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Review

Smart Mobility in Urban Areas: A Bibliometric Review and Research Agenda

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Abstract: Transportation systems globally face challenges related to congestion, decreased quality of life, limited accessibility, increased harmful emissions and costs, growing use of private cars and in some cases lack of intra and intermodal integration. Smart Mobility is believed to be a solution to some of these challenges by providing comprehensive and intelligent mobility services, decreasing transportation costs, promoting safety, and combating pollution and traffic congestion. Despite this potential, there is still uncertainty surrounding what smart mobility is and whether it is moving toward improving the quality of life and making cities more sustainable. To address this gap, this paper conducts a bibliometric review of 3223 Web of Science Core Collection-indexed documents to provide a comprehensive understanding of smart mobility research. The findings reveal a lack of multi-disciplinary approaches in previous studies with a strong emphasis on technological aspects and limited social or economic considerations in current research. The review identifies four distinct periods of smart mobility research, with recent interest sparked by advancements in big data, deep learning, artificial intelligence, and real-time technologies in transport systems. However, there is a dearth of research on smart mobility in developing countries, where urban populations are rapidly increasing. Thus, the review proposes a research agenda to address the current gaps in knowledge. Furthermore, the review provides an updated and integrated definition of smart mobility as the use of advanced technologies, such as the Internet of Things (IoT), big data analytics, and artificial intelligence, to improve transportation efficiency, mobility for all, and sustainability while safeguarding the quality of life. The primary challenge for smart mobility is the co-evolution with existing transport systems, making further research on integration with these systems and real-time technologies essential for advancing smart mobility research. The paper's main contribution is an integrated conceptualisation of smart mobility research and novel research topics that build on this unified base.

Keywords: smart mobility; sustainability; urban transportation; advanced technologies; co-evolution

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1. Introduction

With the rapid growth of urbanisation, cities worldwide are facing unprecedented challenges, such as increasing traffic congestion, air pollution, and energy consumption [1]. Smart mobility is emerging as a promising solution to address these challenges by integrating advanced technologies to enable efficient, safe, and sustainable transport systems [2,3]. Smart mobility is a multidisciplinary research field that encompasses transportation engineering, computer science, urban planning, environmental science, and social science [4].

Despite its potential benefits, the concept of smart mobility is still evolving [5], and the trajectory of research in this area is unclear [6]. It is thus essential to examine the current state of knowledge and identify research gaps to guide future research in this field [7]. The analysis of the top 20 articles on smart mobility indicates that smart mobility research is fragmented and confined to specific disciplines, with limited influence on the wider business community [7,8]. While some scholars approach smart mobility research from the environmental perspective [9,10], others focus on governance or policy approaches [11,12]. Some researchers examine the field from a conceptual background and suggest that smart mobility should incorporate accessibility, attractiveness, effectiveness, and sustainability, rather than just technological aspects [12–15]. In the literature reviewing smart mobility research, the techno-centric focus has given inordinate attention to information and communication technologies (ICT) and other innovative technologies [16]. Early theories have shown mixed results when empirically tested, leading scholars to question the real value of existing smart mobility solutions and if they measure up to the metrics of evaluating sustainability in urban contexts [17,18]. The implementation of smart mobility solutions has resulted in several scenarios, including the reproduction of transport poverty [14,19] as the problem of social exclusion prevails [13,17]. The emergence of new and advanced digital technologies, such as the Internet of Things (IoT) [20], artificial intelligence [21], and big data (Data Science) [22] have renewed hope but also raised concern amongst scholars and practitioners of smart mobility. This is because smart mobility integrates advanced technologies, such as the Internet of Things, big data analytics, and artificial intelligence to enable the seamless movement of people and goods [23]. Further, how these technologies integrate with existing systems is largely unexplored, making it difficult to determine in advance, the benefits and attending consequences [24].

However, despite the continued interest in smart mobility, the uncertainty surrounding the definition of smart mobility has not been resolved and little is known of the direction that smart mobility research is taking and whether it is evolving toward the goal of sustainable cities [25]. This paper aims to provide a comprehensive overview of smart mobility research by conducting a bibliometric review of 3223 Web of Science Core Collection-indexed documents. The review analyses the key research themes, research trends, and collaborations among researchers, and identifies the gaps in existing literature [26–29]. The paper provides an integrated conceptualisation of smart mobility research, highlighting the need for interdisciplinary research, and presents a research agenda to guide future research [30,31].

The specific objective of this study is to evaluate the past and present state of smart mobility using bibliometric analysis and through a focused systematic review to suggest avenues for future research in this research field.

This review extends earlier analyses by Gamboa-Rosales et al. [2], Esfandabadi et al. [15] and Leviäkangas and Ahonen [19], covering a wider scope of the smart mobility literature and encompassing sustainability transitions and quality of life. More importantly, the paper consolidates the foundation knowledge of smart mobility and provides direction for future research. Thus, the study makes two contributions. The first is an integrated conceptualisation of smart mobility [31], which creates a unified base on which to build subsequent studies. Using the unified base, the second contribution is empirical, as the proposal is for research pathways for the future study of smart mobility. The bibliometric analysis addressed the following research questions:

1. Which scholars, countries, and sources have made the most significant contribution to the research in smart mobility?

2. What is the intellectual structure of the literature on smart mobility?

3. What are the key cross-discipline themes that scholars have applied to define smart mobility research?

4. What are the possible future enquiries in the field of smart mobility?

The paper is organised as follows. Section 2 provides an overview of the definition of smart mobility and its key features. Section 3 describes the methodology used in the bibliometric review. Section 4 presents the results of the review, including the research themes, trends, and collaborations among researchers. Section 5 discusses the gaps and challenges in existing literature while Section 6 develops a research agenda for future research. Section 7 concludes the paper by summarising the key findings and implications of the study.

Overall, this paper aims to contribute to the growing body of knowledge on smart mobility by providing a comprehensive review of the current state of research and identifying research gaps and priorities for future research. The paper highlights the need for a more holistic and interdisciplinary approach to smart mobility research that incorporates social, economic, and environmental considerations.

2. What Is Smart Mobility?

Smart mobility is a concept that aims to use technology to improve transportation efficiency and sustainability while enhancing mobility for all [32–34]. Smart mobility combines various transportation modes and uses real-time data to provide tailored transportation solutions to individuals, organisations, and cities [35–37]. This section examines the various definitions of smart mobility, its evolution, the role of technology, unintended consequences, and the interdisciplinary nature of smart mobility research.

2.1. How Has Smart Mobility Been Defined So Far?

Although the concept of smart mobility is gaining traction in scholarly literature, its definition is still lacking and differs based on the context—developing, emerging, and developed economies. Numerous authors have made efforts to come up with a singular definition for smart mobility [3,20], however, there is currently no consensus on what precisely constitutes smartness in this context [38–40]. Nonetheless, it is generally agreed that smart mobility aims to use technology to improve the efficiency, safety, sustainability, and accessibility of transportation [41]. Smart mobility also involves the integration of different transportation modes [42], including walking, cycling, public transport, and private vehicles, to provide seamless, reliable, and personalised transportation services [43]. Furthermore, smart mobility incorporates technology, integrated planning, and personalised transportation services to provide seamless, sustainable, and accessible transportation solutions [40,41]. Hence, the key features of smart mobility include real-time data, interoperability, user-centred design, and sustainability [6,20,37].

2.2. The Role of Technology in Smart Mobility

Technology plays a critical role in smart mobility. It enables real-time data collection, analysis, and sharing [44,45], which enhances transportation efficiency, safety, and sustainability. Technology also provides various transportation options and enables personalised transportation services [43]. Big data analytics, artificial intelligence (AI), and the IoT are some of the key technologies that are transforming the way society thinks about mobility [22,35,46]. Big data analytics is essential in the management and planning of transportation systems [47]. It helps to collect, store, and analyse vast amounts of data generated from various sources such as sensors, Global Position Systems (GPS), and social media [48]. This data can be used to understand mobility patterns, optimise routes, and improve traffic flow [49]. For example, big data analytics can help to identify traffic bottlenecks and suggest alternative routes hence reducing congestion [22]. Individuals and institutions in many aspects of urban mobility can use these results for urban traffic management, and transport planning, as well as in framing the future [50]. AI on the other hand can be used to analyse and interpret data to identify patterns and trends. This can be used to optimise traffic flow, reduce congestion, and improve safety. For example, AI-powered traffic management systems can analyse real-time data to adjust traffic signals, reduce wait times, and improve traffic flow [23,47]. Furthermore, AI has the potential to transform urban decision-making processes and improve urban governance and citizen participation [51]. The IoT is also critical to smart mobility. It enables the integration of different devices and sensors to create a connected network of transportation systems [52]. This network can be used to monitor traffic, collect data on air quality, and detect accidents or other incidents. For example, connected vehicles can communicate with each other to improve safety and reduce congestion. In summary, digital technologies have the potential to transform the mobility of cities and urban areas. These technologies have the potential to address transportation demand, supply, and management of urban spaces by reducing congestion, emissions, and energy consumption while enhancing accessibility and social equity.

While these technological advances can provide improvements to transport systems and mobility, they can have unintended consequences on the environment and society [53]. For example, the increased use of autonomous vehicles could lead to increased vehicle miles travelled and a rebound in car use, offsetting the potential energy and emission savings [54]. Similarly, the proliferation of ride-hailing services could increase congestion and undermine public transit [55]. Smart mobility technologies could also have social equity implications, as they may not be accessible to all, leading to a digital divide in transportation [56]. There are also concerns about data privacy, cybersecurity, and the potential for these technologies to exacerbate existing social inequalities [52,53]. Therefore, it is essential to approach the use of these technologies with care and consider their potential impacts on society as a whole [56–59].

2.3. Evolution of Transport Planning and the Emergence of Integrated Transport Planning and Smart Mobility

Transport planning has evolved from focusing on single modes of transportation to integrated planning that considers the entire transportation system [58]. Integrated transport planning aims to provide seamless, convenient, and sustainable transportation solutions by considering various transportation modes, land use, and urban design [60]. Smart mobility builds on integrated transport planning by using technology to enable real-time [31] data-driven decision-making [61] and personalised transportation services [62]. Smart mobility evolution follows the same pattern of niche innovations, which develop and integrate with the existing socio-technical regime within the wider socio-technical landscape. The niche innovation can either upend the existing regime or evolve on an incremental trajectory [63]. Unlike conventional socio-technical systems in which radical innovations depended on windows of opportunity to break through, transitions in smart mobility are steered through governance and policy initiatives [24]. Thus, smart mobility requires a coordinated approach to enhance its effectiveness. This can be achieved through active collaboration and participation of all stakeholders in decisions related to transport planning and sustainability [64].

Traditional transport planning takes the view that travel is a derived demand, not a valuable activity, with the value at the destination [54]. Traditionally transport planning was supply-based since traffic was the input metric that determined how much to adjust the infrastructure capacity to support the traffic flow. Traditional transport planning comprised two pillars, namely infrastructure management and development, and traffic management [65]. Integrated transport planning, on the other hand, is demand-based, which considers the mobility-needs of people to determine the quantity to supply [66].

Transport planning in urban areas addresses four key aspects: transport demand, transport supply, urban space management, and deployment of environmentally friendly technologies [67]. Different policy directions are required to give effect to each of these four aspects [68].

2.4. The Role of Governance and Policy in Smart Mobility

Effective governance and policy frameworks are essential for the development and implementation of smart mobility solutions [69]. The complex nature of smart mobility requires collaboration between various stakeholders, including government agencies, private sector actors, and citizens, to ensure maximum benefits and minimal negative impacts [70].

Policymakers face the challenge of creating a conducive environment that promotes innovation and investment in smart mobility solutions [71,72]. This requires a regulatory framework that is adaptable to market needs while ensuring safety, privacy, and security [62,63]. Sometimes, a regulatory sandbox approach that allows experimentation with new technologies and business models in a controlled environment may be necessary [73].

Governance and policy have a crucial role in ensuring that smart mobility solutions are developed and implemented in a socially equitable manner that reduces inequalities [74]. Therefore, targeted policies and initiatives may be necessary to address issues such as affordability, access to mobility services, and the needs of vulnerable populations [75,76].

Furthermore, governance and policy can promote interoperability and standardisation of smart mobility solutions [77], which is crucial given the fragmented nature of the ecosystem and the involvement of multiple stakeholders in the development and implementation of solutions [62,65]. Policymakers can encourage collaboration and ensure compatibility with existing infrastructure and technologies by promoting interoperability and standardisation [78].

Finally, governance and policy can play a role in promoting public awareness and participation in the development and implementation of smart mobility solutions. This requires effective communication and engagement strategies that seek to involve citizens and other stakeholders in the decision-making process [79]. By involving citizens in the development of smart mobility solutions, policymakers can ensure that these solutions are developed in a way that reflects the needs and aspirations of the wider community [13].

2.5. State of Smart Mobility Scholarship

Smart mobility research is interdisciplinary and involves experts from various fields, including transportation, urban planning, engineering, computer science, economics, and social sciences. Furthermore, smart mobility scholarship is a diverse field with various studies exploring different aspects of the field, such as shared mobility [80], micro-mobility, attitudes [81], and autonomous vehicles [59–61]. While some studies have focused on the technologies that enable smart mobility such as big data [82], few have reviewed the field as a whole [83,84]. The evolution of transport planning towards integrated transport planning [47,85] and smart mobility has also been examined in several studies, along with the potential for technology to address transport demand, supply, and management of urban spaces [65,66]. In a separate study, the potential unintended consequences of technological advances on the environment and society have also been acknowledged, including privacy concerns, increased energy consumption, and potential negative impacts on vulnerable populations [86].

Thus, smart mobility scholarship is growing in diverse fields and effective smart mobility solutions require a coordinated approach that involves collaboration among stakeholders, including governments, the private sector, academia, and civil society [87,88]. To fully realise the potential of smart mobility solutions and address societal challenges such as urban sustainability, social equity, and public health, further research is needed. Additionally, addressing the challenges and opportunities for the widespread adoption of smart mobility solutions is a potential area for exploration. This bibliometric review addresses this research gap by conducting a bibliometric analysis of smart mobility in a wider context and thereafter using the results to identify avenues for future research.

The next section presents the various techniques and procedures employed for the collection and analysis of bibliometric data.

3. Methodology

A performance evaluation and longitudinal mapping of scientific publications in the field of smart mobility were undertaken using bibliometric analysis. Bibliometric analysis is a rigorous method that relies on quantitative techniques to analyse large datasets and reveal knowledge gaps thus situating the intended contribution of researchers in the field and providing insights into new research areas [89]. The analysis of research articles published in the Web of Science Core Collection database included the period between 1981 and 2021.

To undertake the bibliometric analysis, the study adopted the metrics of performance, described in Figure 1.

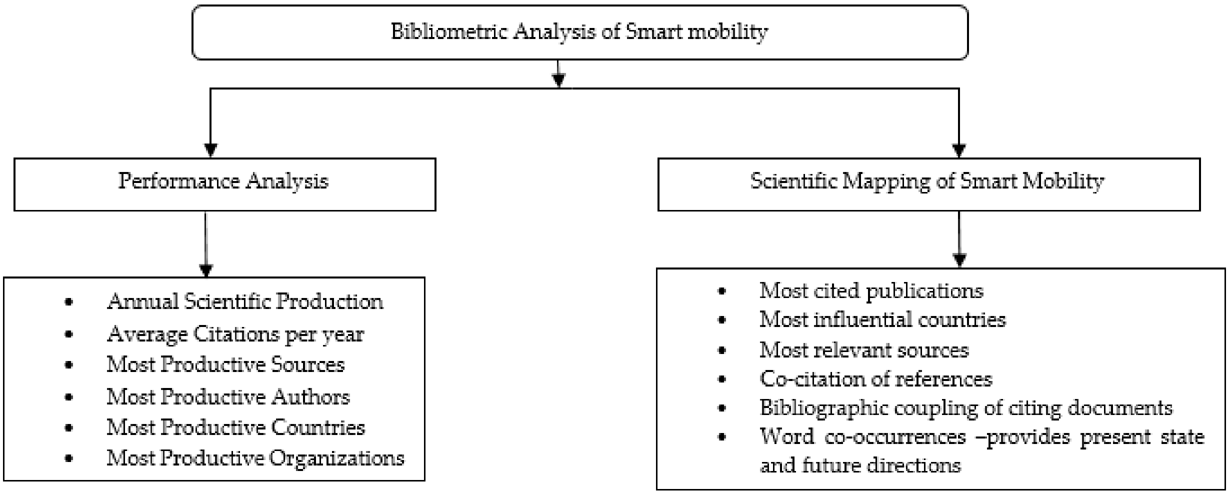

Figure 1. Bibliometric Performance Metrics used in Analysing Smart Mobility Literature. Source: [90].

3.1. Research Design

The research design comprised the search strategy and the analysis method. The search strategy entailed the selection and refining of the right keywords, choosing the right database, selecting filtering criteria for search field items, and defining the appropriate analysis period [26]. Different combinations of smart urban mobility, intelligent transport, and urban/city were written together in parenthesis. Consequently, the iterations yielded the following combination of keywords: ("smart mobility" OR "smart urban mobility" OR "intelligent transport" OR "sustainable urban mobility" OR "mobility as a service" OR "shared mobility" OR "carsharing" OR "car-sharing" OR "ridesharing" OR "ridesourcing" OR "ride-sourcing") AND (Urban or City or Cities). The keyword search considered the full record (Title, Abstract, Keywords, and Sources) and cited references queried from the Web of Science Core Collection (WoSCC) database on 6 March 2023 at 12:15 h. The WoSCC comprises three citation indices—Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (AHCI). This collection indexes high-quality peer-reviewed journals, conference proceedings, and book series [91]. WoSCC database was selected due to its reliability in indexing guaranteed quality publications [92]. In total, the search returned 3238 articles. A screening of erroneous entries and publications without titles, an abstract, and keywords reduced the number to 3234 items. The quality inclusion criteria covered all peer-reviewed articles listed in the WoSCC database, without limiting the subject area and without regard to whether the articles were thematically similar or not. Only publications written in English were included [90] resulting in a final tally of 3223 documents.

3.2. Method of Analysis

Descriptive performance analysis and science mapping with two software packages; Biblioshiny (R version 4.2.0, Bibliometric package 3.2.1) and VOSViewer (Version 1.6.18) [93]) were used to analyse the results. This study employed co-citation and co-word analyses to identify the most influential publications and authors in the field of smart mobility. Co-citation analysis is a bibliometric technique that identifies the relationships among publications based on the frequency of their citation in other publications [89]. Co-word analysis, on the other hand, identifies the relationships among words used in publications to reveal the main topics and themes in a research field [27]. These two methods enabled the identification of the intellectual structure of the smart mobility research field, including the most influential publications and authors, research topics, and trends. These techniques are widely used in bibliometric analysis and have been shown to be effective in identifying the structure of research fields and the relationships among publications and authors [26].

4. Results

The first publications in smart mobility were in 1981 with one document, growing to 579 publications per year by 2022. As shown in Figure 2, the period 2018 to 2022 has over 75% of the published documents. The overall annual growth rate in smart mobility research for the whole period is 36%. This growth rate can be classified as strong, considering the annual growth rate of global scientific publications is about 3% [94].

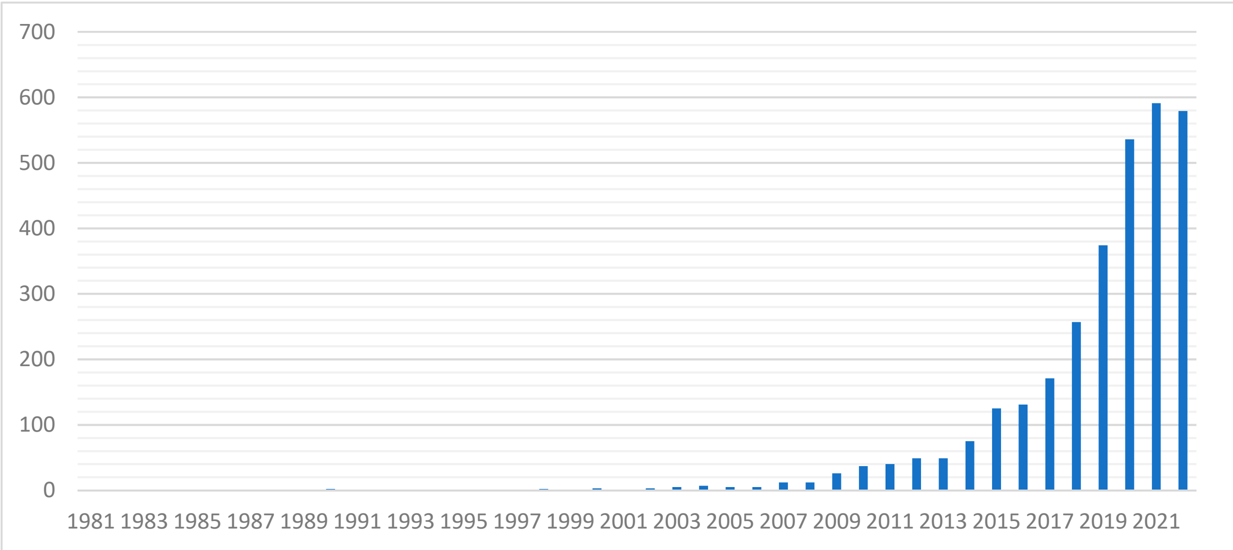

Figure 2. Number of Publications on Smart Mobility per Year: 1981–2021.

Across the 42-year period, a number of production peaks are observed, signifying interest in the field. For example, the first period of interest in smart mobility was observed after the first United Nations Conference on climate change in Berlin [95] which corresponds with the signing of the Kyoto protocol in 1997 [96]. The second period of publication peaks corresponds with the establishment of the United Nations' sustainable development goals in the year 2015 [97]. The dramatic growth in smart mobility publications from 2018 onwards can be attributed to the emergence of big data [92].

The next sections synthesise the trends and the structure of the knowledge, based on productivity, citation, co-citation analysis, and co-word analysis.

4.1. Productivity Analysis: Scholars, Countries, and Sources with the Most Significant Contribution

The following sections describe the most productive and influential sources, authors, and countries of smart mobility research, collectively referred to as constituents in the smart mobility field.

4.1.1. The Most Productive Sources in Smart Mobility Research

Most of the publications in smart mobility were from IET Intelligent Transport Systems (404), Sustainability (246), Transportation Research Record (134), Transportation Research Part C Emerging Technologies (102), and Transportation Research Part A: Policy and Practice (95). Thus, smart mobility research is undertaken in diverse areas. While some areas contribute to the development of the technologies, models, and science of smart mobility, others pertain to the application aspects of the field, such as in social sciences. For instance, publications in IET Intelligent Transport Systems, IEEE Transactions on Intelligent Transportation Systems, and Energies are concerned with technologies, models, and algorithms of smart mobility, while Sustainability, Transport Research Record, and Transport Research Part A: Policy and Practice are concerned with the applications of smart mobility. Other journals, such as Sensors and Transport Research Part C: Emerging

Technologies, concern areas with an interplay between aspects of the application and technical advances according to the social-technical transitions theory [98].

Table 1 shows that the most influential articles on smart mobility are published in engineering and transport journals. The fastest-growing journals in terms of the number of publications are IET Intelligent Transport System, Sustainability, and Sensors. Journals, such as IEEE Transactions on Intelligent Transportation and Transport Research Record, are growing. To classify the journals, Table 1 lists the top 20 most productive journals in the field of smart mobility ranked according to their h-index.

Table 1. Top 20 Most Productive Journals on Smart Mobility Research (1981–2021).

R	Sources	hSM	gSM	mSM	TC	NPSM	PY
1	IET INTELLIGENT TRANSPORT SYSTEMS	1	1	0	12	404	2007
2	SUSTAINABILITY	12	22	2	599	246	2015
3	TRANSPORTATION RESEARCH RECORD	8	11	1	160	134	2007
4	TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES	14	20	1	484	102	1998
5	TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE	13	19	3	608	95	2012
6	IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS	19	33	NA	1111	84	NA
7	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	13	20	2	436	71	2017
8	SENSORS	15	19	1	522	63	2012
9	TRANSPORT POLICY	10	13	1	876	56	2014
10	TRANSPORTATION	10	14	1	271	55	2015
11	ENERGIES	4	7	1	59	49	2019
12	JOURNAL OF TRANSPORT GEOGRAPHY	5	9	1	89	47	2016
13	INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION	3	4	NA	90	46	NA
14	CASE STUDIES ON TRANSPORT POLICY	5	8	1	86	42	2015
15	JOURNAL OF ADVANCED TRANSPORTATION	2	2	1	11	42	2021
16	SUSTAINABLE CITIES AND SOCIETY	6	10	1	138	38	2018
17	IEEE ACCESS	14	22	2	555	36	2016
18	JOURNAL OF CLEANER PRODUCTION	6	6	1	158	33	2016
19	TRANSPORTATION RESEARCH PART B-METHODOLOGICAL	2	2	0	90	33	2017
20	APPLIED SCIENCES-BASEL	5	7	1	59	31	2018

Key: R-Ranl, TC—Total citations, PY-Year of first publication, hSM—h-index based on Smart Mobility Publications, mSM—m-index based on Smart Mobility Publications, gSM—g-index based on Smart Mobility Publications, NPSM—Number of publications in Smart Mobility Research.

4.1.2. Most Productive Authors in Smart Mobility Research

The top five authors with the greatest contribution to smart mobility literature were Zhang (12), Yang (8), Ozbay (8), Wang (8), and Chen (6). Ranking of the authors by productivity determines the intellectual composition of the field. Table 2 shows the ranking of the top 20 authors based on the h-index.

Most authors of the research in smart mobility come from Engineering and Transportation, each contributing 47%. The other three areas that follow closely are Environmental Sciences Ecology, Computer Science, and Science Technology, each contributing, on average, 12%.

4.1.3. Most Productive Countries

The top five most productive countries, based on the affiliation of the first author are China (351), the USA (213), Italy (114), England (138), and Spain (118). The ranking is based on the h-index. China dominates the ranking with highly impactful research outputs, as evidenced by a higher h-index rank, number of publications (NP), total citations (TC), and greater collaboration. Only a few countries, including Algeria, Serbia, Egypt, and South Africa the developing economies, contribute to research in smart mobility. This suggests a paucity of research in areas that may benefit the most from the developments in sustainable smart mobility. Considering the rapid growth of urban populations in emerging economies, smart mobility is likely to present sustainable solutions.

Smart mobility research is collaborative, with over 65% of the articles published by multiple authors from different countries. As shown in Figure 3, there is a high level of collaboration between China, the USA, England, Spain, and Italy.

Table 2. Most Productive Authors in Smart Mobility Research.

R	Author	h_index	g_index	m_index	TC	NP	PY
1	ZHANG Y	12	19	1.3	391	51	2014
2	YANG H	8	13	1.6	204	34	2018
3	WANG J	8	10	0.0	617	20	NA
4	OZBAY K	8	11	1.6	169	17	2018
5	CHEN Y	6	7	0.0	135	20	NA
6	LI L	6	7	0.6	505	20	2013
7	CHEN X	5	7	0.8	138	26	2017
8	LI J	5	5	0.6	94	23	2014
9	LI X	4	7	0.0	114	21	NA
10	CHEN J	4	5	0.4	100	16	2014
11	WANG Y	3	4	0.5	18	40	2017
12	LI Y	3	5	0.4	50	28	2015
13	WU J	3	3	0.5	13	19	2017
14	WANG H	2	2	0.5	8	25	2019
15	ZHANG J	2	2	0.2	36	21	2014
16	KIM J	2	3	0.4	18	18	2018
17	ZHAO J	2	4	0.4	57	18	2018
18	WANG W	2	2	0.1	125	17	2009
19	LIU Y	1	1	0.5	17	31	2021
20	LIU X	1	1	0.2	12	17	2018

Key: R—Rank, YP—Year of first publication, NP—Number of publications, TC—Total citation.

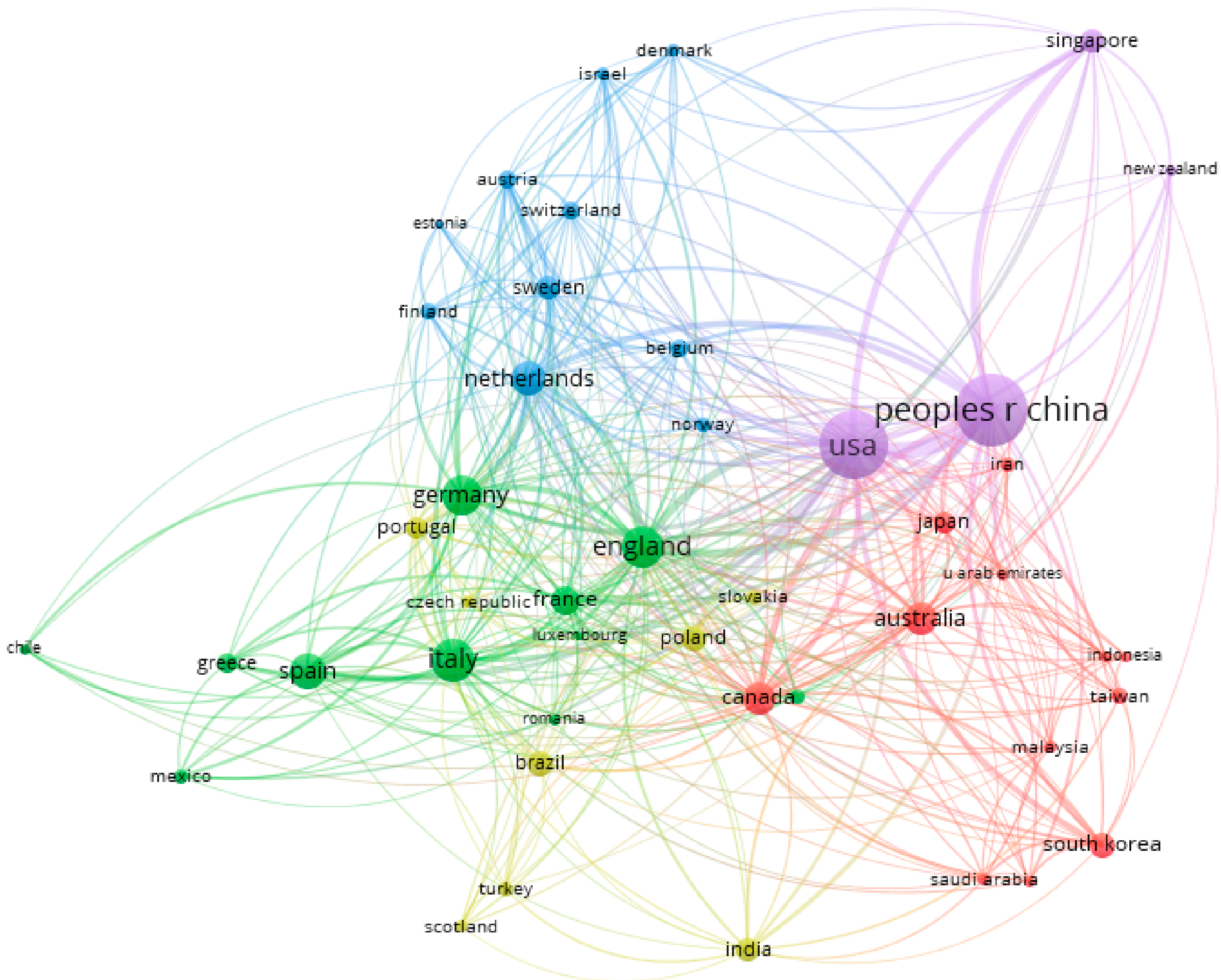

Figure 3. Country Collaboration Map.

From Figure 3 the results show the diversity and international reach of smart mobility research, with the developed economies leading by over 80% of all the publications retrieved from the corpus.

To represent the intellectual structure of the smart mobility field, the next section covers the citation and co-citation analysis.

4.2. Intellectual Structure of the Literature on Smart Mobility

A WoSCC citation analysis revealed that the number of documents is still low but growing fast, signalling an emerging field. Table 3 presents the top 20 articles of smart mobility research and the respective authors. The results of Table 3 shows that smart mobility is a diverse field studied from different discipline and across multiple domains.

Table 3. Top Cited Articles in Smart Mobility Research.

Rank	Authors	Article Title	Summary of the Paper
1	Fagnant, DJ; Kockelman, KM	The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios	The aim of the research was to investigate the environmental and travel implications of shared autonomous vehicles using agent-based models. The study found that the adoption of shared autonomous vehicles can significantly reduce the number of vehicles on the road and greenhouse gas emissions. However, the benefits will depend on factors such as vehicle occupancy rates and the extent of vehicle sharing.
2	Rayle, L; Dai, D; Chan, N; Cervero, R; Shaheen, S	Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco	The research aimed to compare taxis, transit, and ridesourcing services in San Francisco using a survey-based approach. The study found that ridesourcing services were more convenient and faster than taxis and transit, but they were also more expensive. The study also found that ridesourcing services have a significant impact on the overall demand for transportation services.
3	Quddus, MA; Ochieng, WY; Noland, RB	Current map-matching algorithms for transport applications: State-of-the art and future research directions	The aim of this research was to provide a review of current map-matching algorithms used in transport applications and identify future research directions. The study found that map-matching algorithms need to consider real-time processing, map accuracy, and data quality. The study also identified the need to integrate other data sources, such as GPS and accelerometer data.
4	Cohen, B; Kietzmann, J	Ride On! Mobility Business Models for the Sharing Economy	The research aimed to investigate mobility business models for the sharing economy. The study found that mobility services in the sharing economy can provide cost-effective and sustainable alternatives to car ownership. However, the study also identified challenges such as regulatory issues, safety concerns, and competition from traditional transportation services.
5	Min, WL; Wynter, L	Real-time road traffic prediction with spatio-temporal correlations	The research aimed to develop a real-time road traffic prediction model with spatio-temporal correlations. The study found that incorporating spatio-temporal correlations in the model improved the accuracy of traffic predictions. However, the study also identified the need for high-quality data and sophisticated modelling techniques.
6	Farahani, B; Firouzi, F; Chang, V; Badaroglu, M; Constant, N; Mankodiya, K	Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare	The research aimed to investigate the promises and challenges of using IoT in medicine and healthcare. The study found that IoT technologies can improve healthcare services, including remote monitoring, early disease detection, and personalized treatment. However, the study also identified concerns related to data privacy and security, as well as regulatory issues.
7	Buch, N; Velastin, SA; Orwell, J	A Review of Computer Vision Techniques for the Analysis of Urban Traffic	The research aimed to review computer vision techniques used in urban traffic analysis. The study found that computer vision techniques can provide accurate and efficient solutions for traffic analysis tasks such as vehicle detection, tracking, and behaviour analysis. However, the study also identified challenges related to data quality, environmental conditions, and real-time processing.
8	Shaheen, SA; Cohen, AP	Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends	The aim of the research was to provide an overview of the global market trends in carsharing and personal vehicle services. The study found that carsharing services are growing rapidly worldwide, driven by factors such as urbanisation, environmental concerns, and changing mobility preferences. The study also identified emerging trends such as peer-to-peer carsharing and multimodal mobility services.
9	Mecklenbrauker, CF; Molisch, AF; Karedal, J; Tufvesson, F; Paier, A; Bernado, L; Zemen, T; Klemp, O; Czink, N	Vehicular Channel Characterization and Its Implications for Wireless System Design and Performance	The research aimed to investigate vehicular channel characterisation and its implications for wireless system design and performance. The study found that channel models need to consider vehicle mobility, antenna characteristics, and propagation effects. The study also identified the need to develop new channel models for urban environments and higher-frequency bands.

Table 3. *Cont.*

Rank	Authors	Article Title	Summary of the Paper
10	Firnkorn, J; Muller, M	What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm	The aim of the research was to investigate the environmental effects of car-sharing systems using the case of car2go in Ulm. The study found that car-sharing systems can reduce the number of vehicles on the road and emissions, but the benefits depend on factors such as vehicle occupancy rates and vehicle technology.
11	Hidas, P	Modelling lane changing and merging in microscopic traffic simulation	The research aimed to model lane changing and merging in microscopic traffic simulation. The study found that incorporating realistic lane-changing behaviour improves the accuracy of traffic simulations. However, the study also identified the need for more research on merging behaviour and the impact of lane-changing on traffic flow.
12	Ismagilova, E; Hughes, L; Dwivedi, YK; Raman, KR	Smart cities: Advances in research-An information systems perspective	The research aimed to review advances in smart city research from an information systems perspective. The study found that smart city research focuses on integrating ICT solutions to address urban challenges such as transportation, energy, and public services. However, the study also identified challenges related to data management, privacy, and governance.
13	Martin, E; Shaheen, SA; Lidicker, J	Impact of Carsharing on Household Vehicle Holdings Results from North American Shared-Use Vehicle Survey	The research aimed to investigate the impact of carsharing on household vehicle holdings using data from the North American Shared-Use Vehicle Survey. The study found that carsharing can reduce household vehicle ownership, particularly in urban areas. However, the study also identified factors such as demographics and access to public transportation that can affect the impact of carsharing on vehicle holdings.
14	Chen, TD; Kockelman, KM; Hanna, JP	Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions	The research aimed to investigate the implications of the vehicle and charging infrastructure decisions on the operations of a shared, autonomous, electric vehicle fleet. The study found that the choice of vehicle and charging infrastructure affects the operational efficiency and cost of the fleet. However, the study also identified the need for further research on the optimal location and capacity of charging infrastructure.
15	Jittrapirom, P; Caiati, V; Feneri, AM; Ebrahimigharehbaghi, S; Alonso-Gonzalez, MJ; Narayan, J	Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges	The research aimed to provide a critical review of Mobility as a Service (MaaS), including definitions, assessments of schemes, and key challenges. The study found that MaaS has the potential to provide integrated and personalised mobility services, but there are challenges related to interoperability, data privacy, and regulatory frameworks.
16	Boyaci, B; Zografos, KG; Geroliminis, N	An optimization framework for the development of efficient one-way car-sharing systems	The research aimed to develop an optimisation framework for the development of efficient one-way car-sharing systems. The study found that the optimisation framework can help reduce operational costs and improve service quality. However, the study also identified challenges related to data availability, user behaviour, and demand uncertainty.
17	Ning, ZL; Xia, F; Ullah, N; Kong, XJ; Hu, XP	Vehicular Social Networks: Enabling Smart Mobility	The research aimed to investigate the potential of Vehicular Social Networks (VSNs) in enabling smart mobility. The study found that VSNs can improve traffic safety, efficiency, and user experience by facilitating communication and cooperation among vehicles and other infrastructure elements. However, the study also identified challenges related to network scalability, security, and privacy.
18	Ricci, M	Bike sharing: A review of evidence on impacts and processes of implementation and operation	The research aimed to review the evidence on the impacts and processes of implementation and operation of bike-sharing systems. The study found that bike-sharing systems can provide various benefits such as reduced traffic congestion, improved health, and increased tourism. However, the study also identified challenges related to bike availability, user behaviour, and infrastructure maintenance.
19	Bagchi, M; White, PR	The potential of public transport smart card data	The research aimed to investigate the potential of public transport smart card data for mobility analysis and planning. The study found that smart card data can provide valuable insights into travel patterns, demand, and service quality. However, the study also identified challenges related to data quality, privacy, and accessibility.
20	Sharma, PK; Moon, SY; Park, JH	Block-VN: A Distributed Blockchain Based Vehicular Network Architecture in Smart City	The research aimed to develop a distributed blockchain-based vehicular network architecture for smart cities. The study found that the proposed architecture can provide secure and efficient communication and coordination among vehicles and infrastructure elements. However, the study also identified challenges related to scalability, interoperability, and regulatory frameworks.

Citation analysis of authors revealed variations in citation impacts across the disciplines. In addition, the pattern of citation impact did not correspond to the citation count within the database. The most influential authors across the disciplines and the number of documents published are as follows: Fagnant (14), Rayle (7), Quddus (119), Cohen (18), Min (11), Farahani (35), Buch (7) and Shaheen (40).

Co-citation analysis revealed the scholars with the greatest influence on the authors of smart mobility. The scholars with the greatest impact on smart mobility, and their number of citations, are Shaheen (1460), Cervero (427), Fagnat (290), Martin (265), and Finkorn (256). As shown in Tables 3 and 4, both Fagnant and Shaheen have accrued high citation and co-citation scores, suggesting the strong influence the two scholars have in smart mobility research. The analysis also identified scholars from outside the discipline of transport and mobility whose theoretical works are frequently used by smart mobility scholars. Among the most highly co-cited authors is Geels [8], with a link strength of 2518 and 138 accrued citations. From this metric, it is possible to infer that Geel's social technical transition theory has a great influence in shaping the field of smart mobility research.

Table 4. Most Highly Co-Cited Authors in the Literature of Smart Mobility.

Rank	Author	Citations	Link Strength
1	Shaheen, Susan	1460	36,869
2	Cervero, Robert	427	8842
3	Fagnant, Daniel	290	8317
4	Martin, Elliot	265	7194
5	Finkorn, Joerg	256	6752
6	Becker, Henrik	221	6325
7	Hensher, David	234	5991
8	Jorge, Diana	195	5931
9	Rayle, Lisa	235	5648
10	Litman, Todd	288	5282
11	Le vine, Scott	173	4882
12	Kamargianni, Maria	183	4689
13	Tirachini, Alejandro	166	4671
14	Yang, Hai	224	4670
15	Chen, Tong Donna	156	4527
16	Fishman, Elliot	158	4527
17	Ciari, Francesco	147	4495
18	Alemi, Farzad	149	4387
19	Nourinejad, Mehdi	138	4314
20	Sochor, Jana	164	4284

To reveal the intellectual structure of the smart mobility field, co-citation maps aided in the visualisation of the relationships among the co-cited scholars. On the co-citation map, the size of the node corresponds to the co-citation count of authors while proximity reflects the similarity of domains [26]. The co-citation map of Figure 4 identifies five clusters that are shaping the smart mobility discourse.

An inspection of the map in Figure 4 suggests that the intellectual structure of smart mobility comprises five main domains, each represented by a cluster. These are smart cities, urban transport planning, traffic engineering, sustainability, and integration.

From the map of Figure 4, three domains, namely smart cities, sustainable mobility, and urban transport planning, are in close proximity to each other and connected by high-density links. The high co-citation frequency among scholars from the sustainable mobility domain reinforces the dominance of sustainability in the smart mobility literature. This reveals the existence of a community of sustainable mobility scholars, who have a great influence on the research field. The scholars that emerged as the most influential include Shaheen, Cervero, Litman, Banister, Geels, Docherty, and Lyons. The strength of co-citation analysis revealed Geels as a scholar from outside the transport field that has a great influence on the transport discipline.

The domain represented by the traffic-engineering cluster has been largely responsible for developing conceptual models of smart mobility. The authors in the traffic-engineering cluster include Zhang, Yang, Vlahogianni, El Mowafy, Zhang, Bagloea, Wang, and Ma Xi while Fagnant has advanced the research in autonomous vehicles. Thus, the map in Figure 4 outlines the relevance of shared mobility, autonomous vehicles, traffic engineering sustainability, urban planning, and integration in shaping the literature on smart mobility.

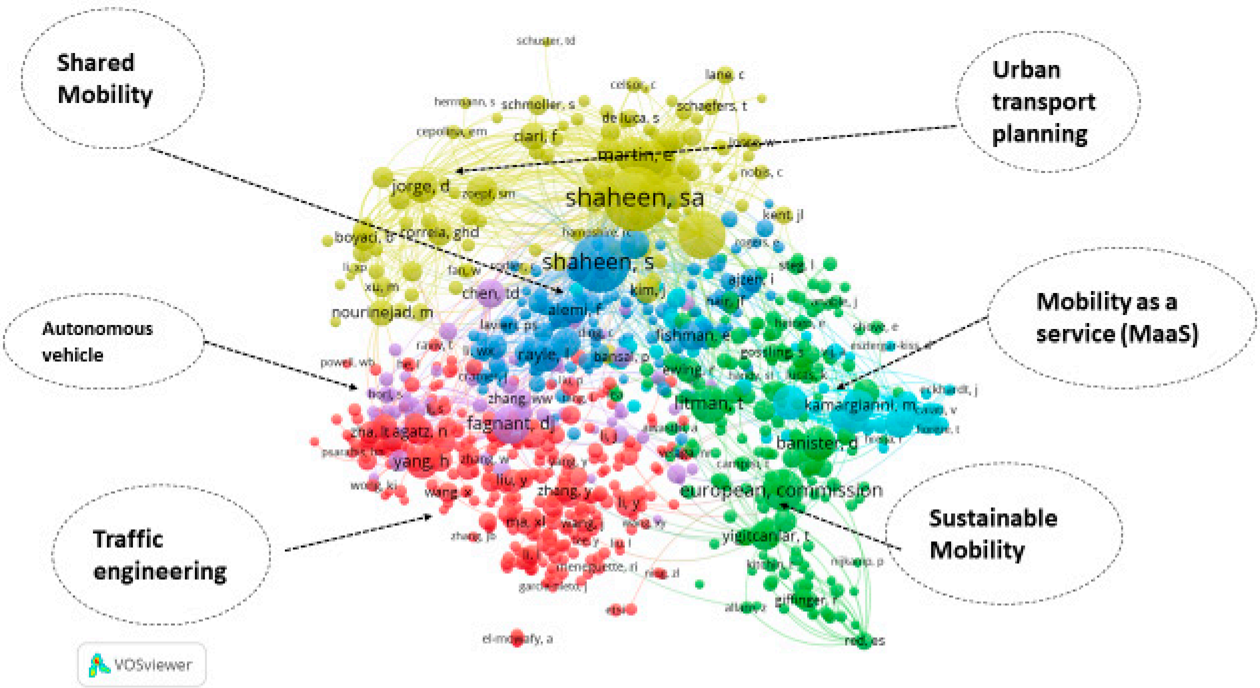

Figure 4. Author Co-Citation Map-Comprising Domains in Smart Mobility Literature.

4.3. Key Cross-Discipline Themes in Smart Mobility Research

4.3.1. Co-Word Analysis

To forecast the future of smart mobility research, co-word analysis provides a preview of emerging and interesting research areas. The analysis revealed 10,214 keywords that appeared in all the smart mobility publications, as indexed in the WoSCC database. The analysis revealed that the most frequently used keywords were carsharing (281), intelligent transport systems (254), smart city (234), and shared mobility (199). By conducting a distinct search through the titles and abstracts, additional significant keywords were discovered, including sustainable mobility, autonomous vehicles, and deep learning. These findings imply that smart mobility research is interdisciplinary in nature and encompasses several interconnected fields. As shown in Table 5, the appearance of keywords such as autonomous vehicles and transport network companies in both titles and abstracts suggest the significance of collaboration with the private sector in the development of smart mobility.

Table 5. Most Frequently Used Words in the Smart Mobility Literature.

Words	Occurrences	Words in Titles	Occurrences	Words in Abstracts	Occurrences
carsharing	281	sustainable urban mobility	122	intelligent transport systems	434
intelligent transport systems	254	intelligent transport systems	81	sustainable urban mobility	314
smart city	234	shared mobility services	27	shared mobility services	111
shared mobility	199	vehicular ad hoc	24	smart mobility	92
smart mobility	173	shared autonomous vehicle	21	urban mobility plans	58
public transport	131	electric vehicle sharing	20	transportation network companies	53
mobility-as-a-service	118	urban mobility plans	18	greenhouse gas emissions	50
ridesharing	110	smart urban mobility	13	global positioning system	48
road traffic	95	shared autonomous vehicles	11	shared mobility systems	40
ridesourcing	88	deep reinforcement learning	10	network companies tncs	38
sustainability	87	traffic flow prediction	10	traffic signal control	36
urban mobility	81	cooperative intelligent transport	9	shared autonomous vehicles	34
traffic engineering computing	79	traffic signal control	9	electric vehicles evs	33
transportation	78	transportation network companies	9	global navigation satellite	31
sustainable mobility	75	urban mobility planning	9	private car ownership	31

An analysis of each of the author's keyword co-occurrence produced the research hotspots depicted in the keyword co-occurrence map of Figure 5.

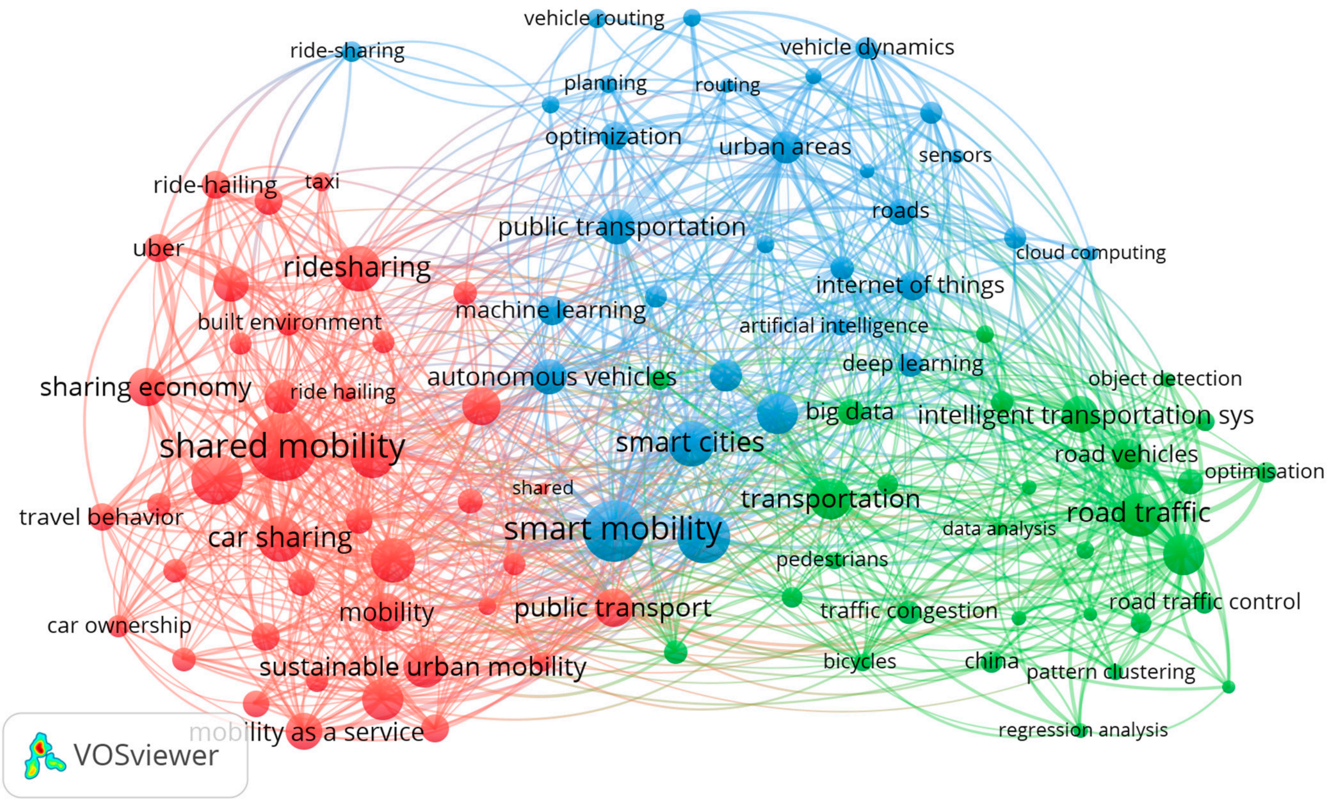

Figure 5. Network Co-occurrence Map Based on Each Author's Keywords (minimum number of occurrences: three).

The network map of Figure 5 shows the size of the circle as proportional to the occurrence of the keywords. The distance between the circles indicates the affinity between keywords, implying topics that tend to be studied together. Moreover, the different colours depict the dimensions or lenses of studying smart mobility [28].

The appearance of words, such as sustainability or sustainable mobility, systems, models, smart city, and traffic engineering, reveal the different standpoints of smart mobility authors. Co-word analysis reinforced the co-citation pattern where research disciplines operate in "silos". The innovative technologies that make smart mobility possible appear as distinct themes that are separate from each other, signalling disciplines evolving independently of each other. Co-word analysis also reveals emerging trends in the smart mobility literature. The first set clusters around the smart mobility field and includes big data, the Internet of Things, integration, innovation, and sustainability. Other emerging concepts, such as artificial intelligence and deep learning, are emergent but cluster around traffic engineering, which is further from the smart mobility cluster. This signals that these new technologies evolve independently of smart mobility research.

4.3.2. Thematic Evolution

This first phase of the analysis presents the thematic evolution of the sub-fields in the smart mobility literature. Four periods are observed: 1981–2017; 2018–2019; 2020–2020; 2021–2022. The period becomes smaller as the years advance due to the surge in publications. Figure 6 presents the results covering the four periods.

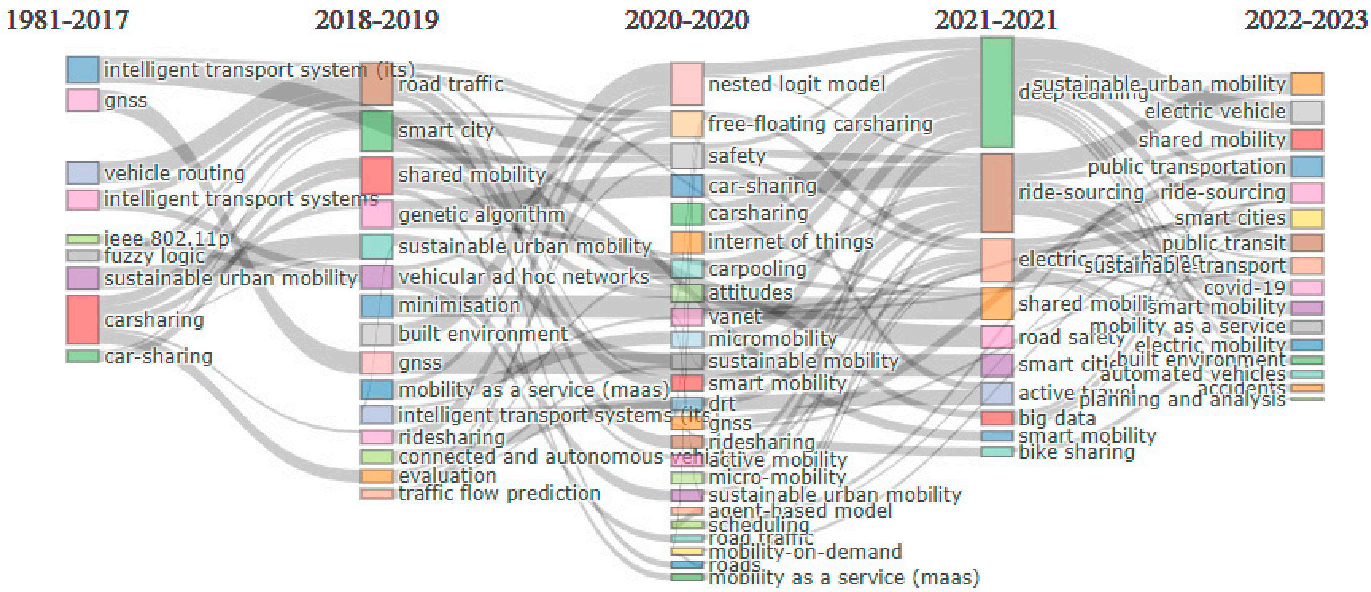

Figure 6. Thematic Evolution of Smart Mobility Literature.

Figure 6 shows that in the early years of smart mobility (1981–2017), research primarily focused on three sub-fields, i.e., intelligent transport systems, road traffic, standards for wireless access in vehicles, and traffic engineering computing. In the period 2017–2019, some themes evolved giving rise to new ones (such as smart city, road safety) and others collapsed (traffic engineering computing) [27].

In the next phase of this analysis, the themes from different sub-fields were emerging or declining, named as niche, basic or transversal, and motor themes.

The period 1981–2017 covered ten key themes and four of them fell in the motor themes quadrant. Among them, traffic engineering and road traffic were the most established, based on the size of the circles. At the same time, intelligent transport systems were a niche theme that was starting to develop.

In the period 2016–2018, nine sub-fields emerged. The ones categorised under motor themes were road safety and road traffic. At the time, the concept of a smart city was not fully developed as a theme and belonged to the basic or transversal themes quadrant while genetic algorithm was a niche theme.

In the period 2020–2020, from the five themes identified, smart mobility was the emerging theme, while the Internet of Things and public transport were developing in the basic theme quadrant. The niche themes were genetic algorithms and artificial intelligence.

In the fourth period 2021–2022, big data emerged as a niche theme. Sustainability was at the intersection of niche and motor themes. Intelligent transport systems resurfaced as a motor theme, while shared mobility and mobility as a service began developing as is evident in the basic theme quadrant. While deep learning was emerging, traffic engineering was disappearing. Notable was the emergence of attitudes suggesting the necessity of user behaviour and preferences in smart mobility.

From the thematic evolution results, it is possible to infer that smart mobility research is carried out in distinct thematic areas in each period. The thematic areas form groups according to their connections to the theme from the previous period. Furthermore, there are themes that were present in just one period and therefore, do not belong to any thematic area group. Examples are big data, deep learning, and artificial intelligence. This is because they are very recent and may be considered as the introduction of a new area or the theme has many connections to others, hence becoming difficult to group [27]. This happened in the third (2020–2020) and fourth periods (2021–2022) of the thematic evolution map.

The results also revealed some themes, such as intelligent transport mobility, that evolved in regular and continuous patterns from the first period to the fourth period, except in the third period (2020–2020). This suggests that some themes develop and once they reach maturity, they disappear. The dominance of a theme in Figure 6 is determined by the size of the bar.

Considering the size of the bars in different periods, it is possible to infer that some themes evolve in an increasing pattern; others are constant, while others evolve in a sporadic way. For instance, intelligent transport systems have evolved in a stable manner and delivered new themes. It is also apparent that the themes of road traffic and intelligent transport systems (ITS) are present in all the periods, meaning they have maintained the interest of researchers for the entire period. Finally, the theme of traffic engineering is showing signs of exhaustion, indicating that it is being retired.

In summary, intelligent transport systems, or ITS and road traffic, are the most important themes or sub-fields in the smart mobility research field for the entire period analysed. On the other hand, smart mobility is an important basic theme that has good indicators of growth.

5. Discussion

The main goals of this review were to conduct a performance evaluation and scientific mapping of the smart mobility field and thereafter, suggest avenues for future research. Performance analysis was based on author productivity, citation, and co-citation analysis while science mapping was based on co-word analysis and the evolution of thematic maps. Smart mobility research started in 1981 and the number of publications has grown by more than 75% since 2018. Productivity analysis revealed that scholars in engineering and transport engaged the most with smart mobility research, each contributing 47%. However, citation patterns showed that 16 of the top 20 most cited scholars were from transport disciplines. Moreover, transport exhibited the greatest citation impact in the smart mobility literature. This was the case despite the fact that engineering produced almost the same number of documents as transport. The study revealed that developed countries were the most productive in smart mobility research pointing to a paucity of research from developing countries. The fact that China was identified as the country with the most prolific authors is noteworthy, suggesting that China is at the forefront of smart mobility research. This can be attributed to China's considerable investments in smart city technologies, and its emphasis on promoting sustainable urban development and mitigating traffic congestion, which has all contributed to a robust focus on developing smart mobility solutions [99]. China's leadership in this field can also be attributed to its distinctive social and political context, as well as its large population and rapid urbanisation.

Open access journals emerged as the publication outlets with the highest growth rate of 66%. In particular, IET Intelligent Transport Systems, Sustainability, Sensors, and IEEE Access were the top publication titles based on the number of publications. It was notable that smart mobility research consists of disciplines approaching the field with a focus on limited dimensions. While some areas contribute to the development of the technologies, models, and science of smart mobility, others advance the application aspects of the field, such as the social sciences. These findings reveal that the evolution and growth of smart mobility research have assumed uneven trajectories lending support to Hodson et al. [100], who argue that unequal attention to all dimensions of mobility has a negative impact on urban sustainability. The majority of the journal articles that have reviewed the smart mobility literature have focused on technical dimensions, with fewer focusing on social issues.

Author co-citation analysis revealed five main clusters contributing to smart mobility literature. These are smart cities, urban transport planning, traffic engineering, sustainability, and integration. Three of these domains, namely smart cities, sustainable mobility, and urban transport planning are in close proximity to each other and feature densely connected clusters of scholars who are highly cited. This finding points to the existence of a community of sustainable mobility scholars, many of whom have great influence in the research field. The scholars that emerged as the most influential include Fagnat and

Shaheen. Other scholars such as Geels emerged as influential in transport suggesting the potential application of multi-disciplinary concepts and related fields, such as geography, to define future research in smart mobility. The author co-citation map enabled the identification of the theories and concepts that are shaping the discourse on smart mobility. These include multi-level perspective (MLP), socio-technical transition theory, and sustainability transitions. Unlike the present where each discipline approaches smart mobility from silos, the future of smart mobility will be characterised by co-evolution and multi-domain interactions among industries, markets, technology, policy, culture, and civil society. In summary, the greatest traction in smart mobility research emanates from transport owing to a high citation and co-citation impact among scholars in that field. This trend suggests that smart mobility is considered a core construct in transport studies. On the other hand, the productivity, citation, and co-citation impact in other fields, such as science and engineering, are relatively low. This is surprising given the central role of science and engineering in originating the enabling technologies for smart mobility [20].

The main theme under investigation in this study was smart mobility, which can now be defined as the use of advanced technologies, such as the IoT, big data analytics, and artificial intelligence, to improve the efficiency, accessibility, and sustainability of transport systems. Smart mobility systems aim to optimise the use of existing transport infrastructure, reduce traffic congestion, and improve air quality, using innovative technologies, such as connected and autonomous vehicles, real-time traffic management systems, and smart public transport systems. The goal of smart mobility is to create more liveable, efficient, and sustainable cities by improving the way that people and goods move within urban environments. It is therefore possible to infer the nexus between smart mobility and quality of life. Thus, through the finding of co-word analysis, this study extends the existing definition of smart mobility to include sustainability and quality of life. Co-word analysis reinforced the co-citation pattern where research disciplines operate in "silos". The innovative technologies that make smart mobility possible appear as distinct themes considering the separation distance in the co-word analysis map. This signals the uneven evolution of smart mobility in different disciplines. Co-word analysis also revealed emerging trends in the smart mobility literature. The first set of clusters around the smart mobility field includes big data, Internet of Things, integration, innovation, and sustainability. Other emerging concepts, such as artificial intelligence and deep learning, are emergent but clustering around traffic engineering, which is distant from smart mobility. This signals that these smart technologies are important to smart mobility, but they evolve independently.

Seeking to identify the direction of smart mobility research, the study accomplished two tasks that made both conceptual and empirical contributions. First, the study reviewed diverse and fragmented pieces of literature, tracing the intellectual, conceptual, and social history of smart mobility research. Thus, the primary contribution of the study was an integrated conceptualisation of smart mobility that created a unified base upon which subsequent studies can build. In the first contribution, the review offers a definition of smart mobility as the use of advanced technologies, such as the IoT, big data analytics, and artificial intelligence, to improve transportation efficiency, mobility for all, and sustainability while safeguarding the quality of life. Furthermore, the study revealed that smart mobility has assumed uneven trajectories with varying interest in developed and developing countries, therefore making an empirical contribution. In the final analysis, the study proposes novel research topics that form a basis for future research agendas. The study makes two recommendations. First, scholarly efforts on socio-technical transitions and multi-level perspective research have the potential to enrich the field of smart mobility. In particular, the practical implication for socio-technical transitions with rapid technological evolution [46] is an area that needs further investigation. The review's identification of cross-disciplinary themes emphasises the diverse array of factors that must be taken into account in smart mobility research, such as environmental impact, social fairness, and governance. The emphasis on incorporating smart mobility with existing transportation systems and examining alternative business models for smart mobility services stresses the significance of considering the real-world application of smart mobility solutions.

Second, focused scholarly efforts on socio-technical transitions in the context of developing and developed cities [101] have the potential to extend the knowledge-base. The focus on examining user behaviour and preferences regarding smart mobility, along with the development of new evaluation techniques for smart mobility systems, underscores the necessity for research that is more user centric. Additionally, the demand for increased research on smart mobility in developing nations emphasises the importance of ensuring that the advantages of smart mobility are available to everyone, regardless of their socioeconomic status.

Notwithstanding the effort to carry out this study with the best approach, it has to be read in light of its limitations. First, the study might not have considered all publications, especially if they were not indexed in the WoSCC corpus. Second, there was a chance of overlooking important insights due to the subjective interpretation of the study findings. Finally, as pointed out earlier, the choice of a search strategy could have omitted insightful articles that did not bear the rubric of "smart mobility". Thus, we propose that future research in this area should consider a more comprehensive approach to the literature review, including multiple databases and sources, including grey literature to ensure that all relevant studies are included. This includes grey literature that may provide valuable insights and information on smart mobility which is an emerging field. Additionally, future studies should strive to minimise subjective interpretation of findings by employing rigorous and transparent methods for data analysis and synthesis such as systematic review and meta-analysis. Finally, researchers should consider using a broader range of search terms to capture a wider range of studies related to the subject of smart mobility. By addressing these limitations, future studies can build upon the findings of this study and provide a more comprehensive understanding of the topic of smart mobility.

6. Research Agenda

Although scholars have suggested that smart mobility is a multi-disciplinary field [61], the findings from this review show that the research of smart mobility draws from inside the transport field with limited influence from outside. Therefore, smart mobility research has not exhaustively applied theoretical perspectives from management and evolutionary economics. Looking outside the discipline can enable broader engagement with other research areas, paving the way for mutual enrichment across domains. Accordingly, we developed a research agenda for the following areas that are emergent around mobility but were beyond the scope of the review.

Smart Technologies:

Despite their central role in enabling mobility, smart technologies have received limited research attention. In particular, how the smart mobility technologies integrate with existing transport systems, whether on an incremental or a disruptive basis. In addition, there are fertile lines of enquiry on the implication of a socio-technical context on smart mobility and determining when the smart technology is good enough to integrate. Thus, there is an avenue to draw from evolutionary economics [102] and incorporate the concepts of sustainability transitions [103] and deep transitions [104].

The following research questions represent an agenda for smart technologies:

1. How can smart mobility eliminate mobility disruptions?
2. How can smart mobility technologies integrate with existing transport systems?
3. What is the implication of co-evolution and multi-domain interactions among actors, industries, markets, technology, policy, culture, and civil society in the face of rapidly changing technological progress?

Economics Context

Niche-regime interaction, diffusion, and acceleration of smart mobility technologies, as well as applications for country-specific and different cities, are ripe for enquiry. The questions in support of this research agenda are:

1. What is the role of markets and consumers, civil society, and policymakers in overcoming lock-ins to enable the diffusion of smart mobility technologies?
2. What does smart mobility mean for developing cities that are constrained by resources?

Transport

While the focus has been on the "hard side" of mobility (technology), the sustainability paradigm, which represents the "soft side", requires attention. In addition, integration and real-time systems present new opportunities for exploration [54]. The following questions present a research agenda:

1. What aspects of transport are ripe for integration?
2. How can integration alleviate traffic congestion, and pollution and reduce transport costs?
3. How can cities realise a people-centred mobility system?

7. Conclusions

This review sought to undertake a performance evaluation and scientific mapping of the smart mobility field. This bibliometric review provides a comprehensive understanding of the current state of research on smart mobility and highlights the need for a more integrated and multi-disciplinary approach to further advance this field. The review demonstrates that current research has a strong emphasis on technological aspects with limited social or economic considerations, and there is a significant gap in knowledge regarding the application of smart mobility technologies in developing countries.

The review identifies four distinct periods of smart mobility research, with increased interest in recent years due to advancements in big data, deep learning, artificial intelligence, and real-time technologies. However, the primary challenge for smart mobility remains the co-evolution with existing transport systems, making further research on integration with these systems and real-time technologies essential for advancing smart mobility research. The study identifies multi-disciplinary themes that act as the glue binding the various streams of smart mobility research. The multi-level perspective in smart mobility is not only a promising area for future research but also an important perspective as cities strive to reap the benefits of smart mobility. Unfortunately, it is beyond the scope of the review to undertake an in-depth examination of how cross-fertilisation of themes can be applied to benefit smart mobility literature as a whole. This suggests the need for a review of how smart mobility themes have been applied across disciplines.

In addition, the review established that smart mobility involves utilising cutting-edge technologies, such as the IoT, big data analytics, and artificial intelligence, to enhance the efficiency, accessibility, and sustainability of transportation systems, as well as preserving the quality of life. Due to the techno-centric focus, smart mobility may have been missing other important dimensions that can enhance its application and contribute to the quality of life. The disciplines of engineering and computer science have hitherto enriched the smart mobility field with less contribution from the social sciences that address the application aspects of mobility.

Therefore, a research agenda is proposed that suggests future research avenues to address the current gaps in knowledge. This agenda emphasises the need for a more integrated and multi-disciplinary approach to smart mobility research, with a focus on social and economic factors, and the application of smart mobility technologies in developing countries.

Nonetheless, it is important to point out that despite the careful effort to evaluate and synthesise the literature on smart mobility, the review is not without limitations. First, the WoSCC database may have missed some relevant publications in the field. Second, there was a chance of overlooking some insights due to subjective interpretation of the study findings. Finally, bibliometric findings may lack the depth and breadth required for a smart mobility study.

Overall, this review provides an integrated conceptualisation of smart mobility research, defining smart mobility as the use of advanced technologies to improve transportation efficiency, mobility for all, and sustainability while safeguarding the quality of life. The review highlights the potential benefits of smart mobility for improving the quality of life and sustainability of urban areas, and the importance of considering social, economic, and environmental factors when designing smart mobility systems.

In conclusion, this review has marked the contours of the current smart mobility research. The review emphasises the need for further research to advance the field of smart mobility and realise its full potential for improving the quality of life and sustainability of urban areas.

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