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Research Article

Exploring Research Trends and Themes in Intelligent Transportation Systems in the Last 10 Years (2014 – 2023)

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Abstract: Intelligent Transportation Systems (ITS) are actively working towards transforming transportation systems by implementing solutions that improve the quality and quantity of transportation and traffic data at both individual and collective levels. This research aims to comprehensively analyze the field of Intelligent Transportation Systems (ITS) through a thorough bibliometric analysis covering the period from 2014 to 2023. The goal is to gain an in-depth understanding of the evolution of ITS research. This research employs bibliometric analysis to uncover trends and patterns in studies related to "Intelligent Transportation Systems." The research data is sourced from the Scopus database, encompassing information from document titles, abstracts, and keywords. The time frame considered for this study spans from 2014 to 2023. Studies were identified using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) framework. From the 39,846 records identified from the Scopus database, 1,839 studies were included in the analysis. Subsequently, the results are analyzed using the VOS viewer software. The analysis highlights a significant shift in research focus, with core themes like "intelligent transportation sys," "vehicle," "algorithm," and "system" remaining central. Cybersecurity and associated risks have gained prominence due to increased connectivity in ITS. The study identifies promising research directions, including experimental technology validation, real-time traffic management solutions, and IoT and smart city concept integration. This research provides a comprehensive and novel overview of the ITS field's evolution and trends, offering actionable insights for advancing intelligent transportation systems.

Keywords: Bibliometric Analysis; PRISMA; Scopus Database; Transport Services Flow; VOS Viewer.

1. Introduction

In the 1980s, a group of transportation professionals developed the concept of Intelligent Transportation Systems (ITS) or Smart Transportation Systems. Initially, ITS was known as Intelligent Vehicle-Highway Systems (IVHS), emphasizing the advancement of technology to enhance the interaction between vehicles and roadways. This idea emerged in response to the growing complexity of challenges in urban transportation and traffic [1]–[3]. ITS represents integrating information and communication technology to improve the transportation system's efficiency, safety, and traffic management [4], [5].

Intelligent Transportation Systems (ITS) actively transform urban and interurban transport, providing sustainable solutions to current mobility challenges. These systems are committed to sustainable mobility through their innovative and flexible nature [6], [7]. The primary drivers are transport effectiveness, efficiency, and user security [8]. ITS actively aims to revolutionize transport systems by introducing solutions that enhance the quality and quantity of transport and traffic information on both

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individual and collective levels [9]. This leads to a more informed and efficient traffic and transport services flow. ITS distinguishes itself by its holistic approach, actively integrating various transportation components, including infrastructures and vehicles, and all involved stakeholders [10], [11]. This integration is essential for creating a cohesive and efficient transportation network.

Furthermore, ITS is in a state of rapid evolution and expansion, reflecting the dynamic and interdisciplinary nature of the transport sector. The intersection of transportation with other knowledge areas emphasizes its broad relevance and the potential for wide-ranging impacts, encompassing technology, urban planning, environmental science, and social policy. ITS actively represents more than just technological advancements; they signify a paradigm shift in the perception and management of transportation. By focusing on sustainability, efficiency, and the integration of diverse elements and stakeholders, ITS actively reshapes the future of urban and interurban mobility, making it more adaptable to the needs of modern societies and the challenges they confront [12].

Bibliometric tools and methods are widely recognized and prevalent techniques for analyzing fundamental and applied research outcomes. These methodologies are increasingly esteemed as valuable means of assessing the progression, productivity, impact, and quality of academic, scientific, and business endeavors. The bibliometric analyses of Intelligent Transportation Systems (ITS) in the literature showcase a variety of approaches, reflecting the multifaceted nature of this field. These approaches include examining the intellectual structure of ITS research, which delves into the foundational theories and concepts driving advancements in this area. Such analyses, cited in references [13]–[16], provide insight into the theoretical underpinnings and evolving paradigms of Intelligent Transportation Systems (ITS).

Bibliometric studies focusing on publications [17], [18] shed light on the trends in ITS research over time, including the growth in the number of publications and the emerging themes within this domain. This perspective is crucial for understanding the trajectory of ITS research and its growing significance in the academic and practical realms. Authorship analyses [19]–[22] in ITS research reveal the key contributors, influential authors, and collaborative networks that shape the field. These studies help identify leading experts and institutions and the patterns of collaboration and knowledge exchange that drive innovation in ITS.

Research on journals [23] and [24] that publish ITS-related articles provides insight into the dissemination channels and the impact of this research within the academic community. This perspective is vital for understanding how ITS research is communicated and how it influences related fields. Moreover, specific areas within the transport field, such as urban smart mobility [25], automotive technologies [26], [27], and the automotive supply chain [28], have been the focus of bibliometric studies. These analyses illuminate specialized areas within ITS, showcasing the diversity and depth of research in each subfield. However, it is essential to note that these analyses above have often concentrated on specific thematic areas. This underscores the potential for a holistic approach encompassing all themes, their variations, and components found within the literature. Such a comprehensive perspective would facilitate a more thorough understanding of the entire ITS research landscape, providing insights into the interconnectedness of various aspects and themes [29], [30]. It would ensure that diverse elements, from technological advancements to policy considerations, are considered, ultimately guiding a more well-rounded approach to ITS research and development [2].

This research aims to thoroughly analyze the Intelligent Transportation Systems (ITS) field through comprehensive bibliometric analysis. It goes beyond examination to comprehensively assess ITS research's growth, evolution, and performance. The analysis covers the period from 2014 to 2023, providing a contemporary perspective. This research strives to uncover ITS research's intricate intellectual structure through bibliometrics, identifying growth patterns, emerging trends, influential contributors, and pivotal works. In essence, this exploration enhances our understanding of the intellectual landscape of ITS research, offering valuable insights to guide future developments, inform policies, and foster innovation in intelligent transportation systems.

2. Material and Methods

2.1. Research Approach

Bibliometric analysis is a sophisticated quantitative method essential for assessing and critically examining key indicators within scholarly publications in a specified field. This analytical approach, deeply embedded in creating detailed knowledge maps through exhaustive databases, is geared towards unveiling emerging patterns and trends in a particular study area. The seminal contributions of researchers have been instrumental in highlighting its pivotal role in academic research [31]–[34].

Fundamentally, bibliometric analysis is a comprehensive tool for researchers, enabling them to meticulously compile and interpret data from publications [35]–[38]. This process involves thoroughly investigating the temporal spread of research papers, pinpointing prominent authors, institutions, and journals, and

delineating the disciplinary contours of academic research. It further illuminates the intricacies of collaborative networks, tracking the dynamics of interaction and partnerships among authors and institutions.

The methodology is characterized by three principal components: co-citation analysis, co-authorship analysis, and co-word analysis. Co-citation analysis, as elucidated by [39]–[41], entails an examination of the frequency and patterns of joint citations of two documents. This analysis provides profound insights into a field's intellectual structure and evolution. Co-authorship analysis, as explored in the studies by [42], [43], concentrates on the patterns of authorial collaboration, thus revealing the social fabric of academic research networks. Co-word analysis initiated [44] and expanded upon [45]–[47] involves the scrutiny of the concurrent appearance of keywords in scholarly literature, aiding in the mapping of thematic landscapes and conceptual frameworks within a research domain.

The development and advancement of visual analytics tools such as CiteSpace, CitNet Explorer, Gephi, Pajek, and VOS Viewer, as highlighted by Pradhan (2017), have greatly simplified the process of examining, creating, and representing bibliometric networks [48]. These tools have significantly improved the analysis and visualization of bibliometric data, making it more accessible for researchers. By utilizing these tools, scholars can now identify clusters of keywords, discern emerging research trends, uncover primary research themes, and even pinpoint potential directions for future investigations within a specific field. This approach to bibliometric analysis offers a comprehensive and holistic perspective, as it involves reviewing and analyzing a substantial body of relevant literature. Consequently, bibliometric analysis is invaluable for gaining insights into the complex research landscape, ultimately facilitating evidence-based decision-making in academic and scientific realms.

2.2. Source of Information

Following the perspectives outlined by Sweileh [49] and Khudhair et al. [50], it is noteworthy that the scientific data utilized in this research was collected from the comprehensive Elsevier Scopus database. This choice of data source underscores the significance of utilizing a reputable and extensive database to ensure the reliability and robustness of the research findings.

Scopus is an impressive academic repository with over 87 million records from various sources, including 27.1 thousand journals, 140 thousand conferences, and 261 thousand books. Scopus is updated daily with approximately 11 thousand new indexed articles. In 2021, there was a significant increase with the addition of 4,042,234 new items, or about 4.74%. This includes an additional 1198 journals (up by 4.80%), 18 thousand standalone book titles (increased by 7%), 170 thousand book items (increased by 8%), and 576 thousand additional conference papers (increased by 5%). This growth underscores the vital role of Scopus in supporting academic research and the dissemination of knowledge [51]. Hence, it can be inferred that Scopus offers one of the most comprehensive perspectives on the current state of global research.

Scopus provides users a wealth of bibliometric analysis acceleration features and global coverage [52]. These features include multi-criteria filters that enable the segmentation of the worldwide dataset based on various criteria, such as journal names, document types, publication years, author names, author affiliations, citation counts, and more. This capability enhances Scopus's usability for conducting sophisticated and refined bibliometric analyses. Researchers can leverage these functionalities to gain valuable insights and information relevant to their research inquiries.

2.3. Data Processing and Analysis

Bibliometric analysis is a pivotal quantitative approach that scrutinizes extensive academic datasets, such as collections of research articles, to unearth pivotal themes within a specified scholarly domain and forecast emergent streams of inquiry [53]. The intrinsic value of bibliometric analysis is widely recognized; however, Van Eck and Waltman posit that the method's utility is significantly amplified by the interpretive power of visual data representations [54]. On this premise, the VOS viewer software emerges as the chosen platform for the present study.

Developed by Nees Jan van Eck and Ludo Waltman at the Centre for Science and Technology Studies (CWTS) of Leiden University in 2010, the VOS viewer is a formidable tool for creating and exploring network data visualizations [55]. The software's capabilities encompass the visualization and analysis of networks built from various academic components such as publications, journals, scholars, institutions, nations, keywords, and concepts. These networks are interlinked through diverse scholarly relationships including, but not limited to, co-authorship, occurrences within literature, citations, bibliographic coupling, and co-citation dynamics [56], [57].

The utility of a VOS viewer is not confined to network generation. As Van Eck and Waltman underscore, the software excels in its ability to assimilate data from an array of scientific repositories and databases such as Scopus, as well as compatibility with numerous reference management systems like RIS, EndNote, and RefWorks [54]. This multifaceted capability endows VOS viewers with the distinction of being an indispensable instrument for

executing thorough bibliometric studies, thereby facilitating a profound comprehension of the intricate patterns and connections that characterize the scientific landscape.

2.4. Procedures

Our research focused on the keyword "Intelligent Transportation Systems," we conducted a comprehensive search within the Scopus database. Our search encompassed the titles, abstracts, and document keywords, and it was explicitly limited to documents published between 2014 and 2023. We employed the following query for our search: "TITLE-ABS-KEY (INTELLIGENT AND TRANSPORTATION AND SYSTEMS) AND PUBYEAR>2013 AND PUBYEAR<2024". Subsequently, we organized the search results based on their relevance. This meticulous search yielded 39,846 documents that precisely aligned with our research criteria.

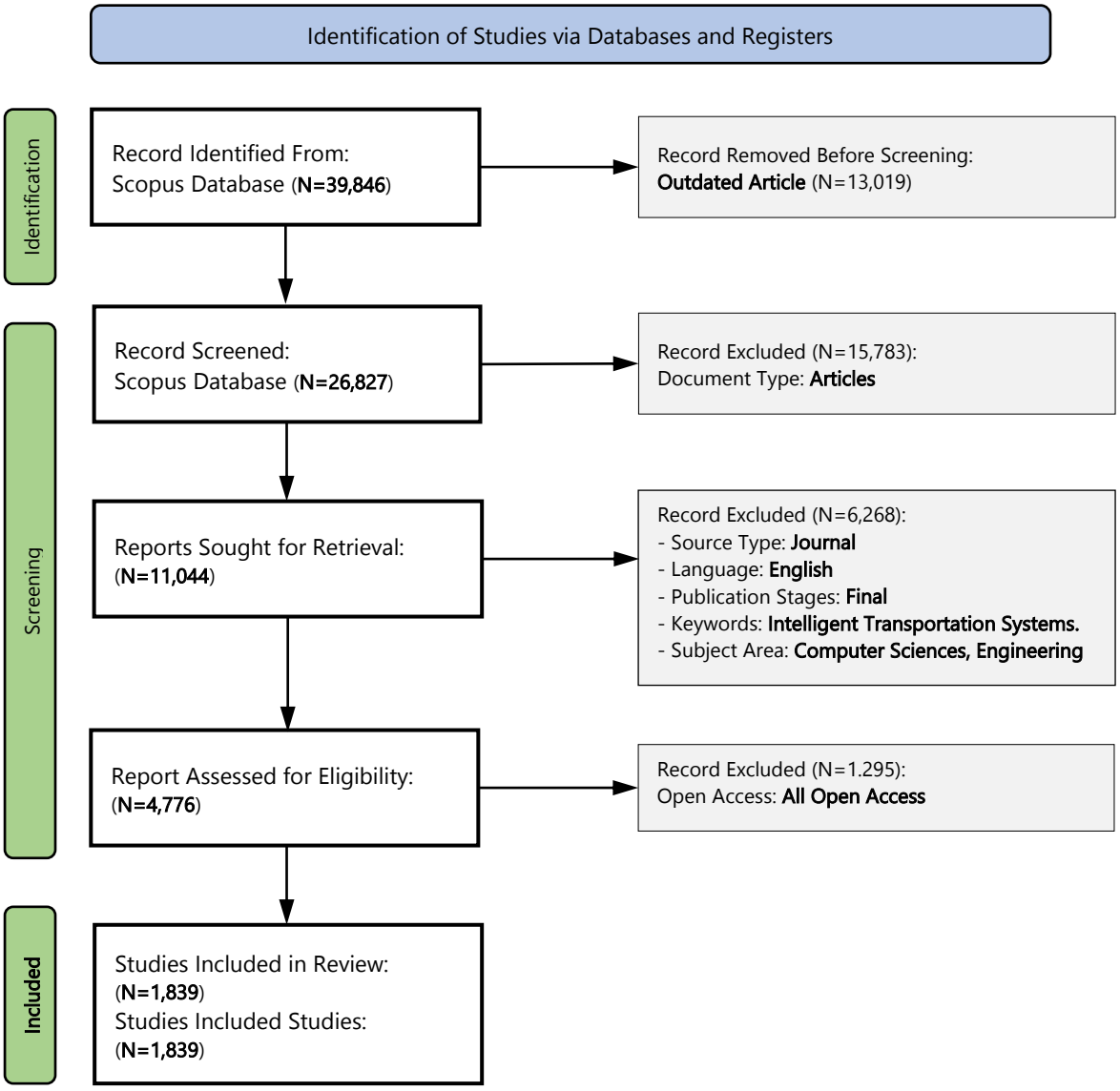

Figure 1. Flow Diagram of PRISMA Methodology

In scientific research, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a framework used to identify studies that meet a particular study's inclusion and exclusion criteria.

The process begins with the identification stage, where researchers use data sources such as databases and academic registries to search for potential studies. They use keywords, fields of study, and other criteria to search for relevant studies. In this research, researchers identified 39,846 records from the Scopus Database. The next step is the screening stage. Researchers examine each study against the predefined inclusion criteria. Only studies that meet these criteria can be included in further analysis. Finally, after careful evaluation, only 1,839 studies that meet the standards of quality and relevance can be

included in the literature review and processed with VOS viewer analysis.

2. Result and Discussion

3.1. Trend of Publication

Over the past decade, the Intelligent Transportation Systems (ITS) sector has displayed a notable upward trend in scholarly output, as evidenced by the data from 2014 to 2023. The graphical analysis points to a substantial increase in research publications, from 42 in 2014 to 322 in 2021, suggesting a heightened focus and investment in ITS. This peak may reflect significant advancements or shifts in the transportation sector's technological and policy landscape.

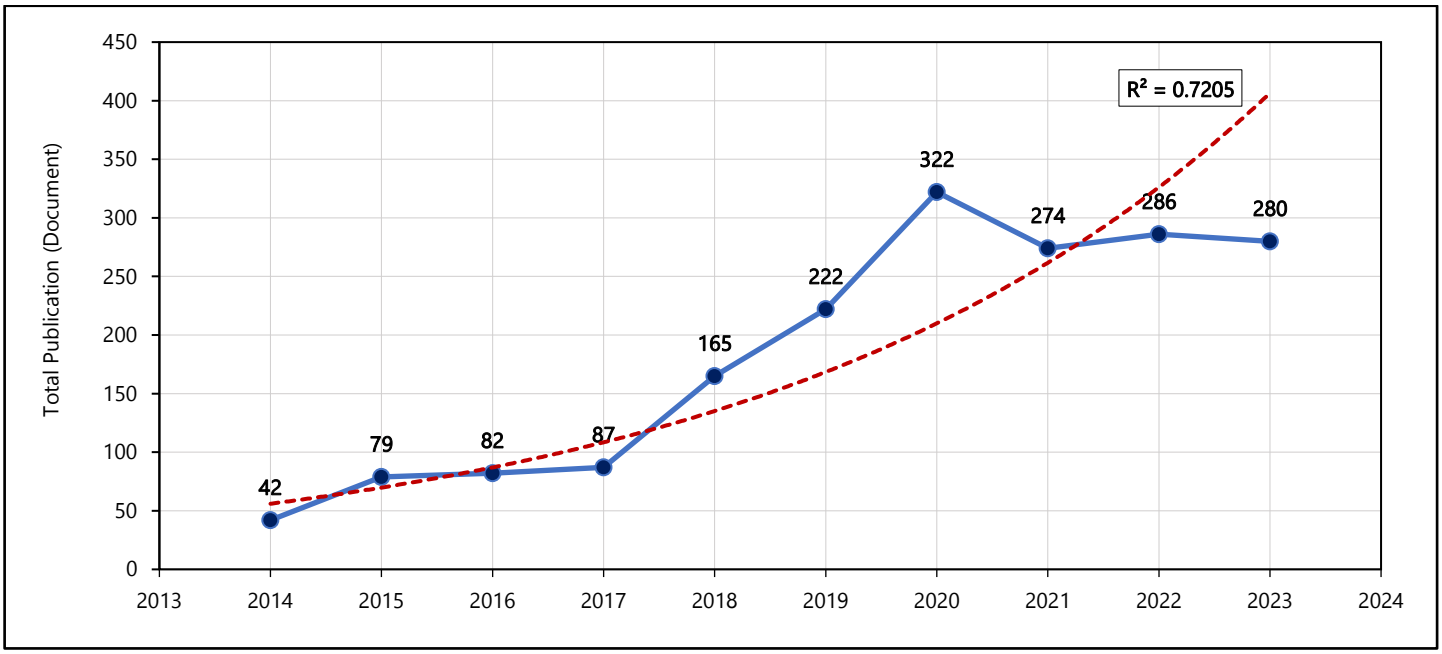

Figure 1. Intelligent Transportation Systems Publication Trend in the last ten years (2014 – 2023)

However, the growth path was not without its ebbs and flows, with a noticeable decline between 2021 and 2022 hinting at the impact of external economic, regulatory, or funding factors temporarily affecting ITS research momentum. The regression analysis, denoted by a dotted trendline with an R^2 value of 0.7205, explains 72.05% of the variability in publication count through an exponential temporal model. This robust percentage, while indicative of a strong correlation, also implies the presence of other influential factors not encompassed by the model. This decade-long data trend reflects the dynamic evolution within the ITS research landscape, shaped by both consistent growth and occasional variances.

3.2. Document by Sourced Journals.

Figure 2 shows the top 10 journals with the most documents from the Scopus database. During the data collection, IEEE Access emerged with the most significant number, recording 302 documents, followed by IEEE Transactions on Intelligent Transportation Systems with 138 documents. Additionally, Sensors Switzerland contributes 106 documents, and Sensors provides 85 documents, explicitly referring to literature that addresses sensor technology.

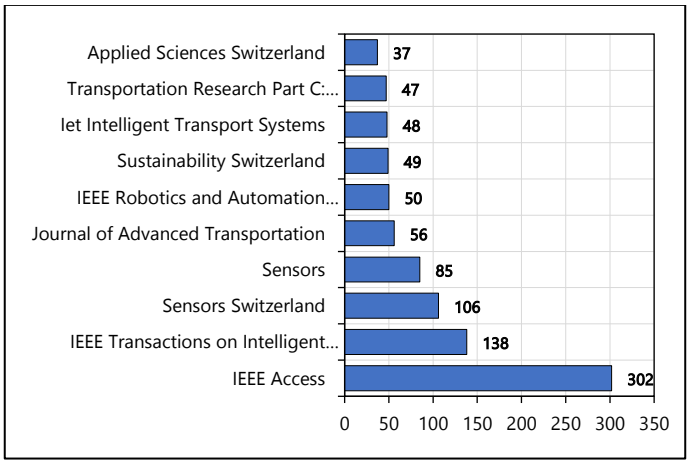

Figure 2. Top 10 Sourced Journals with The Highest Number of Documents.

Furthermore, the Journal of Advanced Transportation includes 56 documents, while IEEE Robotics and Automation Letters contribute 50 documents, likely discussing innovations within the transportation context.

Moreover, Sustainability Switzerland, with 49 documents, and IET Intelligent Transport Systems, with 48 documents, focus on sustainability aspects within transportation systems. Finally, Transportation Research Part C: Emerging Technologies, with 47 documents, and Applied Sciences Switzerland, with 37 documents, also make notable contributions by discussing new technologies and aspects related to Intelligent Transportation Systems (ITS).

3.3. Document by Country

Table 2 describes the leading contributors to the literature on Intelligent Transportation Systems (ITS), spotlighting the concerted global endeavors to propel advancements in intelligent transportation systems. China emerges as the foremost contributor, boasting 621 documented contributions, trailed by the United States (276), the United Kingdom (140), India (129), South Korea (111), Spain (97), Saudi Arabia (94), Italy (85), Pakistan (84), and Canada (72).

Table 1. Top 10 Countries with the Highest Number of Documents.

Country	Number of Document
China	621
United State	276
United Kingdom	140
India	129
South Korea	111
Spain	97
Saudi Arabia	94
Italy	85
Pakistan	84
Canada	72

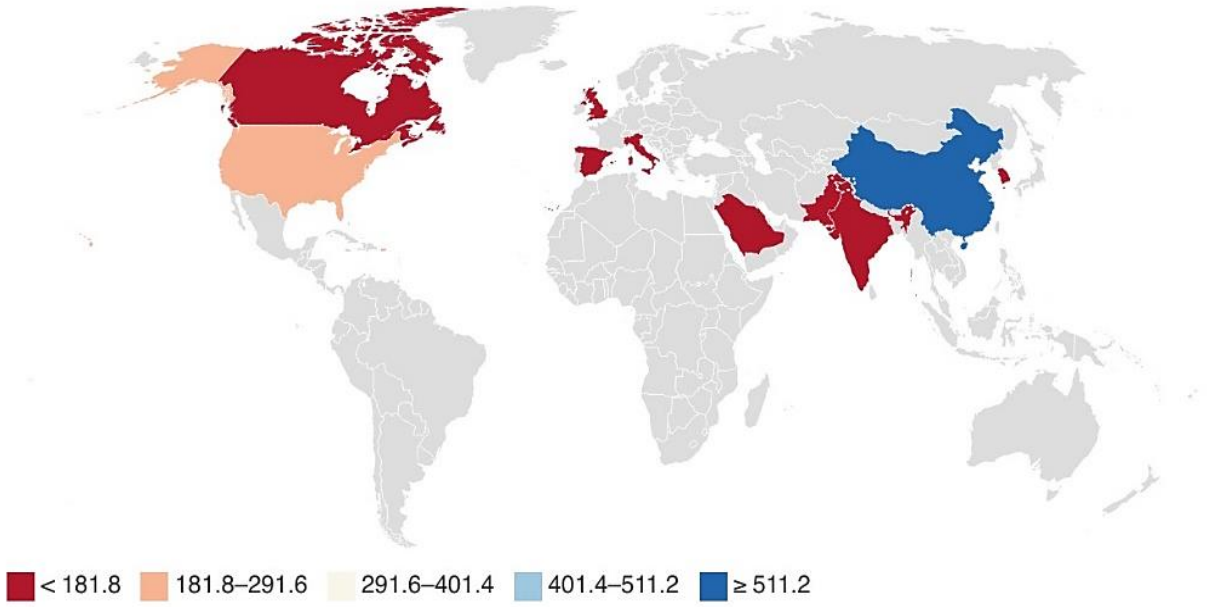

Figure 3. Top 10 Countries with the Highest Number of Documents.

These substantial contributions emphasize the worldwide importance of enhancing transportation systems. China and the United States notably emerged as pivotal leaders in ITS research, displaying a solid dedication to pioneering innovative transportation technologies. The involvement of diverse nations like the United Kingdom, India, South Korea, Spain, Saudi Arabia, Italy, Pakistan, and Canada reflects a collective global commitment to seeking improved solutions for managing transportation systems.

The differing publication counts signify diverse research focuses within each country. Some prioritize autonomous vehicle technology, while others prioritize traffic management or integrated transportation systems. This diversity underscores unique national research inclinations and potential areas of specialization.

3.4. Document by Authors

Figure 4 illustrates the top ten authors with the most documents in the Intelligent Transportation Systems (ITS) field. This figure provides an overview of the research productivity achieved by these authors in this specific discipline.

From the figure, it can be observed that two authors, Cano, J.C. and Calafate, C.T., lead in terms of productivity with 12 documents. They are highly active contributors to scientific research in this discipline. Pau, G. and Aadil, F. produced nine documents in the third position. This

indicates a commendable level of productivity in their research and significant contributions to this field of study.

Furthermore, Manzoni, P., Iskandarani, M.Z., and Cao, Y. have eight documents. This suggests that they also play essential roles in contributing to the scientific literature in this discipline. With seven documents each, authors Wymeersch, H., Parida, M., and Collotta, M. have also made significant contributions to scientific research in their respective Intelligent Transportation Systems (ITS) areas.

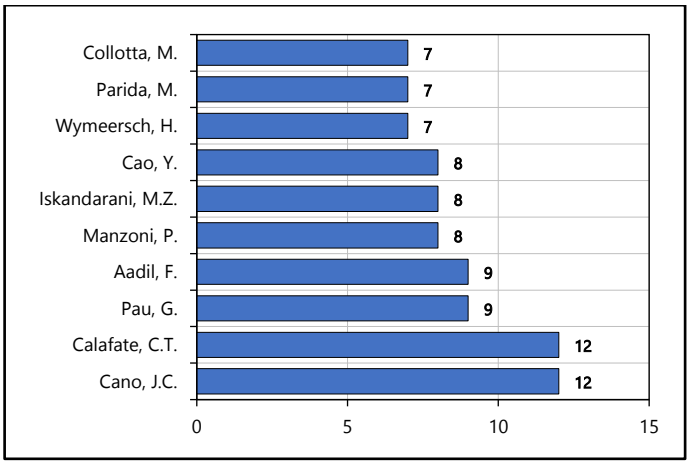

Figure 4. Top 10 Authors with The Highest Number of Documents.

3.5. Document by Affiliation

Figure 5 presents the top ten affiliations that have significantly contributed to academic literature based on the number of documents they have produced, particularly in Intelligent Transportation Systems (ITS). These affiliations represent institutions and organizations actively engaged in research and scholarly activities.

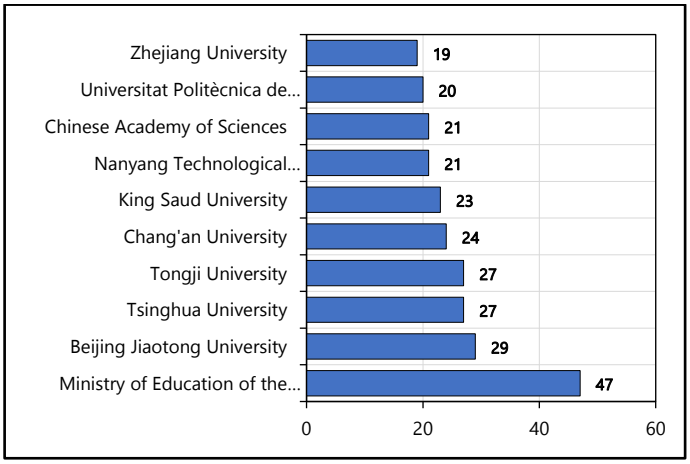

Figure 5. Top 10 Affiliations with The Highest Number of Documents.

At the forefront of this list is the "Ministry of Education of the People's Republic of China," with an impressive 47 documents reflecting the substantial commitment of the Chinese government to research and education. This underscores the importance placed on academic achievements and the advancement of knowledge in ITS. Following closely are Beijing Jiaotong University and Tsinghua University, prestigious academic institutions in China, each with 29 and 27 documents, respectively. Their substantial research output highlights their dedication to advancing knowledge in the field. Tongji University and Chang'an University are tied for the fourth position, each contributing 27 documents, signifying their significant role in academic literature, particularly transportation and engineering. King Saud University ranks fifth on the list with 23 documents, emphasizing its noteworthy contribution to academic research, especially within Saudi Arabia. Nanyang Technological University and the Chinese Academy of Sciences share the sixth position with 21 documents, underlining their substantial contributions and prominent roles on the global research stage. Universitat Politècnica de València in Spain has produced 20 documents demonstrating its contributions to European academic research. Finally, Zhejiang University completes the list with 19 documents, indicating its active involvement in research and scholarly activities related to ITS.

3.6. Trends in Research Subjects/Topics Based on Occurrence and Relevance.

Trends in research subjects/topics based on occurrence and relevance are valuable for researchers, institutions, and policymakers as they provide insights into the evolving landscape of a specific field of study, helping to guide research priorities and resource allocation to the overall goals and objectives.

In this context, occurrence means how frequently a particular term, subject, or topic appears in research articles, publications, or scholarly works. It quantifies the prevalence or frequency of discussion and research related to a specific subject.

Relevance indicates the significance or importance of a particular term, subject, or topic within the research context or field of study. It measures how closely aligned a subject is with the current research trends and the overall goals and objectives of the field.

Table 2 provides a comprehensive overview of the occurrence and relevance of article subjects within three distinct clusters: Cluster 1 (Red), Cluster 2 (Green), and Cluster 3 (Blue). Each cluster represents a specific thematic area within intelligent transportation systems (ITS). This table is a helpful resource for researchers, allowing them to identify key research topics and trends in intelligent transportation systems based on the frequency and relevance of specific keywords within distinct thematic clusters.

Table 2. The Occurrences and Relevance of Article Subjects Trend.

Cluster 1 (Red)			Cluster 2 (Green)			Cluster 3 (Blue)		
Term	Occur.	Relev.	Term	Occur.	Relev.	Term	Occur.	Relev.
Intelligent Transportation Systems	1179	0.35	Vehicle	991	0.36	Sensor	213	0.28
System	923	0.25	Technology	732	0.29	Internet	190	0.54
Model	780	0.59	Communication	348	1.27	Smart City	136	0.33
Data	748	0.53	Solution	337	0.18	Context	130	0.21
Algorithm	566	0.18	Safety	328	0.29	Thing	114	2.11
Approach	566	0.27	Service	317	0.38			
Time	785	0.2	Challenge	289	0.27			
Study	417	0.41	Scheme	249	0.88			
Accuracy	398	1.39	Infrastructure	242	0.81			
State	293	0.81	Simulation	224	0.18			
Experiment	278	0.94	Vehicular Ad Hoc Network	173	5.5			
Framework	268	0.22	Simulation Result	154	1.02			
Speed	241	0.42	Security	134	2.28			
Experimental Result	208	1.6	Vanets	128	5.37			
Effectiveness	185	0.19	Vanet	108	6.15			
Traffic Flow	172	1.06						
Intersection	149	0.26						
Traffic Congestion	125	0.57						
Real-Time	104	0.36						

Cluster 1 (Red): This cluster is characterized by a focus on "Intelligent Transportation Systems" (ITS), which is the central subject with 1179 occurrences and a relevance score of approximately 0.35. This indicates that ITS is a primary and significant topic in the literature analyzed. Additionally, terms like "System," "Model," "Data," and "Algorithm" are notable within this cluster, underlining the importance of modeling, data analysis, and system components in the context of intelligent transportation.

Cluster 2 (Green): Cluster 2 is centered around the theme of "Vehicle," which appears 991 times with a relevance score of around 0.36. This suggests a strong emphasis on vehicle-related topics, possibly related to intelligent vehicle technologies. "Technology" and "Communication" are prominent keywords, highlighting the significance of technological advancements and communication systems in ITS. Furthermore, "Safety" is another crucial aspect in this cluster, focusing on ensuring the safety of intelligent transportation systems.

Cluster 3 (Blue): Cluster 3 notably emphasizes "Sensor", with 213 occurrences and a relevance score of approximately 0.28. Sensors play a crucial role in data collection and monitoring within ITS. "Internet" is another significant keyword, suggesting the importance of the Internet of Things (IoT) and Internet connectivity in this cluster. "Smart City" is also present, implying a focus on integrating ITS into the broader context of smart city infrastructure. The keyword "Thing" likely refers to IoT devices and their role within intelligent transportation systems.

This table provides valuable insights into the prominence and relevance of various subjects within the ITS literature. It reveals the primary thematic areas within each cluster, showcasing the core research interests in ITS. Cluster 1 highlights the foundational aspects, including system modeling and data analysis. Cluster 2 centers on vehicle technologies, communication, and safety. Cluster 3 emphasizes the role of sensors, IoT, internet connectivity, and smart city integration.

3.7. Network Visualization

The visualization (Figure 6) illustrates a vibrant and interconnected research landscape, were traditional traffic management research blends with cutting-edge topics like vehicular networks and smart cities, reflecting the dynamic nature of intelligent transportation system studies.

Red Cluster: This cluster appears densely connected, suggesting a solid interrelationship between its keywords. Keywords like "traffic flow," "traffic congestion," "model," and "algorithm" are prominent. This indicates a significant focus on modeling and algorithms to understand and mitigate traffic issues. The concentration and density of connections suggest that this is a well-established area of research with substantial overlap in themes and methodologies.

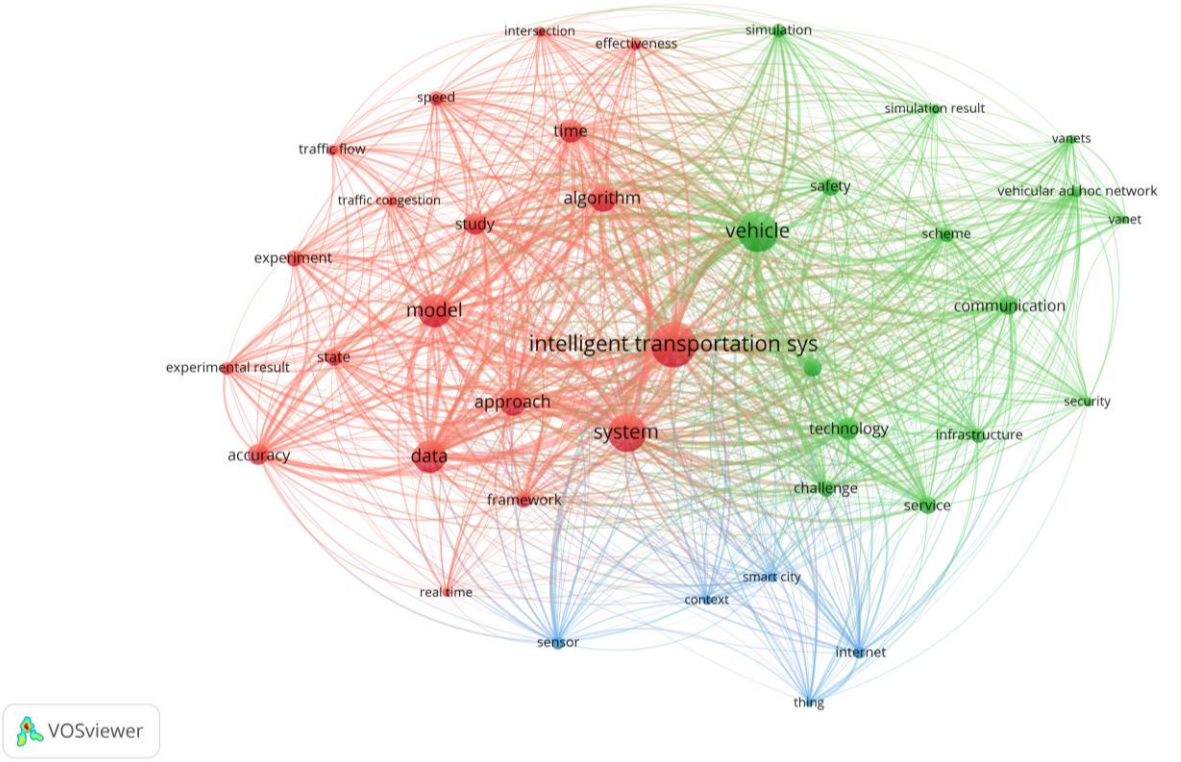

Figure 6. Network Visualization of Intelligent Transportation Systems.

Green Cluster: The keywords in the green cluster, such as "vehicular ad-hoc network," "communication," "security," and "service," point towards research on the communication aspects of intelligent transportation systems, emphasizing the importance of network security and service quality. This could reflect an emerging or evolving field, as indicated by the connections' lighter, more spread-out nature.

Blue Cluster: This cluster seems to include "smart city," "sensor," "internet," and "context," which implies a focus on the integration of intelligent transportation systems within the broader context of smart city infrastructure, including the use of sensors and the internet. This might indicate interdisciplinary research that blends transportation with urban planning, information technology, and IoT (Internet of Things).

The visualization also indicates the degree of interdisciplinary nature of the research area, with numerous inter-cluster connections suggesting that topics like "model," "data," and "algorithm" are central to the field and interact with a variety of other topics.

3.8. Overlay Visualization

The VOSviewer visualization (Figure 7) provides a comprehensive view of the evolving landscape of intelligent transportation systems research from August 2019 to April 2020. It highlights the fluid nature of research topics, indicating the current focus areas and the trajectory of academic interest over time.

The varying colors of the nodes, transitioning from red to blue across the timeline, illustrate how research emphases have shifted. Early research topics, represented by redder nodes, might encompass foundational theories and models, while bluer nodes indicate the rise of recent themes like VANETs, signaling a shift towards more contemporary issues and technologies.

Central nodes such as "intelligent transportation sys" and "vehicle," along with "algorithm" and "system," are indicative of the core subjects within the field, underlining their consistent relevance. Due to their prominence and interconnectivity, these nodes suggest a multidisciplinary approach within the research community, with critical themes serving as hubs that link various aspects of the intelligent transportation discourse.

The network's clusters reveal concentrated efforts in specific areas, such as the interrelation between "vehicle" and "safety," highlighting the intensive study into safety mechanisms and technologies. The emergence of topics like "vanet" towards the timeline's blue end reflects the field's responsiveness and adaptability to new technological advancements and industry needs.

Terms that serve as bridges, like "technology" and "system," are pivotal, connecting disparate clusters and fostering a comprehensive understanding of the field. These bridging concepts are crucial for developing integrated solutions to the complex challenges in intelligent transportation systems.

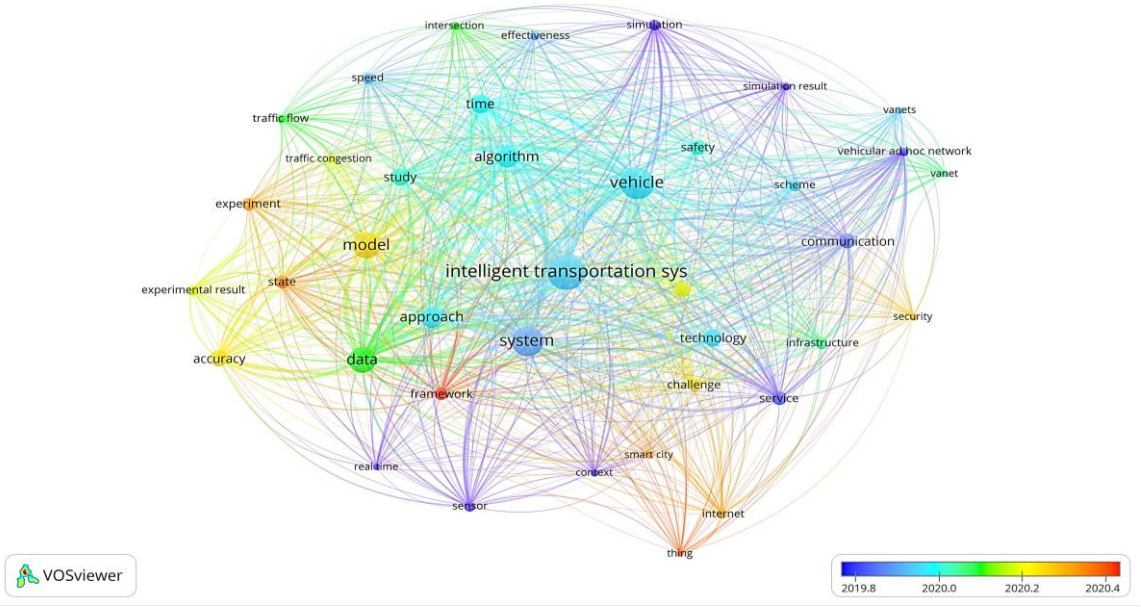

Figure 7. Overlay Visualization of Intelligent Transportation Systems.

This visualization is more than a mere academic tool; it is instrumental for policymakers and funding agencies to discern research trends and allocate resources effectively. It lets stakeholders track how innovations, regulations, and standards drive research direction. The visualization's macroscopic perspective of shifting focus areas over a specified period underscores the research community's need for flexibility and forward-thinking. It reaffirms the significance of an interdisciplinary approach in tackling the multifaceted issues of intelligent transportation systems, ensuring that research and policy remain congruent with the rapid pace of technological change.

3.9. Density Visualization

In the density visualization (Figure 8), words like "intelligent transportation sys," "vehicle," and "system" stand out, indicating that these topics are at the core of research in intelligent transportation systems. This suggests a strong focus on developing and implementing technologies to enhance transportation efficiency, safety, and reliability.

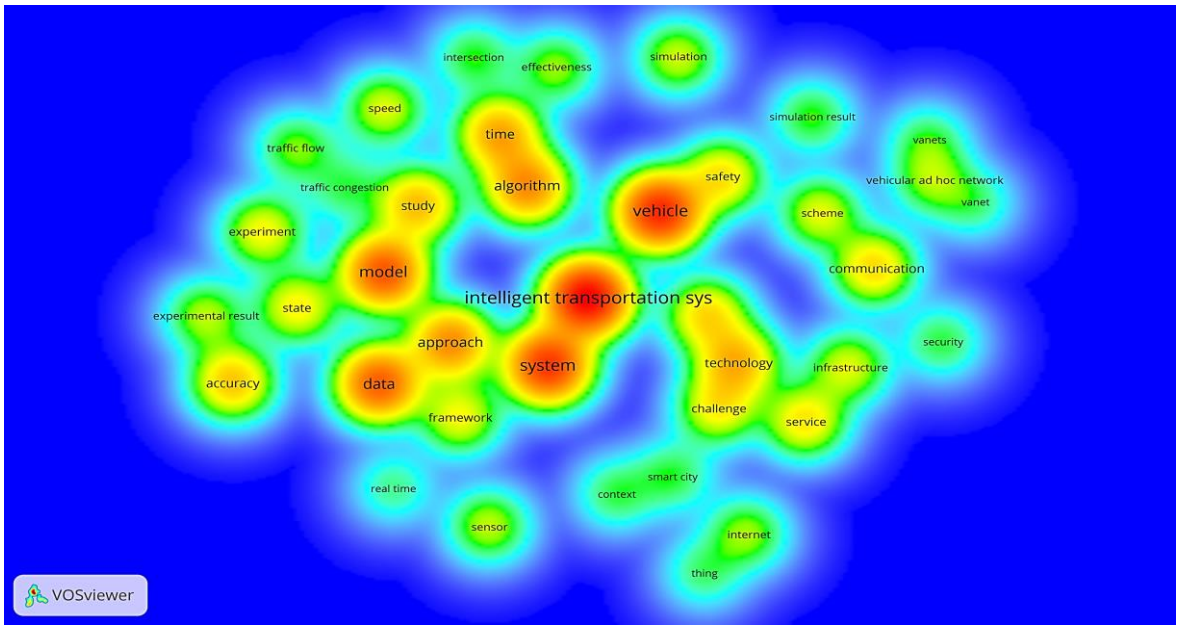

Figure 8. Density Visualization of Intelligent Transportation Systems.

The interconnection between "vehicle," "safety," and "communication" highlights that vehicle safety heavily relies on advanced communication systems. This may include Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications, crucial for accident prevention and effective traffic management.

The terms "model" and "data," appearing in bright colors, underscore the significance of accurate data collection and effective modeling in predicting and managing traffic flow. They also play a critical role in designing responsive and adaptive transportation systems.

Clusters encompassing "communication," "vanets" (Vehicular Ad-hoc Networks), and "security" highlight the importance of communication and security technologies in the context of intelligent transportation. Security has become a significant concern with the increasing connectivity and cyber risks in connected transportation systems.

The density visualization reveals that intelligent transportation systems are multidisciplinary, integrating aspects from engineering, information technology, cyber security, and traffic management. Areas with less brightness on the map, such as "experimental result" or "real-time," may indicate opportunities for further research. Researchers can focus on experimental validation of existing technologies or developing real-time solutions for traffic management.

Policymakers and practitioners in the transportation sector can utilize the findings of this analysis to guide investments and policies. By understanding the relationships between concepts and current trends, they can better determine infrastructure development priorities and regulations supporting innovation in intelligent transportation systems.

4. Conclusion

This research extensively analyses the growth, evolution, and intellectual landscape of Intelligent Transportation Systems (ITS) within the scientific literature. Its primary objective is to unveil the central trends in the ITS research field, offering professionals, scientists, and academics valuable insights to identify strengths and emerging research opportunities in their respective areas of interest. The analysis reveals a significant shift in focus from long-standing topics to emerging ones, with core research themes like "intelligent transportation sys," "vehicle," "algorithm," and "system" retaining their enduring importance. Moreover, cybersecurity and associated risks have gained prominence due to increased connectivity in ITS, emphasizing the crucial nature of research in this area. The study also highlights promising avenues for further research, including experimental validation of existing technologies and the development of real-time solutions for traffic management, along with integrating Internet of Things (IoT) technologies and smart city concepts. This research offers a comprehensive and novel overview of the ITS field's evolution and key trends, providing actionable insights and contributing to the advancement of intelligent transportation systems.

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