Trends and Challenges in Simulation Modeling for Electric Motorcycle Adoption: Insights from a Bibliometric Study

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Abstract. This paper presents a comprehensive bibliometric analysis of research on the adoption of electric motorcycles, with a particular focus on simulation and modeling approaches. Data were retrieved from the Scopus database for the period 2011–2025 using targeted keywords related to electric motorcycles, adoption, simulation, and modeling. The analysis was conducted using the Bibliometrix R package and VOSviewer, employing parameters such as publication year, document type, and keyword co-occurrence. The results reveal a significant upward trend in related publications, especially after 2019, with "electric vehicle" and "electric motorcycle" identified as dominant research themes. The findings highlight the growing academic interest in simulation modeling as a valuable tool to understand the complex factors influencing electric motorcycle adoption. This study provides insights into emerging research hotspots and suggests future directions for advancing sustainable transportation through simulation-based studies.

Keywords: Electric Motorcycle, Adoption, Bibliometric Analysis, Sustainable Transportation, Technology Acceptance.

1 Introduction

Motorcycles have become an essential mode of transportation for many households in Indonesia, particularly due to their advantages in synchronization, accessibility, and affordability. These vehicles offer flexibility in route selection and travel time planning, significantly enhancing mobility across both urban and rural areas. This flexibility is especially important for navigating the dense traffic conditions common in cities of all sizes throughout Indonesia. Additionally, motorcycles are well-suited for narrow roads frequently found in residential neighbourhoods. Their compact size and manoeuvrability make them more practical than larger vehicles when space is limited in urban environments.

Based on the latest available data from the Indonesian Central Statistics Agency [1], there were approximately 133 million registered motorized vehicles in 2023, with motorcycles accounting for a substantial portion [2]. For instance, as of 2018, the number of motorcycles amounted to approximately 112.8 million units [3], increasing

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to about 120 million units in 2019 [4]. This increasing trend thunders that motorcycles are still by and large the vehicle of choice in Indonesia, outpacing cars since a very long time ago.

High levels of greenhouse gases and air pollutants from motorized two- and three-wheelers which is especially worse than cars are partially responsible. Therefore, electrification of vehicles in particular, motorcycle is a potential solution for the air-pollution problem. But it is very difficult to promote the public to transform from the usage of traditional motorcycles to electric motorcycles, which is a typical complex social issue with multiple influencing factors. Understanding this aspect warrants further investigations using simulation modeling methods.

Simulation modeling plays a crucial role in analyzing and predicting the adoption of electric motorcycles [5]. By capturing the dynamic interactions among various stakeholders users, manufacturers, policymakers, and infrastructure providers simulation models allow researchers and decision-makers to test scenarios, evaluate interventions, and anticipate adoption trends. This approach is especially valuable for complex social systems where direct experimentation is impractical.

Given the increasing interest in electric motorcycle adoption and the recognized value of simulation modeling, it is essential to map the current research landscape. Bibliometric analysis provides a systematic method to identify publication trends, research hotspots, and collaboration networks in this field. This study aims to analyze the evolution of scientific publications on electric motorcycle adoption, highlight key research themes, and suggest directions for future studies, with a particular emphasis on simulation and modeling approaches.

Bibliometric analysis was selected as the primary methodology for this study due to several advantages over traditional systematic literature reviews (SLR). While SLR focuses on qualitative synthesis of content, bibliometric analysis provides quantitative insights into research patterns, collaboration networks, and emerging trends through statistical analysis of publication metadata [6]. This approach is particularly valuable for mapping the intellectual structure of a rapidly evolving field like electric motorcycle adoption, where understanding research evolution and identifying knowledge gaps requires systematic quantification of publication trends, citation patterns, and keyword co-occurrence networks [7]. Furthermore, bibliometric analysis enables the identification of research hotspots and future directions through objective, data-driven visualization techniques that complement traditional narrative reviews.

A bibliometric analysis should be carried out before conducting any more research on electric motorcycle adoption through simulation modelling. In this paper, we aim to explore and demonstrate some of the publications collected by the Scopus Database in the field of science and research. Especially, the study wants to observe the development of electric motorcycle research, highlight the significant trends found and recommend future directions for investigation.

2 Methodology

Experts use mathematical and statistical analysis, known as bibliometrics, to analyze only research articles, reviews and books from scientific publications [8]. They let

researchers discover how shares of publications in the research community work [9, 10]. For a systematic study, we used bibliometrics to focus on particular subjects using chosen studies with attention to authors, citations, keywords and countries [11, 12]. Thanks to bibliometric indicators, we offer background information and an in-depth analysis of the themes under discussion here. This method uses the same ideas found in works by [10, 13].

2.1 Study Design

The study design phase includes defining the research objectives as well as topics you want to study and identifying correct bibliometric methods to answer them. This stage is important for the analysis scope and objectives you must set in beginning of the study. Researchers will also need to know how long they are analyzing, and whether or not the trend is captured via time slices. The study design adds definition and clarity to every step in the entire bibliometric process.

Building upon the previous explanation, the research questions are formulated as follows:

1. RQ1: How have scientific publications on the adoption of electric motorcycles evolved over time?
2. RQ2: What insights can be derived from the observed research trends?
3. RQ3: What are the potential directions for future studies in this field?

2.2 Data Collection

Data Collection is a multistep process that starts with fetching data from bibliographic databases, to convert this data to a format that is readable and useful, cleaned for accuracy. Bibliometric data sources are typically Scopus. Next, as well as creating the data dump we will process the raw data by cleaning to remove duplicates and standardizing metadata as appropriate.

This study adopts a bibliometric approach to systematically review research on the adoption of electric motorcycles, particularly focusing on simulation and modeling methods. The bibliometric analysis was conducted using the Bibliometrix R package and VOSviewer, which are widely recognized for their effectiveness in quantitative literature analysis and visualization.

Before collecting data from Scopus, the first step that needs to be taken is to understand the research area to be studied. After that, appropriate search parameters must be determined, using Boolean rules to facilitate data filtering. Next, the time period or research period should be set as a reference for the data collection process. In addition, selecting the right analytical tools is also essential to ensure the data can be processed optimally. Finally, a thorough examination of the information is conducted, as presented in Table 1, to ensure that the data obtained is relevant to the research needs.

Table 1. Data collection workflow.

Step 1	Defining the area of research	Simulation and modeling to adoption electric motorcycle
Step 2	Database Selection	Scopus
Step 3	Search parameter for field	(TITLE-ABS-KEY ("electric motorcycle" OR "electric scooter" OR "electric bike" OR "electric motorbike" OR "battery-powered motorcycle" OR "electric two-wheeler" OR "zero-emission motorcycle" OR "eco-friendly motorcycle" OR "electric two-wheeled vehicle") AND TITLE-ABS-KEY ("adoption" OR "intention" OR "willingness to" OR "diffusion") AND TITLE-ABS-KEY ("simulation" OR "modeling")) AND PUBYEAR > 2010 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final"))
Step 4	Time period	2011 - 2025
Step 5	Tools for analysis	Bibliometrix R package, VoSviewer
Step 6	Examination of information	Report, Analysis, and discussion of results

– Keyword Selection Justification

The search strategy was developed through an iterative process combining: (1) preliminary literature review to identify core terminology, (2) consultation with domain experts, and (3) pilot searches to optimize recall and precision. Keywords were grouped into three categories: vehicle types ('electric motorcycle', 'electric scooter'), adoption concepts ('adoption', 'intention', 'willingness'), and methodological approaches ('simulation', 'modeling').

– Exclusion Criteria

The following exclusion criteria were applied: (1) documents not published in English, (2) non-final publication stages (e.g., articles in press), (3) documents without abstracts or keywords, (4) duplicate records, and (5) studies focusing solely on e-bikes without motorcycle context to maintain focus on two-wheeled motorized vehicles.

– Deduplication Process

Duplicate removal was conducted using Scopus's built-in deduplication algorithm, followed by manual verification of titles and DOIs. Records with identical titles, authors, and publication years were flagged for review.

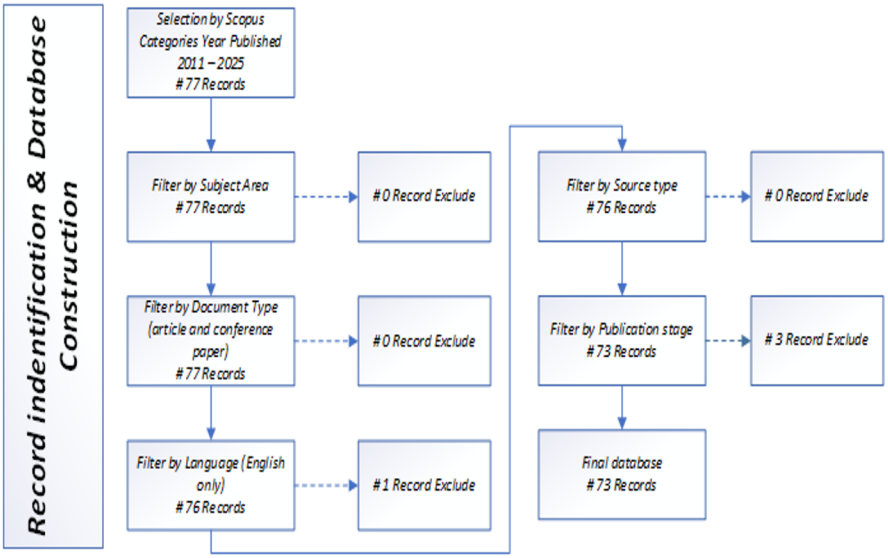

Fig. 1. Data collection workflow.

The data collection workflow from table 1 for this study focuses on the simulation and modeling of electric motorcycle adoption. The Scopus database was selected as the primary source, with search parameters targeting keywords such as "electric motorcycle," "adoption," "intention," "simulation," and "modeling," while restricting the publication years to 2011–2025, the language to English, and the publication stage to "final." Data analysis tools, including the Bibliometrix R package and VOSviewer, were employed to process and visualize the findings. The final step involves reporting, analyzing, and discussing the results to provide comprehensive insights into the research area. Fig. 1. explains the process of record identification and database construction for research using data from Scopus. The process begins with selecting data based on Scopus categories for the publication years 2011–2025, resulting in 77 records. The data is then filtered through several stages, namely by subject area (with no records excluded), document type (articles and conference papers, with no records excluded), language (English only, excluding one record), source type (with no records excluded), and publication stage (excluding three records). After completing all filtering stages, the final database consists of 73 records.

2.3 Data Analysis

Data analysis is related to descriptive statistics and network sourcing to find out the established patterns and relationships in the available data. Intellectual Structure, Research Fronts and Social Networks: methods of extracting the individual keyword from text via co-citation, bibliographic coupling or co-word analysis. Parsing big data into valuable insights may require cutting-edge statistical tools and picking appropriate algorithms.

The next step is to import the exported results, which are in CSV format into the R Studio tool using the bibliometrix (biblioshiny) plugin and VOSViewerThe R Studio with the bibliometrix (biblioshiny) plugin has been proved to be an advantageous software infrastructure for the Systematic Literature Reviews (SLR) driven by the bibliometric study.

The Bibliometrix is an extended computational framework for performing quantitative research in bibliometrics, through which users can analyze and visualize scientific literature efficiently, that was constructed by Ssimo Aria and Vincenzo Cuccurullo [14, 15]. This Biblioshiny combined with R Studio, enables users to run sophisticated analysis without much programming experience, thus making it the tool of choice for various other researchers [16, 17].

The interface of the Biblioshiny applications enable to upload bibliographic data to generate multiple display formats such as networks of scientific collaborations, maps of concepts and citation networks [18]. With this tool, researchers can see how the authors, institutions and keywords relate and it supports the quick detection of changes and gaps in research [19]. As Biblioshiny is userfriendly and R provides analysis, users can easily study how publications develop, for example by looking at their annual increase and the citation pattern.

VOSviewer for visualizing bibliometric networks is added as an extension of biblioshiny. VOSviewer is very effective at displaying the relationships existing among authors, keywords and journals in the literature [20]. Users of Biblioshiny and VOSviewer can perform a complete systematic review, check data with statistics and show complex trends in an easy-to-understand way [14].

Carrying out systematic literature reviews with bibliometric analysis can be done easily using R Studio together with the bibliometrix (biblioshiny) package. As a result, findings are more accurate and the study as a whole can be better understood through useful charts and graphs [15, 21]. The following table, Table 2., presents the findings from the bibliometric analysis (based on the main information database).

Table 2. The main information database.

Description	Result
MAIN INFORMATION ABOUT DATA	
Timespan	2011:2025
Sources (Journals, Books, etc)	55
Documents	73
Annual Growth Rate %	19.42
Document Average Age	2.83
Average citations per doc	16.5
References	3864
DOCUMENT CONTENTS	
Keywords Plus (ID)	562
Author's Keywords (DE)	248

Description	Result
AUTHORS	
Authors	206
Authors of single-authored docs	2
AUTHORS COLLABORATION	
Single-authored docs	2
Co-Authors per Doc	3.38
International co-authorships %	20.83
DOCUMENT TYPES	
article	53
Book chapter	1
Conference paper	15
Conference review	4

2.4 Data Visualization

Results are mapped through different mapping strategies (concept maps, dendrograms and network) to obtain data-driven insights. Visualization enables humans to grasp complex relationships, and patterns in an easily digestible form. There may also be the use of temporal and even spatial visualizations to depict changes in which research topics evolve over time, or specific themes emerge and die out geographically.

2.5 Interpretation

The final step is to read the visualizations and analytical results, to infer conclusions regarding the research field. Researchers need to situate the results in an expansive unity of scientific landscape and discern principal patterns, hotspot topics or impacting authors/institutions. Objectiveness of bibliometric methods notwithstanding, one cannot ignore the interpretation viewpoint that should be enriched with relevant expertise in the specific field.

3 Result

3.1 Data Visualization Result

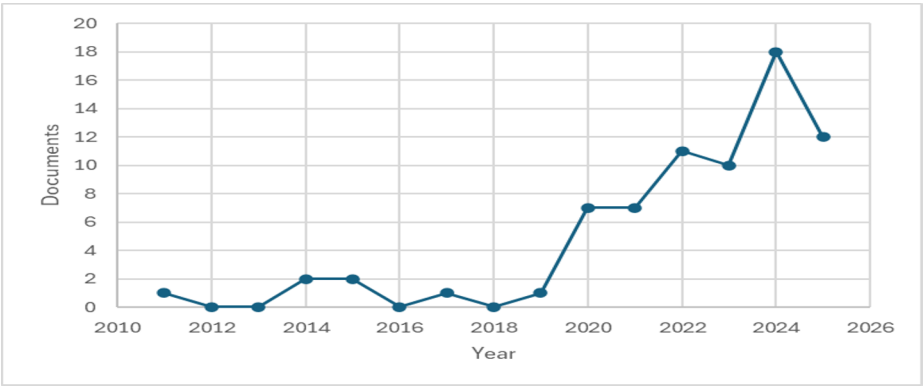

Fig. 2. Documents by year.

The trend in the Fig.2. shows a gradual increase in the number of publications related to "Simulation and modeling to adoption of electric motorcycles" over time, with distinct phases. From 2010 to 2018, publication activity was minimal, indicating limited research interest during this period. Starting from 2019, the trend shifted upward, reflecting a growing focus on this topic. The number of publications increased steadily, reaching a significant peak in 2024 with the highest number of publications (18), marking the height of research activity. Overall, the trend highlights an emerging interest that intensified over the years.

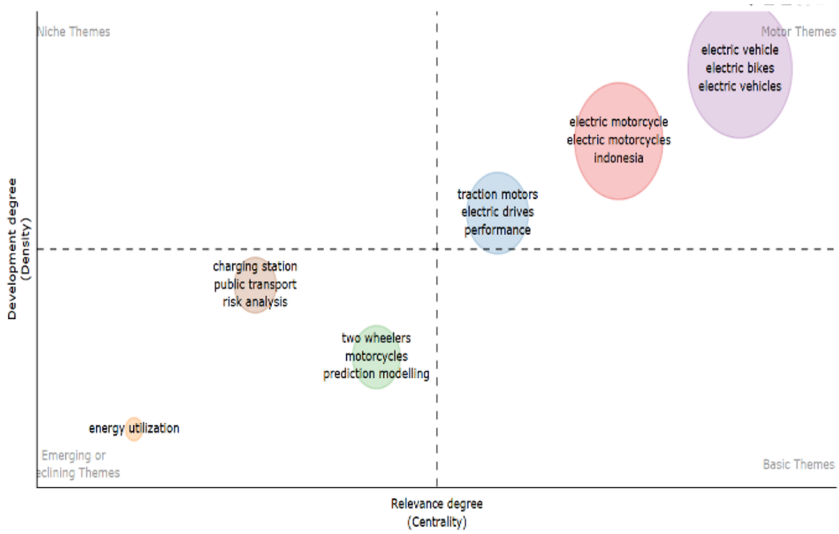

Fig. 3. Thematic map.

Fig.3. is a thematic map that depicts the relationship between relevance degree (centrality) and development degree (density) of various research themes related to the adoption of electric motorcycles. The horizontal axis (centrality) indicates the relevance or importance of the theme within the overall context of the research, while the vertical axis (density) shows the level of development or depth of research on the theme. The themes are divided into four quadrants: Motor Themes (themes that are relevant and well-developed), Basic Themes (themes that are relevant but less developed), Niche Themes (themes that are developing but less relevant), and Emerging or Declining Themes (themes that are less relevant and less developed). To sum, research with themes 'electric vehicle' and 'electric motorcycles' are in the Motor Themes quadrant, which considering this theme is most salient and unfolding fastest, while research with themes 'energy utilization' are in the Emerging or Declining Themes quadrant, suggesting this theme is less salient and less unfolding.

Themes "electric vehicle" and "electric motorcycles" are in the Motor Themes quadrant, meaning that these themes have a high relevance level and coverage of the research. As for center of the word, category like ”energy utilization” are on the Emerging or Declining category quadrant, indicating that these category are less relevant and less developed. On the other hand, topics such as "two wheelers" or "prediction modelling" can be found in the Basic Themes quadrant, informing that they remain highly relevant, but not fully developed. Niche Themes “Charging station” and “risk analysis” were in the Niche Themes quadrant and thus they developed in certain studies but less relevant more generally.

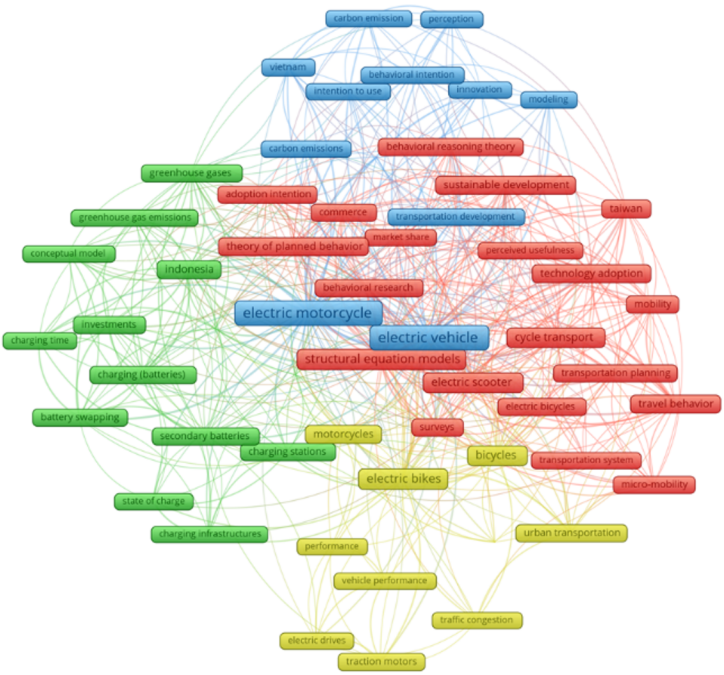

Fig. 4. Keywords network map (network visualization).

Fig. 4. Keywords co-occurrence network visualization showing four main research clusters: (Red) Behavioral factors and technology adoption, (Blue) Theoretical approaches to electric vehicle user behavior, (Green) Technological innovation and infrastructure, (Yellow) Urban micro-mobility transformation. Node size represents keyword frequency, link thickness indicates co-occurrence strength.

The bibliometric network visualization representation illustrates that the research theme associated with electric vehicles is dominated by technical, behavioral and environmental ones, especially considering the aspects "electric vehicle" and "electric motorcycle". Concepts such as "change of the battery," "adoption of the technology," And "theory of planned behavior" are linked with one another, and the antecedents have the symmetrical relation between technological innovation and user's behavior. Additionally, environmental issues like "carbon emissions" and "sustainable development," as well as geographical contexts such as "Indonesia," "Vietnam," and "Taiwan," emphasize the regional relevance of this research. Overall, this research highlights the importance of electric vehicles in supporting sustainable transportation.

3.2 Interpretation Result

The analysis of the Co-Occurrence Network of Keywords uncovers patterns and trends by examining frequently used terms in the field [22]. Table 3 offers a detailed breakdown of keywords and the clusters formed through this analysis. The software, by default, organizes elements according to their normalized association strength. It's important to note that clusters in VOSviewer are exclusive, meaning each element belongs to only one cluster. However, not all elements may be included in a cluster, leaving some ungrouped. The clusters identified earlier, depicted in Fig. 4, are color-coded to match the clusters in the first column. This cluster analysis reveals four distinct research themes, ranked by the total link strength of the top three keywords in the dataset.

Table 3. Key research topic.

Cluster	Keywords	Total link strength	Co-occurrences	Topic
1 (Red)	Structural Equation models	97	16	Behavioural Factors and Technology Adoption of Electric Vehicles
	Technology adoption	53	7	
	Sustainable development	51	7	
2 (Blue)	Electric vehicle	167	29	Theoretical Approaches to Electric Vehicle User Behaviour
	Electric motorcycle	131	33	
	Transportation development	21	3	
3 (Green)	Indonesia	49	7	Technological Innovation and Infrastructure for Electric Vehicles
	Greenhouse gases	36	4	
	Secondary batteries	36	5	

Cluster	Keywords	Total link strength	Co-occurrences	Topic
4 (Yellow)	Electric bikes	80	15	Transforming Urban Transportation through Micro-Mobility
	bicycles	59	9	
	motorcycles	29	7	

Explanation of Table 3. Regarding key research topics is as follows:

- Red Cluster, Research in this cluster focuses on behavioral factors and the adoption of electric vehicle technology. "Structural Equation Models" are used to analyze the relationships between variables, such as technology adoption and sustainable development. This highlights the importance of understanding user behavior in supporting the transition to electric vehicles.
- Blue Cluster highlights key topics related to electric vehicles and electric motorcycles. The research emphasizes the importance of theoretical approaches, including user behavior and transportation development. The dominance of keywords like "electric vehicle" and "electric motorcycle" reflects a focus on electric vehicle innovation as a future transportation solution.
- Green Cluster emphasizes technological innovation and reducing environmental impact. Research related to "Indonesia," "greenhouse gases," and "secondary batteries" highlights the importance of developing infrastructure and technology to support electric vehicles, particularly in the context of reducing greenhouse gas emissions.
- Yellow Cluster, This cluster focuses on micro-mobility, such as electric bikes, regular bicycles, and motorcycles. The research highlights the crucial role of these small vehicles in supporting sustainable urban transportation, especially in urban environments with high mobility demands.

4 Discussion

The upward trend in publications reflects increased academic and practical attention to electric motorcycle adoption as a response to environmental challenges and urban mobility needs. The dominance of simulation and modeling approaches, particularly agent-based modeling, demonstrates their value in capturing the complex interplay of behavioral, technological, and policy factors.

Simulation modeling enables researchers to test various policy interventions such as subsidies, infrastructure development, and public awareness campaigns within a virtual environment before real-world implementation.

While this bibliometric analysis encompasses global literature on electric motorcycle adoption, Indonesia emerges as a prominent geographical focus within the research landscape. This reflects the country's significant motorcycle market and growing interest in electric vehicle transition. However, the analysis also reveals international research contributions from countries such as Vietnam, Taiwan, and other developing

nations with similar transportation patterns, indicating the global relevance of electric motorcycle adoption research.

The thematic analysis also suggests that while core topics such as technology adoption and user behavior are well-established, areas like energy utilization and risk analysis remain underexplored. Future research can address these gaps by integrating more comprehensive simulation scenarios and interdisciplinary perspectives.

5 Conclusion

The main objective of this study is to address three key questions: RQ1, RQ2, and RQ3. First, this research aims to analyze the development of scientific publications related to the adoption of electric motorcycles over time. Second, it seeks to identify the observed research trends. Third, it aims to provide insights into potential directions for future research in this field. It was concluded from the analysis that research on the simulation and modeling of electric motorcycle acceptance based on data obtained from the Scopus database is gaining a growth trend for the number of publications per year. This is also sign that they are seeking for environmental hygiene by choosing electric motorcycles that emit low carbon, according to the environment friendly.

This study provides a systematic bibliometric analysis of research on the adoption of electric motorcycles, emphasizing simulation and modeling methodologies. The results indicate a significant increase in scholarly attention to this topic, particularly since 2019. Major research themes include technology adoption, behavioral factors, and infrastructural innovation, with Indonesia identified as a key geographical focus.

Simulation modeling has emerged as a critical tool for understanding and accelerating the adoption of electric motorcycles. It allows for the exploration of complex social, technological, and policy dynamics that influence user decisions. Future research should further investigate emerging topics such as energy utilization and risk analysis, and expand the use of advanced simulation techniques like agent-based modeling to support evidence-based policy and sustainable transportation planning.

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