Smart Mobility in Urban Areas

Subjects: Management

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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.

Keywords: smart mobility ; sustainability

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].

2. Smart Mobility

Smart mobility is a concept that aims to use technology to improve transportation efficiency and sustainability while enhancing mobility for all [5][6][7]. Smart mobility combines various transportation modes and uses real-time data to provide tailored transportation solutions to individuals, organisations, and cities [8][9][10]. 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][11], however, there is currently no consensus on what precisely constitutes smartness in this context [12][13][14]. Nonetheless, it is generally agreed that smart mobility aims to use technology to improve the efficiency, safety, sustainability, and accessibility of transportation [15]. Smart mobility also involves the integration of different transportation modes [16], including walking, cycling, public transport, and private vehicles, to provide seamless, reliable, and personalised transportation services [17]. Furthermore, smart mobility incorporates technology, integrated planning, and personalised transportation services to provide seamless, sustainable, and accessible transportation solutions [14][15]. Hence, the key features of smart mobility include real-time data, interoperability, user-centred design, and sustainability [10][11][18].

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 [19][20], which enhances transportation efficiency, safety, and sustainability. Technology also provides various transportation options and enables personalised transportation services [17]. Big data analytics, artificial intelligence (AI), and the IoT are some of the key technologies that are transforming the way society thinks about mobility [8][21][22]. Big data analytics is essential in the management and planning of transportation systems [23]. 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 [24]. This data can be used to understand mobility patterns, optimise routes, and improve traffic flow [25]. For example, big data analytics can help to identify traffic bottlenecks and suggest alternative routes hence reducing congestion [21]. 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 [26]. 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] [27]. Furthermore, AI has the potential to transform urban decision-making processes and improve urban governance and citizen participation [28]. 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 [29]. 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 [30]. 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 [31]. Similarly, the proliferation of ride-hailing services could increase congestion and undermine public transit [32]. Smart mobility technologies could also have social equity implications, as they may not be accessible to all, leading to a digital divide in transportation [33]. There are also concerns about data privacy, cybersecurity, and the potential for these technologies to exacerbate existing social inequalities [29][30]. Therefore, it is essential to approach the use of these technologies with care and consider their potential impacts on society as a whole [33][34][35][36].

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 [35]. Integrated transport planning aims to provide seamless, convenient, and sustainable transportation solutions by considering various transportation modes, land use, and urban design [37]. Smart mobility builds on integrated transport planning by using technology to enable real-time [38] data-driven decision-making [39] and personalised transportation services [40]. 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 [41]. 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 [42]. 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 [43].

Traditional transport planning takes the view that travel is a derived demand, not a valuable activity, with the value at the destination [31]. 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 [44]. Integrated transport planning, on the other hand, is demand-based, which considers the mobility-needs of people to determine the quantity to supply [45].

Transport planning in urban areas addresses four key aspects: transport demand, transport supply, urban space management, and deployment of environmentally friendly technologies [46]. Different policy directions are required to give effect to each of these four aspects [47].

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 [48]. 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 [49].

Policymakers face the challenge of creating a conducive environment that promotes innovation and investment in smart mobility solutions [50][51]. This requires a regulatory framework that is adaptable to market needs while ensuring safety, privacy, and security [40][41]. Sometimes, a regulatory sandbox approach that allows experimentation with new technologies and business models in a controlled environment may be necessary [52].

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 [53]. Therefore, targeted policies and initiatives may be necessary to address issues such as affordability, access to mobility services, and the needs of vulnerable populations [54][55].

Furthermore, governance and policy can promote interoperability and standardisation of smart mobility solutions [56], which is crucial given the fragmented nature of the ecosystem and the involvement of multiple stakeholders in the development and implementation of solutions [40][44]. Policymakers can encourage collaboration and ensure compatibility with existing infrastructure and technologies by promoting interoperability and standardisation [57].

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 [58]. 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 [59].

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 [60], micro-mobility, attitudes [61], and autonomous vehicles [36][37][39]. While some studies have focused on the technologies that enable smart mobility such as big data [62], few have reviewed the field as a whole [63][64]. The evolution of transport planning towards integrated transport planning [23][65] 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 [44][45]. 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 [66].

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 [67][68]. 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.

References

1. United Nations United Nations Department of Economic and Social Affairs: World Urbanization Prospects. Available online: https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf (accessed on 8 March 2023).
2. Gamboa-Rosales, N.K.; Celaya-Padilla, J.M.; Hernandez-Gutierrez, A.L.; Moreno-Baez, A.; Galván-Tejada, C.E.; Galván-Tejada, J.I.; González-Fernández, E.; Gamboa-Rosales, H.; López-Robles, J.R. Visualizing the intellectual structure and evolution of intelligent transportation systems: A systematic analysis of research themes and trends. Sustainability 2020, 12, 8759.
3. Hensher, D.A. Tackling road congestion—What might it look like in the future under a collaborative and connected mobility model? Transp. Policy 2018, 66, A1–A8.
4. Barbosa, W.; Prado, T.; Batista, C.; Câmara, J.C.; Cerqueira, R.; Coelho, R.; Guarieiro, L. Electric Vehicles: Bibliometric Analysis of the Current State of the Art and Perspectives. Energies 2022, 15, 395.
5. Soares Machado, C.A.; de Salles Hue, N.P.; Berssaneti, F.T.; Quintanilha, J.A. An Overview of Shared Mobility. Sustainability 2018, 10, 4232.
6. Ahmad, S.; Puppim de Oliveira, J.A. Determinants of Urban Mobility in India: Lessons for Promoting Sustainable and Inclusive Urban Transportation in Developing Countries. Transp. Policy 2016, 50, 106–114.
7. Sovacool, B.K.; Kester, J.; Noel, L.; de Rubens, G.Z. Contested Visions and Sociotechnical Expectations of Electric Mobility and Vehicle-to-Grid Innovation in Five Nordic Countries. Environ. Innov. Soc. Transit. 2019, 31, 170–183.
8. Javed, A.R.; Shahzad, F.; Rehman, S.U.; Zikria, Y.B.; Razzak, I.; Jalil, Z.; Xu, G.; Bin Zikria, Y.; Razzak, I.; Jalil, Z.; et al. Future smart cities requirements, emerging technologies, applications, challenges, and future aspects. Cities 2022, 129, 103794.

9. Jittrapirom, P.; Caiati, V.; Feneri, A.-M.M.; Ebrahimigharehbaghi, S.; Alonso-González, M.J.; Narayan, J.; Alonso-Gonzalez, M.J.; Narayan, J. Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. URBAN Plan. 2017, 2, 13–25.
10. Zawieska, J.; Pieriegud, J. Smart city as a tool for sustainable mobility and transport decarbonisation. Transp. Policy 2018, 63, 39–50.
11. Paiva, S.; Ahad, M.A.; Tripathi, G.; Feroz, N.; Casalino, G. Enabling Technologies for Urban Smart Mobility: Recent Trends, Opportunities and Challenges. Sensors 2021, 21, 2143.
12. Edwards, S.; Hill, G.; Goodman, P.; Blythe, P.; Mitchell, P.; Huebner, Y. Quantifying the impact of a real world cooperative-ITS deployment across multiple cities. Transp. Res. Part A-Policy Pract. 2018, 115, 102–113.
13. Ghosh, B.; Arora, S. Smart as (un)democratic? The making of a smart city imaginary in Kolkata, India. Environ. Plan. C Polit. Space 2022, 40, 318–339.
14. Allam, Z.; Sharifi, A. Research Structure and Trends of Smart Urban Mobility. Smart Cities 2022, 5, 539–561.
15. Rothkrantz, L.; Svitek, M.; Pribyl, O. Intelligent Mobility in Smart Cities; MDPI Publishing: Basel, Switzerland, 2022; ISBN 9783036541471.
16. El-Agroudy, M.; Abou-Senna, H.; Radwan, E. Mobility-as-a-Service: Simulation of Multi-Modal Operations in Low-Density Cities. Transp. Res. Rec. 2022, 2676, 235–246.
17. Arnaoutaki, K.; Bothos, E.; Magoutas, B.; Aba, A.; Esztergar-Kiss, D.; Mentzas, G. A Recommender System for Mobility-as-a-Service Plans Selection. Sustainability 2021, 13, 8245.
18. Kovačić, M.; Mutavdžija, M.; Buntak, K. New Paradigm of Sustainable Urban Mobility: Electric and Autonomous Vehicles—A Review and Bibliometric Analysis. Sustainability 2022, 14, 9525.
19. Christensen, T.H.; Friis, F.; Nielsen, M.V. Shifting from ownership to access and the future for MaaS: Insights from car sharing practices in Copenhagen. Case Stud. Transp. Policy 2022, 10, 841–850.
20. Lyons, G. Getting smart about urban mobility—Aligning the paradigms of smart and sustainable. Transp. Res. Part A Policy Pract. 2018, 115, 4–14.
21. Kong, L.; Liu, Z.; Wu, J. A systematic review of big data-based urban sustainability research: State-of-the-science and future directions. J. Clean. Prod. 2020, 273, 123142.
22. Butler, L.; Yigitcanlar, T.; Paz, A. Smart urban mobility innovations: A comprehensive review and evaluation. IEEE Access 2020, 8, 196034–196049.
23. Schwedes, O.; Hoor, M. Integrated Transport Planning: From Supply- to Demand-Oriented Planning. Considering the Benefits. Sustainability 2019, 11, 5900.
24. Zhang, W.E.; Shemshadi, A.; Sheng, Q.Z.; Qin, Y.; Xu, X.; Yang, J. A User-Oriented Taxi Ridesharing System with Large-Scale Urban GPS Sensor Data. IEEE Trans. Big Data 2021, 7, 327–340.
25. Lam, C.T.; Liu, M.; Hui, X. The geography of ridesharing: A case study on New York City. Inf. Econ. Policy 2021, 57, 100941.
26. Zeng, H.; Jiang, C.; Lan, Y.; Huang, X.; Wang, J.; Yuan, X. Long Short-Term Fusion Spatial-Temporal Graph Convolutional Networks for Traffic Flow Forecasting. Electronics 2023, 12, 238.
27. Mageto, J.; Twinomurinzi, H.; Luke, R.; Mhlongo, S.; Bwalya, K.; Bvuma, S. Building resilience into smart mobility for urban cities: An emerging economy perspective. Int. J. Prod. Res. 2022.
28. Fernandez-Heredia, A.; Fernandez-Sanchez, G. Processes of Civic Participation in the Implementation of Sustainable Urban Mobility Systems. CASE Stud. Transp. Policy 2020, 8, 471–483.
29. Rathore, M.M.; Ahmad, A.; Paul, A.; Rho, S. Urban planning and building smart cities based on the Internet of Things using Big Data analytics. Comput. Netw. 2016, 101, 63–80.
30. Banister, D. Cities, mobility and climate change. J. Transp. Geogr. 2011, 19, 1538–1546.
31. Banister, D. The sustainable mobility paradigm. Transp. Policy 2008, 15, 73–80.
32. Tirachini, A.; Chaniotakis, E.; Abouelelad, M.; Antoniou, C. The sustainability of shared mobility: Can a platform for shared rides reduce motorized traffic in cities? Transp. Res. Part C-Emerg. Technol. 2020, 117, 102707.
33. Jin, S.T.; Kong, H.; Wu, R.; Sui, D.Z. Ridesourcing, the sharing economy, and the future of cities. Cities 2018, 76, 96–104.
34. Meng, L.; Somenahalli, S.; Berry, S. Policy implementation of multi-modal (shared) mobility: Review of a supply-demand value proposition canvas. Transp. Rev. 2020, 40, 670–684.

35. Melo, S.; Macedo, J.; Baptista, P.P. Guiding cities to pursue a smart mobility paradigm: An example from vehicle routing guidance and its traffic and operational effects. Res. Transp. Econ. 2017, 65, 24–33.

36. Fosso, S.; Epie, R.; Guthrie, C.; Queiroz, M.M.; Andr, K.D. Technological Forecasting & Social Change Are we preparing for a good AI society ? Bibliometr. Rev. Res. Agenda 2021, 164, 120482.

37. Jeon, C.M.; Amekudzi, A.A.; Guensler, R.L. Sustainability assessment at the transportation planning level: Performance measures and indexes. Transp. Policy 2013, 25, 10–21.

38. Zapolskyt, S.; Tr, M.; Burinskien, M.; Zapolskyte, S.; Trepanier, M.; Burinskiene, M.; Survile, O. Smart Urban Mobility System Evaluation Model Adaptation to Vilnius, Montreal and Weimar Cities. Sustainability 2022, 14, 715.

39. Lu, K.; Han, B.; Zhou, X. Smart Urban Transit Systems: From Integrated Framework to Interdisciplinary Perspective. Urban Rail Transit 2018, 4, 49–67.

40. Gandia, R.; Antonialli, F.; Nicolai, I.; Sugano, J.; Oliveira, J.; Oliveira, I. Casual Carpooling: A Strategy to Support Implementation of Mobility-as-a-Service in a Developing Country. Sustainability 2021, 13, 2774.

41. Geels, I.F.W. The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technol. Anal. Strateg. Manag. 2005, 17, 445–476.

42. Markard, J.; Geels, F.W.; Raven, R. Challenges in the acceleration of sustainability transitions OPEN ACCESS Challenges in the acceleration of sustainability transitions. Environ. Res. Lett. 2020, 15, 081001.

43. Decker, B.; Hećimović, H.; Wołek, M. Sustainable Urban Mobility Planning in Central Eastern Europe: Case Examples from Poland and Croatia. Procedia-Soc. Behav. Sci. 2012, 48, 2748–2757.

44. Butler, L.; Yigitcanlar, T.; Paz, A. Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities: A systematic review of the literature. Cities 2021, 109, 103036.

45. Gueriau, M.; Cugurullo, F.; Acheampong, R.A.; Dusparic, I. Shared Autonomous Mobility on Demand: A Learning-Based Approach and Its Performance in the Presence of Traffic Congestion. IEEE Intell. Transp. Syst. Mag. 2020, 12, 208–218.

46. Haque, M.M.; Chin, H.C.; Debnath, A.K. Sustainable, safe, smart—Three key elements of Singapore's evolving transport policies. Transp. Policy 2013, 27, 20–31.

47. Bardal, K.G.G.; Gjertsen, A.; Reinar, M.B. Sustainable mobility: Policy design and implementation in three Norwegian cities. Transp. Res. Part D-Transp. Environ. 2020, 82, 102330.

48. Canitez, F. Transferring sustainable urban mobility policies: An institutional perspective. Transp. Policy 2020, 90, 1–12.

49. Liu, X.; Yu, J.; Trisha, S.; Beimborn, E. Exploring the Feasibility of Mobility as a Service in Small Urban and Rural Communities: Lessons from a Case Study. J. Urban Plan. Dev. 2020, 146, 05020016.

50. Polydoropoulou, A.; Pagonia, I.; Tsirimpa, A.; Roumboutsos, A.; Kamargianni, M.; Tsouros, I. Prototype business models for Mobility-as-a-Service. Transp. Res. Part A-Policy Pract. 2020, 131, 149–162.

51. Mounce, R.; Beecroft, M.; Nelson, J.D. On the role of frameworks and smart mobility in addressing the rural mobility problem. Res. Transp. Econ. 2020, 83, 100956.

52. Icasiano, C.D.A.; Taeihagh, A. Governance of the Risks of Ridesharing in Southeast Asia: An In-Depth Analysis. Sustainability 2021, 13, 6474.

53. Pangbourne, K.; Mladenovic, M.N.; Stead, D.; Milakis, D. Questioning mobility as a service: Unanticipated implications for society and governance. Transp. Res. Part A-Policy Pract. 2020, 131, 35–49.

54. Sadri, A.M.; Lee, S.; Ukkusuri, S.V. Modeling Social Network Influence on Joint Trip Frequency for Regular Activity Travel Decisions. Transp. Res. Rec. 2015, 2495, 83–93.

55. Grahn, R.; Qian, S.; Matthews, H.S.; Hendrickson, C. Are travelers substituting between transportation network companies (TNC) and public buses? A case study in Pittsburgh. Transportation 2021, 48, 977–1005.

56. Porru, S.; Misso, F.E.; Pani, F.E.; Repetto, C. Smart mobility and public transport: Opportunities and challenges in rural and urban areas. J. Traffic Transp. Eng. Ed. 2020, 7, 88–97.

57. Anthony Jr., B.; Petersen, S.A.; Ahlers, D.; Krogstie, J. Big data driven multi-tier architecture for electric mobility as a service in smart cities A design science approach. Int. J. Energy Sect. Manag. 2020, 14, 1023–1047.

58. Savastano, M.; Suciu, M.; Gorelova, I.; Stativ, G. How smart is mobility in smart cities? An analysis of citizens' value perceptions through ICT applications. Cities 2023, 132, 104071.

59. Vanheusden, W.; van Dalen, J.; Mingardo, G. Governance and business policy impact on carsharing diffusion in European cities. Transp. Res. Part D-Transp. Environ. 2022, 108, 103312.

60. Shaheen, S.; Martin, E.; Hoffman-Stapleton, M. Shared mobility and urban form impacts: A case study of peer-to-peer (P2P) carsharing in the US. J. Urban Des. 2021, 26, 141–158.
61. Butler, L.; Yigitcanlar, T.; Paz, A.; Areed, W. How can smart mobility bridge the first/last mile gap? Empirical evidence on public attitudes from Australia. J. Transp. Geogr. 2022, 104, 103452.
62. Mahrez, Z.; Sabir, E.; Badidi, E.; Saad, W.; Sadik, M. Smart Urban Mobility: When Mobility Systems Meet Smart Data. IEEE Trans. Intell. Transp. Syst. 2022, 23, 6222–6239.
63. Mangiaracina, R.; Perego, A.; Salvadori, G.; Tumino, A. A comprehensive view of intelligent transport systems for urban smart mobility. Int. J. Logist. Appl. 2017, 20, 39–52.
64. Zhu, J.; Xie, N.; Cai, Z.; Tang, W.; Chen, X.M. A comprehensive review of shared mobility for sustainable transportation systems. Int. J. Sustain. Transp. 2022, 1–25.
65. Yang, L.; van Dam, K.H.; Zhang, L. Developing goals and indicators for the design of sustainable and integrated transport infrastructure and urban spaces. Sustainability 2020, 12, 9677.
66. Taiebat, M.; Xu, M. Synergies of four emerging technologies for accelerated adoption of electric vehicles: Shared mobility, wireless charging, vehicle-to-grid, and vehicle automation. J. Clean. Prod. 2019, 230, 794–797.
67. Górka, K.; Szyja, P. Cooperation of local governments and enterprises to support the provision of sustainable transport infrastructure. Manag. Environ. Qual. Int. J. 2015, 26, 739–751.
68. Cruz, S.S.; Paulino, S.R. Experiences of innovation in public services for sustainable urban mobility. J. Urban Manag. 2022, 11, 108–122.
