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Property Rights And Urban Development: A Systematic Review Of Institutional Dynamics In Informal Settlements

Mauro Dos Santos Ortiz[1], Martin Wolter[1], Pedro Henrique Eisenkraemer[2], Manohar Chamanab[2], Stephen Bayneb[2], Kaynan Maresch[3], Daniel Pinheiro Bernardonc[3] , Mauricio Sperandio[3], Glauco Oliveira Rodrigues[3]
[1] *(Otto Von Guericke University Magdeburg, Magdeburg, Germany)*
[2] *(Texas Tech University, Lubbock, TX, United States Of America)*
[3] *(Universidade Federal De Santa Maria, Santa Maria, RS, Brazil)*

Abstract
Background: *Electric vehicles (EVs) have emerged as a central element in global strategies for sustainable mobility, energy transition, and carbon reduction. The rapid expansion of EV-related research has generated a fragmented body of knowledge spanning modeling approaches, infrastructure planning, environmental assessment, and policy analysis. However, an integrated and structured understanding of this research landscape remains limited.*
Materials and Methods: *This study adopts an integrated methodological approach combining a Systematic Literature Review (SLR), bibliometric analysis, and qualitative synthesis. Scopus-indexed publications published between 2010 and 2025 were analyzed to identify conceptual foundations, methodological trends, and dominant thematic clusters. Bibliometric mapping techniques were used to examine keyword co-occurrence networks and research fronts, followed by an in-depth qualitative interpretation of the main thematic streams.*
Results: *The results reveal five dominant research fronts in the EV literature: system dynamics modeling, forecasting and diffusion analysis, charging-infrastructure optimization, environmental and carbon-impact assessment, and policy-driven market evolution. Keyword co-occurrence networks indicate a strong convergence between mobility and energy systems, emphasizing carbon reduction, grid interaction, and technological innovation. The qualitative synthesis highlights EV transitions as complex adaptive systems shaped by behavioral heterogeneity, policy portfolios, battery technologies, and multi-actor coordination.*
Conclusion: *The findings demonstrate that effective EV transitions depend on integrated policy packages, dynamic planning tools, and cross-sector governance arrangements. This study contributes theoretically by clarifying the structural and thematic organization of EV research and practically by providing actionable insights for policymakers, planners, and decision-makers involved in EV regulation, infrastructure development, and sustainable mobility strategies.*
Key Words: *Electric vehicles; Systematic literature review; Bibliometric analysis; Energy transition; Sustainable mobility.*

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I. Introduction

Urban mobility systems around the world are undergoing profound transformations driven by rapid urbanization, increased vehicle ownership, and escalating environmental pressures. The transportation sector remains one of the primary contributors to greenhouse gas emissions and air pollution, making it central to global discussions on climate mitigation and sustainable development. As highlighted in studies of multimodal engine technologies, advances in powertrain optimization and fuel strategies show potential for reducing overall emissions; however, these improvements alone are insufficient to counterbalance the increasing demand for mobility (Oke et al., 2024). In emerging economies, these challenges are intensified by population growth, expanding vehicle fleets, and infrastructure constraints, which collectively reinforce cycles of congestion, energy consumption, and environmental degradation. Rajput and Jain (2025) emphasize that these pressures arise from complex interactions between socioeconomic conditions, travel demand, and urban infrastructure, revealing the need for systemic approaches capable of capturing feedback processes and long-term behavioral patterns.

At the same time, the automotive industry is transitioning toward new energy systems, including electric vehicles and hybrid solutions, shaped by government policies, technological innovations, and market dynamics. In China, for example, policy incentives, R&D investment, and evolving consumer markets have played decisive roles in accelerating the adoption of new energy vehicles, illustrating how institutional contexts influence technology diffusion and environmental outcomes (Cai & Liu, 2025). Yet, as multiple studies indicate, research on sustainable mobility remains fragmented. Many contributions examine isolated elements—such as EV charging loads, engine efficiency, consumer behavior, or congestion mitigation—without integrating these components into a unified analytical framework. System dynamics studies address parts of this gap by modeling interdependent variables over time, but they often focus on specific regional cases or single policy interventions, leaving room for broader comparative and integrative analyses.

These gaps highlight the theoretical relevance of developing frameworks that incorporate behavioral, technological, institutional, and infrastructural dimensions simultaneously. Models grounded in system dynamics and related simulation approaches allow researchers to represent nonlinear interactions, feedback loops, and delays that shape transportation systems. However, despite advances in this field, Rajput and Jain (2025) note that studies addressing multiple dynamic parameters—such as fuel demand, emissions, congestion, and vehicle population—within integrated scenarios remain limited. Similar limitations are evident in works examining life-cycle emissions, as the environmental impact of new energy vehicles depends not only on use-phase emissions but also on production, disposal, and supply-chain conditions, which evolve under complex and uncertain policy environments (Oke et al., 2024; Cai & Liu, 2025).

This research context is closely connected to international policy agendas and the United Nations Sustainable Development Goals. The transportation sector plays a critical role in advancing SDG 7 (clean energy), SDG 9 (industry and innovation), SDG 11 (sustainable cities), and SDG 13 (climate action). Government interventions—such as subsidies, emission standards, infrastructure investment, and restrictions on internal combustion engines—are reshaping mobility markets and influencing long-term transition pathways (Oke et al., 2024; Cai & Liu, 2025). In countries facing rapid population growth and urbanization, sustainable mobility strategies also intersect with equity considerations, access to transportation, and public health outcomes. As demonstrated by system dynamics applications to Indian urban mobility, integrated models can support the design of strategies that reduce congestion, emissions, and road accidents simultaneously, contributing to both environmental and social objectives (Rajput & Jain, 2025).

Given these dynamics, this article addresses the following research questions:
(1) How do technological, behavioral, infrastructural, and institutional factors interact dynamically to shape sustainable mobility transitions?
(2) To what extent can integrated modeling approaches—particularly those grounded in system dynamics—simulate the long-term impacts of alternative mobility and energy strategies?
(3) Which policy interventions and technological pathways exert the greatest influence on emissions reduction, congestion mitigation, and vehicle adoption patterns?

This study offers several contributions. First, it synthesizes insights from system dynamics, automotive technology, and environmental assessment into a consolidated conceptual perspective. Second, it advances methodological integration by combining dynamic modeling, scenario analysis, and policy evaluation. Third, it provides actionable insights for policymakers, particularly regarding leverage points within mobility systems and the interplay between technology adoption and regulatory design. Fourth, it positions empirical findings from different national contexts—such as India, China, and the United States—within a comparative framework that highlights how policy environments shape mobility trajectories. Finally, it contributes to theoretical debates on sustainable mobility transitions by illuminating how systemic feedbacks influence long-term outcomes.

The structure of this article is as follows. The next section presents the theoretical foundations of sustainable mobility and reviews empirical studies that apply system dynamics to transportation and automotive systems. Section 3 describes the methodological approach, including the modeling framework, assumptions, and data under consideration. Section 4 details the scenario design and analytical procedures. Section 5 reports the simulation findings and discusses their implications for sustainable mobility policies. Section 6 concludes by summarizing the main contributions, identifying limitations, and suggesting avenues for future research.

II. Theoretical Framework

The theoretical evolution of sustainable mobility and electric vehicle transitions has been shaped by a progressive shift from technology-centric analyses toward broader systemic interpretations that incorporate environmental, institutional, and behavioral dimensions. In early stages, studies on EVs primarily emphasized their potential to reduce tailpipe emissions and replace fossil-fuel technologies; however, more recent research has recognized that the environmental, economic, and social impacts of EV systems extend far beyond the vehicle itself and are influenced by policy design, battery production, recycling practices, consumer decision-making, and long-term energy transitions. Works examining government incentives reveal that price-threshold subsidies, for instance, can significantly alter firm strategies and reshape market structures by influencing cost-reduction behavior and emissions outcomes (Cheng et al., 2022). This type of economic mechanism demonstrates how EV transitions rely on institutional frameworks capable of generating stable incentives for technological upgrading, thereby reflecting a substantial evolution in the conceptualization of sustainable mobility.

At the same time, environmental concerns surrounding battery life cycles and critical materials have become central to theoretical debates. Research shows that although EVs eliminate tailpipe CO emissions, their broader environmental performance depends heavily on the carbon intensity of electricity used for charging, the environmental burden of lithium-ion battery manufacturing, and the management of end-of-life materials. These insights emerge from life-cycle assessment and carbon-footprint studies, such as those examining the effects of banning internal combustion engines and assessing prospective emissions from alternative fuels and EV adoption rates (Morfeldt et al., 2021). Complementary analyses in the field of circular economy demonstrate that the design stage determines much of the future environmental impact of EV batteries, reinforcing the need for product-level innovation. Picatoste et al. (2022) highlight that circular design criteria—such as modularity, component disassembly, and enhanced reparability—are essential to improving resource efficiency but remain underimplemented due to low industrial feasibility and technological constraints.

Institutional perspectives also play an increasingly significant role, particularly in the context of EV battery waste. Lin et al. (2023) argue that the rapid growth of EV sales creates a forthcoming “scrap tide” of retired batteries, which poses environmental and economic challenges if proper regulatory mechanisms are not implemented. Their evaluation of different regulatory schemes—reward–penalty systems, deposit–refund policies, and hybrid models—shows that policymaking in this sector must balance environmental objectives, social welfare, and industrial competitiveness. These insights contribute to a deeper understanding of how institutions shape the sustainability of mobility systems and how environmental policy can generate both intended and unintended consequences.

Alongside institutional theory, socio-technical transition research has expanded the theoretical landscape by emphasizing the multi-dimensionality of EV adoption. The transition to EVs is not merely a technological substitution but a dynamic process mediated by behavioral, infrastructural, and informational factors. Novizayanti et al. (2021) illustrate this by employing an agent-based modeling framework that captures heterogeneous consumer preferences, social influence patterns, and communication dynamics. Their work demonstrates that EV diffusion emerges from the interplay between micro-level decision-making and macro-level structural pressures, aligning with multi-level perspectives on innovation and sustainability transitions.

System dynamics applications further enrich this field by enabling the study of long-term feedbacks and policy impacts across interconnected subsystems. Shen et al. (2023) show that the relationship between transportation, energy systems, emissions, and population dynamics can only be understood through feedback-driven models that simulate uncertainty and temporal evolution. Their findings highlight how emission-reduction potential varies depending on future electricity mixes, efficiency improvements, and behavioral trends, suggesting that national net-zero strategies require integrated modeling approaches that bridge environmental science and policy analysis.

Contemporary debates often revolve around the real net carbon benefits of EVs, the sustainability of battery production, and the comparative effectiveness of different policy instruments. While many studies suggest that EVs can substantially reduce emissions when powered by renewable energy, others caution that environmental gains may be offset by carbon-intensive battery manufacturing or by grid systems heavily dependent on fossil fuels. There are also controversies regarding the scalability of circular practices in the battery sector, given the technological and economic barriers to implementing end-of-life solutions. Moreover, uncertainties persist over whether subsidies, carbon trading, outright bans, or recycling mandates generate the most effective and equitable outcomes. These debates reflect an active and evolving research frontier in which sustainability goals must be reconciled with industrial realities, consumer behavior, and resource constraints.

Given this multifaceted theoretical landscape, the conceptual approach adopted in this study integrates institutional theory, socio-technical transition frameworks, life-cycle sustainability assessment, and systems modeling perspectives. This integration reflects the recognition that EV transitions involve interactions among regulatory structures, technological design, material flows, behavioral processes, and environmental feedbacks. By drawing upon these complementary theoretical foundations, the study positions EV adoption not as an isolated technological phenomenon but as a systemic, multi-layered transformation shaped simultaneously by economic incentives, design choices, governance strategies, and the broader dynamics of sustainable development.

III. Methodology

This study employs a mixed-method methodological design that combines a Systematic Literature Review (SLR), bibliometric analysis, and qualitative thematic interpretation to examine the intellectual, methodological, and thematic evolution of electric vehicle (EV) research. The approach integrates structured search procedures with analytical mapping and interpretive synthesis to ensure methodological rigor, transparency, and replicability. The overall design follows the principles established by Tranfield, Denyer, and

Smart (2003), whose framework for systematic reviews in management emphasizes rigorous planning, structured execution, and transparent reporting. In addition, the study incorporates elements of the PRISMA 2020 protocol to support systematic screening, exclusion logic, and documentation of the literature selection process, strengthening clarity and methodological validity.

The research draws on an SLR as its foundational method, complemented by bibliometric mapping and qualitative interpretation. The SLR allows for the systematic identification, organization, and evaluation of peer-reviewed studies focused on electric vehicles, dynamic modeling, forecasting approaches, charging infrastructures, and sustainable mobility transitions. Bibliometric analysis is used to detect patterns of keyword co-occurrence, thematic clusters, and conceptual linkages within the literature. These quantitative findings are then expanded through a qualitative synthesis that interprets the theoretical, methodological, and policy contributions that emerge across the selected studies. Together, this multimethod strategy makes it possible to capture both the structural characteristics of the field and the deeper conceptual relationships that guide its evolution.

The search strategy was defined through an iterative process involving exploratory searches and refinement of keyword combinations. The final search string combined the terms "electric vehicle*" with complementary expressions such as "system dynamics," "forecasting," "diffusion model," "charging infrastructure," "battery," and "policy analysis," using Boolean operators to increase precision and ensure the retrieval of studies aligned with the objectives of the review. Articles were included if they were peer-reviewed journal publications written in English, fell within the defined time frame, and addressed aspects of EV adoption, modeling, energy systems, or policy evaluation. Exclusion criteria eliminated conference papers, reviews, editorials, studies lacking methodological rigor, and works unrelated to EV transitions. This filtering process ensured that only conceptually relevant and methodologically sound studies formed part of the final analytical corpus.

The primary database used for data retrieval was Scopus, selected due to its comprehensive coverage across engineering, energy systems, environmental sciences, economics, and decision sciences—domains intrinsically related to EV research. The time period examined spans from 2010 to 2025, corresponding to the most transformative period in EV technological development, the emergence of large-scale charging infrastructure research, and the rise of dynamic modeling and machine-learning forecasting approaches. Additional quality filters restricted the dataset to Scopus-indexed journals and, when classification was available, to Q1 and Q2 outlets to ensure high-quality contributions.

Following data retrieval, the study employed three main analytical tools. VOSviewer was used to generate keyword co-occurrence maps, detect thematic clusters, and visually represent the conceptual structure of the field. RStudio, via the Bibliometrix package, allowed for metadata cleaning, keyword harmonization, and computation of descriptive bibliometric indicators. Microsoft Excel was used to organize data, structure inclusion/exclusion logic, and construct analytical matrices for qualitative synthesis. These tools collectively supported both the quantitative and interpretive dimensions of the study.

The methodological process unfolded across six interconnected stages. The first stage involved planning the review, defining objectives, and aligning the study's focus with system dynamics, EV transitions, forecasting models, and sustainability policy research. The second stage consisted of conducting the database search, applying the final search strings, exporting metadata, removing duplicates, and verifying relevance. The third stage involved PRISMA-based screening and eligibility assessment, with inclusion and exclusion criteria applied first to abstracts and then to full texts. The fourth stage comprised bibliometric processing, including metadata cleaning and the generation of co-occurrence networks and cluster visualizations. The fifth stage focused on qualitative coding and thematic synthesis, interpreting the conceptual patterns revealed in the bibliometric maps and integrating them into a coherent narrative aligned with the literature. Finally, the sixth stage involved synthesizing managerial and policy implications derived from the patterns observed, ensuring that the analytical results translated into meaningful guidance for decision-makers and researchers.

Through this multimethod, iterative, and rigorously structured approach, the methodology supports a robust analysis of EV research while providing a theoretically grounded and empirically validated foundation for the findings presented in subsequent sections.

IV. Discussion

Qualitative Literature AnalysisDistribuição temporal

The qualitative examination of the selected literature reveals a multi-layered, technically diverse, and increasingly sophisticated body of research aimed at understanding electric vehicle (EV) diffusion, charging infrastructure optimization, battery technological advancement, policy-driven market evolution, and system-level sustainability interactions. Rather than relying on descriptive metrics such as publication counts or temporal distributions, this section synthesizes the conceptual, methodological, and technological contributions of each study, illuminating the structural patterns that shape the contemporary EV research landscape.

Across the corpus, one observes a clear methodological convergence toward integrated modeling frameworks, particularly those rooted in system dynamics, machine learning, evolutionary game theory, and advanced materials engineering. These approaches reflect the maturation of the field, where static, linear, or single-factor analyses are no longer capable of capturing the complex interdependencies shaping EV adoption, infrastructure development, energy transitions, and market behavior.

A first major stream relates to long-term forecasting and dynamic simulation of EV markets. Xiang et al. (2024) advance the state of the art in charging-station planning by integrating Bass diffusion, long-term load forecasting, and revenue-risk modeling, demonstrating that EV adoption trajectories are highly sensitive to both behavioral uncertainty and charging-load variability (Xiang et al., 2024). In parallel, Zapata et al. (2024) explore the interactions between photovoltaic diffusion and EV penetration using system dynamics, showing that renewable-energy adoption can significantly reshape demand peaks, storage requirements, and charging-infrastructure coordination (Zapata et al., 2024). Qiao et al. (2025) further extend the forecasting literature by using machine learning—specifically LSTM, BiLSTM, and time-series multilayer perceptrons—to model BEV sales under dynamic market conditions, demonstrating that covariates such as price, driving range, charging-pile density, and fuel-to-electricity ratios exert significant and non-linear effects on future BEV market share (Qiao et al., 2025). Collectively, these studies mark a transition from deterministic forecasts to data-driven, uncertainty-aware predictive architectures.

A second central line of inquiry involves policy evaluation, subsidy design, and regulatory mechanisms, emphasizing the decisive role of government intervention in EV uptake. Suryani et al. (2025) demonstrate through a comprehensive system dynamics model that long-term government support, combined with structural improvements in EV technology and power-grid infrastructure, is essential to reduce emissions and stimulate macroeconomic benefits in Indonesia (Suryani et al., 2025). Li et al. (2025) deepen this perspective by examining China's dual-credit policy and its interaction with infrastructure subsidies, revealing that policy synergy—particularly when reinforced by strong collaboration between industry, universities, and research institutions—significantly accelerates technological innovation and new-energy-vehicle diffusion (Li et al., 2025). These works collectively support the notion that EV transitions cannot be understood outside of their institutional contexts and that policy packages—not isolated measures—shape long-term sustainability outcomes.

Beyond macro-policy, several studies investigate micro-structural governance challenges, particularly regarding the management of charging infrastructure. Cai et al. (2025) analyze private charging-pile sharing using evolutionary game theory and prospect theory, revealing that psychological risk perception, management costs, and profit-sharing ratios substantially influence the feasibility of private charging-infrastructure sharing models (Cai et al., 2025). Technical inefficiencies such as uneven spatial distribution, long waiting times, and poor utilization patterns are also highlighted. In a complementary approach, Boubaker et al. (2025) develop an integrated framework combining load-profile forecasting using NARX neural networks and shortest-path optimization via Dijkstra's algorithm to guide EVs toward optimal charging stations, demonstrating how predictive analytics and real-time edge computing can mitigate congestion and operational delays (Boubaker et al., 2025). These studies expand the traditional infrastructure debate by illustrating that infrastructure planning is fundamentally a socio-technical problem, not merely a logistical one.

A distinct branch of the literature focuses on consumer behavior and multi-modal adoption patterns. Venkatesh and Awasthi (2025) employ system dynamics to investigate how government initiatives, cost differentials, infrastructure availability, and user awareness influence the adoption of alternative-fuel vehicles, including EVs, hydrogen vehicles, and biofuel-powered modes (Venkatesh & Awasthi, 2025). Their findings underscore that modal shifts arise from the interplay of financial incentives, cultural behavioral patterns, and broader environmental perceptions, aligning with socio-technical transition theory.

A less common but strategically important thread encompasses battery materials, cathode engineering, and electrochemical performance, which determine the long-term viability of EV technologies. Tao and Zhang (2025) propose an advanced dual-encapsulation strategy for LiMn . Fe . PO cathodes, combining MXenes and amorphous carbon layers to significantly enhance Li-ion diffusion, structural stability, and cycle life (Tao & Zhang, 2025). Although highly specialized, this work demonstrates how materials science underpins broader sustainability goals, as improved batteries reduce charging times, extend vehicle range, and reduce lifecycle impacts.

Finally, several studies emphasize societal, behavioral, and market-structure dimensions that remain underrepresented in purely technical discussions. Novizayanti et al. (2021), although not part of the latest corpus, provide foundational insight by modeling EV adoption through agent-based simulations, emphasizing the heterogeneity of consumer decisions and the role of social influence, infrastructure distribution, and informational asymmetries. Their approach resonates strongly with the behavioral insights embedded in the more recent works in this corpus, especially those addressing private charging-pile sharing and dynamic policy responses.

Synthesizing all contributions reveals several overarching conclusions. First, the field is moving decisively toward holistic, integrative modeling approaches capable of representing multi-sectoral interactions, non-linear feedback mechanisms, and uncertainty propagation. Second, policy remains the most influential enabler of EV diffusion, but its effectiveness depends on designed synergies across regulatory instruments, industrial incentives, and infrastructure programs. Third, infrastructure—especially charging—has emerged as the primary bottleneck, necessitating optimization models that incorporate behavioral, spatial, temporal, and grid-level constraints. Fourth, technological advancements in battery engineering are evolving rapidly, providing foundational improvements that make policy and infrastructure interventions more effective. Finally, a cross-cutting theme across the entire literature is the explicit recognition that EV transitions are not isolated technological choices but complex systems transformations shaped by technological performance, institutional structures, consumer preferences, and energy-grid characteristics.

This qualitative synthesis provides a robust analytical foundation for the subsequent sections by delineating the conceptual and methodological contours of contemporary EV research. It underscores the necessity of integrative modeling frameworks and highlights the convergent pressures—policy, technological, behavioral, infrastructural, and environmental—that define the ongoing evolution of sustainable mobility systems.

Deep Thematic Interpretation / Cross-Study Synthesis

A cross-study synthesis of the selected literature demonstrates that contemporary research on electric vehicles (EVs) is not defined by a single analytical tradition, but rather by the coexistence of interdependent thematic streams that converge around the systemic character of mobility transitions. These streams—technological innovation, policy mechanisms, market behavior, infrastructure optimization, and dynamic modeling—are deeply interwoven, revealing a multidimensional transformation in how EV adoption and sustainability challenges are conceptualized.

A first major theme concerns the centrality of dynamic modeling as the epistemic backbone of EV transition research. System dynamics models, in particular, appear across multiple studies as the preferred method for capturing nonlinearities, feedback loops, and long-term policy impacts. Suryani et al. (2025) employ system dynamics to distinguish how various government-support scenarios shape emissions, income flows, and fleet composition in Indonesia, showing that structural adjustments in technology and infrastructure amplify policy effectiveness. Similarly, Li et al. (2025) use system dynamics to trace the incentive–state–response mechanism of China's dual-credit policy, demonstrating that coordinated political action accelerates innovation cycles and strengthens EV market penetration. These models resemble Xiang et al. (2024), who extend dynamic simulation to charging-station planning, revealing that future demand profiles can be anticipated only through iterative, scenario-driven forecasting. Together, these studies demonstrate that EV transitions are best understood through temporal systems reasoning, where outcomes emerge not from isolated variables but from recursive interactions between market forces, technology, and regulation.

A second thematic structure emerges around policy interdependence and multi-actor coordination, which the literature increasingly frames as indispensable for achieving systemic transformation. The dual-credit analysis by Li et al. (2025) demonstrates that incentivizing technological progress without addressing infrastructure constraints results in limited long-term diffusion. Conversely, infrastructure-only incentives—such as charging-pile subsidies—are delayed in effect unless matched by parallel improvements in innovation capability. This policy complementarity is echoed in Suryani et al. (2025), who show that emission reduction depends simultaneously on economic adjustment, technological substitution, and infrastructure readiness. Cai et al. (2025) add an important behavioral dimension by revealing that private charging-pile sharing is viable only when incentive mechanisms acknowledge psychological risk perceptions and the structural disincentives faced by property management groups. The convergence of these studies indicates that EV policy effectiveness is situated not merely at the regulatory level, but within multi-actor ecological structures that require harmonized incentives across manufacturers, infrastructure operators, consumers, and public institutions.

A third core theme is the technological-material substrate that underpins the feasibility of EV transitions. Battery performance, stability, energy density, and degradation directly influence consumer acceptance, infrastructure load, and long-term environmental impact. Tao and Zhang (2025) demonstrate that dual-encapsulation cathode architectures significantly improve Li-ion diffusion and cycle stability, thereby reducing one of the key bottlenecks limiting EV range and high-rate charging. Their materials-science advancements resonate with the demand-side considerations explored by Qiao et al. (2025), whose machine-learning models show that driving range and technological improvements are among the strongest predictors of BEV market growth. When the battery sciences and forecasting studies are read together, a synergistic relationship becomes evident: technological progress and market evolution are mutually reinforcing, as improvements in electrochemical performance modify adoption curves, reduce infrastructure stress, and alter policy needs.

A fourth thematic layer pertains to infrastructure complexity, encompassing charging-station allocation, grid capacity, spatial forecasting, and user-routing optimization. Boubaker et al. (2025) show that infrastructure challenges cannot be resolved with simplistic proximity-based models; instead, real-time load forecasting and optimal routing algorithms are necessary to prevent congestion and grid instability. Their use of NARX models and Dijkstra's algorithm represents a shift toward intelligent, data-driven infrastructure coordination. Similarly, Cai et al. (2025) highlight that private charging infrastructure, despite its abundance, remains underutilized due to concerns around security, management costs, and incentive structure, indicating that infrastructure capacity alone is insufficient—institutional and behavioral enablers must be in place for effective utilization. Insights from Zapata et al. (2024) further support this view by showing that EV charging loads interact dynamically with distributed renewable-generation systems, producing new balancing challenges and opportunities for demand management. Overall, the literature suggests that infrastructure should be seen not as a static asset, but as a dynamic, information-rich system.

A fifth theme relates to consumer heterogeneity, behavioral mechanisms, and multi-modal transition pathways. While forecasting studies often emphasize macro trends, Venkatesh and Awasthi (2025) illustrate that EV adoption is shaped by complex behavioral interactions involving awareness, perceived cost, trust in government initiatives, and competing modal preferences. Their findings connect with earlier behavioral modeling traditions, such as agent-based simulations, by highlighting that EV uptake is part of a broader shift toward alternative-fuel mobility systems that includes hydrogen, biofuels, and active modes. The cross-study evidence suggests that behavioral inertia, risk perception, and cultural norms remain major barriers to rapid EV diffusion, particularly where infrastructure and policy signals are inconsistent.

Across these thematic domains, several cross-cutting tensions become apparent. One recurring tension lies between rapid market expansion and infrastructure readiness, where surging EV adoption can outpace charging-station deployment and grid resilience. Another tension exists between short-term policy incentives and long-term sustainability outcomes, as some incentives accelerate adoption but risk creating structural dependencies or distorting technological competition—issues identified in both Suryani et al. (2025) and Li et al. (2025). A third tension concerns technological optimism versus material and environmental constraints. While studies such as Tao and Zhang (2025) show that battery improvements are feasible, the broader literature recognizes that resource availability, recycling infrastructure, and lifecycle impacts must be systematically addressed.

What ultimately emerges from this synthesis is that EV transitions constitute a complex adaptive system, in which market forces, policy frameworks, technological evolution, and user behavior coevolve. No single intervention—be it technological, policy-based, or infrastructural—is sufficient on its own. The literature points decisively toward integrated strategies that couple predictive modeling, holistic policy packages, advanced technologies, and behavioral insights. This multidimensional understanding forms the conceptual basis for interpreting the results presented in the subsequent sections.

Keyword Co-occurrence / Thematic Clusters

The keyword co-occurrence analysis provides a structural overview of how concepts converge within the electric vehicle (EV) research domain. The VOSviewer maps (Figures 1–3) reveal dense semantic regions that represent the main thematic clusters of the field, including system dynamics, forecasting, environmental impacts, charging infrastructure, and diffusion modeling. Each map highlights different layers of conceptual interaction, enabling a multidimensional interpretation of the research landscape.

Figura 1 — Keyword Co-occurrence Network of EV Research: Full Semantic Structure

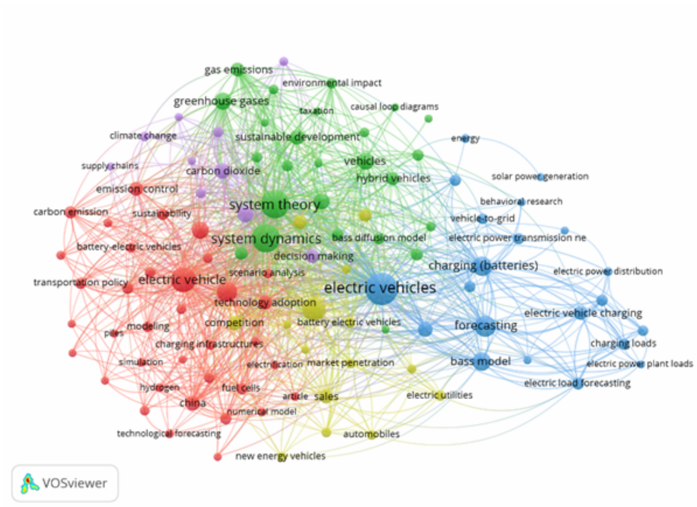

Figure 1 presents the complete semantic structure of the field, showing multiple interconnected clusters built around frequently co-occurring terms. Five major thematic nuclei emerge: electric vehicles, system theory/system dynamics, forecasting and Bass diffusion models, charging infrastructure, and environmental indicators. The term electric vehicles functions as the gravitational center of the map, linking technological elements (batteries, charging loads, vehicle-to-grid systems) with behavioral and institutional dimensions (technology adoption, taxation, policy, competition).

The green cluster, dominated by terms such as system dynamics, system theory, sustainable development, and causal loop diagrams, reflects the methodological shift toward dynamic modeling of emissions, consumer behavior, and policy interventions. This aligns with studies such as Suryani et al. (2025) and Li et al. (2025), who apply system dynamics to evaluate long-term policy effectiveness.

The blue cluster focuses on charging (batteries), electric power distribution, electric vehicle charging, and electric load forecasting. The tight connection between these terms demonstrates how infrastructure planning and grid integration constitute one of the most structurally relevant components of EV transitions. This is consistent with insights from Xiang et al. (2024) and Boubaker et al. (2025), which highlight the complexity of load forecasting and optimal charging-station deployment.

The red cluster, centered on electric vehicle, battery-electric vehicles, simulation, and transportation policy, represents the traditional core of EV research, bridging technology adoption, emission impacts, and policy analysis.

The purple cluster includes greenhouse gases, gas emissions, and environmental impact, emphasizing the climate-centered foundations of EV studies, which resonate with research such as Zapata et al. (2024).

Figura 2 — Structural Cluster Consolidation in EV and SD Research

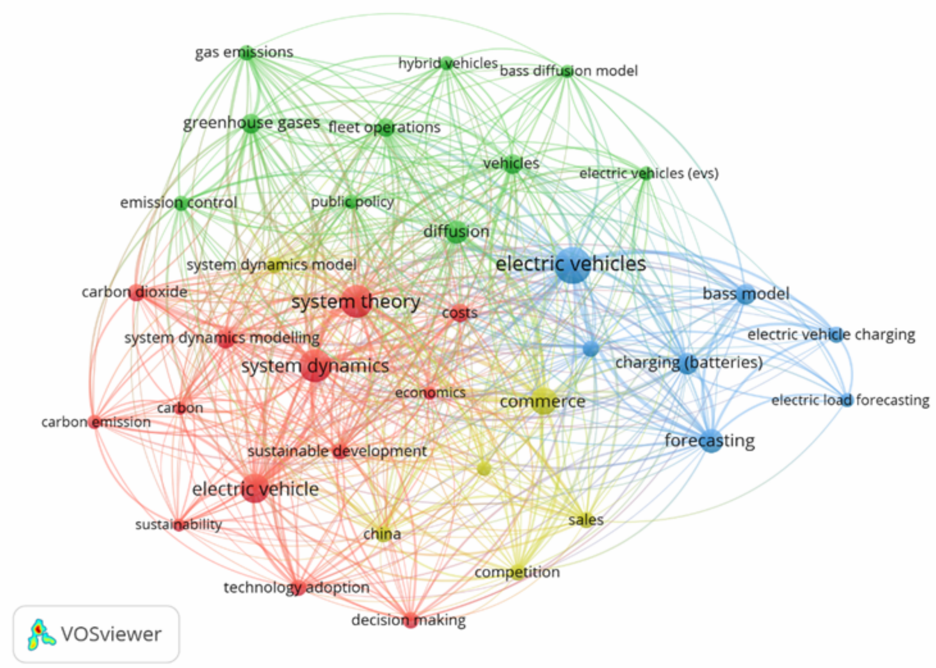

Figure 2 provides a more consolidated view of the field by clustering semantically adjacent concepts into larger thematic units. This map reveals four major axes that structure the literature. The technological–environmental axis includes terms such as greenhouse gases, carbon dioxide, emission control, and hybrid vehicles. This axis reflects the intersection of engineering advancements with environmental mitigation goals, echoing technical contributions like those of Tao and Zhang (2025). The systemic–analytical axis is anchored by terms like system dynamics, system dynamics modelling, scenario analysis, and decision making. This underscores the central methodological role of dynamic simulation, which enables researchers to evaluate long-term outcomes under policy uncertainty. The market–behavioral axis groups concepts such as sales, commerce, competition, and technology adoption. This cluster mirrors the growing interest in market evolution and consumer behavior, emphasized in forecasting works such as Qiao et al. (2025) and behavioral analyses like Venkatesh and Awasthi (2025). The energy–infrastructure axis connects charging (batteries), electric vehicle charging, electric load forecasting, and electric power distribution, highlighting the essential role of grid coordination and prediction algorithms in supporting EV diffusion.

Figura 3 — Thematic Integration Map of EV Diffusion, Forecasting, and Policy Dynamics

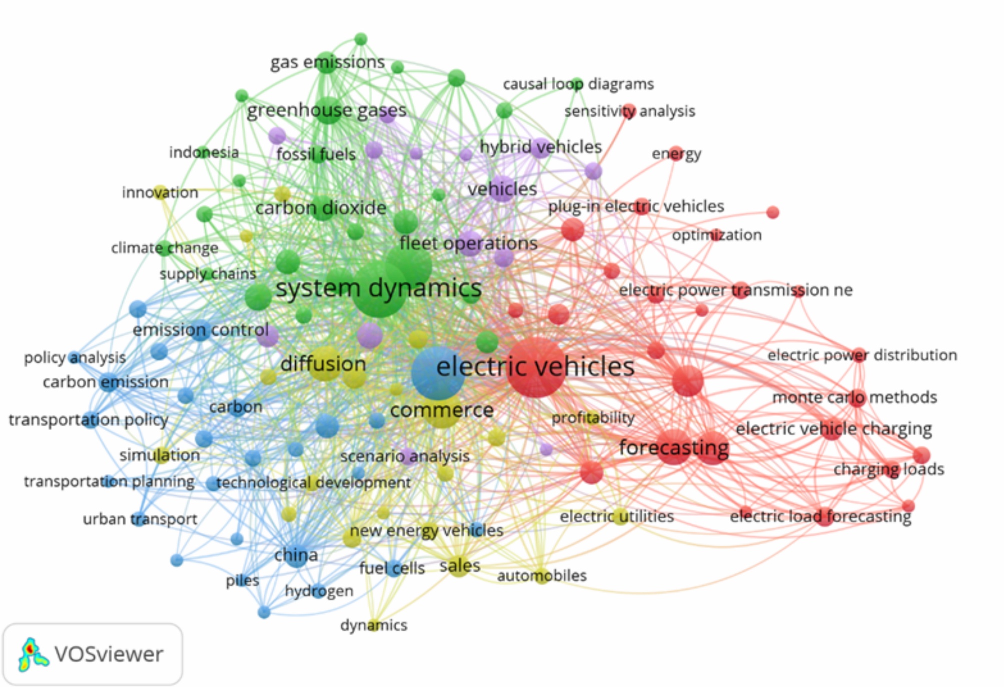

Figure 3 illustrates how themes converge in the most recent phase of the literature, showing intense cross-linkages between technology diffusion, forecasting methods, and environmental policy analysis. The green cluster again highlights system dynamics, diffusion, fleet operations, carbon dioxide, and policy analysis, underscoring the increasing alignment between environmental goals and dynamic modeling of fleet transitions. Studies such as Li et al. (2025) and Suryani et al. (2025) exemplify this integration by linking policy instruments directly to carbon outcomes and system behavior. The red cluster, built around electric vehicles and forecasting, reflects an advanced methodological layer using Monte Carlo methods, optimization, and scenario analysis. This confirms that stochastic modeling and predictive analytics have become indispensable tools for anticipating adoption rates and infrastructure needs. The blue cluster highlights electric power distribution, charging loads, electric power transmission, and electric utilities, showing that EV research increasingly overlaps with energy system planning, urban transport, and distributed generation challenges. The yellow and purple clusters reveal emerging research frontiers, including innovation, fossil fuels, supply chains, and new energy vehicles, which indicate the field's expansion beyond conventional EV topics toward broader mobility systems, hydrogen integration, and material transitions.

Managerial / Policy Implications

The cross-study synthesis reveals several managerial and policy implications that are central to accelerating the adoption of electric vehicles (EVs), strengthening energy–mobility integration, and achieving long-term carbon-reduction goals. The studies assessed collectively emphasize that EV transitions are not solely technological transformations but require coordinated interventions across policy, market, infrastructure, and organizational domains. The implications below translate the analytical insights into actionable strategies for policymakers, system planners, and industry leaders.

A first implication concerns the strategic design of policy packages, rather than isolated regulatory instruments. Research demonstrates that policy effectiveness emerges from complementarities between incentives, innovation support, and infrastructure readiness. For example, the dual-credit system analyzed by Li et al. (2025) shows that EV diffusion increases substantially when subsidies are aligned with technological innovation incentives and infrastructure expansion. Similarly, Suryani et al. (2025) highlight that government support produces meaningful environmental and economic benefits only when accompanied by structural improvements in fleet composition, grid capacity, and consumer readiness. These results suggest that policymakers should employ integrated policy portfolios that combine financial incentives, infrastructure mandates, R&D investment, and regulatory coordination rather than relying on single mechanisms.

Second, the literature underscores the managerial importance of forecasting and dynamic modeling as tools for decision support. Studies such as Xiang et al. (2024) and Qiao et al. (2025) demonstrate that long-term demand forecasting, scenario analysis, and machine-learning predictions significantly improve decision-making around charging-station investment, grid expansion, and market development. In a context where EV uptake is highly sensitive to technological improvements, consumer behavior, and external shocks, decision-makers should adopt forecasting tools as part of routine strategic planning. This includes the use of system dynamics models to evaluate policy impacts over time and predictive analytics to support infrastructure siting, supply-chain management, and risk mitigation.

Third, results show that charging infrastructure requires managerial approaches that integrate technical efficiency, behavioral incentives, and organizational coordination. Boubaker et al. (2025) demonstrate that load forecasting and optimized routing significantly reduce congestion and improve charging-station profitability, while Cai et al. (2025) show that psychological factors, trust, and management structures determine whether private charging resources can be effectively shared. This implies that infrastructure managers must adopt hybrid strategies that combine engineering optimization (e.g., load balancing, spatial allocation, real-time routing) with institutional mechanisms such as pricing models, property-management agreements, and community-level incentive schemes. Policymakers should also establish standards for interoperability, quality assurance, and minimum service requirements to ensure equitable access and system-wide reliability.

Fourth, the literature suggests that battery technology is a strategic lever for both managers and policymakers. Technological advancements—such as the dual-encapsulation strategy proposed by Tao and Zhang (2025)—directly influence consumer acceptance, infrastructure stress, and lifecycle emissions. Policymakers should prioritize R&D funding for high-performance battery chemistries, recycling technologies, and circular-economy solutions. Industry leaders, in turn, must integrate technological innovation into market strategies, recognizing that battery performance, durability, and recyclability increasingly determine competitive advantage and regulatory compliance.

A fifth implication relates to consumer behavior and market segmentation, which remain underappreciated in traditional policy designs. Venkatesh and Awasthi (2025) demonstrate that awareness, perceived risk, infrastructure visibility, and cost perception shape adoption patterns at a granular level. This indicates that communication campaigns, incentive visibility, and tailored financial instruments (e.g., differentiated tax credits, low-interest financing) are essential to target diverse consumer groups, especially in emerging markets where behavioral inertia is strong.

Finally, the research points to the growing relevance of ecosystem coordination, emphasizing collaboration among governments, utilities, automotive firms, energy providers, technology developers, and municipalities. Effective EV transitions require harmonization of objectives across sectors—such as aligning transportation policy with renewable-energy targets, integrating charging-load forecasting into utility planning, and ensuring land-use compatibility for large-scale charging deployment. Policymakers and managers should therefore establish multi-stakeholder governance platforms to coordinate planning, share data, harmonize standards, and anticipate cross-sectoral impacts.

Directions for Future Research

The synthesis of the literature highlights persistent gaps and emerging frontiers that present opportunities for advancing theoretical, methodological, and empirical research on electric vehicle (EV) transitions. As the field evolves toward increasingly complex, interdisciplinary frameworks, future studies must address limitations in current approaches and explore new conceptual pathways capable of capturing the socio-technical, economic, and environmental dimensions of mobility transitions.

A first gap concerns the limited integration between energy systems modeling and mobility forecasting. While several studies examine charging loads, grid interactions, or BEV market evolution separately, there remains insufficient work that fully couples mobility demand, grid dynamics, renewable-energy variability, and storage technologies within unified simulation environments. Future research should develop end-to-end system architectures capable of jointly representing EV adoption, charging behavior, grid reinforcement needs, renewable-generation intermittency, and demand-response mechanisms. Multi-sectoral integrated assessment models would allow policymakers to evaluate trade-offs, co-benefits, and systemic risks with higher fidelity.

A second persistent gap lies in the insufficient representation of consumer heterogeneity and behavioral complexity. Although some studies incorporate behavioral factors, most forecasting models still rely on aggregated assumptions that ignore socio-demographic differences, cultural norms, trust in institutions, or variations in technological literacy. Further research is needed to embed behavioral economics, agent-based modeling, and cognitive frameworks into EV diffusion models, enabling more realistic predictions of adoption dynamics across income groups, regions, and mobility cultures. This is particularly relevant for emerging economies, where adoption is shaped by contextual constraints that are often overlooked in global analyses.

A third research direction involves the expansion of EV studies into the supply-chain domain, especially considering battery materials, recycling capacity, resource scarcity, and geopolitical dependencies. Current models rarely consider upstream constraints or material substitution pathways, despite their long-term implications for market feasibility and sustainability. Future work should integrate life-cycle assessment, circular-economy modeling, and supply-chain dynamics to evaluate scenarios in which technological improvements may be offset by shortages of lithium, cobalt, or rare-earth metals, or where recycling technologies redefine battery economics.

Methodologically, the field would benefit from hybrid modeling approaches that combine system dynamics, machine learning, evolutionary game theory, and econometric estimation. While machine learning excels at short-term forecasting and handling high-dimensional datasets, system dynamics provides explanatory power and captures long-term structural evolution. The integration of these methods could produce robust models capable of managing both prediction accuracy and conceptual transparency. Such hybrid models would also help address uncertainties inherent in adoption behavior, technological innovation rates, and fluctuating policy landscapes.

Another promising direction concerns charging-infrastructure optimization under uncertainty. Most current approaches assume predictable patterns of mobility, yet real-world charging behavior is influenced by weather, time-of-day variability, socio-economic differences, and psychological factors. Future studies should incorporate stochastic user behavior, real-time routing decisions, and adaptive pricing to design more resilient infrastructure strategies. Additionally, research should investigate the potential of shared private charging, community-level microgrids, and distributed energy resources to mitigate spatial and temporal imbalances in charging demand.

A further area requiring attention is the evaluation of long-term policy effectiveness under dynamic conditions. Policies such as subsidies, carbon credits, dual-credit systems, or internal combustion engine bans often produce complex unintended consequences—market distortions, technological lock-in, or inequitable access—that remain insufficiently studied. Dynamic policy evaluation frameworks that incorporate feedback loops, delays, and multi-actor interactions are needed to assess how policies evolve over time and how combinations of instruments can be optimized for environmental and economic outcomes. Finally, several emerging or neglected research questions warrant deeper exploration. These include:

- The integration of evs with hydrogen systems, autonomous mobility, and shared mobility services;
- The implications of EV adoption for urban form, public transport, and land-use planning;
- The role of artificial intelligence, digital twins, and real-time analytics in managing large-scale charging networks;
- The social equity dimensions of EV transitions, including affordability, accessibility, and energy justice;
- The macroeconomic impacts of shifting from fossil-fuel-based transportation to electrified systems.

Together, these directions indicate that future EV research must be more interdisciplinary, policy-aware, and systems-oriented. By bridging environmental science, behavioral research, energy systems engineering, and computational modeling, scholars can develop more comprehensive frameworks to support a resilient, equitable, and sustainable transition to electric mobility.

V. Conclusion

This study set out to systematically examine the evolution of electric vehicle (EV) research by integrating a structured literature review with bibliometric mapping and qualitative thematic interpretation. The objective was to identify how methodological traditions, conceptual frameworks, and policy debates have shaped the field, and to translate these insights into meaningful contributions for scholars and decision-makers. The analysis demonstrated that EV research has grown into a complex, interdisciplinary domain where system dynamics, forecasting models, diffusion theory, charging-infrastructure planning, and environmental policy increasingly converge.

The findings reveal a scientific landscape characterized by deep thematic interconnection and growing methodological sophistication. Keyword co-occurrence networks highlight the central role of electric vehicles as a unifying concept that links diverse clusters such as system dynamics, charging-load forecasting, renewable-energy integration, technological innovation, and carbon-emission mitigation. The qualitative synthesis shows that EV transitions are not merely technological substitutions but multifaceted socio-technical transformations shaped by policy instruments, infrastructure readiness, consumer behavior, supply-chain dynamics, and energy-system interactions. The literature consistently emphasizes that advances in battery technologies, dynamic modeling, and charging-infrastructure optimization are reshaping the boundaries of what EV systems can achieve. Simultaneously, policy design—whether through subsidies, dual-credit schemes, or infrastructure incentives—remains one of the most influential drivers of adoption. These insights consolidate the understanding that EV transitions function as complex adaptive systems in which feedback loops, nonlinearities, and multi-actor coordination play decisive roles.

From an academic standpoint, the study contributes to the literature by offering an integrative, system-oriented perspective that synthesizes conceptual, methodological, and empirical advancements. By combining an SLR with bibliometric and qualitative analyses, the work provides a structured overview of how the field has matured and where its theoretical boundaries are shifting. The recognition of EV transitions as deeply interdependent with energy systems, urban planning, and circular-economy strategies enriches current theoretical discussions and opens avenues for interdisciplinary integration across decision sciences, engineering, environmental studies, and public policy.

In practical terms, the study offers several implications for policymakers, managers, and infrastructure planners. The evidence suggests that successful EV transitions depend on carefully coordinated policy portfolios rather than isolated instruments. Dynamic modeling and forecasting tools should be incorporated into strategic planning to anticipate demand, guide infrastructure deployment, and evaluate long-term policy impacts. Furthermore, charging infrastructure requires hybrid management strategies that integrate technical optimization with behavioral and institutional mechanisms. Battery innovation emerges as a critical strategic lever that influences market acceptance, environmental performance, and industrial competitiveness. Finally, consumer heterogeneity must be addressed through targeted incentives, awareness strategies, and differentiated financing mechanisms to ensure equitable adoption.

Despite its contributions, the study has limitations. Dependence on Scopus as the primary database may exclude relevant work indexed elsewhere, and bibliometric analyses rely on metadata consistency, which can influence cluster structures. The rapid pace of technological change in EV systems means that new developments may outpace existing literature, and the absence of empirical simulations limits the study's applicability for context-specific operational planning. Nonetheless, these limitations do not diminish the value of the integrative perspective offered here; rather, they highlight areas where further research is needed.

In conclusion, the study reaffirms that EV transitions are among the most complex and consequential elements of global sustainability agendas. Their success will depend on the ability of researchers and practitioners to integrate technological innovation, systemic modeling, infrastructural planning, and inclusive policy design. By providing a detailed synthesis of the conceptual and methodological trajectories of the field, this work lays a foundation for future investigations and supports the development of more coherent, strategic, and impactful pathways toward sustainable electric mobility.

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