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Exploring Trends and Future Research Directions in the Adoption of Electric Micromobility Vehicles

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Abstract

Our study conducts bibliometric and co-occurrence network analysis to explore key trends in the field of electric micromobility research. The paper is focuses on examining how academic attention has shifted across research domains, identifying changes in thematic keywords, assessing the evolution of multidisciplinary studies, and pinpointing influential authors in micromobility. Using the Scopus database, we analyzed 1,471 articles (as of March 2024), revealing that while engineering initially dominated this field, since the 2020s, both social sciences and medicine have emerged as critical areas of study for electric micromobility vehicles (EmV). Our analysis of key terms shows that "electric scooters" has consistently been central across different periods, underscoring a sustained focus on micromobility's core themes. Additionally, we observed a marked increase in interdisciplinary research after 2015, particularly at the intersection of engineering, social sciences, and environmental science, highlighting a collective effort to address complex urban mobility issues. This article also identifies Cherry Christopher as the most frequently cited author in micromobility, reinforcing the foundational role of earlier research in guiding contemporary academic discussions. By uncovering these trends, the analysis points out the increasing relevance of social science perspectives as a promising future research direction in the context of EmVs - encompassing topics such as user behavior, public acceptance, regulatory frameworks, social equity, and gender-based approaches. These aspects complement the traditionally engineering-driven approaches. While the growing thematic diversity suggests a shift toward more nuanced and multifaceted investigations, the precise role and impact of interdisciplinarity in this field remain subject to further exploration.

Keywords

electric micromobility, e-scooter, e-bike, bibliometric analysis, co-occurrence network analysis

1 Introduction

Urban environments in Europe have been designed traditionally with a focus on automobile usage, shaping road networks and shared spaces primarily for drivers (Zöldy, 2024). However, the reliance on automobiles has led to negative consequences, including greenhouse gas emissions, air pollution, noise pollution, and chronic traffic congestion. These issues complicate daily commutes and adversely affect public health, prompting residents to reconsider their travel habits (Janikian et al., 2024; Liao and Correia, 2022; Zhong and Sun, 2022).

Recognizing these problems, the European Commission prioritizes the development of innovative, smart, and sustainable mobility solutions. The overarching goal is to transform urban mobility, encouraging designs that promote accessibility, livability, and vibrant public life (Corti et al., 2024). As urban mobility patterns continue to evolve, the literature increasingly examines emerging low carbon emission transport modes, such as e-scooters and e-bikes, which represent potential alternatives to private cars (Nagy and Csiszár, 2022).

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By employing a comprehensive bibliometric approach – complemented by co-occurrence and co-authorship network analyses – this study maps the intellectual structure and evolution of e-scooter research. It reveals main thematic domains, shifts in scholarly focus, and patterns of academic collaboration. The findings highlight the growing importance of interdisciplinary engagement and the integration of diverse perspectives as essential drivers of innovation in addressing contemporary urban mobility challenges and informing evidence-based planning and policy development.

Our research is timely and relevant for two main reasons: first, there has not been a comprehensive study specifically focused on electric micromobility vehicles before, and second, these methods are particularly suited to synthesizing the existing literature on the topic and highlighting research gaps or underexplored areas.

Our study is structured as follows: The second section introduces a short a literature review on the examined area. The third section details the data collection method and methodology. The fourth section presents our results, the fifth section discusses our findings, while the last section provides interpretations of the results, conclusions, limitations of the research, and directions for future research.

2 Literature review

Evolution and adoption of micromobility vehicles has emerged as a transformative trend in urban transportation, primarily focusing on small, lightweight vehicles such as e-scooters, e-bikes, and other personal mobility vehicles (PMVs) that are designed for short-distance travel at speeds below 30 km/h. The global market for micromobility is expected to grow significantly, potentially reaching $195.42 billion by 2030, reflecting its increasing popularity and utility in addressing issues such as road congestion and pollution (Boglietti et al., 2021).

Shared micromobility services have also shown rapid growth, with companies like Lime and Bird expanding their reach globally, helping millions of users adopt these new forms of urban transport. In Europe and the US, e-bikes, and e-scooters are especially popular, with usage patterns showing that younger and middle-aged people are the most frequent users (Christoforou et al., 2021; Jaber and Hamadneh, 2024; Liao and Correia, 2022).

The growing interest in electric micromobility vehicles (EmVs) is driven by a combination of engineering and social factors. These include usability-oriented design elements (such as ease of use, environmental impact, and functionality; see Khateeb et al., 2004; Vetturi et al., 2023), as well as user-related social aspects (Jaber and Hamadneh, 2024).

The academic landscape surrounding micromobility is expanding, with significant attention on fields such as engineering (Khateeb et al., 2004; Vetturi et al., 2023), computer science, environmental science, and social sciences. However, a conducted literature search reveals a surprising lack of comprehensive studies dedicated to the electric micromobility market, despite its prominence as a tool for sustainable urban transport.

- Abduljabbar et al. (2021) visualized the evolving landscape of micromobility, focusing on its implications for sustainable urban transport.
- Sengul and Mostofi (2021) utilized the PRISMA method to compare global literature on the future role of micromobility in urban settings. However, neither study conducted a gap analysis specifically addressing e-scooters or e-bikes, which represents a missed opportunity given their increasing prevalence in urban transport networks.
- Yuniaristanto et al. (2023) investigated electric motorcycle adoption, a close but distinct category from e-bike and e-scooters. The study is largely centered on consumer behavior towards electric motorcycles in Southeast Asia, offering valuable insights into factors driving electric vehicle (EV) adoption, but it doesn't adequately cover e-scooters. This distinction is crucial, as e-scooters typically target short-distance urban travel, while electric motorcycles serve broader commuting needs.
- Zhou et al. (2023) provided a bibliometric overview of electric bicycle research from 1976 to the present. This study offers a comprehensive analysis of trends, identifying key authors, institutions, and topics within the field of electric bicycles, but fails to address e-scooters. Given the overlaps between the two markets in terms of shared use and electric propulsion, an integrated study could enhance understanding across both sectors.
- Maryani et al. (2024), in contrast, focused on a bibliometric analysis of behavior and motorcycle accidents, shedding light on safety issues, but again bypassing the unique characteristics of e-scooters. This study's focus on accidents does offer some transferable insights into micromobility safety concerns, a topic of growing importance as cities grapples with how to integrate e-scooters into existing transport networks.

- Liao and Correia (2022a) also conducted a comprehensive review of shared e-mobility modes, including electric car sharing, e-bike sharing, and e-scooter sharing. Their study offers a thorough examination of usage patterns, demand estimation, and potential impacts on transportation systems. However, it does not specifically delve into the bibliometric or co-authorship aspects of e-scooter or e-bike research.

Despite the increasing academic interest in electric micromobility, significant gaps remain - particularly in terms of bibliometric and co-occurrence network analyses that could provide a structured overview of the field. These analytical approaches are especially valuable in this context, as they enable the systematic mapping of academic research, helping to identify key trends, influential contributors, thematic clusters, and underexplored areas (Molontay and Nagy, 2021).

2.1 Research questions

The literature review of electric micromobility vehicles and related technologies reveals a rapidly growing field with significant variations in data collection and processing methods. To better understand these trends and the broader structure of existing research, we have formulated three primary research questions to guide our investigation on electric micromobility vehicles:

1. In which research areas has academic attention been the greatest between 1994 and 2023? What kind of trends can be identified?
2. What are the predominant keywords characterizing research themes in each period? Do they indicate a discernible shift in scholarly focus across different timeframes?
3. Who are the most frequently cited authors related to electric micromobility?

3 Materials & methods

To address the research questions outlined above, we employed a combination of bibliometric analysis, keyword co-occurrence network analysis, and co-authorship network analysis.

While bibliometric analysis enables the quantitative assessment of publication outputs, author impact, and disciplinary distribution, co-occurrence network analysis reveals conceptual linkages and the emergence of dominant research themes. In parallel, co-authorship network analysis helps identify collaboration patterns, institutional clusters, and the extent of interdisciplinary cooperation within the field. Together, these approaches offer a robust, data-driven framework for capturing both the intellectual and social structures of the academic discourse surrounding electric micromobility technologies.

As the outcomes of bibliometric and network-based analyses are highly sensitive to the choice of data sources and temporal coverage, we relied on the Scopus database, which offers broad, multidisciplinary access to peer-reviewed academic literature. We investigated literature published between 1994 and 2023, limiting our scope to English-language documents, as commonly applied in similar bibliometric research.

The electric micromobility dataset was refined by filtering with specific keywords: electric scooter, e-scooter, electric micromobility, e-bike:
(KEY ("electric scooter" OR "e-scooter" OR "electric micromobility" OR "e-bike") AND PUBYEAR<2024).

The data was retrieved on March 5, 2024, and in total, 1,471 raw data records were downloaded. The data was processed using in the workflow and codes of Molontay and Nagy (2021). After the data preprocessing, the resulting data table had 1,412 rows and 26 columns.

Firstly, we study the research areas that are assigned to the papers according to Scopus. More than half of the papers were categorized under multiple research areas, reflecting the interdisciplinary nature of electric mobility research.

In this paper, in addition to the co-authorship network, we also examine the co-occurrence networks of research areas and keywords. In the research area network, each node represents a distinct field, and two nodes are connected if both fields are assigned to at least one publication (Wei and Zhang, 2020). In the keyword co-occurrence network each node represents a keyword, and two nodes are linked if the corresponding keywords appear together in at least one publication (Wei and Zhang, 2020). Regarding the keyword analyses, the letters of all keywords were converted to lowercase and have also been lemmatized, i.e., plural versions have been converted to singular to avoid duplicates and redundancy.

4 Results

4.1 The focused research areas

By answering the first research question, we aimed to identify the primary fields that dominate e-scooter research and track how interest in these areas has evolved. In total, 25 different research areas were identified. However, more than half of the papers had more than 1 research area. As shown in Fig. 1, Engineering is the most prominent research domain, providing the foundational knowledge

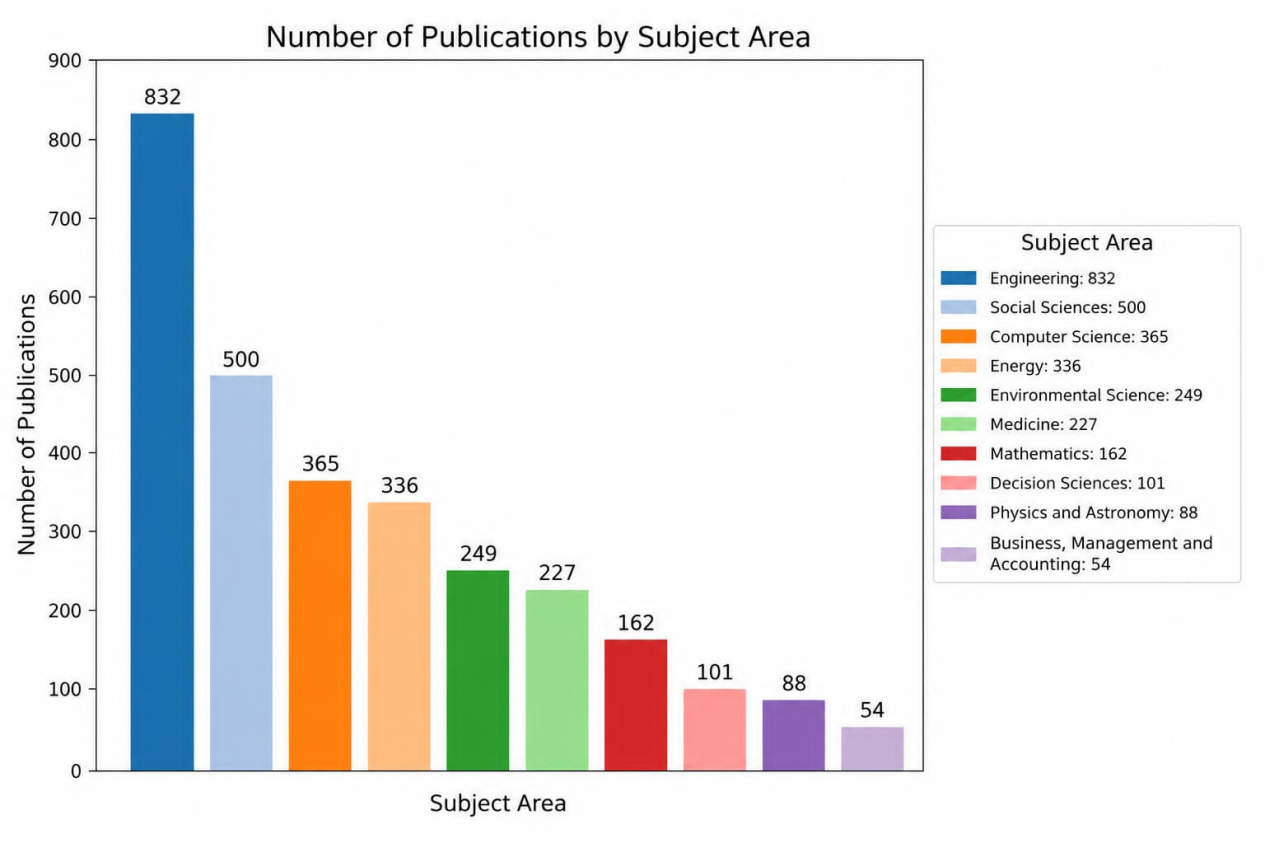

Fig. 1 Research areas
Source: Own editing

and innovative solutions needed to address the technical challenges associated with electric mobility vehicles.

To see the evolution of the research fields, we examined the number of publications by research areas over the years. Fig. 2 illustrates that significant growth is observed across various fields, particularly after 2010. Engineering, along with Mathematics, Physics, Astronomy, and Computer Science, show substantial and consistent increases in publications. Emerging areas such as Medicine, Social Sciences, Engineering combined with Environmental Science and Social Sciences also display notable growth. The period post-2015 marks a sharp rise in research output across most areas, indicating heightened research activity and interdisciplinary focus in recent years. To further explore the extent and evolution of this interdisciplinarity, we examine the proportion of publications classified as multidisciplinary over time.

A paper is called a multidisciplinary paper if there is more than one research area occurs in it. Fig. 3 shows the ratio of articles with multiple research areas over the years. Initially, there was a significant rise in the ratio pre-2000, indicating an increase in interdisciplinary research. Post-2010, the ratio has stabilized and gradually increased, reflecting a growing trend in interdisciplinary studies. Recent years have shown consistent interest in papers covering multiple research areas, despite some fluctuations. Overall, the data suggests an increasing trend toward interdisciplinary research, highlighting its growing importance in addressing complex problems.

By constructing the research area co-occurrence network, we can identify which research areas frequently appear together.

Table 1 presents the most frequently co-occurring research domain pairs, with Engineering and Mathematics being the most prevalent pair. Following that, Engineering also appears in the next 5 pairs. This indicates a strong interdisciplinary approach in the electric vehicle field, with a significant focus on integrating engineering principles with various other scientific domains. The pairing of Engineering with Environmental Science and Energy also suggests an emphasis on sustainable and eco-friendly technological advancements for the e-scooters.

4.2 The predominant keywords

By analyzing keyword trends, we seek to uncover shifts in research priorities and emerging topics in e-scooter studies.

The data are sourced from two aspects, the Author Keywords and Index Keywords. Author Keywords indicate the keywords given by the authors. Index Keywords indicate the keywords generated by Scopus algorithms. Like

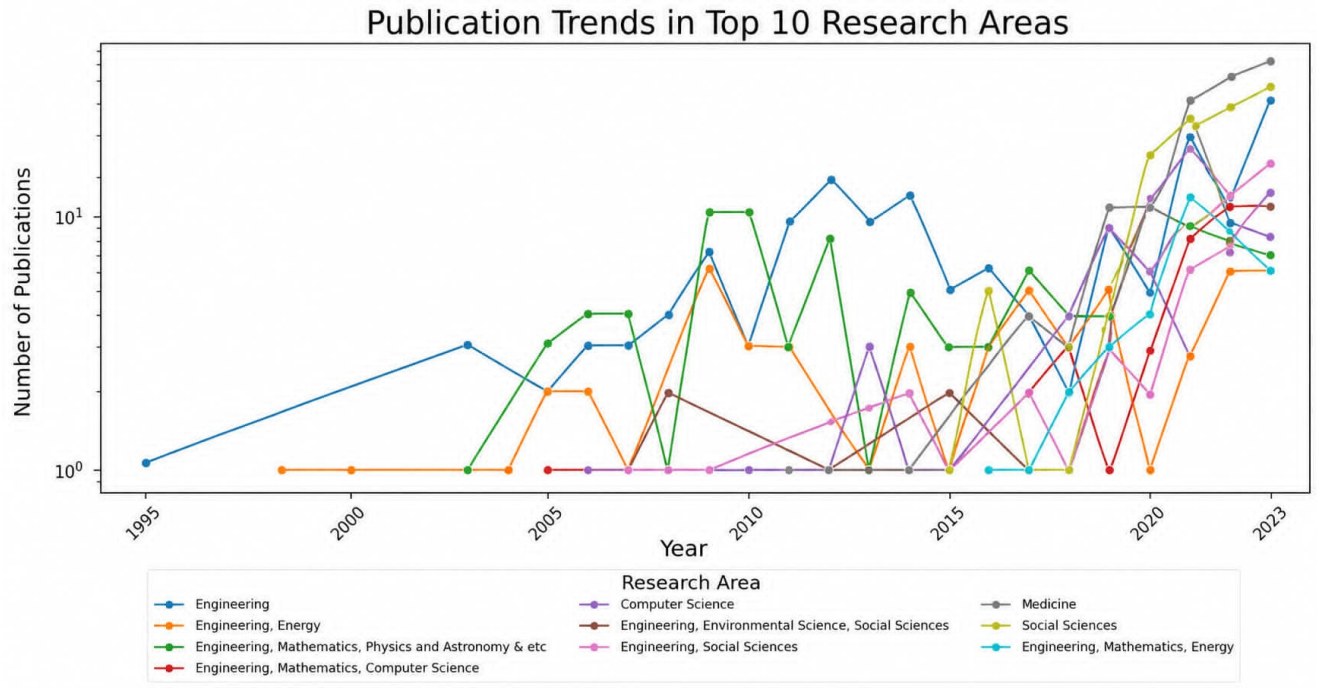

Fig. 2 Number of publications by research areas over the years
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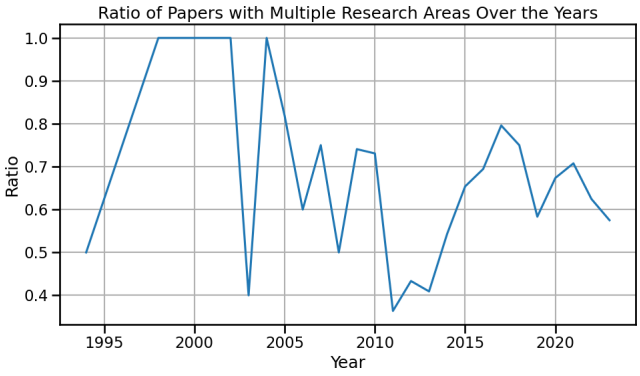

Fig. 3 Multidisciplinarity
Source: Own editing

Table 1 Co-occurrence of research areas

Research area 1	Research area 2	Count
Engineering	Mathematics	213
Engineering	Social Sciences	182
Engineering	Computer Science	172
Engineering	Energy	164
Engineering	Environmental Science	121
Engineering	Physics and Astronomy & etc.	114
Mathematics	Physics and Astronomy & etc.	105
Environmental Science	Social Sciences	104
Energy	Environmental Science	77
Mathematics	Computer Science	75

Source: Own editing

research areas, keywords provide a more detailed categorization. A total of 10,981 keywords were identified, of which the 10 most frequent ones are presented in Table 2. Alongside

Table 2 The most frequently appearing keywords

Keywords	Count
Electric scooters	524
Electric vehicles	267
E-bike	205
Human	197
Vehicles	194
Electric vehicle	179
E-scooter	176
Bicycles	172
Humans	160
Micro-mobility	158

Source: Own editing

relevant terms, broader context keywords such as "human", "vehicles", and "micro-mobility" are also prominent.

Figs. 4 and 5 show the word cloud of the keywords of the papers published before and after 2019. Nevertheless, the "electric scooter", "electric vehicle", "e-bike", and their versions, remain the most frequent keywords no matter what period it is. While before 2019 the keywords demonstrate mainly engineering aspects (synchronous motors, power electrics, fuel cells, permanent magnets, electric batteries, etc.), from 2019, more social science related factors are highlighted related to sustainability, accidents, city design, integration, consumers.

To study which topics are the most prominent, we constructed the keyword co-occurrence network. The keyword co-occurrence network has the following characteristics:

Fig. 4 Word cloud of the most frequent keywords of publications before 2019
Source: Own editing

Fig. 5 Word cloud of the most frequent keywords of publications since 2019
Source: Own editing

- Number of nodes: 9,847
- Number of edges: 226,194
- Number of connected components: 5
- Size of the largest component: 9,831

The most frequently appeared keyword pairs are shown in Table 3.

The keyword co-occurrence table reveals that terms like "human", "female", and "male" frequently appear together. This high frequency likely results from Scopus's indexing algorithms, which prioritize broad demographic terms to ensure comprehensive coverage. As a result, these general keywords dominate the co-occurrence network.

Table 3 Keyword co-occurrences

Keyword 1	Keyword 2	Count
electric vehicle	electric scooter	269
bike	e-bike	193
female	human	142
human	male	141
female	male	136
human	traffic accident	126
e-scooter	micro-mobility	124
adult	human	123

Source: Own editing

Fig. 6 shows the density map visualization of the keyword co-occurrence network created using VOSviewer. It showcases the relationships between various keywords in research related to e-bikes and electric scooters. The size of each keyword reflects its frequency of occurrence, with larger keywords appearing more frequently in the dataset. The proximity of keywords indicates how often they co-occur, suggesting common research themes. Notable keywords such as "e-bike", and "electric scooters" are central, indicating high relevance and frequent use in the literature. The color intensity represents the density of co-occurrences, with brighter areas signifying stronger associations between keywords. Related to these two focus areas, the sustainability (sustainable mobility, environmental awareness), engineering (motor, control, parameters, etc.), city design (charging standardization, impact) and attitudinal (consumer identity, attribute reduction) aspects are highlighted.

4.3 The most frequently cited authors

Table 4 presents the 10 most highly cited papers identified in the dataset, together with their authors.

Handling the authors individually, a ranking table (Table 5) was created to measure their quantitative impact on the examined area:

- Total number of citations
- Number of papers
- Number of citations per paper

Unlike Table 5, which only measured simple quantitative outputs, Table 6 provides a completely different perspective. We used H-index as a metric for measuring an

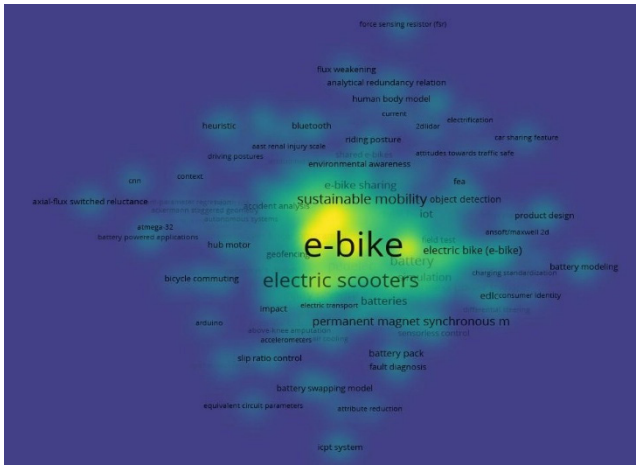

Fig. 6 Density map of the keyword co-occurrence network
Source: Own editing

Table 4 Most cited papers

Title	Authors	Number cited	References
Battery choice and management for new generation electric vehicles	Affanni, A., Bellini, A., Franceschini, G., Guglielmi, P., Tassoni, C.	385	Affanni et al., 2005
Thermal management of Li-ion battery with phase change material for electric scooters: Experimental validation	Khateeb, S. A., Amiruddin, S., Farid, M., Selman, J. R., Al-Hallaj, S.	344	Khateeb et al., 2005
Factors influencing the choice of shared bicycles and shared electric bikes in Beijing	Campbell, A. A., Cherry, C. R., Ryerson, M. S., Yang, X.	320	Campbell et al., 2016
Design and simulation of a lithium-ion battery with a phase change material thermal management system for an electric scooter	Khateeb, S. A., Farid, M. M., Selman, J. R., Al-Hallaj, S.	310	Khateeb et al., 2004
E-bikes in the Mainstream: Reviewing a Decade of Research	Fishman, E., Cherry, C.	305	Fishman and Cherry, 2016
Spatiotemporal comparative analysis of scooter-share and bike-share usage patterns in Washington, D.C.	McKenzie, G.	250	McKenzie, 2019
Are e-scooters polluters? The environmental impacts of shared dockless electric scooters	Hollingsworth, J., Copeland, B., Johnson, J. X.	214	Hollingsworth et al., 2019
Integrating e-scooters in urban transportation: Problems, policies, and the prospect of system change	Gössling, S.	210	Gössling, 2020
The red-light running behavior of electric bike riders and cyclists at urban intersections in China: An observational study	Wu, C., Yao, L., Zhang, K.	196	Wu et al., 2012
Emergency department visits for electric scooter-related injuries after introduction of an urban rental program	Badeau, A., Carman, C., Newman, M., Steenblik, J., Carlson, M., Madsen, T.	174	Badeau et al., 2019

Source: Own editing

Table 5 Quantitative metrics of authors

Author name	Total number cited	Number of papers	Cited per paper
Cherry, C.	1,345	15	89.67
Al-Hallaj, S.	682	3	227.33
Selman, J. R.	682	3	227.33
Farid, M. M.	682	3	227.33
Khateeb, S. A.	682	3	227.33
Guglielmi, P.	493	7	70.43
Weinert, J. X.	415	5	83
Affanni, A.	385	1	385
Bellini, A.	385	1	385
Franceschini, G.	385	1	385
Tassoni, C.	385	1	385

Source: Own editing

Table 6 Top Authors h-index

Author name	h_index
Cherry C. R.	12.0
Fyhri A.	12.0
Yang H.	9.0
Lin C. H.	8.0
Zhang X.	7.0

Source: Own editing

author's productivity and citation impact. It is noteworthy that, among the authors listed in Table 6, only Christopher Cherry also appears in the Table 5. The remaining authors differ, suggesting that the rankings are based on different criteria. Table 6 reveals that the most influential authors are Cherry Christopher and Fyhri Aslak.

5 Discussion

The results demonstrate that electric micromobility research has matured into a highly interdisciplinary field, driven by the interplay of engineering, Social Sciences, policy, and environmental considerations. Electric micromobility research has seen a substantial growth in academic attention, particularly since 2018. Engineering and Social Sciences dominate the landscape. Other disciplines, including Medicine, Mathematics, Energy, and Computer Science, have also contributed, often in collaboration with Engineering. The rise in interdisciplinary publications highlights a shift towards integrated approaches to address complex societal and technological challenges (Lee et al., 2004 ; Sun et al., 2021).

In terms of keywords, the analysis reveals a strong presence of various micromobility device-related terms (alongside the concept of micromobility), with the "human" keyword likely linked to Social Science and Medicine disciplines. Prior to 2019, results suggest a stronger emphasis on engineering, with occasional references to policy (see e.g., Olabi et al., 2023), whereas post-2019, there is a noticeable shift towards social science, policy,

and accident-related topics (see e.g., Gössling, 2020; Kazemzadeh and Sprei, 2022; Kumar et al., 2024; Nikiforiadis et al., 2021). These trends are further corroborated by the pairing patterns observed.

The co-occurrence analysis highlighted the prominence of e-bikes, which have been at the forefront for a longer period. Additionally, sustainability, urban planning, behavioral approaches, and engineering emerge as the most frequently paired themes, reflecting the evolving interdisciplinary nature of research in this domain. This shift underscores the increasing integration of technical, societal, and policy dimensions in addressing the challenges of micromobility and urban development.

From our perspective, the proportion of multidisciplinary articles has generally increased over time, especially after 2010. There was a significant increase before 2000, followed by fluctuations around 2000, and then a steady and gradual increase after 2010. This trend suggests that interdisciplinary research is becoming more prevalent.The relationship with co-authorship patterns is evident, as the increasing trend towards interdisciplinary research correlates with a high degree of co-authorship, with most articles involving multiple authors and spanning multiple research areas. This is further supported by the research field co-presence network, which shows that fields such as Engineering often appear alongside other fields like Environmental Science, Social Science, Computer Science and Mathematics, indicating a strong interdisciplinary approach (see e.g., Wen et al., 2025). (This does not mean that studies focusing on one area disappear, in fact, the number of research focusing only on Engineering, Medicine, Computer Science or Social Science shows an increase from 2015.)

The comparison between the most cited papers and the most cited authors, alongside the evaluation of the authors' quantitative metrics, reveals a striking convergence in results. Notably, Cherry Christopher emerges as a central figure, consistently highlighted across all dimensions of analysis, despite other researchers not achieving the highest h-index. Moreover, it is particularly intriguing that a previously unranked researcher (not part of the highest ranked researchers), has now risen to be considered one of the most influential figures, alongside Cherry Christopher. This unexpected development adds a new layer of complexity to the assessment of scholarly impact, indicating the need for further, deeper analyses.

6 Conclusion

Our findings reveal that academic research on electric micromobility vehicles (EmVs) has undergone a notable transformation over the past decade. While earlier studies – particularly prior to 2019 – were predominantly situated within engineering domains, focusing on technological components such as synchronous motors, power electronics, and battery systems, the landscape has gradually diversified. A marked shift occurred around 2020, concurrent with the emergence of shared e-scooters in urban mobility systems, prompting increasing academic interest from the Social Sciences and, to a lesser extent, the Medicine field. Since then, topics such as sustainability, accident prevention, consumer integration, and urban design have become more prominent. Although the trend toward interdisciplinarity has not followed a strictly linear trajectory, the growing proportion of publications addressing multiple research areas suggests a steady move toward more multifaceted and cross-disciplinary inquiry. Keyword co-occurrence analysis further supports this shift: while traditional engineering terms continue to dominate, more recent years have seen the emergence of socially oriented terms, including gender-related keywords – most notably the frequent co-appearance of "male" and "female" – indicating the increasing relevance of gender-based perspectives. Notably, Cherry Christopher has emerged as the most influential author in the field, consistently ranking highest across citation-based metrics.

The implications of our results underscore the necessity of adopting interdisciplinary frameworks in both academic and policy contexts. The absence of isolated disciplinary silos within the field reflects the interconnectedness of technological, societal, and environmental challenges associated with EmVs. Effective responses to these challenges – whether related to infrastructure development, urban integration, or sustainable usage – require coordinated insights from engineering, the social sciences, and public policy.

Researchers must recognize that disciplinary boundaries can limit the scope of innovation, and that collaborative, cross-sectoral efforts are essential to addressing the full complexity of micromobility systems. For policymakers and regulatory bodies, this perspective is equally critical: the success of regulatory frameworks hinges not only on technical feasibility, but also on social acceptability, behavioral patterns, and equitable access.

Gender-based approaches, for instance, have gained visibility in recent years, highlighting the importance of understanding differential usage patterns and safety perceptions among user groups.

From a practical and engineering standpoint, the results of this study emphasize that the design and deployment of electric micromobility technologies cannot be grounded solely in technical performance. Engineers must increasingly account for user diversity and behavioral dynamics, including gender-specific needs and experiences. The integration of social aspects into the design process – whether in terms of ergonomics, safety features, or accessibility – can contribute to more inclusive and adaptable solutions. Moreover, the study reinforces the value of collaboration across disciplinary lines: engaging with social scientists, urban planners, public health experts, and policymakers can lead to more resilient and sustainable innovations. In this sense, the research not only maps the intellectual contours of the electric micromobility research field, but also demonstrates the practical value of interdisciplinary approaches in addressing the evolving demands of urban mobility.

Nonetheless, it is important to acknowledge that the findings are shaped by the parameters of the study itself. The results reflect the selected data period (1994 – 2023), the reliance on Scopus as the primary data source, and the specific data-cleaning procedures applied, all of which may have influenced the trends and patterns identified. Furthermore, certain micromobility modes – such as Segway and hoverboard – were excluded from the analysis, as they did not appear prominently in the literature as core elements of the micromobility discourse. Future research could address these limitations by broadening the scope of data sources and re-evaluating excluded modes, thereby ensuring a more comprehensive understanding of the field's evolution and structure.

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