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Exploring the Evolution of Electric Vehicle Charging Infrastructure: A Bibliometric Perspective on Public Electric Vehicle Charging Station Location Planning

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Abstract

The rapid expansion of electric vehicles (EVs) is a crucial factor in achieving low-carbon mobility and promoting sustainable regional development. The attainment of this objective depends on technological advancement, institutional readiness, spatial equity, and governance capabilities. The establishment of Stasiun Pengisian Kendaraan Listrik Umum (SPKLU) in Indonesia must be understood within a framework that connects infrastructure planning to social, economic, and political factors. This research analyzes the evolution of international scientific dialogue regarding EV charging infrastructure through a bibliometric lens, focusing on publications from 2010 to 2025. This study utilizes Scopus data and analytical tools, including VOSviewer and Publish or Perish, to identify leading authors, key journals, and emerging subject trends. The results suggest that future SPKLU planning in Indonesia requires an integrated framework that aligns technological precision with public governance principles. This approach should account for decentralization dynamics, regional disparities, and institutional capacity, ensuring that improvements to EV infrastructure contribute to carbon-reduction goals while fostering equitable and sustainable regional development.

Keywords: Bibliometric Analysis, Decentralization, Electric Vehicle, Spatial Equity, Sustainable Regional Development.

1. INTRODUCTION

The transportation industry is vital to economic development and accounts for a substantial share of global CO_2 emissions. In response to environmental issues, the pursuit of greener mobility alternatives has intensified [1]. Electric vehicles (EVs) are widely recognized for their ability to reduce greenhouse gas emissions, enhance energy security, and promote sustainable urban development [2]. Furthermore, the implementation of electric cars (EVs) might reduce emissions by up to 24.8% if traditional vehicles are replaced with battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) [3]. Shenzhen, China, oversees the largest electric bus and electric taxi fleets worldwide, demonstrating the substantial impact of strong regulatory backing [4].

The success of electric vehicle adoption is significantly contingent upon the presence of a reliable and accessible charging infrastructure [5]. The strategic positioning of public charging stations, such as Stasiun Pengisian Kendaraan Listrik Umum (SPKLU) or Public Electric Vehicle Charging Station (PEVCS) in Indonesia, is crucial for ensuring dependability, convenience, and effective energy management [6]. The World Economic Forum underscores the necessity for public charging stations to incorporate features such as contactless, open-loop payment systems to improve user convenience [7]. Moreover, there is an initiative to establish fast-charging stations at regular intervals, specifically every 60 kilometers along highways, to accommodate the increasing demand for electric vehicles [8].

Prior research has investigated multiple facets of electric vehicle (EV) charging infrastructure. Prakobkaew et al. (2024) and (2019) analyzed optimization models for station placement utilizing geographic information systems (GIS), whereas Almaghrebi et al. examined the impact of consumer behavior on charging demand. Despite their value, these studies frequently examine technological, spatial, or policy aspects in isolation, without a holistic and integrative framework. Notwithstanding the increasing attention, the literature regarding EV charging infrastructure remains disjointed. Most studies concentrate on discrete elements, such as technical design or user behavior, without offering a cohesive framework for strategic location planning. Furthermore, systematic mapping of the domain by bibliometric methods remains limited.

The lack of such an analysis impedes understanding of the global intellectual framework, thematic trends, and significant contributors in this domain. The literature predominantly features research from industrialized economies, whereas the unique challenges and opportunities in emerging markets such as Indonesia remain relatively underexamined.

This study conducts a bibliometric analysis of EV charging infrastructure research, focusing on the strategic planning of SPKLU locations. This study aims to address the subsequent research inquiries.

1. Who are the preeminent authors, journals, and institutions in the discipline?
2. What are the prevailing themes and research clusters in the planning of EV charging infrastructure locations?
3. In what manner have research patterns developed over time?

This study seeks to offer a thorough overview of scientific advancements in SPKLU location planning by identifying global research trends. The results are anticipated to influence future research trajectories and direct infrastructure development initiatives, particularly in emerging economies such as Indonesia. Moreover, as governments globally establish aggressive electric car adoption objectives, exemplified by the European Union's aim to deploy at least 30 million zero-emission vehicles by 2030, the significance of robust charging infrastructure development will grow.

2. LITERATURE REVIEW

2.1. Global Overview of Electric Vehicle Infrastructure Research

The swift advancement of electric vehicle infrastructure research is propelled by worldwide pledges to decarbonization and the shift towards sustainable urban mobility. The transportation industry continues to be a significant source of greenhouse gas (GHG) emissions, accounting for approximately 28% of total U.S. emissions in 2022. Consequently, the electrification of automobiles has emerged as a vital solution to alleviate the environmental consequences of reliance on fossil fuels. By the conclusion of 2021, the global count of electric vehicles surpassed 16.5 million units, bolstered by over 1.8 million public charging stations. The International Energy Agency (IEA) anticipates that this figure will exceed 245 million by 2030, emphasizing the necessity of establishing a robust, broad, and resilient charging infrastructure to maintain this growth.

Despite this rapid growth, the adoption of electric cars faces some substantial challenges. The high upfront cost of electric vehicles, mostly due to battery technology expenses, remains a limiting issue in certain regions. Range anxiety, characterized by the fear of depleting battery capacity before reaching a charging station, continues to erode customer trust, particularly in regions with insufficient charging infrastructure. Moreover, extended charging times compared to traditional refueling techniques reduce convenience and perceived reliability. To address these challenges, technological advancements have emerged in three main charging categories: slow home-based Level 1 chargers, faster Level 2 chargers commonly located in workplaces or commercial zones, and DC Fast Chargers (DCFCs), which significantly reduce charging time to approximately 20 minutes for a distance of 60–100 miles. The emergence of superfast chargers has made queue time a crucial factor, alongside travel duration, in shaping user behavior, hence elevating the significance of charging station accessibility and placement.

With the rise in electric car use, research increasingly underscores the necessity for multidisciplinary integration among transportation systems, spatial planning, and energy networks. The instantaneous power demand of DCFCs causes stress on local systems, often requiring substantial capacity that is underutilized. Consequently, researchers advocate for the incorporation of Energy Storage Systems (ESS) at charging sites to balance power demand, alleviate peak loads, and improve energy distribution. These developments indicate that research on EV charging infrastructure has progressed beyond simple technological design, expanding into a multidisciplinary field encompassing system optimization, behavioral modeling, and urban sustainability frameworks.

2.2. Spatial Planning and Policy Considerations

The geographical distribution of Electric Vehicle Charging Stations (EVCS) is inherently complex, requiring the integration of spatial, economic, technological, and behavioral considerations. A significant body of research focuses on advanced modeling approaches and GIS to determine optimal locations for charging stations. A common methodology combines Multi-Criteria Decision Analysis (MCDA) techniques, such as Analytic Hierarchy Process (AHP), Fuzzy-AHP, and TOPSIS, with GIS-based spatial mapping. These hybrid frameworks allow researchers to evaluate several aspects, including accessibility, land cost, grid capacity, and environmental risk, while generating suitability maps that identify high-priority locations for infrastructure development. The fuzzy extensions of these models, such as Fuzzy-AHP and Fuzzy-TOPSIS, have demonstrated notable proficiency in addressing uncertainty and expert subjectivity, hence enabling a more flexible and accurate evaluation of site selection criteria.

Alongside multi-criteria techniques, optimization-based approaches have gained considerable importance. Models such as the Set Covering Problem (SCP), Maximal Covering Location Problem (MCLP), and p-Median Problem (PMP) are frequently employed to reduce costs, optimize coverage, and improve accessibility. SCP models endeavor to encompass all demand nodes within a certain critical distance while minimizing the number of facilities, whereas MCLP seeks to optimize overall demand coverage with a limited number of stations. Conversely, the PMP prioritizes minimizing the overall distance between demand sites and their nearest charging stations, often resulting in facility placements that better accommodate densely populated metropolitan areas. Moreover, contemporary research amalgamates user equilibrium and traffic assignment models to replicate the decision-making processes of electric vehicle drivers about charging stations, affected by factors such as detour distance, waiting time, and cost. Stochastic Dynamic User Choice Equilibrium (SDUCE) models improve this framework by including queuing delays and uncertainty in user utility assessments, yielding more behaviorally precise planning results.

The literature recognizes the critical need of integrating policy, environmental resilience, and socio-economic factors into EVCS design. Accessibility is essential, with studies highlighting the need of placing chargers near major roads, densely populated areas, and significant sites like as shopping centers, offices, and public facilities. Resilience and environmental considerations are equally important, including vulnerability to natural calamities such as flooding or wildfires that may threaten long-term operational stability. Technical and economic constraints, like grid connectivity and land availability, must be included into planning frameworks to avert costly infrastructure upgrades or supply-demand imbalances.

Policy-driven initiatives, exemplified as the U.S. National Electric Vehicle Infrastructure (NEVI) program, have demonstrated the importance of coordinated and equitable implementation strategies. Scholars consistently promote flexible, incremental expansion models that start with high-demand urban networks and gradually expand into suburban and rural areas. The incremental rollout should be directed by continuous monitoring of real-world consumption data rather than static projections, guaranteeing congruence with actual demand surges. Moreover, charging networks must employ diverse strategies: Level 2 chargers are ideal for residential and commercial environments where vehicles are parked for prolonged periods, whereas DC Fast Chargers are preferable for highways and heavily used routes. These insights underscore that efficient electric vehicle infrastructure design requires optimal geographical distribution and integration across energy, transportation, and governance systems to guarantee that electrification substantially aids sustainable urban transformation.

3. MATERIALS AND METHOD

Bibliometric analysiss is a recognized and widely employed approach for systematically assessing large bodies of academic literature. Mapping scientific outputs clarifies developmental pathways within a certain field and outlines research boundaries [12]. This study utilizes bibliometric methods to examine the structure and evolution of significant entities, such as authors, keywords, publications, journals, institutions, and countries, within the field of electric vehicle charging infrastructure, with a particular emphasis on the planning of SPKLU locations. Aria and Cuccurullo, (2017) demonstrated that bibliometric mapping effectively uncovers the intellectual structure of a research topic, offering valuable insights on knowledge advancement and collaborative interactions. Donthu et al., (2021) illustrated the versatility of these approaches through co-authorship and co-citation analyses in marketing research, pinpointing leading researchers and seminal publications, while emphasizing the significance of bibliometric tools in detecting research trends. Despite the fast proliferation of research on electric vehicle infrastructure, existing studies are disjointed across several disciplines, such as transportation planning, power systems, and urban sustainability, and lack a cohesive synthesis that integrates diverse perspectives. This study conducts a comprehensive bibliometric analysis to outline the knowledge structure, key contributors, and emerging research areas in the field. Zhang et al. (2020) conducted a bibliometric study of the growth of electric vehicle technology and policy, illustrating how these methods may delineate issue clusters and frontiers, therefore guiding policymakers and stakeholders toward strategic goals. These examples validate the legitimacy of the existing technique and emphasize its importance for SPKLU site planning research. Bibliographic data were collected from major scientific databases, including Scopus, Google Scholar, and Crossref, based on availability and the completeness of material. Scopus was selected as the primary database because to its consistent bibliographic records and extensive coverage of peer-reviewed literature in engineering, environmental science, transportation, and energy policy.

3.1. Criteria For Data Selection

The exclusion criteria were established to ensure that the dataset accurately reflected the research parameters relevant to the development of electric car charging infrastructure sites. Publications were subjected to a screening procedure that evaluated the publication year, document type, source indexing, and relevancy to the topic matter. This refining phase guarantees the quality, consistency, and thematic coherence of the data employed for bibliometric analysis. Consult Table 1 for further details.

This study aims to deliver a comprehensive analysis of the development of EV charging infrastructure, particularly concentrating on the planning of SPKLU locations, by employing robust bibliometric methodologies alongside a meticulously designed search strategy spanning the last twenty years. This study, based on the methodological frameworks established by Aria and Cuccurullo (2017), Donthu et al. (2021), and Zhang et al. (2020), delineates the intellectual landscape of the discipline and offers practical recommendations for policymakers, planners, and industry stakeholders seeking to improve EV charging networks.

Table 1. Exclusion Criteria [15]

No	Criteria	Exclusion
1	Period	Publications outside the range of 2010–2025 were excluded.
2	Document type	Only journal, Review and Conference Paper; other document types were excluded
3	Source	Publications not indexed in Scopus, Google Scholar, Crossref were excluded to ensure data consistency and reliability.
4	Study Area	Publications in pure sciences (e.g., Medicine, Physics and Astronomy, Mathematics, Biochemistry, Pharmacology, Immunology, Chemistry) were excluded to focus on interdisciplinary fields.

3.1 Analytical Framework

The research procedure, following the bibliometric protocol set out by Öztürk et al., (2024), consisted of three separate phases:

1. Selecting a suitable database and collecting data,
2. Extracting and validating data, and
3. Representing data and doing bibliometric analysis.

The gathered metadata was analyzed using VOSviewer and Publish or Perish software. The assessment included many components:

1. Trends in yearly publications,
2. Networks of keyword co-occurrence,
3. Mapping of author and institutional partnerships,
4. Analyses of citations and co-citations, and
5. Identification of topic clusters in electric vehicle infrastructure research.

The selection of prolific writers and pivotal journals was informed by Lotka’s Law, concerning author productivity, and Bradford’s Law, pertaining to journal significance

3.2 Data Acquisition

The preliminary stage was the extraction of bibliographic entries from the database, selected for its vast coverage and detailed metadata. This study will analyze the latest research on Electric Vehicles using bibliometric network analysis, concentrating on phrases such as "Electric Vehicle Charging," "EV Charging Station," "Charging Infrastructure," "Location Planning," "Site Selection," and "Spatial Planning." The preliminary data collection included articles from 2007 to 2025; however, the conclusive analysis was restricted to the timeframe from 2010 to 2025 to emphasize the post-2010 increase in research pertaining to EV infrastructure, subsequent to worldwide decarbonization pledges. This era underscores the evolution of innovation and success within the industry, demonstrating notable accomplishments in electric car technology, the development of charging infrastructure, and urban planning initiatives that have shaped the current landscape of electric vehicle charging. Figure 1 depicts the pertinent statistics.

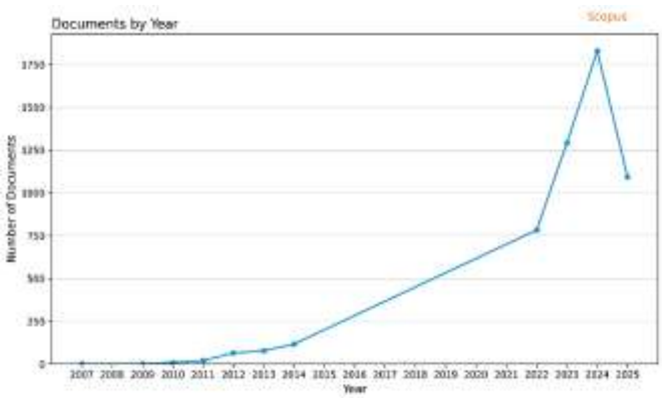

Figure 1. Preliminary Data Acquisition

Figure 1 depicts the annual development of publications related to electric vehicle (EV) charging infrastructure and spatial planning from 2007 to 2025. A preliminary search in Scopus produced 3,189 documents. After refining the corpus through duplication elimination, relevance assessment, and document-type filtering, 512 articles were selected for bibliometric mapping, focusing on co-authorship and co-occurrence. A selection of 6 fundamental papers was subsequently made based on citation frequency, keyword pertinence, and the prevalence of notable writers in the discipline. This selection guarantees that these works exemplify the most significant and thematically coherent studies for comprehensive qualitative comparative analysis, as outlined in Tables 2 and 3. The data reveals a steady increase from 2007 to 2014, followed by moderate growth until 2021, then a substantial rise from 2022 to 2024, reaching a zenith of almost 1,800 articles in 2024. Despite a slight decline anticipated in 2025, this trend exemplifies the rapid expansion of scholarly attention to the development of EV infrastructure. This analysis focuses on the period from 2010 to 2025 to maintain consistency, along with the global increase in electric vehicle use and decarbonization efforts. This period includes the most vigorous phase of research advancement, while ensuring sufficient data representation from both developed and emerging nations.

4. RESULTS AND ANALYSIS

This bibliometric analysis finds and evaluates the most prominent and thematically relevant scholarly articles that contribute to the discourse on Electric Vehicle charging infrastructure and strategic site design. The selected sources are based on their citation frequency, scholarly reputation, and pertinence to the topics of transportation technology, spatial planning, energy management, and optimization modeling. The primary objective is to elucidate the global intellectual framework of this research domain while accounting for the contextual factors influencing emerging economies, particularly Indonesia, where challenges such as decentralization, inconsistent infrastructure, and fragmented regulations impede the establishment of SPKLU. The current literature predominantly comprises research from developed nations; yet, the diversity of publications cited underscores the need for interdisciplinary integration of technological, geographical, and governance viewpoints to promote the sustainable development of electric vehicle networks

4.1 Examine the advancements in Electric Vehicle infrastructure and the strategic planning of SPKLU sites, highlighting the progression of the sector, the establishment of clusters, and the contributions of principal players)

This bibliometric study delineates its findings into two principal components. The initial component analyzes the quantitative attributes of the area, including annual publishing trends, leading journals, notable authors, and institutional collaborations, thereby addressing Research Question 1 (RQ1). This section provides a representation of the Network Map of Authors and Institutions, illustrating the development and clustering of research cooperation across many areas and fields. The second component incorporates the thematic dimensions derived from keyword co-occurrence and longitudinal trend analysis, answering Research Questions 2 and 3 (RQ2–RQ3). The studies reveal the main thematic clusters, the development of subfields, and the evolution of research emphasis from 2010 to 2025. The findings jointly outline the intellectual framework of EV infrastructure research while highlighting significant gaps in research and governance, particularly with the inadequate attention to socio-political, regulatory, and spatial equality concerns critical for developing nations. Addressing these shortcomings is essential for adapting global optimization theories to the institutional realities and regional inequalities in the Indonesian setting.

Table 2. Comparative Review of Quantitative and Methodological Aspects of the Analyzed Articles

No	Source / Main Focus	Geographical Context	Sector and Research Theme	Research Approach (Quantitative/Qualitative)
1	Application of Multi-Criteria Decision Analysis for Optimal Siting of Electric Vehicle Charging Stations in Oklahoma [17]	Oklahoma, United States	EV Charging Station Infrastructure Planning (EVCS). Optimal site selection focusing on resilience (against natural disaster risks such as flooding and wildfires), accessibility, and demand.	Quantitative. Integrates MCDA, specifically AHP and Fuzzy-AHP, with GIS and Voronoi Diagram–based Spatial Optimization. Employs numerical sensitivity analysis (polynomial regression).
2	EV Fast Charging Station Planning Considering Competition Based on Stochastic Dynamic Equilibrium [18]	Shenzhen City, China and Sioux Falls Network	Electric Power and Transportation Systems. Planning of Fast Charging Stations (FCS) in a competitive environment, integrated with PV and ESS.	Quantitative (Optimization and Simulation). Employs a Two-Level Iterative Optimization Model, SDUCE (based on a Logit discrete choice model), Distributionally Robust Optimization (DRO), and Genetic Algorithm (GA).
3	Incorporating	Sioux Falls	Transportation and Power	Quantitative (Game-Theoretic

No	Source / Main Focus	Geographical Context	Sector and Research Theme	Research Approach (Quantitative/Qualitative)
	Institutional and Spatial Factors in the Selection of Optimal Locations for EVCS: A Case Study of Beijing, China [19]	Network	Systems. Planning strategies for FCSs in a competitive market, accounting for queuing effects and on-site ESS sizing optimization.	Optimization). Applies a Double-Layer Iterative Methodology (for *Nash equilibrium* search), User Equilibrium Traffic Assignment Model (UE-TAP) integrated with Queuing Theory, and Linear Programming (LP).
4	Suitable Site Selection of Public Charging Stations: A Fuzzy TOPSIS MCDA Framework on Capacity Substation Assessment [20]	Cuenca, Ecuador.	Power Systems and Urban Planning. Site selection of public charging stations focusing on substation capacity assessment and modeling EV adoption growth.	Quantitative (Hybrid GIS–MCDA). Implements a GIS-based Fuzzy TOPSIS MCDA framework. Uses Geographically Weighted Regression (GWR) for EV adoption modeling and Kriging Interpolation for environmental data.
5	Planning Strategy for an Electric Vehicle Fast Charging Service Provider in a Competitive Environment [21]	Beijing, China.	Urban and Transportation Planning. Optimal site selection for public charging facilities integrating institutional factors (government policy) and spatial variables with demand estimation based on socio-demographic data.	Quantitative (Classical Location Optimization) and Qualitative (for Input). Compares classical optimization models: Set Covering Problem (SCP), Maximal Covering Location Problem (MCLP), and P-Median Problem (PMP). Demand estimation uses a Delphi-type ranking method (expert inputs converted into weights).
6	Planning of Electric Vehicle Charging Infrastructure: A Review and a Conceptual Framework [22]	Yangtze River Delta Region,	Transportation and Power Systems. Multi-Objective Dynamic Optimization for *vehicle–pile–network* collaborative planning. Integration of V2G and energy management.	Quantitative (Advanced Multi-Objective Optimization). Utilizes an Enhanced NSGA-III Algorithm and a MATLAB/OpenDSS Co-Simulation Platform based on a coupled transport–power network model.
7	Synergistic Strategy for Electric Vehicle Charging Infrastructure Planning and Energy Management Based on Multi-Objective Optimization [23]	Thane District, India	EVCI Infrastructure Planning. Development of a Hybrid GIS–MCDM–ML Conceptual Framework for scalable and predictive site selection.	Quantitative (Hybrid Model). Integrates GIS (spatial filtering), MCDM (AHP for prioritization), and Machine Learning (ML) (*Random Forest Regression*) for demand forecasting.

Table 2 delineates the global progress in research on electric vehicle charging infrastructure (EVCI) planning, emphasizing geographical optimization, energy management, and institutional integration. The research, although aligned in their objective of determining best sites and techniques for EV charging stations, demonstrate differences in geographical settings, methodological approaches, and analytical frameworks, underscoring the growing complexity of the topic.

The prevalence of quantitative focus in almost all studies signifies a growing reliance on computer modeling and optimization techniques in EVCI research. The integration of MCDA, GIS, and simulation-based optimization frameworks, including AHP, Fuzzy-AHP, TOPSIS, and NSGA-III, highlights the multidisciplinary nature of modern techniques. Research in Oklahoma (USA) and Cuenca (Ecuador) underscores the significance of resilience and spatial accessibility through the integration of MCDA with GIS and regression-based forecasting techniques to evaluate environmental, infrastructural, and social factors. Research in China, particularly in Shenzhen and Beijing, examines competitive charging network planning via stochastic user equilibrium models and game-theoretic frameworks to mimic market dynamics and legislative limitations. These studies highlight the increasing imperative to account for institutional, behavioral, and geographical interdependencies in the development of EVCI.

Several studies, notably those conducted in Beijing, utilize a hybrid method that combines quantitative location models (SCP, MCLP, P-Median) with qualitative expert-based inputs (Delphi-type weighting), as opposed to relying solely on technical optimization. This methodological variation underscores the recognition that geographical and institutional elements cannot be fully encapsulated by numerical models alone. Integrating stakeholder viewpoints and policy frameworks improves comprehension of the contextual elements influencing EVCI development.

Recent contributions, including studies from India's Thane District and the Yangtze River Delta Region, illustrate a methodological transition towards hybrid and intelligent systems. The amalgamation of machine learning algorithms with multi-objective optimization and co-simulation platforms signifies a new era in EVCI design, integrating predictive analytics with systemic coordination between transportation and power networks. These methods improve accuracy and scalability while promoting sustainable decision-making in increasingly urbanizing regions.

The summary demonstrates that EVCI research has evolved from static spatial optimization to dynamic, data-driven, and context-sensitive frameworks. The growing amalgamation of engineering models, policy factors, and machine learning-driven forecasts indicates a transition towards holistic planning frameworks. This progression exemplifies a wider trend in sustainable infrastructure development, where technical precision, institutional adaptability, and environmental resilience are acknowledged as interconnected pillars crucial for attaining efficient and equitable electric mobility networks.

Table 3. A comparative analysis of the primary results, consequences, and recommendations of the examined publications

No	Source / Main Focus	Key Findings	Implications and Recommendations
1	Application of Multi-Criteria Decision Analysis for Optimal Siting of Electric Vehicle Charging Stations in Oklahoma	The ideal spacing is 6–10 kilometers in urban regions and 15–20 kilometers in rural regions. Stresses the necessity for a geographically tailored charging plan, including DC fast charging along roads and Level 2 charging in residential and occupational environments. Fuzzy-AHP enhances the dependability of assessments performed by specialists.	Requires adaptive phased deployment strategies based on real-world demand. Future studies should integrate grid capacity constraints and evaluate optimal power levels, including V2G/G2V considerations.
2	EV Fast Charging Station Planning Considering Competition Based on Stochastic Dynamic Equilibrium	Competition necessitates that service providers install supplementary charges to minimize wait times, hence improving service quality. Neglecting competition leads to exaggerated demand and profits. ESS and photovoltaic (PV) technologies have shown economically viable for peak shaving and price arbitrage.	Future models should include irrational user behavior (e.g., *risk aversion*) and competitor reactions to pricing. Wasserstein-based DRO ensures superior out-of-sample performance and system robustness.
3	Incorporating Institutional and Spatial Factors in the Selection of Optimal Locations for EVCS: A Case Study of Beijing, China	The P-Median Problem (PMP) outperforms the Set Covering Problem (SCP) and the Maximum Coverage Location Problem (MCLP) by minimizing demand-weighted distance, hence positioning stations closer to high-demand populations. The PMP stays invariant as the number of stations (p) increases.	Planning should incorporate institutional and spatial constraints (e.g., existing gas stations, parking areas). PMP recommended to prioritize user convenience and accessibility for high-demand clusters.
4	Suitable Site Selection of Public Charging Stations: A Fuzzy TOPSIS MCDA Framework on Capacity Substation Assessment	Disregarding competition leads to a 27.5–45.2% inflation of daily profit estimates. Electric car users tend to go towards stations with shorter wait periods. ESS significantly reduce operational costs and enable price arbitrage.	Must consider competitor responses (e.g., station expansion) to avoid overinvestment. Further research is needed on price differentiation strategies under competition.
5	Planning Strategy for an Electric Vehicle Fast Charging Service Provider in a Competitive Environment	Fuzzy TOPSIS outperforms traditional AHP in addressing uncertainty and imprecision in expert assessments. GWR identifies insurance costs, new residential projects, and building materials as key factors influencing electric car adoption. The substation can support up to 35,000 electric cars, despite increasing peak demands.	The proposed hybrid MCDA framework supports transformer capacity evaluation under EV growth. Future studies should incorporate socio-demographic criteria influencing mass EV adoption.
6	Planning of Electric Vehicle Charging Infrastructure: A Review and a Conceptual Framework	Collaborative optimization reduces service radius by 28.4% and lessens the peak-valley load imbalance by 37.1% relative to single-objective planning. V2G integration mitigates peak demand; yet, it increases battery degradation costs. Ideal vehicle-to-grid engagement: 30–35%.	Implement dynamic electricity pricing to shift charging to off-peak hours. Policymakers should cap V2G participation rates to prevent excessive battery wear and maintain system efficiency.

The examined publications together highlight that the effective development of EVCI requires the incorporation of geographical, technological, and behavioral dimensions. Numerous individuals employ quantitative and multi-criteria methods, such as Fuzzy-AHP, TOPSIS, and P-Median models, emphasizing the need for location-specific execution and adaptive planning. Research constantly demonstrates that competition and institutional factors significantly influence infrastructure performance; neglecting these elements leads to exaggerated demand and profitability. The combination of ESS and renewable sources enhances grid stability and economic feasibility. Moreover, multi-objective optimization frameworks suggest that collaborative transportation and power network planning could reduce service disparities and improve energy efficiency; however, governmental interventions are essential to tackle battery degradation and vehicle-to-grid participation. The synthesis underscores the imperative for data-driven, context-specific, and policy-supported measures to ensure the sustainable and equitable advancement of EVCI.

4.2 Cartography of Collaborative and Research Network

A co-authorship network analysis using VOSviewer was conducted to clarify the structure and dynamics of international research collaboration in EVCI. This graphic aims to outline the key authors, collaborative networks, and relationships that characterize the conceptual framework of EVCI research. Figure 2 illustrates the collaboration network derived from the bibliometric data evaluated by the author.

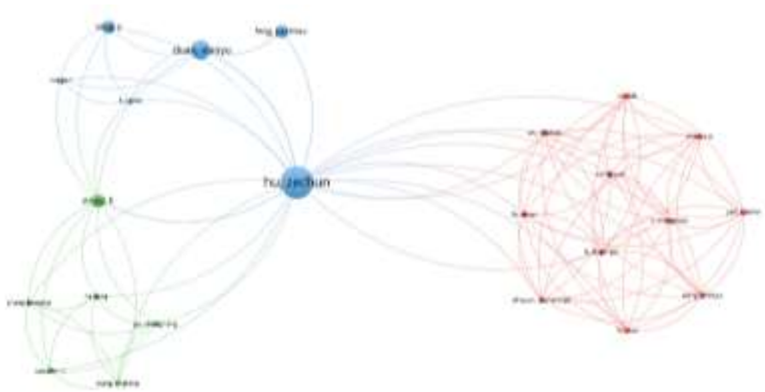

Figure 2. Visualization of the Co-authorship Network Using VOSviewer

The VOSviewer map of author cooperation in the paper "Exploring the Evolution of EV Charging Infrastructure" reveals a clear clustering pattern that signifies considerable collaboration among certain research groups. Notable authors, such as Hu and Zechun, operate as essential connections among diverse groups, indicating that intellectual unity within the EVCI field is mostly driven by a select few influential academics. This concentration of influence suggests that global progress in electric car infrastructure design depends on a limited network of leading institutions and academics, primarily from technologically advanced regions. The collaborative network mostly consists of authors from China, Europe, and the United States, with limited presence from developing countries like Indonesia. This underrepresentation highlights a regional research weakness, since context-specific issues such as infrastructure injustices, access disparities, and limitations in institutional capacity within developing economies are rarely incorporated into mainstream electric car research. The global discussion on electric vehicle infrastructure design mostly emphasizes technological efficiency and optimization, overlooking socio-institutional adaptability and policy significance in diverse local settings. Thematic focus primarily underscores quantitative and model-based approaches, encompassing spatial optimization, smart grid integration, and energy management systems. While these approaches enhance accuracy and computational integrity, they often overlook critical socio-political and behavioral factors influencing electric car adoption and infrastructure deployment. This methodological consistency creates a research gap between technical modeling and practical application, particularly in domains where institutional and governance challenges are more pronounced.

Despite the significant expansion of research on electric vehicle infrastructure and SPKLU (charging stations) in recent years, the partnership map highlights some persistent essential challenges. The bibliometric visualization generated by VOSviewer reveals that worldwide research in this domain is primarily defined by clusters of authors and institutions situated in China, Europe, and the United States. This indicates a strong but unequal research framework, in which intellectual and technical progress is primarily driven by a limited number of top nations and research networks. A key limitation noted is the insufficient participation of writers and organizations from emerging economies, particularly in Southeast Asia, including Indonesia. This gap suggests that local perspectives, especially on infrastructural challenges, policy implementation, and consumer behavior in emerging contexts, are inadequately integrated into the global body of knowledge. The scholarly discourse on SPKLU mostly focuses on technical optimization and smart grid modeling, with minimal consideration of the social, economic, and policy dimensions crucial for localized implementation. This concentration of research effort signifies a degree of intellectual reliance, wherein innovations, methodologies, and frameworks for electric vehicle infrastructure development frequently conform to paradigms established by research centers in developed countries. Indonesia experiences a gap between technological advancement and contextual applicability, since research seldom addresses specific challenges such as unequal regional development, regulatory fragmentation, or constraints in institutional capacity for the implementation of SPKLU across the archipelago. To address these challenges, strong regional and multidisciplinary collaboration networks are essential. Collaboration across universities, government agencies, and business organizations should be encouraged to enhance research skills and formulate evidence-based policies tailored to Indonesia's unique energy transition context. Increasing participation from local scholars and integrating socio-technical viewpoints into existing global frameworks will enrich the diversity of concepts and ensure that developments in EV infrastructure are inclusive, sustainable, and culturally relevant.

4.3 Research Gaps and Opportunities

Examining the evolution of research on EVCI requires the identification of existing research gaps and emerging possibilities to determine where future studies may yield the most substantial contributions. A bibliometric technique enables the visualization of dominant topics, research interconnections, and areas that remain underexplored. A keyword co-occurrence analysis was conducted using VOSviewer software to elucidate these patterns. This image provides a comprehensive overview of the intellectual landscape in EVCI research, particularly with the establishment of SPKLU sites.

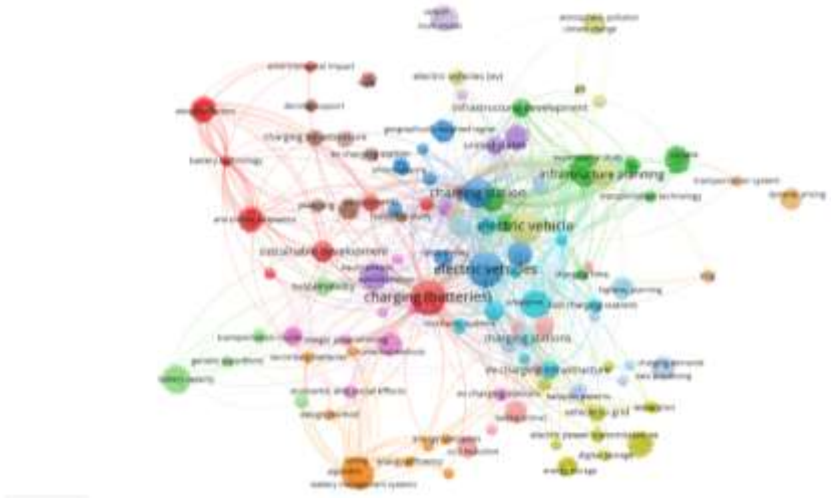

Figure 3. Co-occourance

Figure 3 illustrates a co-occurrence map that outlines the thematic framework of research on EVCI, with a focus on site planning. The picture reveals that the principal clusters revolve on terms such as electric vehicle, charging infrastructure, planning, and optimization, indicating that the existing literature is predominantly shaped by engineering-oriented and computational studies. These research primarily concentrate on improving geographical distribution, network coverage, and cost-efficiency using algorithms and simulation models. The map indicates a significant research gap: socio-spatial, governance, and contextual factors in the development of SPKLU locations are insufficiently addressed. Terminology associated with policy, equality, urban planning, and sustainability is situated peripherally, signifying a deficiency in interdisciplinary integration between technical modeling and spatial policy perspectives.

This gap offers considerable research opportunities, particularly for emerging economies such as Indonesia. Future research can advance current EVCI studies by developing integrative frameworks that merge spatial decision-support models with local governance dynamics, socio-economic factors, and regulatory structures. Incorporating spatial equity and regional readiness into SPKLU planning would improve infrastructure accessibility and align national decarbonization goals with sustainable urban development. Therefore, while global research has advanced in optimization methodologies, substantial opportunities remain to contextualize EVCI location planning within diverse urban and regional settings, offering both theoretical improvement and practical importance for sustainable transportation transitions

4.4. Discussion

The evolution of research on Electric Vehicle charging infrastructure demonstrates a notable intellectual transition from early technological studies centered on battery systems and charging efficiency to a more holistic examination of spatial planning, energy management, and policy integration. This movement signifies an increasing recognition that electric vehicle infrastructure presents both a technical problem and a spatial governance issue, requiring thorough planning at regional and municipal levels. Bibliometric mapping delineates three key evolutionary periods. During the initial phase (2010–2014), research predominantly focused on technology efficiency and system design, emphasizing charger kinds, power capacity, and grid integration. In the development phase (2015–2020), research commenced the amalgamation of optimization and location-allocation models, marking the preliminary convergence of energy systems and urban spatial analysis. The mature stage (2021–2025) has a clear theme convergence, with sustainability, spatial planning, and policy integration as the primary principles. This progression demonstrates the growing emphasis on holistic frameworks that integrate technical, environmental, and socio-political considerations in the planning of SPKLU. This evolution aligns with Lotka's Law and Bradford's Law from a bibliometric viewpoint. Author production is significantly concentrated, with a small cohort of principal scholars accountable for the majority of publications. Simultaneously, journal dispersion reveals that a limited number of high-impact journals, including Energies, Sustainability, and Applied Energy, prevail in citation metrics. This exemplifies the specialization and concentration of global intellectual impact patterns typical of emergent, technology-driven research domains.

Recent literature suggests that efficient planning for SPKLU settings necessitates the amalgamation of spatial modeling with insights derived from policy and governance. The integration of multi-objective optimization, GIS, and transportation planning theories enables a thorough comprehension of the ideal sites and strategies for establishing charging stations. However, bibliometric research demonstrates that this integration is mostly concentrated in developed nations, which possess robust institutional frameworks and data infrastructures. In rising countries such as Indonesia, research indicates a gap between technology promise and the readiness of spatial policy. The need for sustainable mobility is rising; nevertheless, research on context-specific SPKLU planning remains inadequate. This disparity underlines the necessity for flexible frameworks that amalgamate national energy transition policies with local urban planning competencies.

5. CONCLUSION

This work does a bibliometric analysis of the worldwide discourse on Electric Vehicle charging infrastructure, concentrating on the strategic planning of SPKLU sites from 2010 to 2025. The findings demonstrate a rapid conceptual evolution from preliminary engineering and design-centric research to a more sophisticated integration of optimization, spatial planning, and sustainability elements, highlighting the advancement of this discipline. The shift from static spatial optimization to dynamic, data-driven, multi-objective modeling frameworks, augmented by GIS and artificial intelligence, exemplifies the increasing complexity and practical importance of the discipline. The global intellectual framework exhibits considerable centralization, predominantly shaped by scholars and institutions from China, Europe, and the United States, leading to a pronounced regional imbalance in research emphasis. This disparity creates a significant contextual void, wherein the infrastructural, institutional, and socio-political obstacles encountered by emerging nations such as Indonesia are insufficiently represented in mainstream studies on electric vehicle infrastructure. Thematic mapping reveals this disparity, demonstrating that the literature prioritizes technological efficiency and optimization, but governance, equality, and localized spatial policy are mostly overlooked. Future study on SPKLU planning in Indonesia should concentrate on formulating governance frameworks that amalgamate spatial concerns with technology innovations and contextual realities. Frameworks must integrate decentralized policy dynamics, regional disparities, and institutional capacities to ensure that the development of EV infrastructure aligns with energy transition and carbon reduction goals, while also fostering inclusive, equitable, and sustainable regional development. Fostering collaboration among local institutions, politicians, and the commercial sector is crucial for adapting global knowledge and transforming technological innovations into contextually relevant, socially integrated solutions for Indonesia's electric car ecosystem.

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