

EXPLORING THE KNOWLEDGE LANDSCAPE OF GEOMATICS IN URBAN MOBILITY: A BIBLIOMETRIC ANALYSIS

Sassi Naoufal^{1*}, Akourri Omar², Benbba Brahim³,

^{1*}PhD Student, Materials, Systems and Energy Engineering Laboratory (MaSEEL) - UAE/U04FST Tangier-Abdelmalek Essaadi University- Morocco - <https://orcid.org/0009-0001-0078-1180>,
Email ID: nowalamta@gmail.com

²Professor, Materials, Systems and Energy Engineering Laboratory (MaSEEL) - UAE/U04FST Tangier, Abdelmalek Essaadi University- Morocco - <https://orcid.org/0009-0006-8005-2469>,
Email ID: oakourri@uae.ac.ma

³Professor, Marketing, Logistics and Management Laboratory (MLM Lab, ENCG Tangier, Abdelmalek Essaadi University- Morocco- <https://orcid.org/0009-0009-5570-1692>,
Email ID: b.benbba@uae.ac.ma

Abstract

Objectives: To map the scientific production related to geomatics and urban mobility through a comprehensive bibliometric approach.

Methods: We applied bibliometric analysis using VOSviewer on Scopus-indexed documents, combining co-authorship, keyword co-occurrence, and citation analyses to identify trends, clusters, and influential actors.

Findings: Results show a rising interest in geomatics and urban transport research. Thematic evolution reveals a shift toward AI, sustainable mobility, and smart city integration. Europe and Asia dominate output, but multimodal equity is underexplored.

Novelty: This is the first study to synthesize global research trends at the intersection of geomatics and urban mobility, revealing emerging gaps and proposing future directions for interdisciplinary exploration.

Keywords: bibliometric analysis; geomatics; urban mobility; GIS; remote sensing; smart transport; spatial analysis; sustainable mobility

Introduction

In the 21st century, urbanization has rapidly intensified worldwide, leading to increasingly complex challenges in planning and managing urban mobility systems. According to the United Nations (2018), more than 55% of the global population currently lives in urban areas—a figure expected to reach 68% by 2050. This demographic trend exerts immense pressure on transportation networks, environmental sustainability, and urban infrastructure. In response, policymakers and researchers are turning to advanced technological solutions, including those offered by geomatics, to enable smarter, more sustainable urban mobility.

Geomatics refers to the field of science and technology that deals with the collection, analysis, and interpretation of spatial data using tools such as Geographic Information Systems (GIS), remote sensing (RS), Global Navigation Satellite Systems (GNSS), spatial statistics, and photogrammetry (Konecny, 2003). These tools provide essential support for urban transport planning, traffic forecasting, multimodal integration, and real-time decision-making. The applications of geomatics in urban mobility are numerous, from designing optimal public transport routes (Cats et al., 2015), to modeling urban logistics networks (Taniguchi & Thompson, 2015), and detecting patterns in commuting behavior (Lin et al., 2020).

GIS technologies have transformed the ability to analyze traffic congestion, accessibility, land use, and socio-demographic factors affecting travel behavior (Convery & Williams, 2019). By integrating multiple data layers, GIS enables visualization of spatial relationships that are critical for policy

interventions. For instance, in developing countries, GIS has supported bus route optimization in cities like Nairobi and Lagos, where traditional transport infrastructure is insufficiently mapped (Salon & Gulyani, 2019). Similarly, remote sensing, through satellite and aerial imagery, has provided powerful capabilities for monitoring urban sprawl and its effect on mobility (Weng, 2012; Herold et al., 2005). Recent advancements in data science have further expanded the possibilities of geospatial analysis. The combination of geomatics with big data, sensor networks, and artificial intelligence has led to the development of intelligent transport systems (ITS) and smart mobility platforms (Bibri & Krogstie, 2017). These systems rely heavily on spatial data to forecast travel demand, monitor air pollution, and support shared mobility services. In this context, geomatics has shifted from a support tool to a core element in decision-making frameworks for sustainable urban mobility (Geurs et al., 2010; Marsden et al., 2014).

Despite this progress, the literature on the intersection between geomatics and urban mobility remains fragmented. Multiple subfields have evolved independently, leading to thematic silos across disciplines such as civil engineering, urban planning, transportation geography, and computer science. While several review articles have been published on specific tools—such as GIS for transport planning (Shaw et al., 2008) or RS in urban growth modeling (Taubenböck & Kraff, 2014)—a comprehensive understanding of the broader knowledge structure is lacking. There is also a limited view of how research themes have evolved over time, which countries and institutions are leading the field, and how interdisciplinary collaborations are shaping the future of urban mobility.

Bibliometric analysis offers a robust method to address this gap. As a quantitative approach, bibliometrics involves the statistical analysis of scientific publications to evaluate patterns of authorship, collaboration, citation, and knowledge diffusion (Donthu et al., 2021). It enables the identification of influential papers, key research clusters, emerging topics, and historical trajectories. Compared to systematic reviews, which rely on thematic synthesis, bibliometric methods provide a data-driven visualization of the intellectual landscape, which is particularly useful for interdisciplinary fields like geomatics and transport.

By applying co-authorship, co-citation, and keyword co-occurrence analyses, the study will reveal the intellectual structure and thematic evolution of the field. It will also examine global research networks, the role of institutions, and country-level contributions, highlighting the dynamics of scientific production in this interdisciplinary domain. The research questions guiding this analysis include:

What are the publication trends and scientific output related to geomatics and urban mobility? Which authors, institutions, and countries have contributed most significantly to this field? What are the main research themes, and how have they evolved over time? Which journals and conferences serve as the primary publication venues? What are the emerging areas that require further investigation?

In addressing these questions, the study aims to provide a knowledge base for scholars, practitioners, and policymakers interested in harnessing the potential of geomatics for sustainable urban mobility. By mapping the conceptual and methodological foundations of the field, it will also identify research gaps and propose directions for future exploration.

The remainder of this paper is organized as follows. The next section describes the bibliometric methodology, including data collection, processing, and analytical tools. This is followed by a presentation of the results, including publication trends, authorship patterns, thematic clusters, and emerging topics. The discussion section interprets the findings in light of current policy challenges and technological trends, and the final section concludes with a summary of contributions and recommendations for future work.

Methodology

This study adopts a quantitative, exploratory research design through bibliometric analysis to map and understand the scientific production at the intersection of geomatics and urban mobility. Bibliometric methods are widely used to provide a comprehensive overview of academic disciplines by statistically analyzing publication patterns, citation behaviors, and thematic structures (Donthu et

al., 2021; Aria & Cuccurullo, 2017). The rationale for choosing this method lies in its objectivity and scalability, which allow researchers to assess large volumes of scientific literature in a systematic and replicable way (Merigó & Yang, 2017). Given the interdisciplinary nature of geomatics—spanning environmental sciences, engineering, planning, and information systems—and the multifaceted challenges of urban mobility, a bibliometric approach is particularly suited to examine the field's intellectual landscape, identify research gaps, and forecast future directions.

Bibliometric analysis provides both performance metrics and science mapping techniques. Performance analysis quantifies the productivity and impact of researchers, institutions, journals, and countries, typically through publication counts, citation analysis, and h-indexes (van Eck & Waltman, 2010). Science mapping, on the other hand, reveals structural and dynamic relationships among scholarly contributions by analyzing co-authorship, co-citation, and keyword co-occurrence networks (Zupic & Čater, 2015). In this study, both dimensions are considered. The workflow involves three stages: (1) data collection through a curated query in Scopus; (2) data preprocessing and normalization; and (3) bibliometric analysis using VOSviewer.

The Scopus database was selected as the primary source of bibliographic data. Scopus offers broader coverage compared to Web of Science in areas relevant to geomatics, such as engineering, computer science, and environmental planning (Falagas et al., 2008). Furthermore, it provides comprehensive metadata, including citation counts, keywords, authorship details, institutional affiliations, and subject categories. Google Scholar was excluded due to inconsistencies in metadata, and while Web of Science remains a strong alternative, its indexing of conference proceedings and technical journals in applied sciences is more limited. The data extraction was performed in February 2025, ensuring up-to-date coverage.

To ensure a precise yet inclusive dataset, a Boolean search string was developed iteratively and validated through sample screenings. The final query was applied to the TITLE-ABS-KEY fields (title, abstract, and keywords) in Scopus:

```
TITLE-ABS-KEY (geomatic* OR "geospatial technology" OR "geographical information system*" OR GIS OR "remote sensing" OR "spatial analysis") AND TITLE-ABS-KEY ("urban transport*" OR "transport management" OR "urban mobility" OR "traffic management" OR "public transport" OR "urban logistics")
```

This query was designed to capture literature at the intersection of geomatics and urban mobility from multiple disciplinary perspectives. Only journal articles, conference proceedings, and review papers were included to ensure scientific rigor; editorial notes, book reviews, and non-peer-reviewed content were excluded. The search was limited to English-language publications to ensure consistency and avoid translation bias.

To process and visualize the bibliometric data, one main tool was employed: VOSviewer (van Eck & Waltman, 2010) was used to create co-authorship networks, co-occurrence maps of keywords, and citation-based clustering. The software allows for mapping of high-dimensional bibliometric data using force-directed layouts, enabling the identification of thematic clusters and influential authors or institutions.

Although bibliometric methods offer high objectivity, several limitations must be acknowledged. First, the reliance on a single database (Scopus) may result in underrepresentation of grey literature and non-indexed research, particularly from low- and middle-income countries. Second, restricting the analysis to English-language publications introduces a degree of linguistic bias. Third, citation counts do not always reflect scientific quality or impact, as they may be influenced by author prominence or self-citation. To mitigate these limitations, sensitivity checks were performed, and transparency in query construction and data filtering was maintained throughout. Ethical considerations were minimal given that all data were derived from publicly available bibliographic sources.

Results

Scopus Analysis

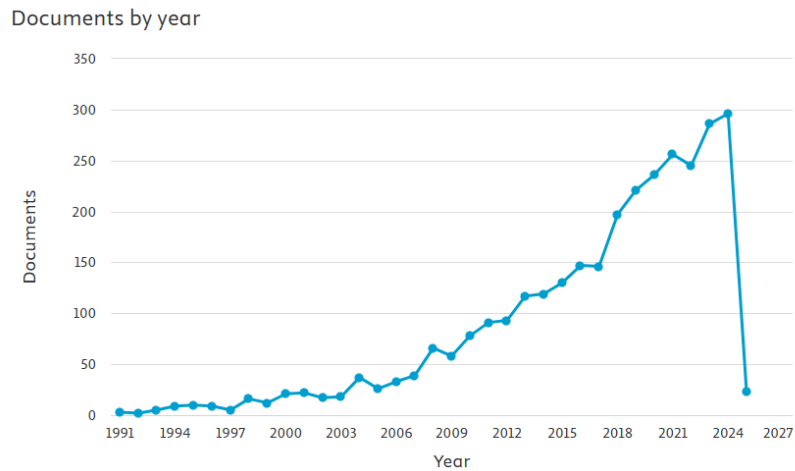


Figure 1: Document per Year - Scopus Analysis

This Scopus trend analysis graph represents the evolution of publications in geomatics applied to urban transportation over time. The gradual increase from the 2000s reflects the growing importance of GIS, remote sensing, and spatial analysis in transport planning. The sharp rise after 2015 corresponds to the integration of AI, machine learning, and big data into the field, enhancing real-time mobility management and environmental monitoring. The peak in 2024 suggests a high level of academic interest, while the sudden drop in 2025 is likely due to incomplete data for the year. The overall trend highlights the increasing role of geomatics in smart urban mobility solutions.

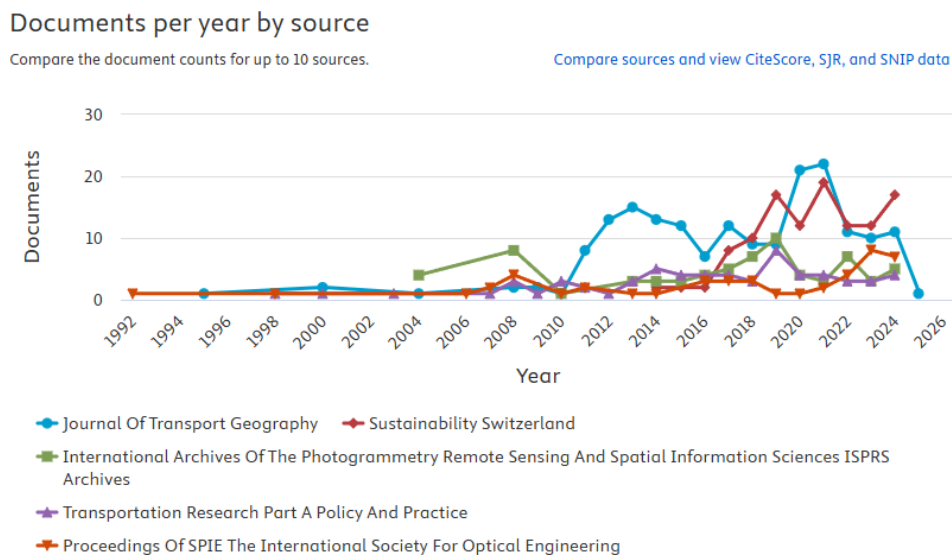


Figure 2: Document per year by source - Scopus Analysis

The Journal of Transport Geography (blue) has shown the highest publication activity, peaking around 2020-2022, reflecting the increasing role of spatial analysis in mobility studies. Sustainability Switzerland (red) has gained prominence in recent years, emphasizing the growing interest in sustainable transport solutions. The International Archives of Photogrammetry and Remote Sensing (green) had an early peak around 2007, likely due to technological advancements in GIS and remote sensing. The recent rise in multiple sources highlights an interdisciplinary expansion, integrating

policy, photogrammetry, and optical engineering into transport and geomatics research. The drop in 2025 is likely due to incomplete data rather than a decline in interest.

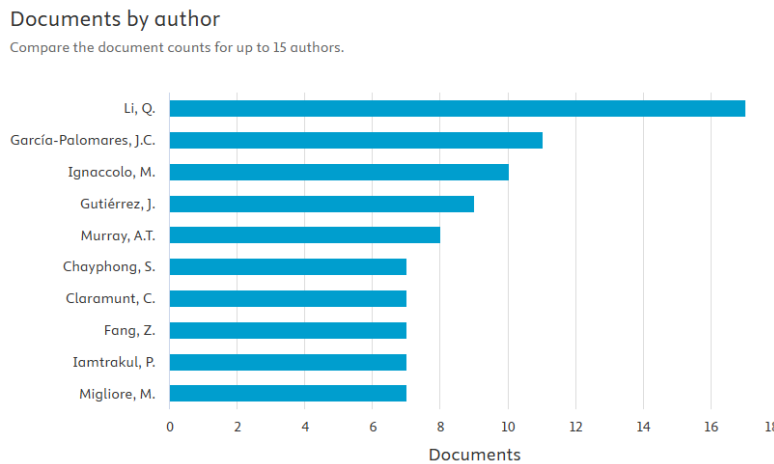


Figure 3: Documents by author - Scopus Analysis

This graph presents the top contributing authors in geomatics and urban transportation research based on their publication count. Li, Q. leads with the highest number of documents, indicating a strong influence in the field, likely focusing on GIS, remote sensing, or transport modeling. García-Palomares, J.C., Ignaccolo, M., and Gutiérrez, J. are also prominent, suggesting significant contributions to spatial analysis and transport planning. The presence of authors like Murray, A.T. and Chayphong, S. reflects interdisciplinary work, potentially integrating urban mobility, sustainability, and infrastructure optimization. The broad distribution of authors highlights a diverse and collaborative research environment, reinforcing the increasing importance of geomatics in smart and sustainable urban transport solutions.

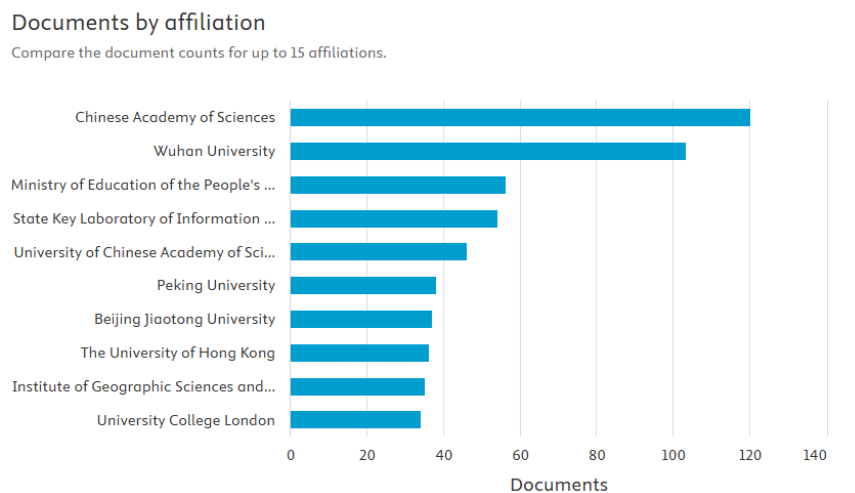


Figure 4: Documents by affiliation - Scopus Analysis

This graph highlights the top research institutions contributing to geomatics and urban transportation studies. The Chinese Academy of Sciences leads in publications, followed closely by Wuhan University, both known for advancements in remote sensing, GIS, and spatial analysis. Other key contributors, such as the Ministry of Education of China and the State Key Laboratory of Information, indicate strong government support for research in geomatics. Peking University and Beijing Jiaotong

University also play a significant role, particularly in transportation planning and smart mobility. Outside China, institutions like University College London and The University of Hong Kong reflect international contributions, emphasizing the global interest in intelligent and sustainable urban transport solutions.

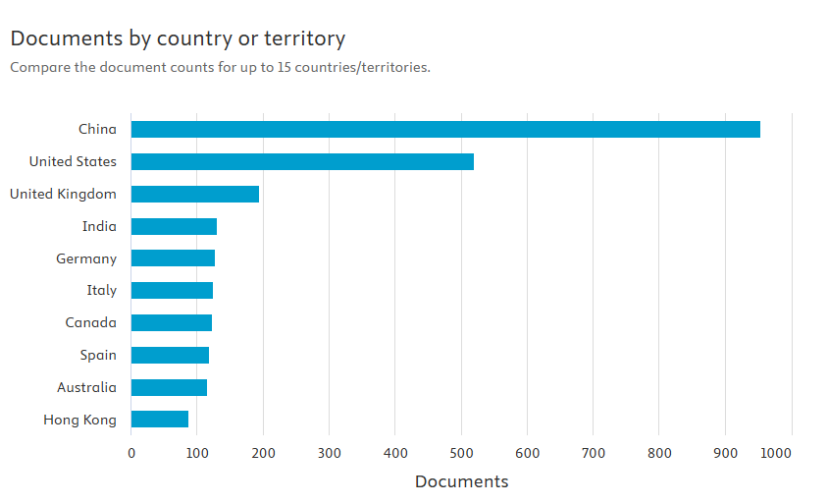


Figure 5: Documents by Country - Scopus Analysis

China leads with the highest number of publications, reflecting its strong investment in GIS, remote sensing, and smart mobility solutions. The United States follows, indicating its significant role in technological advancements and urban planning research. The United Kingdom, India, and Germany also show notable contributions, highlighting their focus on sustainable transport and geospatial applications. Countries like Italy, Canada, and Spain demonstrate growing research efforts, while Hong Kong appears as a regional hub for innovation. The global distribution emphasizes the increasing interdisciplinary and international collaboration in geomatics for urban transport management.

Documents by subject area

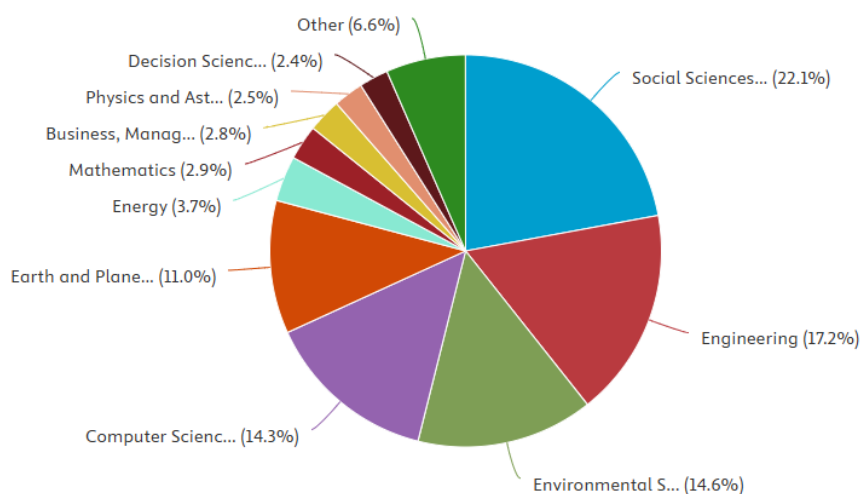


Figure 6: Documents by Subject area : Scopus Analysis

Social Sciences (22.1%) lead, highlighting the focus on urban planning, policy, and human mobility studies. Engineering (17.2%) and Environmental Sciences (14.6%) reflect the strong integration of infrastructure development, sustainability, and ecological impact assessments. Computer Science (14.3%) is significant due to the growing use of GIS, AI, and machine learning. Earth and Planetary Sciences (11.0%) emphasize geospatial analysis and remote sensing applications. The contributions from Energy (3.7%), Mathematics (2.9%), and Business & Management (2.8%) suggest increasing interest in transport optimization, smart cities, and economic sustainability. This distribution confirms that geomatics is a multidisciplinary field shaping modern urban mobility solutions.

Bibliometric Analysis

- **Key words Co occurrence**

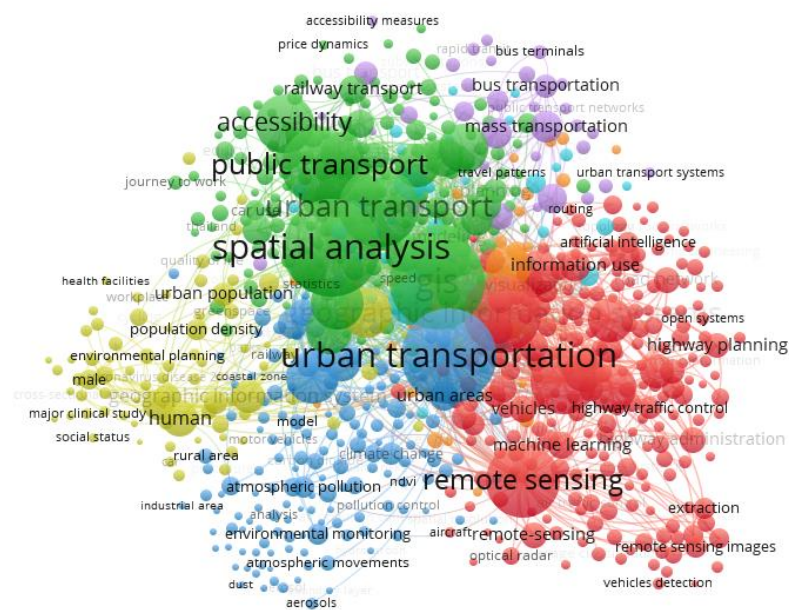


Figure 7: Co Occurrence of Key words – Vosviewer elaborated by authors

The analysis of clusters in the research map reveals distinct thematic areas that contribute to urban transportation studies. At the center, the green cluster focuses on spatial analysis, urban transport, and public transport, emphasizing the crucial role of spatial analysis in understanding transportation systems and accessibility. Closely linked to infrastructure planning and network optimization, this cluster serves as the foundation of urban transport research. On the right, the red cluster is dominated by technological advancements, including remote sensing, artificial intelligence, and machine learning. These innovations play a key role in enhancing transport management and planning, particularly through automation and sensor-based monitoring.

In contrast, the blue cluster at the bottom addresses environmental aspects such as atmospheric pollution, climate change, and environmental monitoring. This highlights the growing concern for sustainable transport solutions that mitigate pollution and promote environmentally friendly policies. On the left, the yellow cluster focuses on social and demographic dimensions, integrating concepts like urban population, population density, and environmental planning. This cluster underlines the importance of incorporating population needs into transport policies to ensure accessibility and equity. Finally, the purple cluster, positioned at the top, relates to transportation infrastructure, including bus systems, railway networks, and mass transportation. These elements are essential for addressing mobility demands in expanding urban areas.

Beyond these thematic clusters, the network analysis highlights the high level of interconnectivity among technological, environmental, and social dimensions. Spatial analysis and urban transportation emerge as central concepts, acting as bridges between clusters and reinforcing the interdisciplinary nature of research in this field. Additionally, the increasing presence of artificial intelligence and machine learning suggests a strong research trend toward leveraging technology to tackle complex urban transport challenges.

In conclusion, this bibliometric map illustrates the interplay between geomatics, advanced technologies, environmental concerns, and social needs, reinforcing the importance of an integrated approach to sustainable urban transportation management.

• **Overlay visualization**

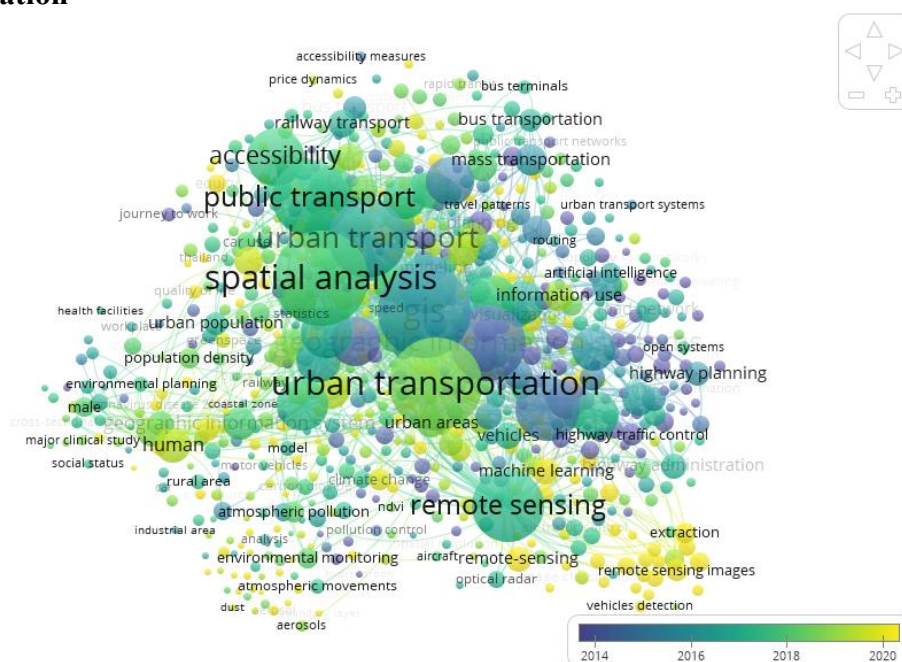


Figure 8: Overlay visualization - Vosviewer- Elaborated by authors

This VOSviewer visualization represents a bibliometric network where colors indicate the average publication year of keywords, providing insights into both thematic clusters and temporal trends. The color gradient at the bottom of the map ranges from blue (2014) to yellow (2020), illustrating the evolution of research topics over time. While blue nodes correspond to older research areas, yellow nodes highlight emerging topics that have gained importance in recent years.

A closer analysis reveals key conceptual trends. The green-blue central area is dominated by urban transportation, spatial analysis, and public transport, indicating that these topics have been consistently studied and serve as foundational pillars of research. In contrast, yellow-colored terms, such as machine learning, artificial intelligence, and remote sensing, point to recent advancements in the field, reflecting a shift toward the use of advanced technologies to enhance urban mobility and transport systems. Meanwhile, blue-colored topics, such as population density, environmental monitoring, and GIS, were early focal points of research but are now being integrated with newer technological approaches.

In addition to technology and environmental considerations, social factors remain an integral part of the discussion. Keywords like population density, urban population, and accessibility are predominantly green, indicating a moderate yet steady research interest in the social and demographic implications of urban mobility. These topics underscore the need for equitable and inclusive transport solutions that address human-centered challenges in mobility planning.

In conclusion, this heatmap analysis highlights urban transportation as the central theme, strongly supported by spatial analysis, GIS, and remote sensing. While emerging technologies like AI and machine learning are increasingly shaping the field, environmental and social considerations remain important, though less dominant, research dimensions. The yellow hotspots illustrate key areas of focus, while the green and blue zones suggest specialized or supporting research themes that contribute to a comprehensive approach to sustainable and intelligent urban mobility.

• Bibliographic coupling - authors

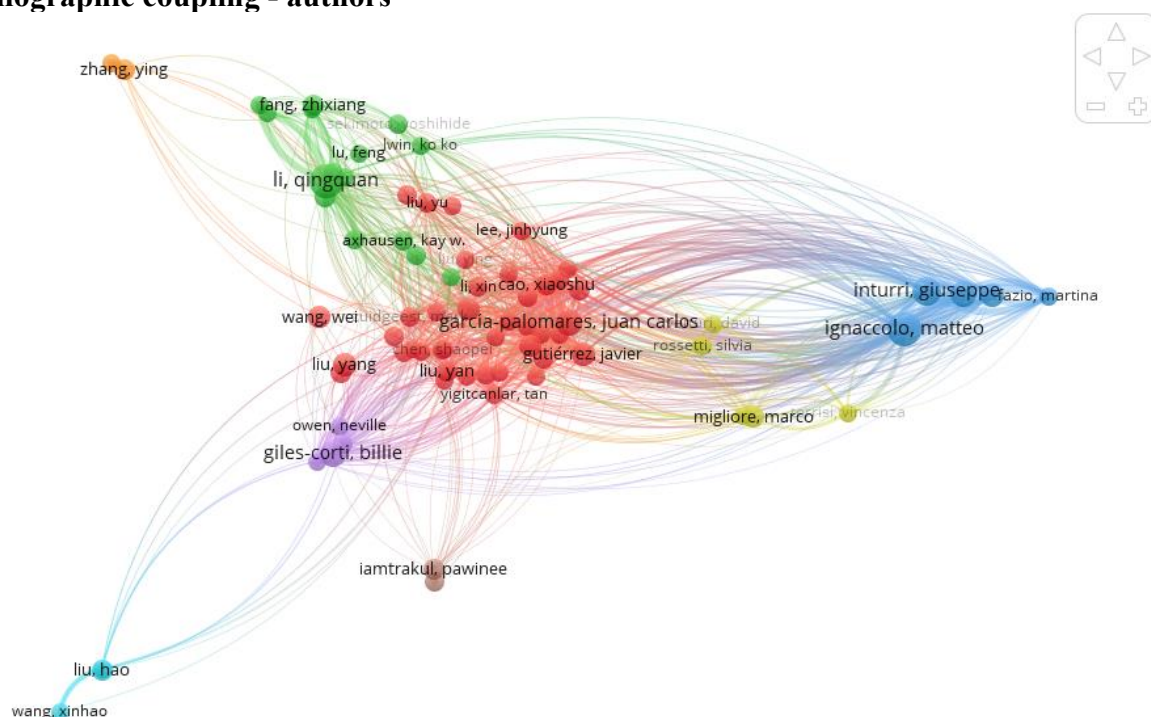


Figure 10: Bibliographic Coupling Authors - Vosviewer - Elaborated by authors

Each node corresponds to an author, with larger nodes indicating higher publication output or stronger collaboration links. The colors denote different clusters of researchers, which are likely formed based on geographic location, institutional affiliations, or specific research themes.

A detailed analysis of clusters and key authors reveals several distinct research groups. At the center, the red cluster is the largest and most interconnected, including Garcia-Palomares Juan Carlos, Gutierrez Javier, and Liu Yu. This suggests strong collaboration in core geomatics and urban transportation studies, reinforcing its central role in the research landscape. To the left-center, the green cluster, featuring Li Qingquan and Fang Zhixiang, appears closely linked to the red cluster, indicating overlapping research areas such as remote sensing and GIS applications.

On the right side, the blue cluster, which includes Inturri Giuseppe and Ignaccolo Matteo, represents a distinct research community. Their connections to the red cluster suggest collaborations in transportation planning and modeling. Meanwhile, the purple cluster in the bottom-left corner, featuring Giles-Corti Billie, appears to focus on health and urban design aspects of transportation, making it a niche but significant research area. Additionally, small peripheral clusters such as Zhang

Ying (orange) and Migliore Marco (yellow) likely represent emerging or regional research groups, characterized by fewer co-authors and specialized topics.

Examining connections and co-authorship links, the thickness of links reveals the frequency of collaboration between authors. Highly connected researchers like Garcia-Palomares and Gutierrez Javier act as bridges between multiple clusters, reinforcing their key role in advancing interdisciplinary research. In contrast, peripheral authors such as Liu Hao and Zhang Ying are positioned on the outskirts of the network, suggesting limited collaborations with other groups. These researchers may be working on emerging topics, contributing independently, or relatively new to the field.

• **Overlay visualization - Authors**

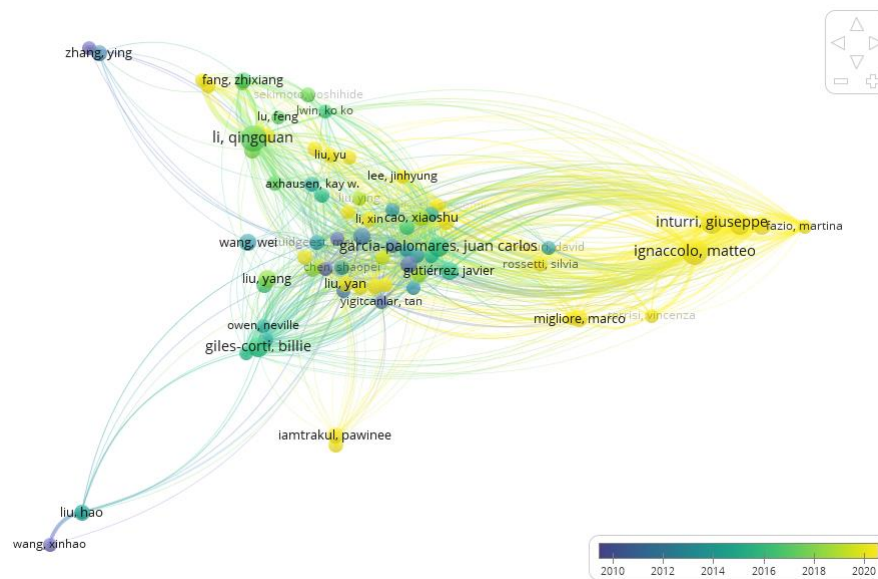


Figure 11: Overlay Visualization - authors - Vosviewer - Elaborated by authors

This VOSviewer map represents co-authorship relationships while incorporating a temporal dimension, indicated by a color gradient from blue to yellow, which corresponds to the average year of publication. Through this visualization, it is possible to observe the evolution of research collaborations in geomatics and urban transportation over time, highlighting the transition from foundational contributors to emerging researchers.

Initially, the blue nodes (2010-2012) represent earlier contributors, such as Zhang Ying and Liu Hao, whose research laid the foundation for subsequent studies. As the field progressed, it experienced a mid-phase expansion of collaborations, as evidenced by the green nodes (2014-2016), where researchers like Li Qingquan, Liu Yu, and Giles-Corti Billie became more active. More recently, a notable shift toward newer research areas is visible through the yellow nodes (2018-2020), where scholars such as Inturri Giuseppe, Ignaccolo Matteo, and Migliore Marco lead emerging collaborations, particularly in cutting-edge and applied research.

Beyond these temporal shifts, an analysis of clusters and connections reveals key structural patterns within the research network. At the center of the network, the dense interconnections of green and yellow nodes indicate ongoing and substantial collaboration, particularly among core researchers such as Garcia-Palomares Juan Carlos, Gutierrez Javier, and Liu Yu. In contrast, peripheral blue clusters, including those featuring Zhang Ying and Liu Hao, correspond to earlier contributors who have fewer active collaborations today, possibly reflecting a decline in involvement or a shift toward niche research areas.

Moreover, a closer look at key observations further supports this interpretation. On one hand, central researchers like Garcia-Palomares Juan Carlos and Inturri Giuseppe exhibit strong connectivity, which reinforces their leadership in collaborative projects and their role in shaping interdisciplinary research efforts. On the other hand, the progression from blue (older research) to yellow (recent research) demonstrates the field's dynamic evolution, where newer contributors build upon foundational studies to expand and diversify research directions. In this context, emerging groups such as those formed by Inturri Giuseppe and Ignaccolo Matteo suggest a growing focus on innovation, particularly in transport modeling, AI applications, and sustainability-driven solutions.

However, while some researchers play a central role in the network, others remain on the periphery. Authors like Zhang Ying and Liu Hao are positioned on the outskirts of the network, suggesting a more limited integration with the central research groups. Their positioning could be attributed to a focus on highly specialized topics, independent research trajectories, or a gradual decrease in research output over time.

In conclusion, this co-authorship network map illustrates how research in geomatics and urban transportation has evolved, transitioning from foundational studies (blue nodes) to technology-driven research (yellow nodes). While established figures like Garcia-Palomares Juan Carlos continue to bridge past and present research efforts, newer contributors are shaping the future of the field through emerging collaborations and interdisciplinary approaches. This evolving structure highlights the growing role of advanced technologies and applied research in addressing contemporary urban transport challenges.

- **Density visualization – Authors**

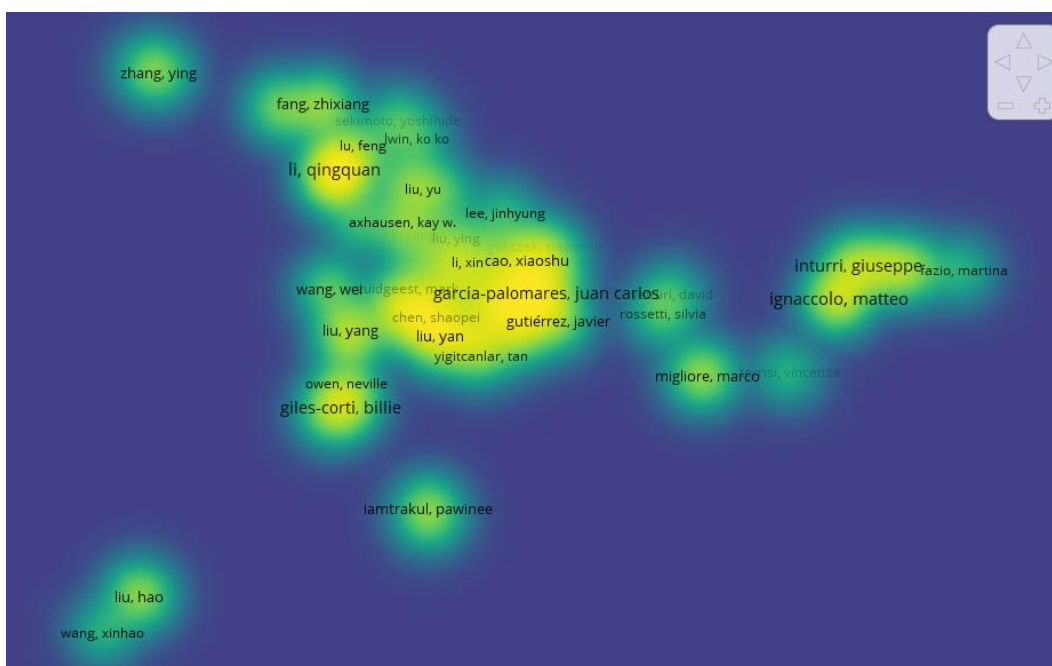


Figure 12: Density Visualization - Authors - Vosviewer- Elaborated by authors

The heatmap colors provide valuable insights into the central contributors, emerging networks, and peripheral researchers.

At the core of the network, the bright yellow areas highlight regions with the highest concentration of co-authorship, representing the most active and influential researchers in the field. Scholars such as Garcia-Palomares Juan Carlos, Gutierrez Javier, and Liu Yu appear in these hotspots, indicating strong collaboration networks and leadership in interdisciplinary research efforts. Surrounding these, the green areas signify moderate levels of collaboration, where researchers like Li Qingquan, Inturri

Giuseppe, and Ignaccolo Matteo play an important but slightly less central role. In contrast, the blue background represents low-density zones, where fewer connections or limited collaborative activity are observed.

A closer look at the key observations further clarifies the structure of the research network. Central collaborators such as Garcia-Palomares and Gutierrez Javier form a dense research hub, reinforcing their significant role in shaping the field. Their strong co-authorship links suggest a highly integrated and influential research community. Meanwhile, peripheral groups—including Liu Hao, Wang Xinhao, and Iamtrakul Pawinee—occupy more isolated positions in the network, indicating limited connections with mainstream researchers. Their placement suggests that they may focus on niche or independent research topics, contributing to specific subfields rather than broad collaborations. Additionally, emerging groups such as Inturri Giuseppe and Ignaccolo Matteo form distinct clusters on the right-hand side, suggesting recent or specialized research directions gaining prominence.

Examining collaborative clusters, three main structures emerge. First, the central cluster, which is bright and highly concentrated, is dominated by Garcia-Palomares and key collaborators, reflecting significant co-authorship and impact in the field. Second, the left cluster, containing Li Qingquan and Fang Zhixiang, indicates a secondary but well-connected network, suggesting important contributions in supporting domains such as GIS and remote sensing applications. Third, the right cluster, led by Inturri Giuseppe and Ignaccolo Matteo, represents a focused group working on emerging topics, particularly in geomatics and urban transportation modeling.

• **Bibliographic coupling: countries**

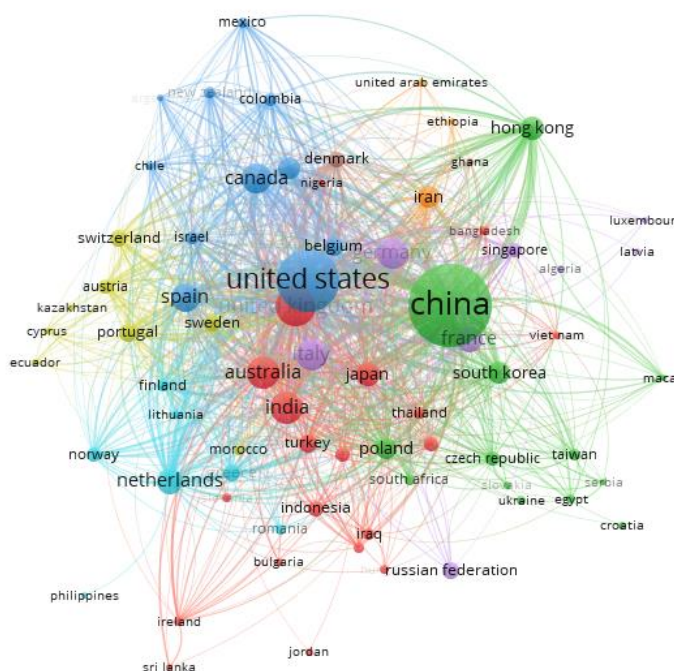


Figure 13: Bibliographic Coupling - Countries - Vosviewer - Elaborated by authors

This VOSviewer map visualizes the global collaboration between countries in geomatics and urban transportation research, where each node represents a country, its size reflects its contribution, and the links indicate co-authorship relationships. Through this visualization, it becomes evident that some countries play a dominant role in global research output, while others act as regional hubs or emerging contributors.

One of the key features of this network is the variation in node size, where larger nodes, such as those representing the United States, China, and India, indicate that these countries are major contributors to the field. Their high publication output and strong international collaborations place them at the center of the research network. Additionally, the thickness of the links between countries, such as those between the United States and China, reflects strong bilateral collaborations, while thinner links, as seen in countries like France and Germany, indicate broader but less intense partnerships across multiple regions. Furthermore, the colors of the clusters represent groups of frequently collaborating nations, reinforcing the existence of regional and strategic research alliances.

Analyzing key clusters and regions, we observe distinct collaborative networks. The red cluster, centered around the United States, includes Canada, Australia, and India, forming a Western research hub, with the United States acting as a global leader in research collaborations, particularly with English-speaking nations. In contrast, the green cluster, dominated by China, consists of South Korea, Singapore, and France, demonstrating China’s role as a major research hub, particularly within Asia and Europe. Meanwhile, the blue cluster, encompassing Germany, Netherlands, Spain, and Sweden, highlights strong intra-European collaborations, emphasizing the region’s high research activity and interconnected networks. Lastly, the purple cluster, consisting of Russia, Poland, and the Czech Republic, suggests a more regionally focused research network, indicating emerging collaborations in Eastern Europe.

Beyond these regional distinctions, some key trends and observations emerge. Firstly, the United States and China remain the two dominant players, forming the strongest international research partnerships and driving the majority of the global output in the field. Secondly, regional hubs, such as France, Germany, and India, serve as bridges between global research leaders and smaller contributors, playing a crucial role in facilitating cross-border collaboration. Additionally, emerging collaborators, including Singapore, South Korea, and Poland, show increasing involvement in international research, highlighting the rising prominence of new academic and research centers.

Interpreting the links and connectivity, the dense interconnections at the center of the map indicate a highly collaborative and internationally engaged research environment, with countries like the United States, China, and Germany fostering partnerships across continents. However, peripheral countries such as the Philippines, Jordan, and Sri Lanka have fewer and thinner connections, reflecting a more localized research focus or limited participation in global academic networks.

• **Overlay visualization - Countries**

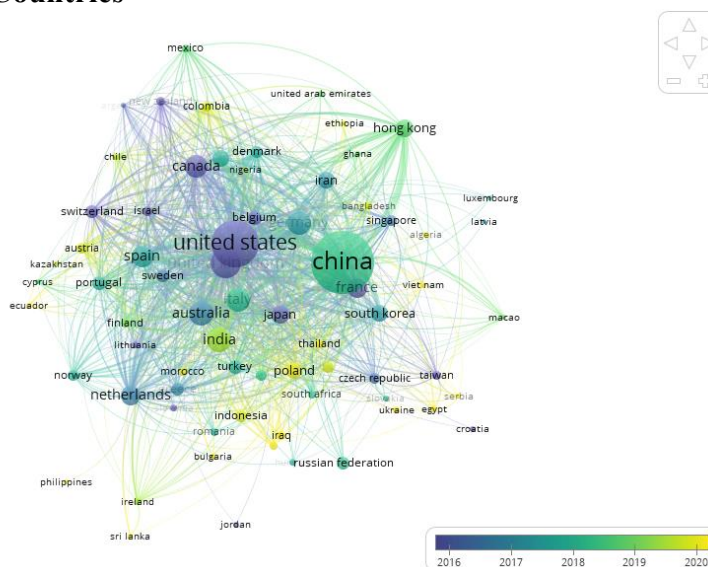


Figure 14: Overlay Visualization - Countries - Vosviewer- elaborated by authors

This approach provides insights into the evolution of global collaborations, highlighting both long-established research networks and emerging contributors.

From a temporal perspective, the blue nodes (2016-2017) represent early contributors, such as the United States, Canada, and the Netherlands, whose darker hues indicate that they established their research networks earlier. In contrast, the green-yellow nodes (2018-2020) correspond to more recent or growing research activity, particularly in countries like China, South Korea, and India, which have expanded their international collaborations in recent years.

Beyond temporal evolution, the size of the nodes indicates each country's contribution to the field. As expected, the United States and China dominate the map, with the largest node sizes, reflecting their leading roles in global research output and collaboration networks. Meanwhile, India, Australia, France, and Germany also hold significant positions, suggesting moderate but important contributions to global collaborations.

A closer look at collaboration patterns reveals that the thickness of the links between countries represents the strength of their partnerships. Notably, United States-China, United States-Canada, and China-South Korea have thicker links, signifying frequent and robust collaboration. Additionally, the dense central network, formed by the United States, China, Germany, and France, highlights their role as facilitators of international research, bridging peripheral countries to the core network. In contrast, countries such as the Philippines, Jordan, and Sri Lanka have thinner links, indicating limited but increasing international collaborations.

Furthermore, regional clustering reveals three main geographical hubs. The North America cluster is centered around the United States, which acts as a key research hub collaborating extensively with Canada, Mexico, and Australia. Similarly, the Asia-Pacific cluster, dominated by China, South Korea, Japan, and Singapore, reflects the region's rapid growth in research activity, reinforcing its expanding role in technological advancements. Meanwhile, the European cluster, composed of Germany, France, the Netherlands, and Spain, showcases strong intra-European collaborations while also maintaining active partnerships with global leaders like the United States and China.

Several key observations emerge from this analysis. Firstly, the United States and China remain the central players in the global research network, forming bridges between various regions and acting as major hubs for knowledge exchange. Secondly, the rise of India, South Korea, and Singapore in recent years reflects their growing focus on research and innovation, particularly in emerging technological fields. Lastly, countries like Vietnam, Bangladesh, and Thailand are becoming newer contributors, as indicated by their lighter colors, demonstrating their increasing engagement in international collaborations.

In conclusion, this map highlights the highly interconnected nature of global research, with the United States and China maintaining their leadership roles. The temporal gradient underscores the recent rise of Asia-Pacific nations, including India, South Korea, and Singapore, while Europe and North America continue to play a significant role in research leadership. Additionally, emerging collaborations from peripheral countries reflect a broader diversification of research efforts, signifying a more globalized and interdisciplinary approach to geomatics and urban transportation research.

• Density Visualization – Countries

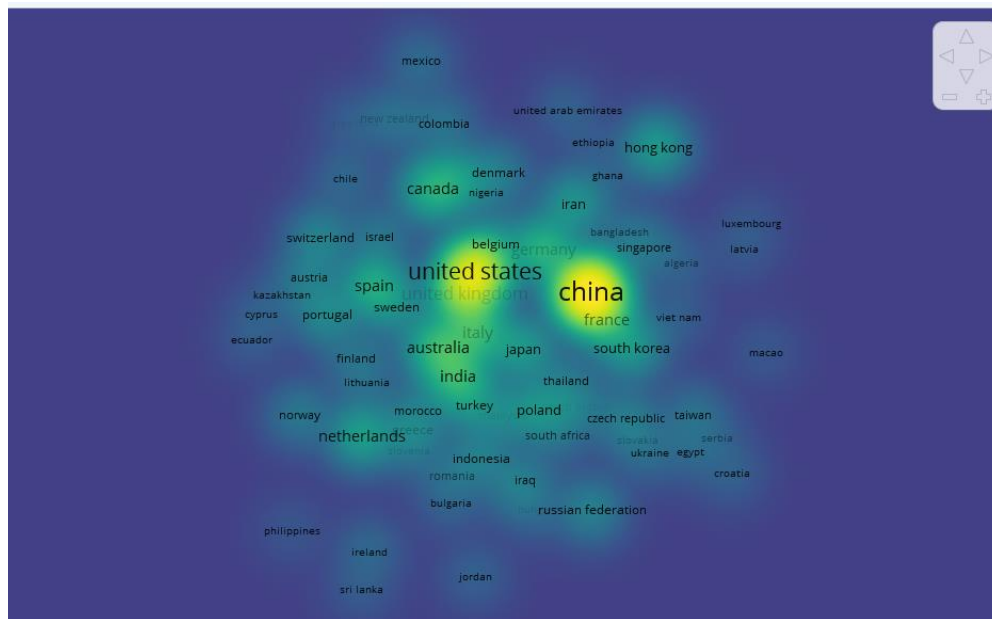


Figure 15: Density visualization - Countries - Vosviewer - elaborated by authors

This VOSviewer heatmap visualization illustrates the density of international collaborations in geomatics and urban transportation research, where the intensity of colors indicates the concentration of research activity and partnerships among countries. This representation highlights global research hubs, regional contributors, and emerging players, offering insights into the distribution of collaborative efforts worldwide.

At the core of the network, the bright yellow areas correspond to the countries with the highest concentration of research activity and international collaborations. The most prominent bright spots are centered on China, the United States, and France, reinforcing their leadership in global research collaboration networks. These nations act as primary drivers of knowledge exchange, fostering strong cross-border partnerships. Surrounding them, the green areas indicate moderate research contributions and collaborations, with key players such as Germany, the United Kingdom, India, and Australia actively participating in global academic networks.

Conversely, the blue background represents lower-density regions, where research contributions and international collaborations are less frequent. This category includes emerging or less active countries, whose engagement in global research efforts remains limited but growing. However, the presence of certain nations in this category does not imply an absence of research but rather a lower intensity of international collaboration compared to central players.

Further analysis reveals notable trends in global collaboration patterns. First, the United States and China emerge as dominant players, as evidenced by their central positioning in the heatmap. Their strong presence signifies not only high research output but also their role as key partners in global research networks, influencing collaborations across multiple regions. Meanwhile, Europe maintains a strong presence, with France, Germany, the Netherlands, the United Kingdom, and Spain forming a highly interconnected European cluster. These countries demonstrate significant contributions and partnerships, reinforcing their historical leadership in research and development.

Beyond these established players, the Asia-Pacific region is experiencing notable growth. Countries such as India, Japan, South Korea, and Australia appear prominently in green areas, indicating their increasing participation in international research collaborations. Their rising prominence reflects ongoing investments in research and innovation, particularly in technological advancements and sustainable urban mobility solutions.

Additionally, emerging regions such as Bangladesh, Vietnam, Singapore, and South Africa are becoming more integrated into global research networks, even though their overall activity levels remain less intense compared to central players. Their growing participation suggests new opportunities for expanded international cooperation and further integration into leading research initiatives. At the same time, peripheral countries such as Jordan, Sri Lanka, and the Philippines exhibit lower densities of collaboration, indicating that while they contribute to global research, their international reach remains relatively limited.

In interpreting central regions, it is evident that China and the United States stand out as primary research hubs, significantly influencing global research trends and partnerships. These two countries not only contribute heavily to scientific output but also facilitate knowledge exchange by collaborating with a diverse range of partners worldwide. Similarly, France and Germany play a pivotal role in European research collaborations, maintaining strong connections with both Western and Eastern research institutions.

In conclusion, this heatmap highlights the pivotal role of China, the United States, and France in driving global research collaborations, while Europe and the Asia-Pacific region demonstrate strong and growing international networks. At the same time, peripheral regions like Africa and Southeast Asia are showing increasing engagement, pointing to new opportunities for integration into the global research landscape. These findings reinforce the highly interconnected and evolving nature of geomatics and urban transportation research, emphasizing the importance of international partnerships in addressing global mobility challenges.

Discussion

At the heart of geomatics research in urban transportation, several core research themes emerge. On one hand, central concepts such as urban transportation, spatial analysis, remote sensing, and public transport remain fundamental pillars, emphasizing spatial planning and advanced technologies as essential tools for optimizing urban mobility systems. On the other hand, the growing prominence of artificial intelligence, machine learning, and highway planning indicates a transition toward intelligent and automated solutions, reshaping the way urban transport networks are analyzed and managed. Beyond technological advancements, environmental and social concerns are also closely intertwined with transport management, as evidenced by the emphasis on atmospheric pollution, climate change, population density, and accessibility. These aspects underscore the need for sustainable and human-centered approaches to urban mobility.

In addition to thematic areas, network and collaboration analysis reveals dense co-authorship patterns among prominent researchers such as Garcia-Palomares Juan Carlos, Liu Yu, and Inturri Giuseppe, reflecting established research groups driving the field forward. The emergence of specific clusters also suggests the growth of specialized subfields, particularly in AI applications and environmental impact assessments. At the international level, the United States and China dominate as central hubs of global collaborations, while emerging research regions such as the Asia-Pacific (Singapore, India, South Korea) and Central Europe (Poland, Czech Republic) are rapidly increasing their presence, reinforcing a more diversified and globally interconnected research landscape. Furthermore, temporal trends indicate a strong shift toward technological integration in recent years, with studies from 2018 to 2020 increasingly focusing on remote sensing, machine learning, and vehicle detection, reflecting the growing role of automation and big data in urban geomatics.

Conclusion and future directions in geomatics research

Given these trends, several key areas are expected to shape the future of geomatics research in urban transportation. First, advanced technology development will continue to play a crucial role, particularly in artificial intelligence and machine learning, which are set to enhance urban traffic modeling, anomaly detection, and route optimization. Additionally, the increased use of drones, high-

resolution satellites, and LiDAR technology is anticipated to provide real-time infrastructure data and improve risk assessments.

Secondly, sustainability will remain a major focus, with an emphasis on eco-friendly transport solutions, including the expansion of bicycle lanes, pollution reduction measures, and electric vehicle integration. In parallel, climate analysis will strengthen its link to transport research, enabling better urban mobility planning in the face of climate change challenges.

Another key priority is social inclusion and accessibility, which will require better integration of demographic data to make urban transport more equitable, particularly for vulnerable populations. Furthermore, multimodal optimization, aiming to seamlessly connect different transport modes, will be essential in enhancing urban connectivity and mobility.

Finally, international collaboration is expected to expand, with a particular focus on strengthening partnerships between the Global North and South. Enhanced cooperation with emerging research nations such as India, Vietnam, and Bangladesh will contribute to a broader exchange of knowledge and expertise. Additionally, the development of global geospatial standards will facilitate data sharing and improve research interoperability across institutions and countries.

Geomatics research in urban transportation management is evolving rapidly, driven by technological advancements and an increasing awareness of environmental and social challenges. As international collaborations and interdisciplinary approaches continue to expand, they will play a pivotal role in addressing urban challenges and proposing sustainable, equitable, and intelligent solutions for the future.

Bibliographic References

1. Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975.
2. Bibri, S. E., & Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable Cities and Society*, 51, 101770.
3. Cats, O., & Jenelius, E. (2015). Planning for the unexpected: The value of reserve capacity for public transport network robustness. *Transportation Research Part A: Policy and Practice*, 81, 47-61.
4. Convery, S., & Williams, B. (2019). Determinants of transport mode choice for non-commuting trips: The roles of transport, land use and socio-demographic characteristics. *Urban Science*, 3(3), 82.
5. Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *FASEB Journal*, 22(2), 338–342.
6. Geurs, K., Zondag, B., De Jong, G., & de Bok, M. (2010). Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings. *Transportation Research Part D: Transport and Environment*, 15(7), 382-393.
7. Herold, M., Couclelis, H., & Clarke, K. C. (2005). The role of spatial metrics in the analysis and modeling of urban land use change. *Computers, Environment and Urban Systems*, 27(4), 369–389.
8. Konecny, Gottfried (2003) *Geoinformation: Remote Sensing, Photogrammetry and Geographic Information*, New York, Taylor and Francis.
9. Lin, P., Weng, J., Alivanistos, D., Ma, S., & Yin, B. (2020). Identifying and segmenting commuting behavior patterns based on smart card data and travel survey data. *Sustainability*, 12(12), 5010.
10. Marsden, G., Ferreira, A., Bache, I., Flinders, M., & Bartle, I. (2014). Muddling through with climate change targets: A multi-level governance perspective on the transport sector. *Climate Policy*, 14(5), 617–636.

11. Salon, D., & Gulyani, S. (2019). Commuting in urban Kenya: Unpacking travel demand in large and small Kenyan cities. *Sustainability*, 11(14), 3823.
12. Shaw, S.-L., Yu, H., & Bombom, L. S. (2008). A space–time GIS approach to exploring large individual-based spatiotemporal datasets. *Transactions in GIS*, 12(4), 425–441.
13. Taniguchi, E., & Thompson, R. G. (2015). City logistics: Mapping the future. *CRC Press*.
14. Taubenböck, H., & Kraff, N. J. (2014). The physical face of slums: A structural comparison of slums in Mumbai, India, based on remotely sensed data. *Journal of Housing and the Built Environment*, 29, 15–38.
15. Weng, Q. (2012). Remote sensing of impervious surfaces in the urban areas: Requirements, methods, and trends. *Remote Sensing of Environment*, 117, 34–49.