar$

(VII) "*signalized intersection$", "intersection management", "signal control", "intersection control*", "flow dynamics", "traffic sign*", "driv* behavio$r", ramp, take$over OR "take over"

(VIII) storage, torque, voltage, "GHz", 6G, 5G, "power transfer", "vehicul* communication$", "wireless communication$", "ad hoc network$"

APPENDIX C

The top-ten most influential sources (with minimum of five published articles) with highest rate of "citation per document" for both macro- and meso-level datasets:

D_{Macro}			
Sources	**#Documents**	**#Citations**	**Citation/Document**
Nature	10	2045	204.50
IEEE Transactions on Robotics and Automation.	18	3294	183.00
IEEE Transactions on Pattern Analysis and Machine Intelligence.	26	3652	140.46
International Journal of Robotics Research.	44	5857	133.11
IEEE Transactions on Automatic Control.	54	6556	121.41
Proceedings of the National Academy of Sciences of the United States.	8	788	98.50
Journal of Artificial Intelligence Research.	9	837	93.00
Journal of Guidance Control and Dynamics.	12	960	80.00

***D**$_{Macro}$*			
Sources	**#Documents**	**#Citations**	**Citation/Document**
IEEE Communications Magazine.	33	2316	70.18
Systems and Control Letters.	12	787	65.58
***D**$_{Meso}$*			
Transportation Research Part A - Policy and Practice	91	5091	55.95
Transportation Research Part C - Emerging Technologies	92	4537	49.32
Transport Reviews	11	536	48.73
Sustainable Cities and Society	7	325	46.43
International Journal of Human-Computer Interaction	16	595	37.19
Transportation	26	923	35.50
Science and Engineering Ethics	15	456	30.40
Transportation Research Part F - Traffic Psychology and Behaviour	89	2666	29.96
Technological Forecasting and Social Change	33	982	29.76
International Journal of Sustainable Transportation	8	235	29.38

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