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Review

Integration of Shared Micromobility into Public Transit: A Systematic Literature Review with Grey Literature

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Abstract: Shared micromobility services have become increasingly prevalent and indispensable as a means of transportation across diverse geographical regions. Integrating shared micromobility with public transit offers opportunities to complement fixed-route transit networks and address first- and last-mile issues. To explore this topic, a systematic literature review was conducted to consolidate knowledge, analyze research achievements and best practices, and provide future research recommendations. This study examined 108 journal papers from the Web of Science (WoS) core collection from 2016 to 2022, along with grey literature. Citation and co-citation analyses were performed to build and illustrate the literature's bibliometric networks. This analysis categorized the literature into four major study themes: policy, sustainability, the interaction between shared micromobility and public transportation, and infrastructure. The implementation approaches of integrating shared micromobility and public transportation in different cities were classified into four categories: physical integration, payment and fee integration, informational integration, and institutional integration. The findings indicate that the relationship between shared micromobility and public transportation varies with spatial–temporal conditions and the population density of the city. Overall, integrating micromobility into public transit can offer faster and more cost-effective mobility options for most trips, contributing to urban resilience, a better air quality, lower greenhouse gas emissions, and livable communities. Based on these insights, further research is recommended to explore dynamic and context-specific strategies for successful shared micromobility and public transit integration, considering diverse urban settings and demographic factors.

Keywords: public transportation; shared mobility; citation analysis; co-citation analysis; urban mobility

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1. Introduction

The Federal Highway Administration [1] broadly defines micromobility as any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assisted bicycles, e-scooters, and other small, lightweight, wheeled conveyances. Shared micromobility has swiftly spread throughout cities around the world, proving to be a preferred transportation mode for many consumers [2]. Many jurisdictions are investigating micromobility as an alternative mode for short trips and active transportation in response to the increased demand for walking and bicycle facilities in cities and towns around the country. Despite a 70% decline in travel across all modes in 2020 owing to the COVID-19 pandemic, shared micromobility ridership in the United States nearly returned to its pre-pandemic levels in 2021, with 112 million trips [2]. At least 128 million trips were taken on shared micromobility across North America (12.9 million in Canada, 107.6 million in USA, and 7.5 million in Mexico) in 2021. In 2023, shared micromobility has expanded its presence to 452 cities and 15 regions worldwide, facilitating over 87,000 trips worldwide every day.

Public transit is an essential form of transportation for many people and is superior in terms of urban space utilization and energy efficiency. Public transportation not only provides broader access to urban and some specially designated or geographically unique areas where access by personal vehicles is restricted or impractical but also offers a safe and cost-effective mode of travel that reduces gridlock and traffic [3].

While bus and rail systems are still fundamental to regional mobility in many cities, they have faced challenges in attracting users due to various factors such as changes in demographics, new workplace policies, adjustments in service levels, lack of funding, urban sprawl, and, possibly, the emergence of new transportation options [4]. So, ultimately, extending the transit system service in terms of the coverage and frequency is really hard to realize [5]. Under many circumstances, the inefficiency of public transport discourages its use, leading to the increased use of private automobiles. In 2021, the percentage of workers in the U.S. who used public transportation to travel to and from work amounted to a scanty 2.5 percent, down from the 4.6 percent of the previous year. This was an all-time low record in the U.S. [6]. A potential remedy to encourage individuals to switch from private vehicles to public transit is to seek less expensive ways of extending coverage and improving the flexibility of the service.

Shared micromobility has emerged as a suitable complement for the first and last miles of public transit as it is a sustainable, healthy, and cost-effective mode of transportation [7–11]. Numerous research articles, guidelines, and manuals discuss policies and procedures for better integrating shared micromobility and public transportation, such as co-locating stations with bus stops, developing mobility-as-a-service apps, and unifying payment systems. Given the potential benefits, transit authorities, shared micromobility operators, and other stakeholders are interested in understanding integration systematically and learning from best practices to guide their integration exercise.

This study conducts a systemic literature review on the integration of shared micromobility and public transportation. It evaluates the current state of progress by reviewing main topics in different countries from contributing journals. Qualitative analyses explore best practices in integrating shared micromobility into public transit planning and projects, assess integration effectiveness across cities, and answer the question of how city features impact the effectiveness of the integration. The findings of this study can help states, cities, and transit agencies stimulate their thinking, explore partnerships with shared micromobility operators, and enhance public transportation planning and operations within multimodal systems.

The rest of this paper is structured as follows: Section 2 outlines the research approach and methodology for the qualitative research. We propose five critical questions to explore the integration of shared micromobility with public transit, covering the examination of key themes in the literature, the identification of influential countries and journals, the assessment of the literature's advancement and evolution, the review of cities' practical implementations for improved integration, and the evaluation methods for the effectiveness of these strategies. Section 3 summarizes the review results, including the main subjects' progression over time, a country analysis, and keyword trends. This analysis also includes a bibliometric co-citation network, which uncovers themes, identifies gaps in knowledge, and suggests potential areas for research. Section 4 analyzes transit and shared micromobility integration practices in several cities, primarily from grey literature. Section 5 covers the effectiveness measurement, current developments insights, and prospective research directions for overcoming integration issues and constraints in future transportation systems.

2. Research Approach

This qualitative study includes a survey of relevant academic and grey literature on integrating shared micromobility services with public transit, as well as an assessment of the performance of cities which have accomplished the integration of public transit and shared micromobility.

2.1. Systematic Literature Review (SLR) Approach

A systematic literature review (SLR) process encompasses the identification, characterization, analysis, interpretation, and critical evaluation of the current body of knowledge in a specific research field. This approach utilizes a rigorously predefined search strategy aimed at achieving a comprehensive and complete understanding of the topic. A SLR differs from traditional literature reviews and has a number of advantages, including a well-developed research methodology which reduces bias in the results and provides a thorough overview of the literature related to the research objectives [12].

The SLR methodology consists of the following key tasks [13], which are usually performed in a sequential way (Figure 1):

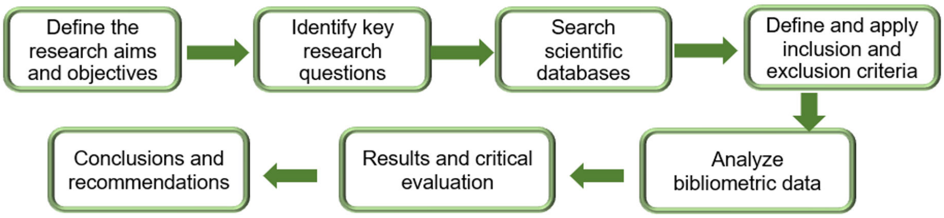

Figure 1. Systematic literature review process.

- Define the study's research aims and objectives;
- Identify the primary research questions;
- Search scientific databases for relevant content and information, iterating the process if needed;
- Establish and implement inclusion and exclusion criteria;
- Analyze the bibliometric data using publicly available tools;
- Evaluate the quality of the results and conduct critical evaluations;
- Conclude by drawing insights and suggesting directions for the future.

The tasks are explored in greater detail in the context of this study. All the search criteria employed in this SLR are aligned with the search strategies executed within the Web of Science (WoS) database, as demonstrated in Figure 2.

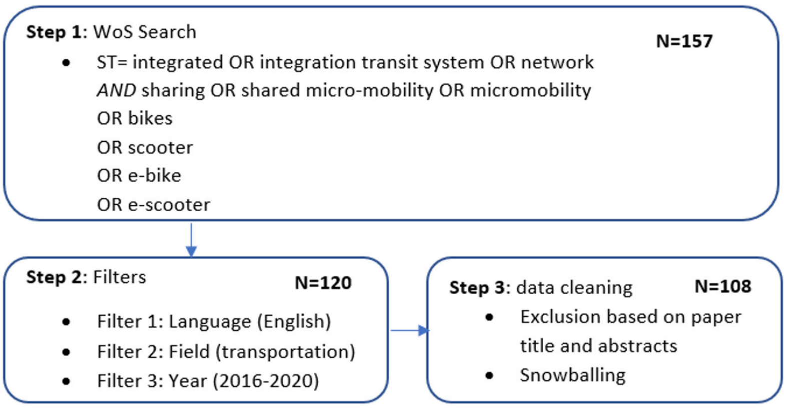

Figure 2. Search of database process.

2.2. Research Questions

This study's research questions are significant and relevant to both researchers and practitioners, which lead to policy or practice modifications and boost confidence in this research's significance and practical implications. Additionally, the questions aim to uncover disparities between commonly held perceptions and reality.

RQ1. What are the main topics reported in the scientific literature on integrating shared micromobility with public transit?

RQ2. Which country and journals have had the largest influence on the development of the literature to date?
RQ3. What is the present state of advancement within the scientific literature concerning the integrating of shared micromobility into public transit, and how has the scholarly discourse on these topics evolved over time?
RQ4. What are the implementations that different cities adopted to improve the integration?
RQ5. How can the effectiveness of the integrated strategies in different cities be evaluated?

Most of the references reviewed and analyzed are from the WoS database core collection. The WoS core collection is the most extensively used database for scientific publishing analyses, containing articles from over 22,000 journals [14].

In addition, this study utilized a logical combination of search terms, including both journal and grey literature, restricted to the transportation research category. It covered the years from 2016 to 2022, focusing on English-written references. After manual data cleaning, 108 unique items were identified and analyzed. The authors can provide a full list of the 108 papers upon request.

2.3. VOS Viewer Analysis

Recent advancements in data collection, analytic techniques, and the graphical representation of bibliometric networks have significantly enhanced the capacity for analyzing vast quantities of scientific literature, which include BibExcel (2017) [15], Cite Space (6.3.R1) [16], Science of Science (Sci2) [17], Pajek (2.05) [18], Publish or Perish (PoP) (8.12.4612) [19], SITKIS (6.289) [20], and VOSviewer (1.6.20) [21]. The authors conducted a comprehensive review of various analytical tools and selected VOSviewer for this study given its capability to represent bibliometric networks. These networks can be constructed based on citation, bibliometric coupling, co-citation, or co-authorship relations. The function of VOSviewer is especially useful for displaying large bibliometric maps in an easy-to-interpret way [22]. To build a network, bibliographic databases from WoS are provided as the input to VOSviewer [23]. The summary provides descriptive statistics for the identified manuscripts, including the year of publication, citations per year, prolific publishing journals, and countries, followed by two types of analyses: a citation analysis to identify important publications and a keyword co-occurrence analysis to investigate major domains of research and research domain development in the previous seven years based on authors' keywords.

2.4. Gery Literature Review Analysis

The grey literature [24] comprises materials and research produced by organizations outside the typical commercial or academic publishing systems, including reports, working papers, government documents, white papers, and evaluations [25]. Including the grey literature alongside peer-reviewed sources enhances the evidence base. Despite the lack of guidelines for grey literature searches in the shared micromobility field, we conducted a comprehensive search and present the relevant resources in this paper. The list of search resources for grey literature in the shared micromobility with public transit domain is provided below:

- Google Scholar;
- ScienceDirect;
- Transport Research International Documentation database;
- Government website: Federal and State DOTs, Government of Canada, and others;
- TNCs Portal: Lyft, Uber, and others;
- Organizations report: National Association of City Transportation Officials (NACTO), TRB, APTA, BBSP, SUMC, Ride Report, and others.

Recognizing the challenges inherent to assessing the quality of the grey literature, we implemented a robust selection process to ensure the inclusion of reliable and valuable sources. Our criteria for including grey literature were based on the source's authority, recency, relevance to our study's aims, and, where applicable, the clarity of its methodological approach. The initial screening involved reviewing abstracts or summaries for relevance to our research questions. Subsequently, the sources were assessed for credibility based on the publishing organization's authority and the document's recency. The final inclusion required a consensus among the authors regarding the source's substantive contribution to our topic.

To mitigate potential biases and quality concerns, we cross-referenced findings from the grey literature with peer-reviewed sources where possible and sought sources from a diverse range of organizations, including both industry and non-profit research bodies.

Including grey literature allowed us to capture a wider array of perspectives and data, enriching our evidence base beyond what is available in peer-reviewed journals alone. This approach is particularly valuable in emerging fields like shared micromobility, where the formal literature may not yet fully represent ongoing developments and practices.

3. Review Result of SLR (Result from WoS)

3.1. Publication and Citation Analysis

The WoS search yielded 108 papers in total. The identified articles received 1757 citations in total by March 2023. The most cited article received 144 citations, while 20 publications had received no citations at the time of this study. Figure 3 shows a year-by-year breakdown of the number of publications and citations. It shows that significantly more publications investigating the integration of shared micromobility into public transit emerged starting from 2020. The growth in citations increased drastically accordingly.

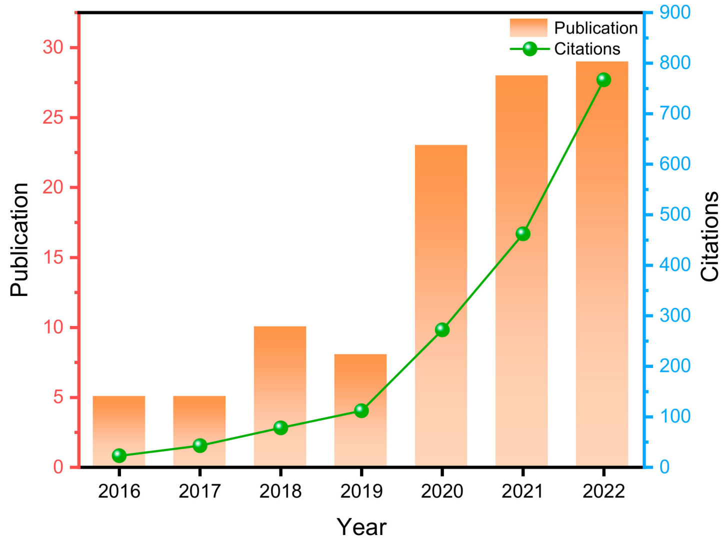

Figure 3. Publications and citations by year.

- Citation Analysis by Countries

It shows, from the authors' information, that the search uncovered research from 20 countries and 229 institutions. Figure 4 displays a thematic representation of the published articles by country that have received the most citations. The four top countries with the most published papers are USA (36.0%), China (35.1%), Italy (3.6%), and Canada (3.6%). In terms of authors' affiliations, the University of Texas System (4.5%), Tongji University (3.6%), the Massachusetts Institute of Technology (MIT) (2.7%), and the University of California System (2.7%) were the organizations attributed with the greatest numbers of published articles. The top three counties with the highest number of citations were China (720), the USA (695), and Slovenia (121).

- Citation Analysis by Journals

This study analyzed data from 35 journals aligning with the search themes. The citation analysis for these journals is shown in Table 1. The journal of *Transportation Research*

Part A: Policy and Practice covers transport-related findings in policy, planning, management, and evaluation. It had 18 relevant articles with 381 citations, which shows that the journal not only leads in the sheer volume of publications but also dominates the citation landscape. This journal is a bellwether in the field, with a high rate of scholarly output and a pivotal role in shaping academic and practical discourse. The *Transportation Research Record (TRR)*, known for publishing key papers on transport planning, administration, and economics, was also a popular choice, with 17 publications and 127 citations.

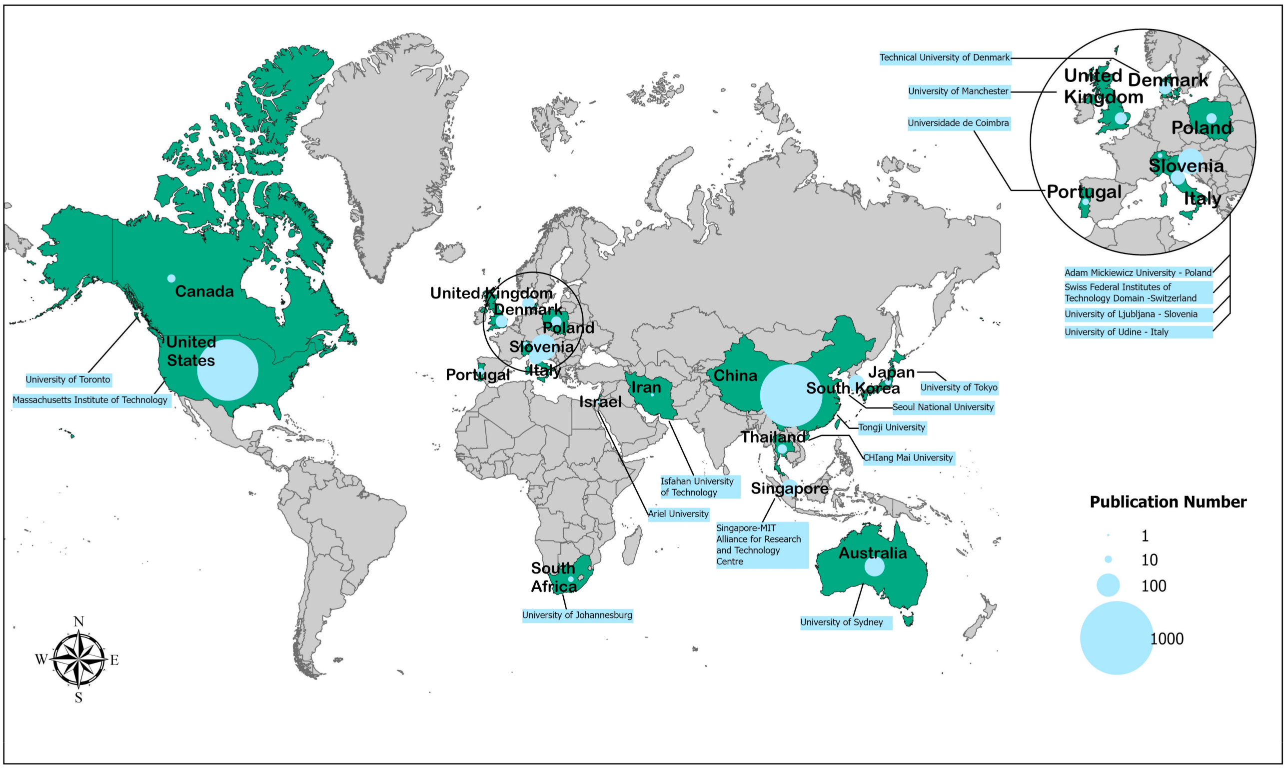

Figure 4. Publications by country and organization.

Table 1. Citation analysis by journals.

Ranking by the Number of Papers	No. of Papers (Percentage)	Ranking by the Number of Citations	No. of Citations (Percentage)
Transportation Research Part A: Policy and Practice	18 (30.5%)	*Transportation Research Part A: Policy and Practice*	381 (28.4%)
Transportation Research Record	17 (28.8%)	*Transportation Research Part C: Emerging Technologies*	223 (16.6%)
Sustainability	10 (16.9%)	*Sustainable Cities and Society*	204 (15.2%)
Transportation Research Part C: Emerging Technologies	8 (13.5%)	*Transportation Research Part D: Transport and Environment*	144 (10.7%)
Sustainable Cities and Society	6 (10.1%)	*Journal of Cleaner Production*	140 (10.4%)
Transportation	6 (10.1%)	*Transportation Research Record*	127 (9.4%)
Transportation Research Part D: Transport and Environment	4 (6.8%)	*Computer & Operation Research*	121 (9%)

On a more granular level, the disparity between the number of papers and the citation counts across journals could be indicative of the intrinsic value and relevance of the research published. For instance, *Transportation Research Part C: Emerging Technologies* commands a considerable citation count despite a moderate publication output, which may signify the burgeoning interest and applicability of emerging technologies in transportation, capturing the zeitgeist of contemporary research trends.

The presence of *Sustainability* and *Journal of Cleaner Production* among the highly cited journals underscores the growing nexus between transportation research and environmental sustainability, signaling a paradigmatic shift in scholarly focus towards more integrative and cross-disciplinary themes which resonate with global challenges and policy imperatives.

3.2. Keywords' Co-Occurrence

The software VOSviewer (1.6.20) generated a network of co-occurring keywords from 108 articles. Figure 5 shows the co-occurring relationship of 56 keywords out of a total of 422 that appeared at least twice in the reviewed articles. In the network, keywords are represented as nodes. The size of each keyword indicates its frequency or prominence in the dataset (likely publications, articles, or abstracts). The lines represent the strength of the co-occurrence links between keywords. For example, keywords like "transport", "demand", "transit", and "shared mobility" are central and have many connections, suggesting that these are core themes of the research analyzed. The colors indicate the time of occurrence or the period during which certain keywords were more prominent, with a gradient from 2019 to 2022. The overlay visualization analysis revealed a varying keywords' focus over the years, with terms like "bike sharing", "parking", and "sustainable transportation" being prominent from 2016 to 2019, followed by "public transport", "ride sourcing", and "accessibility" from 2019–2021. In 2022, "data", "micromobility", and "modal shift" were frequently occurring terms (Figure 5). The focus on "data" highlights the importance of evidence-based planning and the use of analytics to understand and optimize transportation systems. "Micromobility" reflects an increasing interest in flexible, low-carbon modes of transport such as bikes and scooters, which can fill gaps in traditional public transit systems and provide first/last-mile solutions. The term "modal shift" signifies the aim to encourage people to switch from private car use to more sustainable modes of transportation, thereby reducing congestion and emissions and enhancing urban livability. The presence of keywords like "big data", "algorithm", and "optimization" alongside "urban planning" and "public transport" indicates an interdisciplinary approach to studying transport systems, incorporating data science and technology into urban planning and policy analysis.

3.3. Co-Citation

Co-citation is a measure of how often two documents are cited together by other documents. If there is at least one document that cites both of them, we say that the two documents are co-cited. This relationship is used to construct a network where each node represents a document, and each edge represents a co-citation relationship. Co-citation analysis meticulously evaluates this network to ascertain the degree of association between papers. By examining the frequency of citations of two papers within the same primary publication, co-citation analysis determines the degree of association between them. A pivotal outcome of co-citation analysis is the emergence of clusters within the co-citation network. These clusters are formed based on the co-citation strength between documents, with papers which exhibit a high frequency of co-citation naturally grouping together. The co-citation analysis identified five distinct clusters (Figure 6), each comprising groups of articles which exhibit strong internal linkages yet maintain weaker associations with articles in other clusters [20]. In order to create significant clusters and allocate them to specific themes, this endeavor necessitates the establishment of a threshold whereby each paper under consideration must have been cited a minimum of three times. While publications within each cluster encompass several themes, the primary theme of each cluster was determined by selecting the most frequently recurring theme.

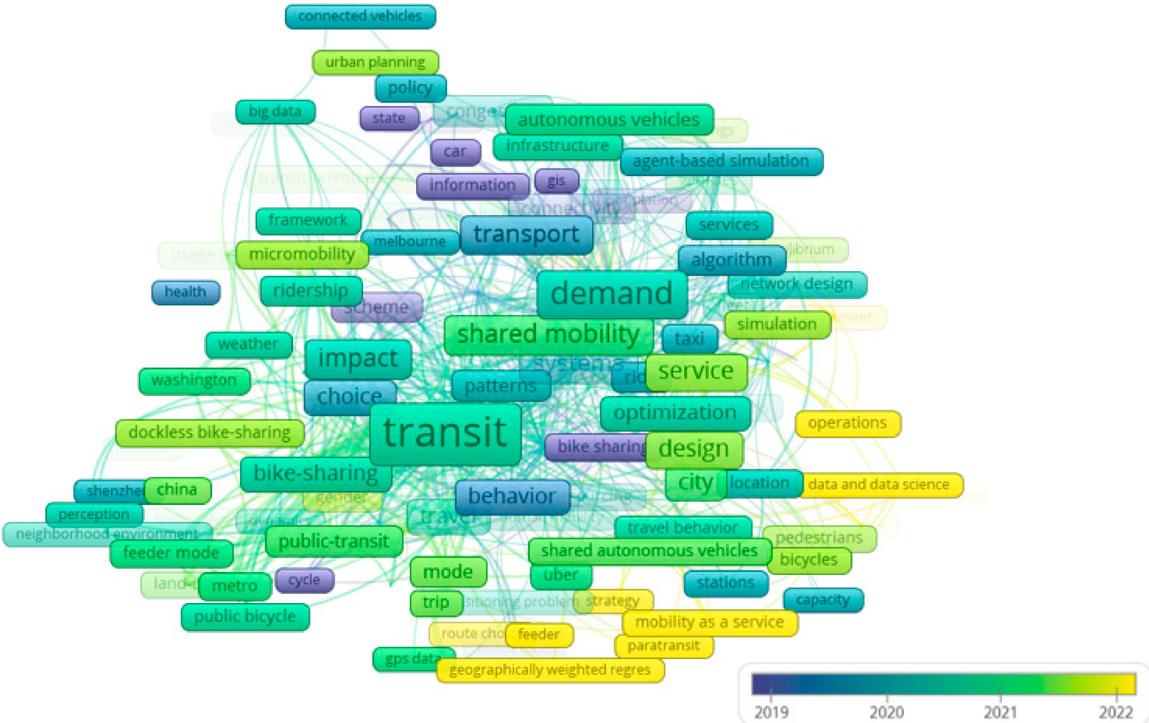

Figure 5. Overlay visualization analysis for keywords.

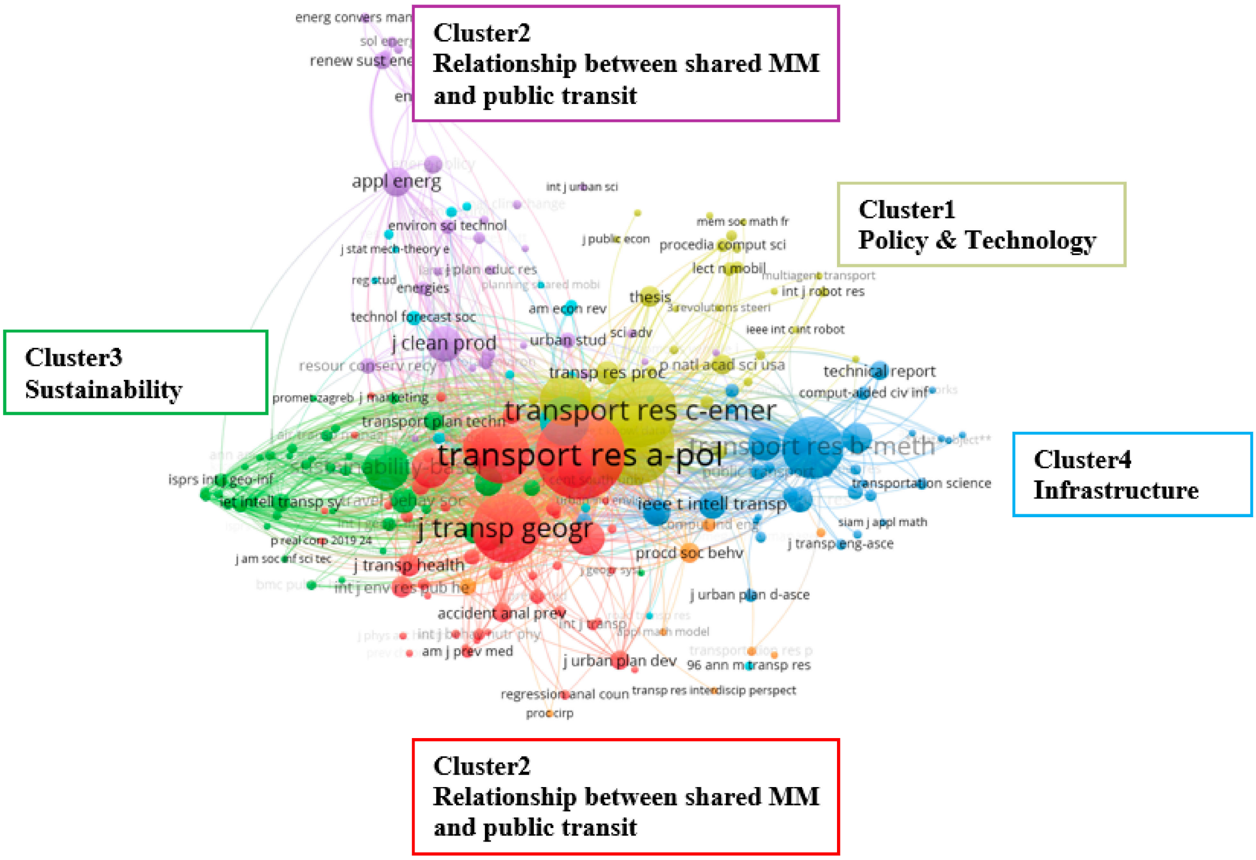

Figure 6. Network visualization of co-citation analysis.

Cluster 1, comprising 22 papers, centers around the theme of "policy& technology". Key topics identified within this cluster include "policy", "equity", "barriers", and "planning". In Cluster 2, which consists of 48 papers, the primary focus lies on the "Relationship between shared micromobility and public transit", exploring keywords such as "substitute", "implement", and "connecting". Notably, the colors red and purple in Figure 6 represent a subset of Cluster 2, exploring the concept of "Shared micromobility as a feeder mode to and from public transit", with 16 papers. Cluster 3 encompasses the theme of "Sustainability", with the majority of publications addressing "benefit", "emission", "pollution", and "physical health". Lastly, Cluster 4 delves into the "infrastructure" theme, comprising eight papers which emphasize "mode" and "site". The analysis of co-citations and examining the frequency and emergence of specific keywords within the literature over different time periods have proven to be invaluable in addressing RQ3. Next, representative references in each of the clusters are discussed below.

- Cluster 1: Policy and Technology

Municipalities worldwide consider micromobility as an innovative mobility solution for future economic growth and are embracing shared micromobility and leveraging emerging technologies by formulating policies to seamlessly integrate bike-share and cycling into their urban transit systems. In addition to numerous thriving markets in other continents, Cairo lunched bike-share in October 2022, signaling a growing momentum for cycling in Africa as well [26].

In the pursuit of enhancing urban livability, the integration of technology for sharing micromobility and the strategic use of data-sharing in transportation have become instrumental in driving new solutions. With this framework, companies are embarking on two distinct trajectories: the first one involves the large-scale deployment of shared vehicle fleets to provide on-demand transport, catering to immediate mobility needs; the second trajectory focuses on leveraging public transit data to enhance the level of service and efficiency of public transportation systems, aiming to optimize routes, reduce wait times, and improve overall accessibility [27].

To optimize the integration of dockless bicycle-sharing services into the metro system and make them a more effective mode of transportation, Yu et al. [28] proposed policy zoning with diverse management strategies for optimal land usage in Shanghai's metro stations. They classified the stations into four district clusters with different features: effective land utilization, potential for promoting shared micromobility services, deficiencies in shared micromobility services, and potential to improve land utilization efficiency. Based on demand patterns and operational performance, specific policy recommendations are offered to enhance the multimodal transportation system. For stations with deficiencies in shared micromobility services, the above study suggests considering microcirculation bus transit or customized bus modes. For stations with the potential to improve land utilization efficiency, the authors recommended implementing additional bicycle fleets and promoting bicycle parking areas' utilization efficiency. These policies aimed to create a seamless and efficient multimodal transportation network and enhance urban livability.

The Institute for Transportation and Development Policy (ITDP) report titled "The Electric Assist: Leveraging E-bikes and E-scooters for More Livable Cities" [29] equips communities with essential tools to ensure the effective implementation of these policies, such as securing fair and affordable access to shared services and providing secure and accessible spaces for users of shared and personal e-bikes and e-scooters. ITDP recommends cities to focus on expanding access to and oversight of electric micromobility by legalizing and classifying e-bikes and e-scooters as non-motor vehicles, standardizing speed limits while utilizing cycling infrastructure, providing safe cycling and parking facilities, implementing the proper management and regulation of shared electric micromobility systems, and utilizing surveys and shared operator data to monitor usage and ridership trends.

- Cluster 2: Relationship between Shared Micromobility and Public Transit

The second cluster of references explores the relationship between shared micromobility and public transit, revealing three types of relationships: substitution, complimentary, and independence, shows in Table 2. Studies have shown that shared micromobility leads to a decrease in bus and subway ridership, with users opting for shared micromobility instead [30]. Numerous studies have been conducted to understand how and when shared bikes are utilized in conjunction with public transportation. Some of these studies indicate that shared bikes serve as one of several feeder modes to public transit [31,32]. At locations with transit services but at a low network density, using shared bikes for accessing and egressing public transit is more prevalent. It also reveals a medium distance of around 1km when shared bikes are predominantly used to connect to rail transit. Similarly, Martin and Shaheen [33] evaluated survey data from two U.S. cities (Washington DC and Minneapolis) and discovered that, in less dense area, bike-sharing established new connections to existing public transit systems. Additionally, bike-share stations near crowded subway stations witnessed increased usage. These findings highlight the potential of shared micromobility services to complement public transit systems, providing convenient first- and last-mile connectivity and bridging transportation gaps in various urban settings. Tourists demonstrate different needs and patterns from residents. Radzimski & Dzięcielski [34] found that, for leisure trips, shared micromobility is often used independently of public transit. In such instances, individuals rent shared micromobility irrespective of the availability of public transit services, as they prioritize the flexibility and freedom of controlling their own schedule by renting the micro vehicles.

Table 2. Relationship between shared micromobility and public transit system.

City	Population (Million) in the Year of the Surveys	Data Source	Year	Main Conclusions (Relationship)
Montreal [33] Toronto [33] Twin Cities [33] Washington DC [33]	3.93 5.62 2.71 0.63	Online mode shift survey	2012	Substitutive: a significant portion of respondents reporting a reduction in rail use in favor of micromobility
Washington DC [35] Minneapolis [35]	0.66 2.71	Survey: modal shift of respondents in response to	2014	Substitutive: in denser urban areas Complementary: in less dense areas
New York City [36]	8.43	City bike trip data subway ridership	2014	Complementary: bike-sharing stations near subway stations enhancing the overall use of both services by facilitating easier access to public transit
Netherlands [37]	16.94	One-day trip diary survey	2015	Complementary: a significant portion of train passengers integrate bicycle use into their travel
Ningbo, Hangzhou, China [38,39]	5.16	Public transport system data and shared bicycle stations' data	2016	Substitutive: bike-sharing directly reduces the need for multiple transfers and travel times
Washington DC [30]	0.63	Daily route-level bus ridership data	2017	Substitutive for the 48% of respondents, reducing rail use Complementary for 40% of respondents, increasing their use of public transit in conjunction with bike-sharing

Table 2. *Cont.*

City	Population (Million) in the Year of the Surveys	Data Source	Year	Main Conclusions (Relationship)
United States [40]	326.8	2017 National Household Travel Survey	2018	Complementary: increased usage of public transit positively influences both the likelihood and frequency of bike-sharing usage
London [40]	8.98	London Cycle Hire (LOCH) docking stations' data (36 weeks)	2019	Substitutive: a 5.93% reduction in a metric due to bike-sharing
Nashville, Tennessee [41]	0.68	Transit data from WeGo Public Transit Shared e-scooter from Bird	2020	Substitutive: a 0.94% decrease in bus ridership due to shared e-scooters Complementary: shared e-scooters promote a 0.86% increase in bus ridership on weekdays
Cologne, Germany [42]	1.12	Free-floating bike-sharing system (BBS) data	2021	Complementary: bike-sharing more effectively enhances or integrates light rail transit systems
Seoul [43]	9.97	Public transport smartcard data	2022	Substitutive: bike-sharing becomes a more competitive choice than buses for certain conditions
Ohio, USA [44]	11.55	General Transit Feed Specification (GTFS)	2022	Complementary: micromobility, particularly in its role in first-mile connections, significantly enhances transit access

- Cluster 3: Sustainability

Acknowledging the critical importance of sustainable and eco-friendly transportation alternatives, numerous cities globally have embraced bike-sharing programs as a pivotal component of their public transit systems, aiming to reduce their carbon footprint and enhance urban mobility. For instance, the evaluation of the BCycle bike-sharing initiative in Boulder, Colorado, conducted by Zhou et al. [45], not only delineates usage patterns among diverse membership demographics but also highlights significant supply and demand challenges at various stations, underlining the program's role in promoting sustainable urban travel.

Further advancing the dialogue on sustainable transportation, the concept of transit-oriented development (TOD) offers a strategic framework for integrating active transportation modes into urban planning. Liu et al. [46] examined the impact of a dockless bike-sharing service from a temporally heterogeneous perspective. Their research emphasized the importance of public management and service in influencing dockless bike-sharing usage during off-peak hours. Such insights are invaluable for urban planners and policy-makers aiming to leverage these services in support of broader sustainable development goals, demonstrating a direct link between innovative transportation solutions and the enhancement of urban sustainability

- Cluster 4: Infrastructure

A well-connected network of bike lanes and sidewalks can make bicycling or walking viable modes of travel. The provision of dedicated infrastructure is considered a crucial policy to increase cycling [47]. Bikeways are the most common type of bicycle infrastructure, with many varieties, including conventional bicycle lanes, painted buffer lanes, contraflow cycling lanes, cycle tracks, off-street bike path, etc. [48]. However, infrastructure has not kept up with user demand so many cyclists have been forced to ride in the main lanes with mixed traffic. Dedicated bike routes connecting the stations of buses or subways with communities in their proximity could encourage travelers to commute by micromobility and public transit. It would promote a modal shift by taking the advantage of integrated shared micromobility and public transit without requiring massive capital investment of a more completed dedicated bicycle lane network.

With the emergence of coronavirus, cycling has become the favored form of transportation in many countries [49]. In response to the COVID-19 pandemic, governments temporarily reallocated street space to promote cycling through various incentives. Kraus and Koch [47] evaluated the valid pull effect of new cycling infrastructure. Their study shows that cycling increased from 11% to 48% on average after 11.5 km of provisional pop-up bike lanes were built, which would generate $1 and $7 billion in health benefits per year if these cycling habits were to stick.

4. Integration Implementation in Practice: Insights from a Grey Literature Review

As of now, only a limited but growing number of published materials discuss the optimal integration of shared micromobility into public transit. These materials, not included in the WoS database, fall under the category of grey literature. In this section, we present the results of our grey literature review.

Numerous studies have highlighted the equitable benefits of integrating shared micromobility into public transit networks. The American Public Transportation Association identified several benefits of such integration, including increased transit ridership, improved transit coverage, enhanced mobility opportunities for low-income riders, and a reduction in the number of car trips. Transport Canada [50] emphasizes the need to effectively connect active mobility options to public transit networks through safe and convenient infrastructure like dedicated bike lanes, sidewalks, and bike parking at transit stops. Despite the availability of various transportation modes, seamless multimodal services are not always accessible in many cities. To address this, municipalities have implemented measures such as enhancing bike paths to transit stations, expanding bike parking, allowing bikes on transit vehicles, and establishing shared-use agreements for secure bike parking options [51].

An ITDP report titled “Maximizing micromobility: Unlocking Opportunities to Integrate micromobility and Public Transportation” [52] investigated how cities implemented multimodal integration and what lessons were learned from their experiences. Integrating different transportation modes offers benefits like improved reliability, lower expenses, and increased adaptability, leading to greater usage and better access. The report provides five essential tips for optimizing micromobility: lead integration with private operators; use it to address transportation gaps; prioritize accessibility; improve physical infrastructure; and leverage travel demand insights.

4.1. Physical Integration

Physical integration involves placing infrastructures for various transportation modes in close proximity to facilitate easy transfer between them, making multimodal trips more competitive with driving. The examples include shared micromobility parking at public transit hubs, protected micromobility lanes connecting to transit hubs, and amenities like bicycle lockers, covered parking, and e-bike charging at public transit hubs. Larger multimodal mobility hubs offer greater benefits but require higher investments and capacity [53].

Transit agencies and governments around the world are working together to enhance multimodal transportation options, including collaborations for wayfinding signage at transit hubs, bike parking at bus rapid transit (BRT) stations, and the increasing popularity of dockless e-scooters near transit hubs. In Barcelona, the city’s bike-sharing program, Biking, has over 420 stations spreading throughout the city, including many located near metro stations [54].

Boulder County in Colorado launched a new program called the Final Mile Initiative [55], which aims to increase the number of people using bicycles by introducing innovative measures. The CO-119 First and Final Mile Study proposes phased recommendations for secure and comfortable multimodal connections to transit stops and a more straightforward bikeway, considering station areas, land use, trip types, transit users, and the street network.

4.2. Payment and Fare Integration

Payment integration enables seamless multimodal travel, and fare integration makes trips more economical and appealing. Table 3 compares cities in the U.S., Canada, Finland, and China with varying levels of transit and shared micromobility payment integration. Bundled mobility programs like Portland's Transportation Wallet combine public transportation, micromobility, and ride-hailing services to reduce parking congestion and encourage non-vehicle travel through bundled fees.

Table 3. Public transit programs and partnerships in various cities.

Location	Population (Million)	Transit Agency(s)	Program Operator(s)	TNC Partner	Integrated Payment
Seattle [56]	0.72	King County Metro	JUMP bikes, Lime, Wheels, Link	Lime, Wheels, Link	No
Los Angeles [57]	3.97	LA County Metropolitan Transportation Authority	Metro Bikeshare	Bicycle Transit System	TAP card
Bay Area [58,59]	7.75	Metropolitan Transportation Commission	Bay Wheels	Lyft	Clipper card
Chicago [60]	2.7	Chicago Transit Authority TriMet	Divvy	Lyft	No
Portland [61]	0.64	TriMet	BIKETOWN	Lyft	For users in designated areas
Pittsburgh [62]	0.32	Pittsburgh Port Authority	Healthy Ride	Nextbike	Connected Card
Helsinki [63]	0.63	Helsinki Regional Transport Authority	Whim	MaaS global	Whim app
Montreal [64]	1.78	Societe de transport' de Montreal	Bixi	None	Opus Card
Toronto [65]	2.93	Toronto Transit Commission	Bike Share Toronto	Shift Transit	No
Guangzhou [66]	15.31	Guangzhou Metro Corporation	Guangzhou Municipal Government	None	Yang Cheng Tong
Pinellas [67]	0.96	Pinellas Suncoast Transit Authority (PSTA)	PSTA U-PASS		Flamingo Fares card

4.3. Informational Integration

Informational integration plays a pivotal role in enhancing the usability of multimodal transportation systems by providing clear, concise information to passengers who plan trips that may involve various transport modes. It is designed to boost confidence among users, making the process of switching between modes like buses, trains, and bikes smoother and less daunting [68]. Key to this approach is wayfinding signage that offers directions and updates, mobile trip-planning applications that aggregate real-time data for route optimization, and multimodal maps in transit stations that illustrate network connections and interchange points.

The value of informational integration lies in its ability to simplify the complexity associated with using multiple forms of transport, thereby encouraging a shift towards more sustainable and efficient travel options. Accessible and detailed travel information directly contributes to a more user-friendly and resilient transportation system, where passengers can make informed decisions with ease. Ultimately, informational integration fosters a more connected, sustainable, and convenient urban mobility landscape.

4.4. Institutional Integration

Institutional integration improves collaboration among agencies, governments, and external partners for more efficient multimodal transportation. Examples include an integrated shared micromobility system in the Greater Toronto Area (GTA), involving multiple municipalities [56], and Seattle's multimodal management, where the city's public transportation authority works in tandem to create a seamless system. Bay Wheels, operated by Lyft, also partners with various public transit providers in the San Francisco Bay Area, offering convenient commuting options [69].

5. Assessment and Effectiveness of Integration

By seamlessly connecting various modes of transportation, cities can encourage sustainable and eco-friendly alternatives for commuters, contributing to a greener and more efficient urban mobility landscape.

According to the literature, the effective integration of shared micromobility and public transit, guaranteeing a rapid and cost-effective alternative for some trips, can help boost urban resilience, improve air quality, reduce greenhouse gas emissions, and make cities more habitable [32,49,70]. Jin et al. [71] performed an online survey and received 10,661 responses from the Netherlands [37], Germany [42], and the UK [40]. They analyzed the responses together with shared bicycle ridership data. The result show that integrating micromobility with public transit helps people access destinations in less time and at a lower cost than when these modes are disconnected. In another study [38], the authors applied a multi-layer coupling spatial network model that considers the geographical information and a series of Bayesian regression models of trip generation. Another study found that shared micromobility reduced the number of transfers and the travel time of passengers' trips effectively [39]. Shared micromobility helps improve the operation efficiency of public transit systems [40]. A preliminary cost-effectiveness assessment was conducted considering both cost and cyclists' preferences for each integration strategy, from which bicycle parking at a transit stop proved to be the most cost-effective strategy. Cui et al. [72] pointed out that the implementation of a shared micromobility system benefit socioeconomically disadvantaged populations by providing greater transportation equity. The research analyzed a year's worth of data, encompassing 17 million trips taken on Citi Bike in New York City [36]. To ensure that transportation services are accessible and reliable for everyone, cities should prioritize teamwork between public and private operators [43]. In addition, it is important to extend the focus beyond just micromobility modes and integrate them with public transportation to encourage more people to use them, increase access to different locations, and decrease dependence on personal vehicles [73]. In addition, depending on infrastructure, capacity, and resources, some forms of integration may be easier to implement than others, providing small and midsize cities with unique opportunities to improve their transportation systems [74]. The American Public Transportation Association [75] suggests that cities that want to improve mobility for all their residents may follow the rules below:

- Cities must take the first step toward integration by ensuring that operators—both public and private—collaborate with the public sector to provide reliable, convenient, and affordable transportation services for all their residents.
- Cities will need to shift their focus from the operational regulation of micromobility control to its integration into public transportation. Regulation alone has not been sufficient to encourage the widespread use of micromobility modes nor has it enabled operating structures that are particularly beneficial to cities, operators, and users.

- Integration is not the ultimate goal. Integration, on the other hand, is a method of increasing access to destinations and services without relying on a private vehicle.

As cities explore ways of permanently keeping interim infrastructures built in response to the COVID-19 pandemic, an opportunity to supplement physical infrastructure with informational or payment integration is presented.

6. Conclusions

This systemic literature review aims to understand the status of the integration of shared micromobility into public transit, its observed benefits, its various formats of integration, experiences, and the lessons learned. This study conducted a literature search and then performed a comprehensive analysis of 108 journal papers from WoS and published documents belonging to the grey literature. These publications were categorized into four main research themes: policy, sustainability, infrastructure, and the relationship between shared micromobility and public transit. The findings from this study show that integrating shared micromobility into public transit can effectively address first- and last-mile issues, complement fixed-route transit networks, and provide faster and more affordable travel options for most trips. The outcomes also highlight the spatial–temporal conditions and the impact of population density on the integration process, potential contributions to urban resilience, improved air quality, reduced greenhouse gas emissions, and enhanced livability in communities. In-depth case studies of cities in the reviewed publications examined user behavior and satisfaction with the integrated transportation system at hand, studied the long-term environmental impacts of integration, and evaluated different integration strategies.

Before diving into the systemic literature review, we listed five research questions, RQ1–RQ5. Below are the answers to the research questions based on the findings of this review effort:

The scientific literature primarily focuses on enhancing first- and last-mile connectivity through micromobility, assessing its effects on public transit usage, the role of policies and regulations, and the application of technology to ensure smooth user experiences. It has progressively emphasized data analytics, modal shifts, and the fusion of micromobility with urban and transport planning.

The most influential contributions come from the United States, China, Slovenia, and Denmark, reflecting their leadership in micromobility adoption and research. The journals "*Transportation Research Part A*" and "*Transportation Research Record*" are notable for their extensive publications in this field.

Research has matured from theoretical explorations to empirical and data-centric investigations. Studies have shifted towards practical implementations, technological developments, user behavior analysis, and the examination of policy implications, indicating a deepening and broadening of the discourse.

Cities have adopted various strategies to enhance micromobility and public transit integration, including setting up bike-share stations at transit nodes, establishing dedicated bike paths, unifying payment systems, and developing comprehensive apps for multimodal travel planning and real-time information, aiming to streamline micromobility use with public transportation.

Evaluating the success of integration efforts can be achieved by analyzing user satisfaction, ridership statistics, and environmental benefits. The metrics of interest include an increased use of public and micromobility transport, a decreased reliance on private vehicles, enhanced access and connectivity for transit, and positive public perception regarding the ease and reliability of using integrated transport modes.

This paper acknowledges some limitations, including its publication cut-off set to March 2023 and its potential overlook of challenges like safety and equity. Future research will aim to offer a more rounded view of the impacts of integrating shared micromobility into public transit.

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