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From Roads to Emissions: Bibliometric Insights into Transportation and Climate Change Research

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ABSTRACT

The study presents a comprehensive bibliometric analysis of academic literature focusing on the intersection of transportation and its impact on climate change. Covering the period from 2018 to 2023, the research scrutinized a substantial dataset of 4,373 papers from the Scopus database. Employing VOSviewer for network visualizations and Microsoft 365 for data analysis, the study meticulously mapped publication trends and citation impacts within this period. This systematic approach provided a thorough understanding of the evolution and current state of research in this vital field, highlighting how academic focus on transportation's role in climate change has intensified over time. Key findings from the study revealed a significant increase in research output, with the number of publications nearly doubling from 483 in 2018 to 932 by 2022, indicating a growing scholarly interest in this area. However, the analysis also uncovered notable variations in citation rates, with a peak citation per publication (CPP) of 24.04 for highly influential papers. This suggests a disparity in the influence of research output, with some studies gaining more recognition than others. Additionally, the study highlighted significant differences in scholarly production and impact across different countries, with the United States leading in publications and citations, followed by China and India. These findings underscore the importance of international collaboration in research, pointing to the need for policies that encourage and support collaborative efforts to tackle the global challenge of climate change through effective transportation strategies.

1. INTRODUCTION

Climate change poses one of the most significant challenges of the 21st century, with transportation playing an essential role in this evolving narrative. The transport sector, especially road transportation, is a major contributor to global greenhouse gas emissions and a key driver of climate change [1]. According to the International Energy Agency, the transport sector accounts for approximately 24% of global CO_2 emissions from fuel combustion, with road vehicles contributing a substantial portion of these emissions [2]. This correlation between transportation and climate change highlights the urgent need for research to guide effective policy and action in this critical area.

Scholarly research is indispensable in understanding and addressing the environmental impact of transportation. To navigate this vast expanse of research, bibliometric analysis emerges as a powerful tool. Bibliometrics, involving the statistical analysis of written publications, enables mapping research trends, identifying key themes, and assessing the impact of scholarly work [3]. Applying bibliometric methods to transportation and climate change research makes it possible to gain a macroscopic view of the field, providing insights crucial for driving informed decisions and strategies [4].

The research landscape in transportation and its impact on climate change is dynamic and complex. Over the years, this research area has evolved, reflecting shifts in technological advancements, policy directions, and global environmental priorities. Key themes have emerged, ranging from sustainable transportation systems and alternative fuels to the socio-economic implications of transport policies [5, 6]. Understanding the evolution of these themes, the interconnectivity of research areas, and the influence of seminal studies is essential for recognizing both the progress made and the gaps that still exist in addressing the challenges posed by transportation-related emissions [7].

While only one known study in this domain, the study [8], utilized CiteSpace for its analysis, the current research uniquely employs VOSviewer. This distinction is noteworthy as it introduces a different analytical perspective and potentially reveals new patterns, trends, and connections

within the literature. Ibrahim et al. [9] stated that VOSviewer's strengths in visualizing bibliometric networks and its ability to handle large datasets user-friendly may allow for the extraction of novel insights, particularly in understanding the intricate relationships between transportation and climate change.

Our methodology advances the bibliometric analysis of transportation and climate change by integrating multiple bibliometric indicators that have yet to be fully explored in previous studies. Specifically, we extend the analytical scope by examining the volume and citations of publications, their scientific influence, and network structures across disciplines. This comprehensive approach helps identify emergent trends and under-researched areas, providing a deeper understanding of the field's evolution and the interconnectivity of its central themes.

This study is designed to explore several critical gaps in the current literature, such as the evolution of research focus on transportation and climate change over the last decade, the identification of the most influential studies and their interlinks with newer research trends, and the understanding of which geographical and institutional collaborations are shaping the research landscape in this field. By mapping the research trajectory comprehensively, our paper highlights key contributors, influential studies, and prevailing research themes. These findings aim to offer valuable insights into current research dynamics, inform future scholarly endeavors, and aid policymakers in crafting effective strategies to mitigate the environmental impacts of transportation. Through this thorough analysis, the paper aspires to contribute meaningfully to the ongoing discourse on sustainable transportation and climate change mitigation.

2. LITERATURE REVIEW

The transportation sector significantly impacts climate change, a defining issue of the 21st century. According to Ibrahim et al. [9], the International Energy Agency reported that the transport sector accounts for about 24% of global CO_2 emissions from fuel combustion, with road transportation being a substantial contributor. Munkejord et al. [10] provided a detailed analysis of carbon dioxide emissions from transport in IEA countries, underscoring the urgent need for a shift in transportation modes and policies. Chapman [11] further emphasized this point, comprehensively reviewing the interplay between transport and climate change.

Research trends in sustainable transportation have been a focal point in recent years. Santos [12] and Pourramazani and Miralles-Garcia [13] discussed the multiple dimensions of energy security, highlighting the role of sustainable transport in mitigating environmental impacts. Onyebuchi et al. [14] and Gössling and Choi [15] introduced the sustainable mobility paradigm, proposing a holistic approach to reducing emissions through improved urban transport systems [16] presented a case study on transport transitions in Copenhagen, showcasing the economic and environmental benefits of prioritizing bicycles over cars.

The effectiveness of policy and regulatory frameworks in transportation for climate change mitigation has also been widely studied. Buehler and Pucher [17] and Marrero et al. [18] examined the energy and emissions impacts of a freeway-based dynamic eco-driving system, highlighting the potential of technological solutions in reducing transport emissions. Warsame [19] and Chan and Daim [20] analyzed Freiburg, Germany's sustainable transport strategies, demonstrating the integration of integrated policies in creating environmentally friendly urban transport systems. Some researches [21-24] provided a forward-looking analysis of transport and CO_2 emissions in the UK, offering insights into potential policy interventions for 2030.

Bibliometric analysis has emerged as a vital tool in assessing the evolution of transportation and climate change research. Mohamud [25] discussed using bibliometrics and patent analysis in forecasting emerging technologies, highlighting their applicability in understanding research trends and directions. Mohamud et al. [26] introduced science overlay maps as a novel method for research policy and library management, which can be effectively applied to analyze transportation research landscapes. Warsame et al. [27] conducted a bibliometric analysis of the Transportation Research journal's publications over its first fifty years, from 1967 to 2016. The study identified leading trends and contributions in transportation research, focusing on impact, topics, authors, universities, and countries.

This literature review underscores the multifaceted nature of research in transportation and its impact on climate change. From the direct contributions of road transportation to global emissions to the evolving paradigms of sustainable mobility and the effectiveness of policy interventions, the literature provides a comprehensive understanding of where the field stands today. Additionally, the role of bibliometric analysis in mapping this research landscape highlights the dynamic and interconnected nature of studies in this area, offering valuable insights for future research directions and policy formulations.

3. METHODOLOGY

3.1 Data collection

The team has opted for the Scopus database as their principal data-gathering tool in our ongoing research, covering 2018 to November 30, 2023. Recognized for its extensive collection of scholarly citations and abstracts, Scopus consolidates academic content from many international publishers. Its credibility as a reliable platform is well-established in the academic milieu. Compared to other databases like Web of Science, Google Scholar, and PubMed, Scopus stands out for its broader inclusion of publications and sophisticated functionalities for conducting keyword searches and bibliometric analysis. Scopus offers 20% more coverage in terms of citations than WoS and is preferred over Google Scholar, which is often critiqued for its inconsistent results. Although PubMed is widely used in scientific research, the researchers' choice of Scopus for this study is rooted in its expansive range and proven reliability.

The data collection process involved the following steps:

Defining the search terms: Keywords specific to the study's focus, namely "Transportation" and "Climate Change," were identified and combined using the TITLE filter to ensure relevance.

Executing the search: The combined search terms were entered into Scopus to retrieve articles from the specified period.

Initial screening: All articles were initially screened based on title and abstract to confirm their relevance to the research themes.

Data export: Relevant articles were then selected for deeper analysis, and their bibliographic data were exported in CSV format for further processing.

3.2 Search strategy

In the context of bibliometric analysis, the careful selection of keywords is essential. This study's query parameters were meticulously chosen to align with the central research questions, focusing specifically on "Transportation" and "Climate Change" as the principal title keywords. This led to constructing two precise keyword pairings to reflect the core thematic elements under investigation. Recognizing the significance of an article's title in engaging scholarly interest, these keywords were selected for their capacity to encapsulate and transmit the foundational concepts of the research efficiently. The search strategy implemented was to apply the combination of TITLE ("Transportation") and TITLE ("Climate Change") in the Scopus database. This approach yielded a corpus of 4373 scholarly documents dating from 2018 through to the 30th of November, 2023, compiled without the imposition of exclusion criteria, as depicted in Figure 1.

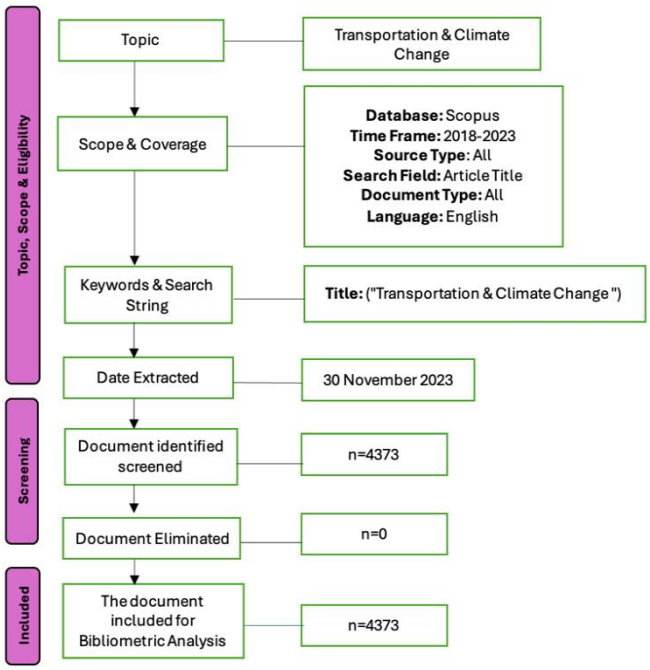

Figure 1. Flow diagram of article searching strategy of transportation and climate change documents

3.3 Tools and data analysis

VOSviewer has been chosen for its particular strengths in visualizing bibliometric networks and its user-friendly handling of large datasets, which is crucial for managing this study's data volume. Unlike CiteSpace, which primarily visualizes citation and co-citation networks, VOSviewer offers additional functionalities such as co-authorship analysis, bibliographic coupling, and co-occurrence of keywords. This capability allows for a more nuanced understanding of the dynamics within the field, revealing the spatial distribution of research activity, authorship patterns, citation networks, keyword prevalence, and international collaborations.

In addition, Microsoft Excel 365 was used to perform initial data cleaning and manipulation, ensuring the dataset was accurately prepared for bibliometric analysis.

4. RESULTS AND DISCUSSION

4.1 Trends in publication numbers over time

The above figure reveals a nuanced landscape of scholarly output and its citations over six years. From 2018 to 2022, there is a clear upward trajectory in the number of published documents, increasing from 483 to 932, signifying a burgeoning interest and intensified research efforts in transportation and its environmental impacts. This could be attributed to the escalating urgency to address climate change, where transportation significantly contributes to greenhouse gas emissions. However, the citation counts do not mirror this growth uniformly; they peaked in 2020 with 12,350 citations but subsequently experienced a decline, descending to 5,782 by 2022. The heightened citation numbers in 2020 could reflect a landmark year for pivotal research that garnered considerable attention, suggesting that certain studies or developments during this period were particularly influential.

Contrastingly, the decline in citation counts post-2020, despite the increasing number of publications, indicates a lag in disseminating and integrating newer research into the academic discourse or saturation in the field, leading to more dispersed citation distribution among a larger body of work. The year 2023 marks a notable deviation in both documents published and citations received, with both figures significantly lower than the previous years. This sharp decline raises questions about the factors influencing such a trend. It may point to a transient shift in research focus within the field, possibly due to emerging innovations or paradigm shifts in transportation technology and climate policy. Alternatively, it could suggest a delay in the academic community's engagement with the latest research outputs or a change in publication and citation practices. This contrasting trend between the volume of research and its scholarly impact provides a rich context for discussion in the paper, potentially shedding light on the evolving dynamics of transportation research in the wake of climate change imperatives.

4.2 Global cooperation and national involvement

Figure 2 depicts a bar graph comparing the scholarly output and impact across various countries in transportation research. The United States is a predominant contributor with the most published documents and citations, indicating an active and influential research community. China and India follow with many publications, although they trail behind the United States in citation counts. This suggests that while these countries are prolific in generating research, the influence measured by citations is disproportionately dominated by the United States. The graph reveals the disparities in global research contributions and their recognition, hinting at the potential factors such as research quality, international collaboration, and access to research networks that can affect a country's scientific impact.

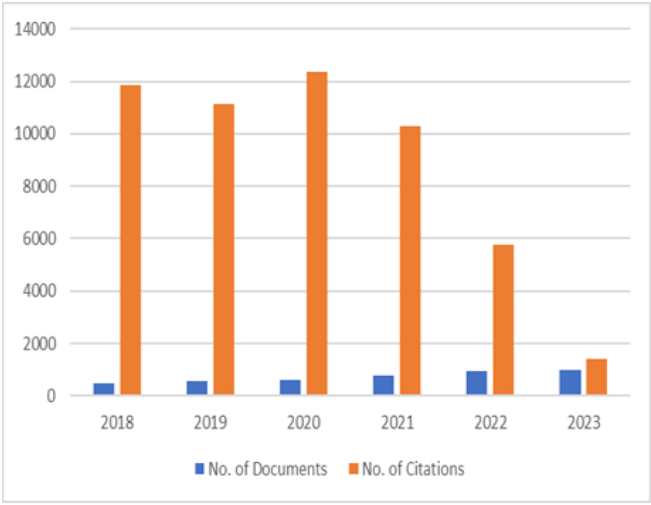

Figure 2. Citation per year

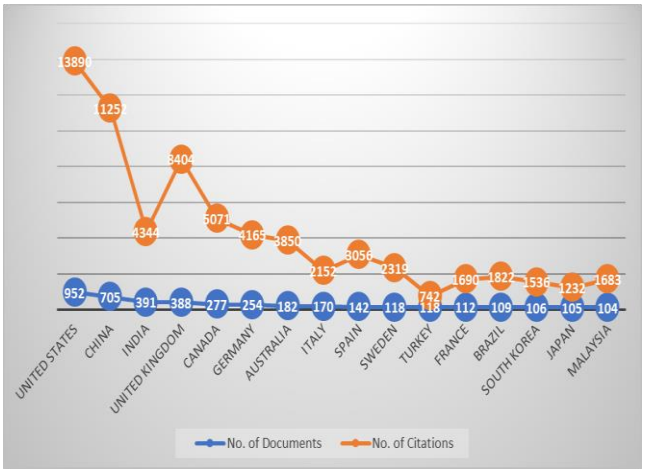

Figure 3. The contribution of numerous nations

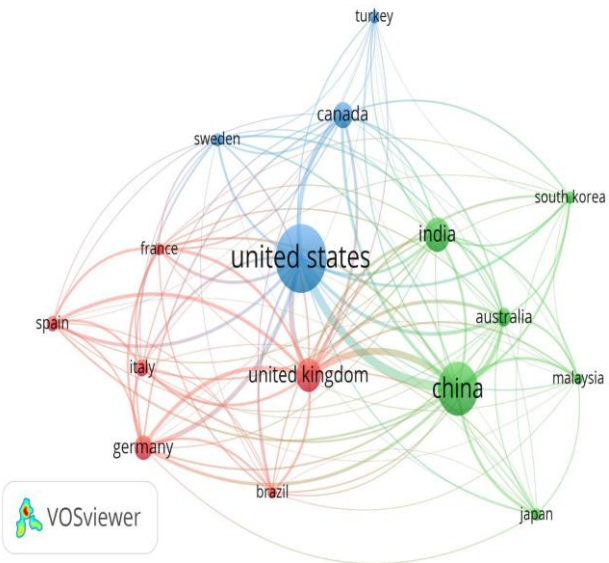

Figure 4. The contribution network of numerous nations

Figures 3 and 4 show the network visualization map from VOSviewer and further elaborate on the relationships and collaborations among these countries. The United States, represented as the most prominent node, sits at the network's epicenter, indicating a high volume of research output and significant international collaborative ties. The visual density and the number of lines emanating from the nodes of China and the United Kingdom underscore their roles as key players in the field, with strong bilateral linkages that likely contribute to the diffusion of knowledge and scholarly impact. The map's intricate web of connections exemplifies the collaborative nature of transportation research. It reveals how countries are interconnected, sharing and building upon each other's work to advance understanding and solutions in transportation and its environmental implications.

4.3 Key journals

Table 1 presents bibliometric data for various journals within the transportation and climate change research field, categorizing their scholarly output and impact through several key indicators. 'Total Publications' (TP) refers to the aggregate number of articles published by each journal within a specified timeframe, which measures productivity or output. 'Total Citations' (TC) quantifies the number of times other researchers have cited articles from these journals, reflecting the reach and influence of the journal's publications within the academic community. 'Citations Per Publication' (CPP) is the average number of citations received per article published in the journal, offering an insight into the relative impact or quality of the research output.

The first journal, 'Applied Energy,' shows a substantial impact with a high CPP of 24.04, indicating that, on average, each publication in this journal is cited over 24 times. This high citation rate, combined with a Cite Score of 21.1, another metric evaluating the average citations received over three years, suggests that 'Applied Energy' is a significant contributor to the field, with its prolific and influential publications. The 'Snip' (Source Normalized Impact per Paper) score of 2.758 and the 'SJR' (SCImago Journal Rank) of 2.907 further corroborate the journal's high standing, pointing to its articles' quality and the prestige associated with the journal in the academic circle.

Comparatively, 'Energies' has a higher TP of 105, indicating a greater volume of published work. However, its lower CPP of 9.59 suggests that while it is an active journal, its articles may have a different level of impact or recognition than those in 'Applied Energy.' This is further reflected in its lower Cite Score of 5.5, Snip of 1.025, and SJR of 0.632. It is important to note that these metrics are not merely indicative of the journal's quality but can also be influenced by the journal's field of focus, the size of its research community, and its accessibility to researchers. Other journals listed, such as "Environmental Research Letters" and "Environmental Science and Pollution Research," display their unique profiles of productivity and impact, with each journal contributing differently to the overall body of knowledge in transportation and environmental research.

Table 1. Most influential sources

Journals	TP	TC	CPP	Cite Score	Snip	SJR	Publisher
Applied Energy	28	673	24.04	21.1	2.758	2.907	Elsevier
Energies	105	1007	9.59	5.5	1.025	0.632	MDPI
Environmental Research Letters	31	629	20.29	10.1	1.656	2.119	Institute of Physics Publishing
Environmental Science and Pollution Research	45	394	8.76	7.9	1.214	0.944	Springer Nature
International Journal of Environmental Research and Public Health	37	353	9.54	5.4	1.28	0.828	Frontiers Media S.A.
Journal of Cleaner Production	117	3960	33.85	18.5	2.379	1.981	Elsevier
Journal of Environmental Management	30	516	17.2	13.4	1.849	1.678	Elsevier
Renewable and Sustainable Energy Reviews	35	1431	40.89	26.3	3.631	3.232	Elsevier
Science of the Total Environment	78	1719	22.04	16.8	2.026	1.946	Elsevier
Sustainability (Switzerland)	151	1879	12.44	5.8	1.198	0.664	MDPI
Sustainable Cities and Society	29	797	27.48	18.4	2.509	2.305	Elsevier
Transportation Research Part D: Transport and Environment	87	1884	21.66	12.3	1.979	2.024	Elsevier

4.4 Keywords analysis

Figure 5 reveals a multi-dimensional inquiry into the relationship between transportation and its environmental consequences. Within the red cluster, the keyword "greenhouse gases" is crucial, with an impressive total link strength, signifying its centrality and the weight of associated research. This cluster encapsulates climate science's chemical and physical dimensions, focusing on directly quantifying and mitigating emissions. High occurrences of related terms like "carbon dioxide" and "alternative energy" within this cluster underscore the sector-specific scrutiny of transportation's contribution to atmospheric composition and the exploration of low-carbon alternatives.

The green cluster, oriented around "climate change," reflects the integrative and systemic challenges transportation poses on global climate dynamics. It is characterized by a dense network of links and a substantial link strength associated with "climate models" and "economics," indicating a rich interdisciplinary dialogue. The frequency of "decision-making" as a keyword within this cluster highlights the transition from theoretical models to actionable intelligence, providing insight into the policy and economic implications of transportation-related climate change. This cluster's substantial links to "risk assessment" and "resilience" emphasize the forward-looking aspect of research concerned with the current impact and the adaptation strategies for future climate resilience.

In contrast, the blue cluster, centralized on "transportation," delves into the operational and technological advancements within the sector. Keywords such as "electric vehicles," which exhibit high link strength and occurrences, pinpoint the shift towards sustainable mobility solutions. This cluster is heavily linked with "urban planning" and "public transport," highlighting the socio-technical transition towards low-emission urban systems. Similarly, the yellow cluster with "environmental impact" underscores the evaluative aspect of transportation research. It connects extensively with terms like "air pollution" and "environmental policy," indicating an emphasis on assessing and legislating the environmental externalities of transportation. The occurrence of "land use" within this cluster suggests a consideration of the spatial-environmental dynamics at play, revealing a holistic perspective on the environmental consequences of transportation infrastructures and practices.

These clusters collectively map the thematic contours of contemporary transportation research as it grapples with the urgency of climate change. They demonstrate a comprehensive scholarly pursuit to understand and mitigate transportation's environmental impacts through a combination of chemical, physical, economic, technological, and policy-oriented lenses.

4.5 Most cited authors

The bibliometric analysis of cited authors within the transportation and climate change research field offers a rich tapestry of scholarly contributions and intellectual interconnections. In Figure 6, authors such as Banister D. stand out with an impressive network of 210 links and a total link strength 2535, complemented by 205 citations. This prominence within the research community highlights Banister's significant influence, likely rooted in foundational research or methodological innovations that have shaped the trajectory of transportation-climate change scholarship.

Contrastingly, Axsen's bibliometric indicators reveal a subtly different mode of scholarly impact. With 202 links and a total link strength of 1951 but fewer citations at 139, Axsen's academic footprint suggests a potent yet targeted influence. The work focuses on particular aspects of transportation research, resonating strongly within specialized segments of the academic community and contributing to nuanced advancements in the field.

The impact of authors like Becker A. presents a distinct narrative of academic influence, marked by 151 links and a total link strength of 1851, alongside 127 citations. This pattern suggests a concentrated and potent engagement with specific research niches. Becker's contributions, while cited less frequently, have nonetheless forged strong ties within particular domains, indicating a depth of research that offers substantial insights into focused areas of the transportation and climate change discourse.

These varied academic profiles illuminate the multifaceted nature of scholarly influence within the transportation climate change domain. The numerical data from citations and link strengths reveal an ecosystem of research where broad-ranging impacts coexist with specialized, in-depth studies, collectively enriching the academic dialogue around the challenges at the intersection of transportation systems and environmental sustainability.

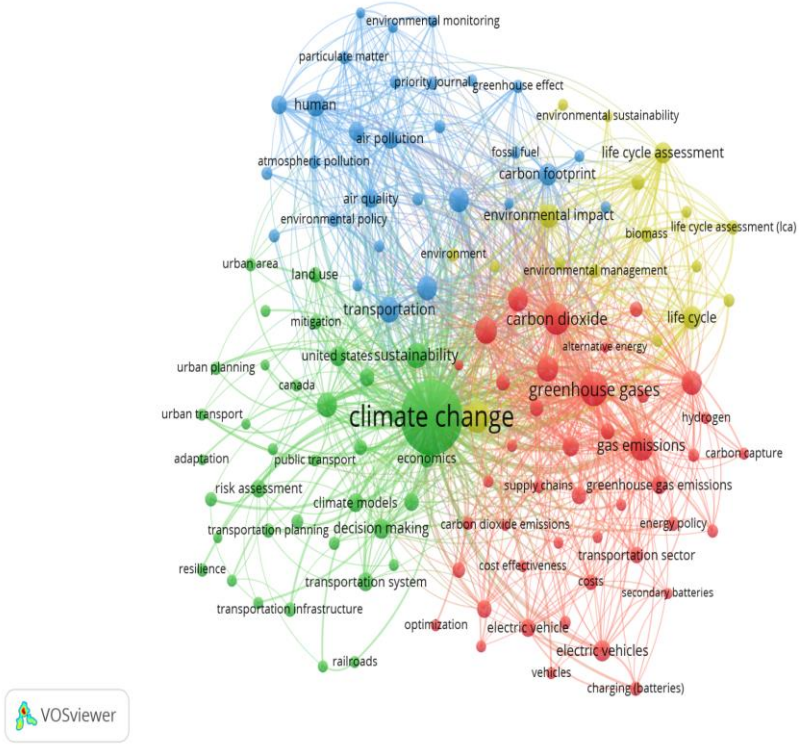

Figure 5. Matching network for the most common keywords

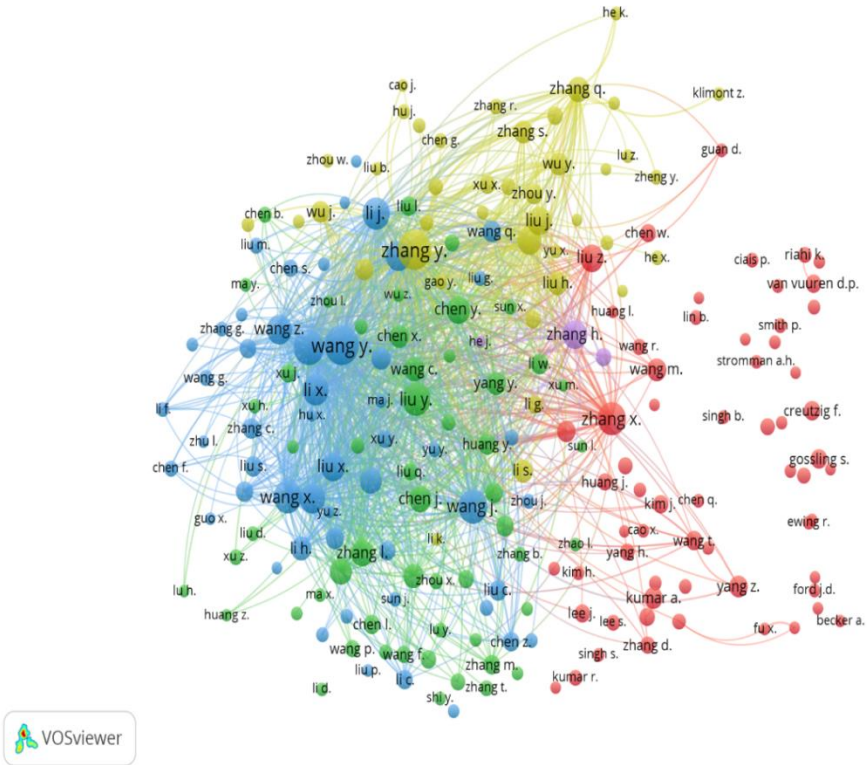

Figure 6. Most cited authors' network

5. LIMITATIONS OF THE STUDY

Several things could be improved in current bibliometric research. Firstly, the use of a single database to search for literature may not provide a comprehensive view of the field, as other databases such as Dimensions, PubMed, and WoS may have different results. Furthermore, using standardized metrics such as the h-index may not accurately capture the impact of a scholar's work, particularly in cases where the work is seminal but needs more citations. Finally, the responsible use of metrics is important, as bibliometric indicators can be taken out of context and used to measure things they were not intended to measure.

6. CONCLUSIONS

Our bibliometric study, "From Roads to Emissions: Bibliometric Insights into Transportation and Climate Change Research," underscores the rapidly increasing volume of research at the intersection of transportation and climate change. This surge in scholarly activity, particularly from 2018 to 2023, reflects a growing academic and policy focus on this crucial area.

Key insights from our analysis indicate a significant rise in publication volume and a varied citation impact, suggesting that while research output is expanding, only a subset of works gain extensive recognition and influence. The United States, leading in both publications and citations, highlights regional disparities in research impact, with other prolific countries like China and India not matching in citation influence.

These findings emphasize the importance of fostering international cooperation and funding collaborative research to enhance the impact and relevance of studies in this field. Policymakers are advised to consider these insights to strategically support research that can drive effective climate action in the transportation sector. Future research should explore the dynamics of research impact and how to optimize collaborative efforts for more significant scientific and policy influence.

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