Communications in Transportation Research 4 (2024) 100148

Contents lists available at ScienceDirect

Communications in Transportation Research

journal homepage: www.journals.elsevier.com/communications-in-transportation-research

Review

Unveiling the determinants of battery electric vehicle performance: A systematic review and meta-analysis

Fangjie Liu [a], Muhammad Shafique [b,*], Xiaowei Luo [a,**]

[a] *Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong, 999077, China*
[b] *Department of Civil and Environmental Engineering, Brunel University London, Middlesex, UB8 3PH, UK*

A R T I C L E I N F O

Keywords:
BEVs
Battery electric buses (BEBs)
BEV performance
Sustainability
Technological advancements
User behavior
Regulatory impact

A B S T R A C T

The transition toward battery electric vehicles (BEVs) is a critical element in the global shift toward sustainable transportation. This meta-analysis delves into the multifaceted factors influencing BEV performance, including environmental, technological, behavioral, and political-economic determinants. The purpose of this review is to systematically organize and assess how these factors impact BEV efficiency and sustainability across various operational scenarios, such as driving, charging, and decommissioning. By examining a wide range of literature, this study constructs a comprehensive framework that categorizes the primary components and performance metrics, revealing complex relationships and potential causal connections. The findings highlight that although technological advancements and regulatory frameworks are the predominant drivers of BEV performance, environmental conditions and user behaviors also play significant roles. The key emerging topics identified suggest further research avenues, particularly in optimizing battery technology and expanding policy support. Additionally, the analysis provides new and systematic insights compared with previous reviews, offering a clearer understanding of the determinants, their impacts, and the interactions between them. These insights are crucial for developing a transparent evaluation system for future research and policy formulation. This comprehensive synthesis not only aids in understanding the current landscape but also in directing future scholarly and practical endeavors in electric vehicle research.

Nomenclature

AC	Alternating current	IGBTs	Insulated gate bipolar transistors
ATM	Asymmetric temperature modulation	IR	Infrared
AWD	All-wheel drive	IVTs	Infinitely variable transmissions
BEB	Battery electric bus	LTO	Lithium titanium oxide
BEVs	Battery electric vehicles	MDIBC	Multi-device interleaved bidirectional DC-DC Converter
BMS	Battery management system	MOSFETs	Metal–oxide–semiconductor field-effect transistors
BROM	Battery range optimization model	MTPA	Maximum torque per ampere
CAV	Connected and autonomous vehicle	OBC	On-board charger
cSMC	Combined sliding mode control	PM	Permanent magnet
CVTs		RWD	Rear-wheel drive

(*continued on next column*)

(*continued*)

	Continuously variable transmissions		
DC	Direct current	SAE	Society of automotive engineers
DCFC	Direct current fast charging	SAC	Sinusoidal amplitude converter
ECR	Energy consumption rate	SiC	Silicon carbide
EMS	Energy management system	SPAR-4-SLR	Scientific procedures and rationales for systematic literature reviews
ESG	Environmental, social, and governance	TCO	Total cost of ownership
EVCS	Electric vehicle charging stations	TMS	Thermal management systems
EVs	Electric vehicle	USABC	United States Advanced Battery Consortium
FT	Full toroidal	V2G	Vehicle-to-grid
FWD	Front-wheel drive	V2I	Vehicle-to-infrastructure
GaN	Gallium nitride	V2V	Vehicle-to-vehicle
		VSI	Voltage-source inverter

(*continued on next page*)

* Corresponding author.
** Corresponding author.
E-mail addresses: muhammad.shafique@brunel.ac.uk (M. Shafique), xiaowluo@cityu.edu.hk (X. Luo).

https://doi.org/10.1016/j.commtr.2024.100148
Received 13 May 2024; Received in revised form 24 June 2024; Accepted 7 August 2024

(continued)

GC–MS	Gas chromatography–mass spectrometry		
GHG	Greenhouse gas	WBGS	Wide bandgap semiconductor
HT	Half toroidal	ZVSC	Z-source DC-DC converter

1. Introduction

The world is facing increasingly severe challenges from climate change, with the destructive consequences of extreme weather events occurring globally, underscoring the urgency of strengthening global disaster response mechanisms (Dottle and Politics, 2023). In light of this, the European Union's 2050 climate strategy demonstrates forward-looking thinking, offering an innovative climate action framework aimed at achieving climate neutrality by 2050 while ensuring a just transition in socioeconomic terms (The European Green Deal, 2020). Moreover, the convening of COP28 signals the international community's firm commitment to climate action, and despite facing unique challenges and controversies, it provides a key platform for global climate governance.

Other countries are also taking action to combat climate change. For example, Japan is working to reduce its greenhouse gas emissions and has set a carbon neutrality goal (Kii et al., 2023). India is pushing solar power to become a world leader in renewable energy (Dey et al., 2022). African nations are utilizing their abundant solar and wind resources to develop renewable energy projects to promote energy diversification (Agoundedemba et al., 2023).

The development of BEVs is one of the key strategies for combating climate change (Alanazi, 2023). With technological advancements and policy support, the BEV market is rapidly expanding, which is critical for reducing greenhouse gas emissions (Shafique et al., 2022) and decreasing dependence on fossil fuels and improving urban air quality (Zhao et al., 2023). BEVs play an essential role in achieving net-zero emission targets for various countries and are a focal point in international climate negotiations such as COP28 (Ferris, 2023). Furthermore, BEBs play a crucial role in the transition to carbon-neutral transport by complementing passenger cars in reducing urban emissions, providing high-capacity, low-emission alternatives that help decrease overall vehicle density and reliance on fossil fuels in city environments (Li et al., 2023a; Schlott, 2020). Therefore, the future of global climate action will largely depend on the innovation and application of sustainable energy technologies, with electric vehicles as a flagship solution, and their influence is steadily growing, as mentioned by International Energy Agency (IEA, 2023).

1.1. Evolution and impact of electric vehicles in the transportation sector

The transportation domain, with its longstanding dependency on internal combustion engines, has been identified as a substantial contributor to global greenhouse gas (GHG) emissions, representing approximately 23% (Aminzadegan et al., 2022) of aggregate emissions across the European Union member states. This entrenched reliance on fossil fuels, particularly within the road transport subsector–which alone accounts for approximately 70% of transportation emissions–is projected to intensify (Gao et al., 2023). If current trends persist, it is anticipated that by 2050, transportation could account for up to 50% of the EU's total greenhouse gas emissions (Ferrer and Thomé, 2023).

The evolution of BEVs from niche products to sustainable, high-performance alternatives to traditional vehicles is driven by significant advancements in technology. Enhanced battery capabilities have extended the vehicle range and minimized charging times, whereas developments in power electronics have improved overall efficiency and reliability (Haustein et al., 2021). The use of lightweight materials has reduced vehicle weight, contributing to performance enhancements (Shui et al., 2024). A focus on the user experience has spurred the creation of sophisticated energy management systems, which optimize battery usage and vehicle efficiency (Ibrahim and Jiang, 2021).

The establishment of a comprehensive charging infrastructure (Funke et al., 2019b), which is increasingly integrated with renewable energy sources, supports the practicality of BEVs for everyday use. The academic community is instrumental in analyzing the larger implications of the transition to BEVs, such as the sustainability of raw material sourcing, the environmental impact across the vehicle's lifecycle, and strategies for end-of-life disposal or recycling (Jones et al., 2023; Ledna et al., 2022; Martins et al., 2023). Environmentally, the shift to BEVs promises a significant reduction in emissions, a benefit that will grow as the grid becomes more reliant on renewable energy sources (Yang and Chen, 2021). With the grid's transition to solar, wind, and hydroelectric power, the carbon footprint associated with BEV operations is expected to decrease further (Ambrose et al., 2020). Smart charging technology enables BEVs to charge during off-peak electricity demand, improving energy efficiency and grid flexibility. Economically, the development of BEVs is propelled by policy and innovation, signaling a shift in manufacturing, maintenance, and energy consumption (Jones et al., 2023). Government incentives and infrastructure investments have lowered the barriers to BEV adoption, stimulating market vitality. Traditional automakers are restrategizing, while new players explore emerging niches. BEVs present economic advantages to consumers and increase the demand for electrical and renewable energy resources. The rising demand for battery materials such as lithium, cobalt, and nickel is transforming supply chains and commodity markets. In response, policies are evolving to maintain market competitiveness and meet environmental, social, and governance (ESG) standards for long-term economic and environmental health (Martins et al., 2023). The widespread adoption of BEVs, including BEBs, influences travel behavior and urban planning, as initiatives to enhance multimodal transit and strategic urban space use gain traction, which is supported by BEV-sharing services and congestion pricing (Dirks et al., 2022; Pucci, 2021). An improved charging infrastructure and policy support for BEV adoption are vital for reducing fossil fuel dependence and fostering a sustainable transportation system (An, 2020).

BEVs are becoming increasingly viable due to urban growth, policy support, and technological advances that promise to lower costs and improve charging infrastructure by 2030 (Aijaz and Ahmad, 2022). This progression, along with strategic marketing and innovative business models, is essential for enhancing energy efficiency, reducing emissions, and fostering sustainable transportation (Patil et al., 2023). As governments enact supportive policies and technology continues to advance, the role of BEVs is set to expand, further decarbonizing the sector and paving the way for a cleaner future.

1.2. Unpacking electric vehicle performance

In this introductory section, we provide an overview of the key performance metrics that define the functionality and appeal of BEVs. These metrics include range capability, energy efficiency, battery life, and environmental impact. Understanding these factors is essential for assessing the viability and market acceptance of BEVs. The discussion sets the stage for more detailed analysis in subsequent sections. Section 2 describes the methodological approaches, laying the groundwork for comprehensive analysis. Section 3 reviews the literature to identify the determinants affecting EV performance and outlines what these determinants are. Section 4 delves into how these determinants influence EV performance. Section 5 discusses the specific determinants in detail, categorizing them into environmental factors, technological factors, behavioral and operational factors, and policy and economic support. Finally, Section 6 concludes the study by summarizing the findings and implications.

The range of a BEV (Woo and Magee, 2020), defined as the maximum distance it can travel on a full charge, and the battery capacity, which measures the total amount of stored electrical energy, are critical for consumer acceptance and practical use of electric vehicles. Pearre et al. (2011) described the range, and Young et al. (2012) detailed the battery capacity, highlighting the technical advances over time (Fig. 1 (McKerracher, 2023)). BEBs have larger batteries than passenger cars do but often achieve similar or lower ranges because of their heavier weight and frequent stop-start urban usage (Gao et al., 2017).

Energy efficiency (Evtimov et al., 2020) in BEVs is crucial, as it describes how effectively electrical energy stored in the battery is converted into driving power. Unlike internal combustion engine vehicles, which lose a significant portion of fuel energy as heat, BEVs achieve higher conversion efficiency, turning a greater proportion of electrical energy into kinetic energy. This metric not only affects performance but also impacts the overall cost-effectiveness (Sheldon and Dua, 2019) and environmental footprint of the vehicle.

The lifespan of a BEV battery is a paramount factor affecting both the vehicle's longevity and its economic value. Despite the reduction in lithium battery costs due to decreased raw material prices (Bloomberg, 2024), the battery remains a major cost component and significant source of emissions over the vehicle's life cycle. The battery lifespan, which is simply defined, refers to the duration or number of charging cycles a battery can undergo before its capacity decreases to an unusable level. This is typically when the battery can hold only 80% or less of its original rated capacity. Battery lifespan is influenced by factors such as charge/discharge rates, depth of discharge, and operating temperatures. Optimizing these factors can significantly extend a battery's useable life and, consequently, the vehicle's service life.

BEVs offer notable environmental benefits, such as zero tailpipe emissions, which are crucial for reducing urban air pollution (Liu et al., 2024). However, the production of BEVs, especially batteries, requires substantial resources and can cause ecological disruption (Yang et al., 2022b). The overall environmental impact depends on the electricity generation methods used for charging and the recycling efficiency of vehicle components after their useful life. This necessitates ongoing monitoring and assessment to devise effective emission reduction strategies for transportation.

The United States Advanced Battery Consortium (USABC) set ambitious targets in 2014 for advanced batteries in BEVs, aiming for a 15-year lifespan, 80% charge in 15 min, and robust performance from −30 to +52 °C (Neubauer et al., 2014). Despite these goals, commercial BEVs still struggle to meet the fast charging target but have exceeded 300 miles of the driving range. These improvements could reduce the battery volume while enhancing the range and acceleration, making BEVs cost competitive with conventional vehicles at lower annual mileage thresholds (Deng et al., 2020). In 2016, Grunditz and Thiringer (2016) undertook an extensive review of BEV data, focusing on traditional metrics such as power and speed. However, as their data grow outdated in the face of rapid advancements in the BEV sector, a comprehensive and current review that includes economic and environmental performance is increasingly vital. This section serves as a foundation for such an updated examination.

1.3. Current research landscape on electric vehicle performance

Recent research in the field of BEVs has demonstrated significant advancements in both the technical and the environmental aspects, aiming at improving their performance and usability. He et al. (2020) developed a Combined sliding mode control (cSMC) algorithm to enhance the regenerative braking system of BEVs, effectively preventing wheel lock-up and improving energy recovery under various adhesion conditions. This contributes to increased efficiency and driving range, adding benefits in terms of safety and reliability.

Battery technology remains a critical area of focus, with various types, such as lithium-ion, solid-state, and nickel manganese cobalt, among others, being explored for optimal performance. Studies by Ahmed et al. (2018), Alamgir (2017), Boretti (2023), Mahmoudzadeh Andwari et al. (2017), Löbberding et al. (2020), and Sharma et al. (2020) have indicated that no single battery technology excels in all performance metrics, necessitating trade-offs among efficiency, emissions, and range. Innovations aimed at improving energy density, recyclability, and charging capabilities are seen as pivotal, with advancements in battery packaging and operating voltages offering potential cost reductions and environmental benefits.

Ambient temperatures and driver behavior also significantly affect BEV performance, especially that of BEBs. Hao et al. (2020) noted that extreme temperatures increase energy consumption and reduce energy range, with real-world usage often deviating from standard test cycles such as the NEDC. This deviation is particularly notable in BEBs, which operate in urban stop-and-go conditions and are strongly influenced by environmental and behavioral factors (Benoliel et al., 2021). Machine learning and advanced algorithms such as those developed by Tang et al. (2021) and Ganesh and Xu (2022) are being utilized to optimize various BEV systems, including cooling and overall operational efficiency, although real-world application challenges remain. Gao et al. (2019) promoted technical improvements such as eco-driving and strategic coasting to increase BEV efficiency and reduce energy losses, particularly in the context of the unique performance demands of BEBs (Blades et al., 2024).

In terms of vehicle design, studies such as those by Mayyas et al. (2017), Momen et al. (2016), and Ruan et al. (2019) have highlighted the

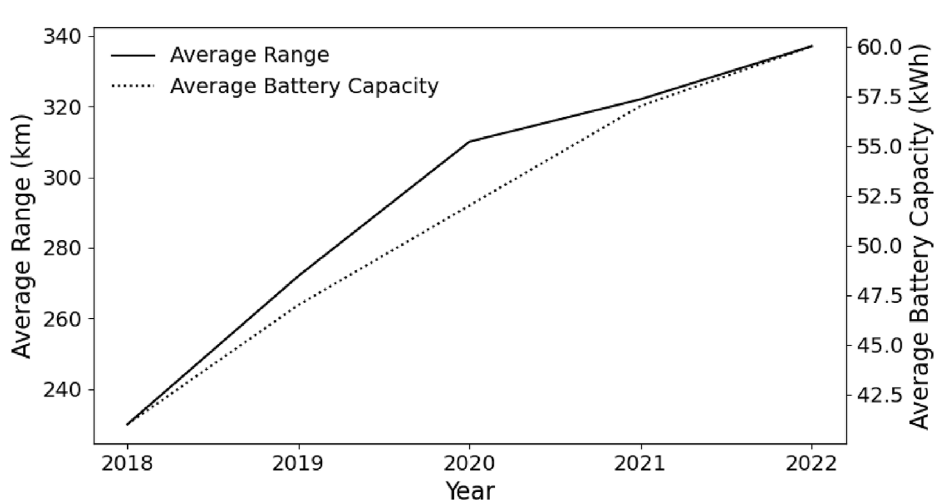

Fig. 1. Average BEV range and battery capacity over time (McKerracher, 2023).

importance of utilizing lightweight materials and making specific improvements in motor and transmission systems to increase the overall energy efficiency and sustainability of BEVs. For example, integrating an electrified continuously variable transmission system with a hybrid energy storage system has shown potential in optimizing vehicle dynamics and extending battery life.

Infrastructure development is another critical area, with research focusing on the strategic placement of charging stations and the adoption of dynamic wireless charging systems to improve usability and reduce range anxiety. Studies by Bauer et al. (2019), Figenbaum (2020), Ngo et al. (2020), Van der Meer et al. (2018), and Zhang et al. (2015) have emphasized the need for a well-coordinated charging infrastructure to match the service levels of conventional vehicles while minimizing operational costs and emissions. Smart charging strategies that align charging times with periods of low grid carbon intensity, as studied by Huber et al. (2021), can further reduce the carbon footprint of BEVs.

Overall, the current research landscape underscores a multidimensional approach involving technological innovations, infrastructure enhancements, and strategic policy interventions to optimize the performance and environmental impact of BEVs. These efforts are crucial as the adoption of electric vehicles continues to grow, driven by global efforts to mitigate climate change and enhance sustainable transportation.

1.4. Aims and research questions of the review

The volume of research concerning the determinants that influence BEV performance has been on an upward trajectory, paralleling the growth of the BEV market. Initially, environmental concerns such as emissions, energy efficiency, and the depletion of fossil fuels may have steered the development and research of BEVs. However, as the field has matured, the evolution of BEVs has been fuelled by innovative developments and combinations of key components. These advancements have generated robust research drivers across various scenarios, including driving range, accessibility, battery capacity, charging methods, transportation choices, and even in contexts such as vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) interactions. In summary, as future transportation paradigms progress, the scope of determinants and scenarios encompassed by these studies is expected to expand.

Given the trend in the literature and the growth trajectory of the BEV market, it is essential to review the key factors that affect BEV performance and understand how they influence the research. This is crucial to avoid potential duplications in research efforts. Preliminary surveys indicate that the relationship between performance and determinants is complex and interdependent, with a blurred hierarchy of classification. Therefore, there is an acute need for a unified and efficient framework and process. This framework synthesizes the characteristics pertinent to BEVs and highlights how they impact future transportation solutions, environmental issues, and socioeconomic factors.

In light of the themes considered in this study and the objectives described above, the research questions for this review are formulated as follows:

RQ 1: Within the many electric vehicle scenarios, how are critical components discerned, and how are the determinants of vehicle performance subsequently delineated?
RQ 2: In what ways does conducting a literature review enhance our comprehension of the interrelations and causal connections between the identified determinants and electric vehicle performance metrics?
RQ 3: What are the emergent key subtopics that stand out as potential focal points for future research in this domain?

These questions aim to guide a structured exploration of the current landscape and future trajectory of electric vehicle performance research.

1.5. Originality and structure of the review

The originality of this study in the realm of BEV performance research is distinguished by its theoretical contributions and policy-relevant insights. Our framework goes beyond traditional keyword-based analyses, providing a more intricate understanding of BEV performance determinants. In doing so, the study becomes a valuable resource for policymakers, who are advocating for informed policy development that incorporates comprehensive impact analysis.

The originality of this review lies in the following:

1) Theoretical contributions: This study introduces an advanced framework for evaluating BEV performance, focusing on the detailed identification of components and determinants. This provides a more complex and dynamic understanding of BEV performance.
2) Policy-relevant review: This review supports policy development by offering a synthesized view of current research, highlighting the need for policies that are responsive to advancements in the BEV sector and suggesting more practical impact analysis methods.

The structure of this paper is organized as follows:

Section 2, “Methodology”: This section introduces the methodology used in the literature review, including the keywords used for literature retrieval, selection criteria, and the research questions addressed.

Section 3, “Identification of the determinants”: This section presents the logic structure for determinant identification and analysis, organizing the discussion around key components and processes, supported by a review of relevant literature to systematically analyze and discuss the determinants identified.

Section 4, “Integrative analysis”: Having identified the key determinants, this section delves deeper into how these determinants affect the performance of important components and processes, and subsequently, the overall performance of Electric Vehicles (EVs).

Section 5, “Discussion”: This section summarizes the determinants across four dimensions: environmental, technical, policy-economic, and operational behaviors. It also offers suggestions on how these determinants can be utilized for future research and the development of EVs.

Section 6, “Conclusions and future research directions”: The conclusion recaps the entire paper and outlines future research directions.

2. Methodology for literature review

The surge in research publications within a rapidly growing field can lead to redundancy and slow the field's progression while also making literature reviews time-consuming for researchers. Review papers address these issues by summarizing existing research, identifying gaps, and suggesting future directions. Paul et al. (2021) emphasized the importance of review papers meeting high standards, including comprehensive summaries and guidance for future studies, and suggested that they should be published in reputable journals to ensure quality and reach.

Review papers should adhere to a meticulous and logical framework to provide accurate conclusions. The process for writing these papers has become more systematic over time and varies by field. The key steps in writing a review include defining the topic, deciding on the review type and questions, establishing search strategies and criteria, and conducting a systematic analysis.

This paper applies the scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR) protocol proposed by Paul et al. (2021) in conjunction with the subject matter of this paper and the steps for establishing an SLR, as suggested by Massaro et al. (2016). Similar to the review paper by Liu et al. (2023), the following research sequence is proposed:

1) Formulate inquiry questions.
2) Draft research guidelines.
3) Select study types, keywords, and perform literature search.
4) Set the framework for review analysis.
5) Analyze and critically discuss the findings.
6) Suggest avenues for future research.

2.1. Search strategy

The literature search results for this study were retrieved primarily from the Web of Science platform. Since the focus of this study is to investigate the key factors influencing BEV performance and how they influence BEV performance, a comprehensive search strategy was employed to consider all potential scenarios and related research topics. The primary keywords were linked via "AND" to combine essential concepts, whereas different expressions and synonyms of the keywords were connected via "OR" to broaden the search scope. The advanced search string was as follows: TS = ((BEV) AND (performance OR efficiency OR "driving range" OR "charge time" OR acceleration OR "energy consumption" OR "emissions")).

The literature search conducted on platforms such as Web of Science returned a total of 1,250 articles related to the performance of BEVs, focusing on aspects such as efficiency, driving range, charge time, acceleration, energy consumption, and emissions.

After several layers of screening and review of the collected literature, the vast majority of the articles focused on the technological determinants and overall performance of BEVs. Additionally, a significant number of studies have concentrated on the impact of environmental determinants on emissions. There were fewer articles covering other types of determinants, but those that met the selection criteria were also discussed in this paper. The results of all the statistical screenings are detailed in Section 4, with an appendix providing a comprehensive table that summarizes the coverage of literature on EVs' performance and determinants. This table categorizes determinants into four groups—Environmental, Technical, Behavioral, and Economic/Political determinants—as refined through repeated analysis and review. EVs' performance is classified into categories such as Overall Performance, User Experience, Economy, Sustainability, and Safety, with the classification criteria for performance detailed in Fig. 5 located in Section 3.2. For instance, if a study investigates the impact of technical factors on overall performance, this is noted in the table in the appendix. The process and analysis of how different influencing factors affect performance are also detailed in Section 4. This structured approach allows for a comprehensive understanding of the prevailing research trends and identifies gaps where further studies could be beneficial.

2.2. Inclusion and exclusion criteria

This systematic review and meta-analysis aim to identify the determinants that influence the performance of BEVs. We focus exclusively on the effects of technological advancements, environmental conditions, user behavior, and economic policies on BEV performance. To maintain clarity and relevance, we established strict inclusion and exclusion criteria.

- Inclusion criteria:
  Studies must focus on the intrinsic attributes of BEVs, including vehicle components and processes that directly affect performance. BEBs are also included in this review.
- Exclusion criteria:
  1) Studies that discuss consumer or government adoption decisions or use multicriteria and multi-objective decision-making methods are excluded, as these do not directly pertain to BEV performance itself.
  2) Research primarily exploring market adoption trends or socio-economic impacts on the popularity of electric vehicles is not considered, as our review concentrates on the performance characteristics of BEVs, not broader market dynamics.
  3) Comparisons between BEVs and other types of vehicles without a detailed analysis of BEV-specific performance factors are excluded.
  4) Studies on fleet management and traffic flow, while related to electric vehicles, do not directly contribute to understanding the core performance issues of BEVs and are therefore omitted.

By adhering to these criteria, our review focuses on the essential factors influencing BEV performance, ensuring that our analysis is both robust and directly relevant to advancing knowledge in this area.

2.3. Study screening and selection outcomes

As illustrated in Fig. 2, a total of 117 studies were included in the final analysis after comprehensive literature screening and subsequent manual inclusion. The initial search yielded many results predominantly covering the concept of BEVs. Further screening focused primarily on whether the topics of the papers directly investigated the factors affecting BEV performance or whether highly relevant and thematic information could be extracted from them. The entire procedure was conducted in accordance with the PRISMA guidelines (Moher et al., 2010), which involves four principal phases: identification, screening, eligibility, and inclusion.

2.4. Meta-analysis process

In our meta-analysis, we first conducted an initial review of the filtered papers to systematically organize the data. A framework was set up for a detailed examination, outlining the main pathways and logical sequences needed to address the research questions. This framework, along with its logical structures, is detailed with diagrams in Section 3. The second step refined the analysis on the basis of this framework and RQ 1. We identified the main scenarios and primary performance indicators relevant to our review theme and categorized this information into three main scenarios and five primary performance categories. In the third step, aligned with the framework and RQ 2, we discussed how various determinants affect the performance of BEVs. These determinants were classified into four categories: environmental, technological, behavioral, and political-economic.

Throughout the review process, we maintained logical coherence and applied a rigorous methodology. We also compiled statistical tables from the literature to provide a clearer picture of the research trends and gaps. Importantly, all categories and classifications of determinants and performance were based on the analytical framework from Section 3, and we did not record direct causal relationships that were not clearly evident in the literature.

3. Identification of the determinants

3.1. Logic structure for determinant identification

In exploring the complexities of BEV performance, it is essential to understand the interdependent relationship between performance indicators and their determinants. Performance metrics such as "ease of use" or "cost-effectiveness", often prioritized by consumers, are influenced by deeper underlying factors such as battery technology and vehicle design. This dynamic interaction illustrates that performance metrics can also serve as determinants depending on the context.

Our research systematically analyzes BEV performance across three lifecycle scenarios: driving, charging, and decommissioning. The driving scenario involves the conversion of electrical energy stored in the battery into mechanical energy by the electric motor, including V2V interactions.

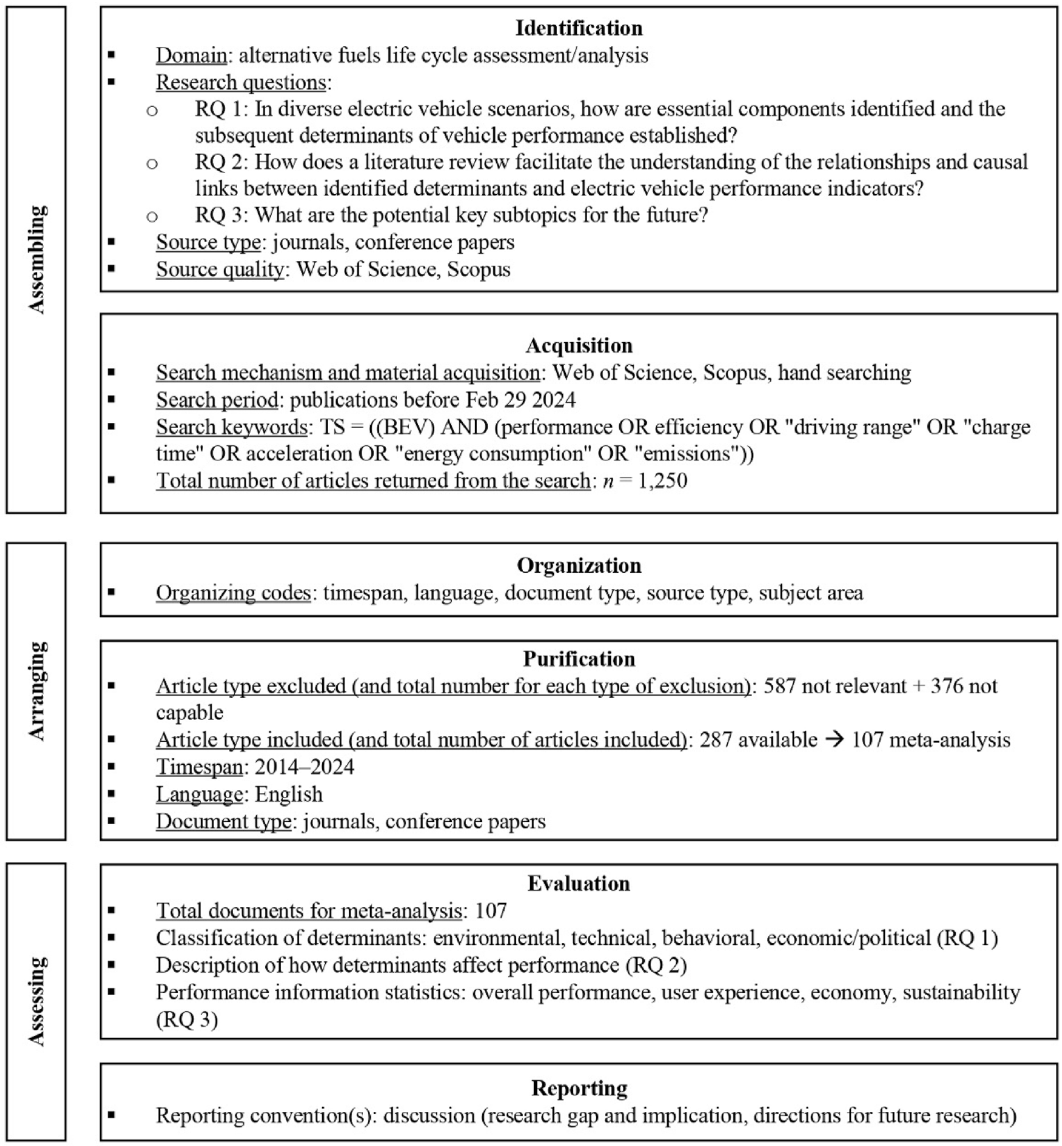

Fig. 2. SPAR-4-SLR protocol.

The charging scenario focuses on the battery receiving electrical energy through an on-board charger (OBC), with potential enhancements from fast-charging stations and innovative approaches such as wireless or photovoltaic charging, including V2G processes. The decommissioning scenario addresses end-of-life processes, particularly concerning battery recycling and disposal.

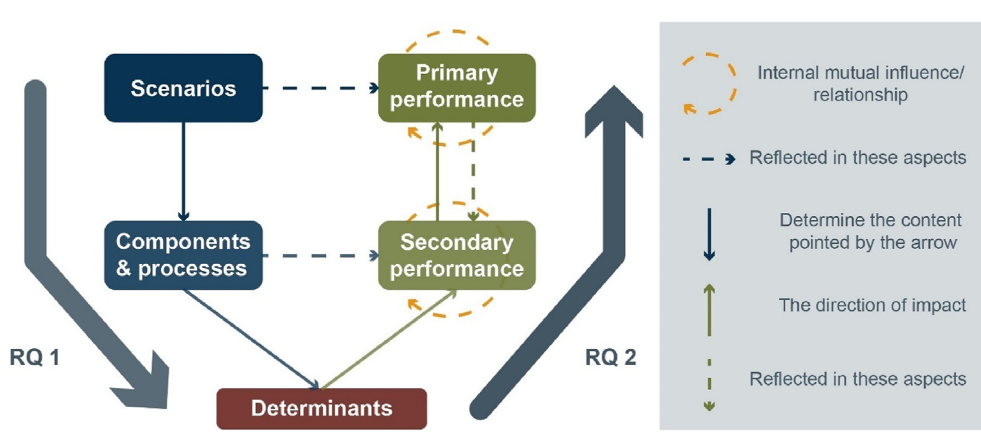

Fig. 3. Determinant identification and analysis logic structure.

Fig. 3 visualizes the identification and analysis of these determinants and scenarios, outlining the logical structure used to guide our research. The performance determinants are first identified on the basis of the components and processes involved in each scenario, as sourced from the literature, completing the resolution of RQ 1. Performance is then categorized into two levels: primary performance, which typically encompasses broad metrics such as user experience and sustainability, and secondary performance, which involves more specific metrics such as power performance, charging time, and emissions.

This detailed analysis provides a foundation for policy formulation and design improvements, ensuring efficient and effective satisfaction of different stakeholder needs. BEVs play multiple roles in contemporary society—not only as consumer products but also as crucial elements in reducing transportation emissions and as vehicles for transporting people and goods. Evaluating BEVs thus requires considering various usage scenarios across their lifecycle, helping to identify key performance indicators specific to each scenario and enhancing our understanding of BEVs' overall performance. This structured approach ensures a clear, logical, and rigorous presentation suitable for academic discourse, avoiding redundancy while maintaining the completeness of the information.

3.2. Application scenarios and primary performance metrics

Contemporary electric vehicles rely on a triad of core components—battery packs, traction inverters, and electric motors/generators—to store, convert, and convey energy, thereby facilitating vehicular propulsion. The principal conduits of energy flow include the electrical route, whereby electrical energy traverses from the battery to the electric motor via the inverter. On this basis, Fig. 4 is set up for further description.

The driving scenario encapsulates the regular utilization of electric vehicles, encompassing fundamental operations such as starting, maneuvering, and halting the vehicle. The key elements impacting the user experience during this scenario include the vehicle's powertrain performance, handling characteristics, stability, and ride comfort. Compared with traditional internal combustion engine vehicles, electric vehicles offer distinctive immediate torque responses and lower operational noise, enhancing the driving sensation. However, factors such as the driving range, charging requirements, and vehicle functionality are also crucial in evaluating the driving scenario for electric vehicles. The charging scenario describes the process of replenishing the electric vehicle's energy supply, involving steps such as connecting to a charging station, the actual charging process, and disconnecting upon completion. An effective charging scenario necessitates widespread and efficient charging infrastructure. When considering electric vehicles, users focus on the convenience of charging facilities, charging speed, and cost associated with charging. Therefore, optimizing the charging scenario is not only indicative of technological advancement but also a key driver in the adoption of electric vehicles. The end-of-life scenario, or scrappage process, involves a sequence of events from the cessation of an electric vehicle's use to its complete dismantlement or recycling. As electric vehicles reach the end of their designed lifespan, battery performance degradation and increased maintenance costs inevitably lead to their market exit. During this process, considerations such as how to handle batteries and other critical components to minimize environmental impact and ensure the maximum recovery and reuse of materials from decommissioned vehicles are paramount. Effective management of end-of-life scenarios is vital for the sustainable development of the automotive industry.

In summary, the driving scenario focuses on the performance and experiential aspects of using the vehicle; the charging scenario emphasizes the efficiency and convenience of energy replenishment; and the end-of-life scenario concerns the termination of the vehicle's lifecycle and environmental stewardship. Together, these scenarios constitute the comprehensive lifecycle management framework of electric vehicles, which plays a pivotal role in assessing their overall environmental impact and user satisfaction for academic and industry research purposes.

The categories for primary performance have also been broadly defined. Upon review, most performance terminologies have been classified into overall performance, user experience, sustainability, and economy. The interrelationships between these categories are illustrated in Fig. 5.

In categorizing the primary performance of BEVs, overall performance integrates critical factors such as power performance, which affects capabilities such as acceleration and hill climbing. Efficiency measures how well the BEV converts electrical energy to kinetic energy, influencing energy consumption and vehicle range—the distance a BEV can travel on a single charge. The charging speed impacts the vehicle's daily usability by determining how quickly the battery can recharge, whereas the battery lifetime indicates durability and value over time. User experience in BEVs centers on how users interact with the vehicle, covering usability for ease of operation, comfort in terms of physical and acoustic conditions during use, and reliability, which ensures consistent

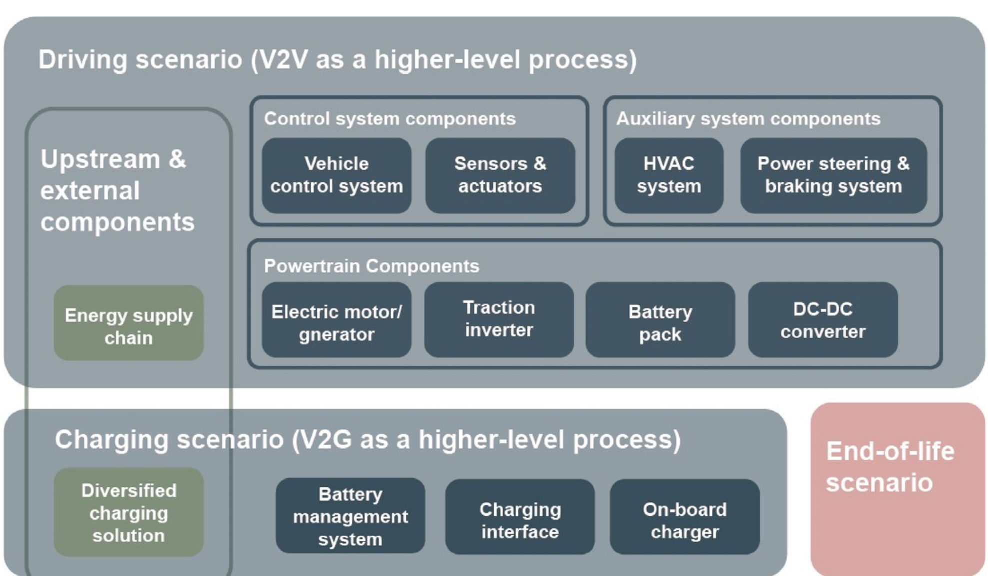

Fig. 4. Scenarios and the components and processes included in the scenarios.

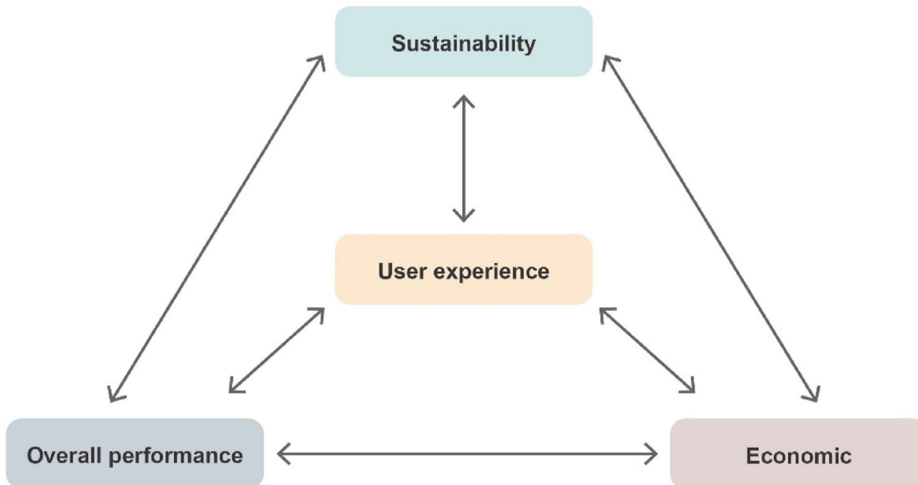

Fig. 5. Primary performance classification.

performance and reduces the likelihood of failure. The economy concerns the financial aspects of owning a BEV, including affordability or the initial purchase cost, maintenance costs, which are generally lower than those for conventional vehicles, and the total cost of ownership, which accounts for all expenses from acquisition to disposal. Sustainability involves evaluating the environmental impact of BEVs, particularly through emissions, which are lower than those of traditional vehicles, and recyclability, which focuses on the responsible disposal and material recovery of components such as batteries at their end of life.

These performance categories offer a holistic framework for assessing BEVs, spanning operational efficiency, user interaction, economic feasibility, and environmental considerations. This approach aids in understanding the comprehensive benefits and challenges associated with BEVs in promoting sustainable transport.

3.3. Component analysis and secondary performance metrics

This section is based on a simplified schematic diagram of a BEV, referred to as Fig. 6, which focuses on the flow of materials and energy. It includes key components such as the powertrain, charging systems, and electrical conversion units. Additionally, external components such as the direct current fast charging (DCFC) and the energy supply chain are considered in charging scenarios. Electric passenger cars and BEBs share similar key components, such as battery systems and electric motors, but differ in scale and application. BEVs are equipped with smaller batteries suited for personal use, whereas BEBs have larger batteries designed to support heavier loads and longer operational times. Furthermore, BEBs include more advanced cooling systems and drive systems tailored for frequent stops and high passenger volumes in urban environments. Various control systems, such as Thermal management systems (TMSs), play a critical role in BEVs. However, owing to their complexity and the multitude of components involved, these systems are not distinctly illustrated in the diagram. Moreover, the presence and sophistication of these systems are considered technical determinants in our research framework and thus are not depicted as in some other documents.

In Fig. 6, the components are categorized by their functions. Part A represents the BEV's power components, which work in combination to drive the vehicle during operation. Parts B, C, and D represent different

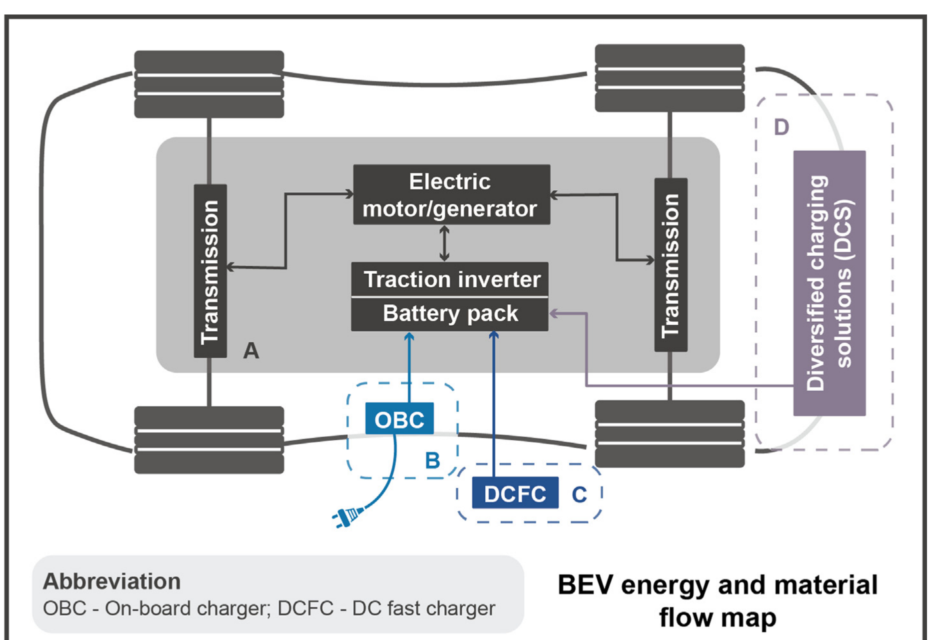

Fig. 6. Layout of BEVs.

charging components that are primarily involved in the vehicle charging process. Next, these components and the relevant processes are discussed in detail.

3.3.1. Battery pack

The battery pack in BEVs is a critical component that directly influences the vehicle's range, cost, safety, and environmental impact (Faraz et al., 2021). Lithium-ion batteries are predominantly used because of their high energy density and longevity; lithium iron phosphate batteries are noted for their safety and stability (Wen et al., 2020); nickel manganese cobalt batteries cater to long-range needs because of their high energy density (Shafique et al., 2023; Sun et al., 2020); and solid-state batteries represent a future technology with potentially increased safety and energy density (Mandade et al., 2023). These batteries are conFig.d in series or parallel to meet the desired voltage and capacity, affecting overall vehicle performance and cost (Dhameja, 2001; Offer et al., 2012). The battery management system (BMS) is crucial for maintaining battery health and performance, managing charging and discharging processes, controlling temperature, and monitoring states such as capacity and voltage (Mishra et al., 2021). The design of a BMS significantly impacts the operational efficiency and lifespan of the battery (Mishra et al., 2021). Battery degradation occurs over time, decreasing performance and capacity. This degradation is influenced by the number of charges–discharge cycles, operating temperatures, and efficiency of the BMS (Timilsina et al., 2023). In practice, the performance of batteries is significantly influenced by the environmental temperature and driving behavior. This often results in discrepancies between controlled laboratory tests and real-world outcomes, a phenomenon that is both common and crucial to understand in the context of BEBs (Guo et al., 2021; Han et al., 2019).

In 2017, Mahmoudzadeh Andwari et al. (2017) conducted a thorough review of technological advancements in BEVs, identifying key impediments to their widespread adoption and crucial performance metrics of BEV batteries such as energy density, power density, cycle life, and cost per kilowatt hour. They also noted the importance of volume, safety, energy efficiency, and self-discharge rates. A significant finding from their review is the nonlinear relationship between battery capacity and the BEV driving range; larger battery capacities do not linearly increase driving ranges because the added weight affects vehicle efficiency. Consequently, they suggest that energy density and power density are more appropriate measures for evaluating battery performance, especially when considering advanced parameters such as the driving range and road efficiency.

As the EV market evolves rapidly, battery technology continues to advance. Future research will explore enhancing battery energy density, extending lifespan, and reducing manufacturing costs (Fichtner et al., 2022). Additionally, finding more environmentally friendly battery recycling and processing methods remains crucial for addressing environmental challenges (Fan et al., 2020). Through technological innovation, BEV battery systems are becoming more efficient, safe, and environmentally friendly.

3.3.2. Traction inverter

In electric vehicles, the traction inverter is a pivotal component that transforms the battery's direct current (DC) into an alternating current (AC), which is essential for driving the motor (Vijaya Sambhavi and Ramachandran, 2023). This conversion not only enhances the motor's efficiency but also provides the requisite speed and torque (Jelodar et al., 2024). The design of the inverter, which typically utilizes efficient power semiconductors such as insulated gate bipolar transistors (IGBTs) (All-ca-Pekarovic et al., 2024) or metal–oxide–semiconductor field-effect transistors (MOSFETs) (Shi et al., 2023), significantly affects the vehicle's overall efficiency, power output, and range. These devices facilitate rapid switching and are integral for implementing advanced control strategies such as the maximum torque per ampere (MTPA) and optimizing performance (Cheng et al., 2024). Additionally, the inverter includes DC-link capacitors and employs a liquid cooling system to manage the heat generated from high-power conversion (Aviles et al., 2023; Jorge et al., 2024). The three-phase voltage-source inverter (VSI) topology is the prevailing operational architecture within traction inverters, where power devices play a crucial role (Vijaya Sambhavi and Ramachandran, 2023). The operational principle of VSI involves modulating six power switches to convert the DC input into three-phase AC output, with each phase being 120° out of phase with each other, creating an approximation of ideal sinusoidal AC waveforms (Kapustin and Shchurov, 2023). This detailed modulation underscores the technical nuances and concrete operational processes of the inverter, which are critical for achieving optimal vehicle functionality. Electric passenger cars and BEBs differ in their traction motor requirements, with BEVs typically featuring smaller, efficiency-focused motors, whereas BEBs require larger, more durable motors with higher power and torque to accommodate heavier loads, frequent starts and stops, and extended operational demands in urban environments (Blades et al., 2024).

For an in-depth understanding of these components and their interactions, it is advised to consult specialized literature, such as the study by Husain et al. (2021), which details the cost implications and operational dynamics of power devices in electric vehicle traction inverters, highlighting their significant cost, which accounts for approximately half of the drive system's expenses.

3.3.3. Electric motor/generator

The electric motor is an essential component for energy conversion in electric vehicles and plays a pivotal role in vehicle operation. It is adept at transforming electrical energy into mechanical energy, achieving conversion efficiencies ranging from 70% to 95% (Chau et al., 2008). Furthermore, during braking, the electric motor has the ability to recuperate mechanical energy back into electrical energy, contributing to the overall efficiency of the vehicle. Within the realm of electric motors, diverse types exist, including both DC and AC motors. BEVs predominantly utilize AC motors, which are available in three principal variations: induction motors, switched reluctance motors, and permanent magnet (PM) brushless motors. Each type of motor presents a distinct set of characteristics regarding structure, cost, reliability, efficiency, and power density, thus offering various advantages and trade-offs that cater to specific performance requirements and design considerations in BEVs (Mahmoudzadeh Andwari et al., 2017).

Compared with traditional vehicles, BEVs are particularly well suited to the stop-and-go driving conditions prevalent in large urban environments. Under such conditions, energy recovery capabilities, which are commonly found in current BEVs, become highly beneficial. The energy excessively released during transitions between motion and standing can be recovered and utilized for subsequent acceleration (Pratico et al., 2020). In contrast, internal combustion engine vehicles, owing to the characteristics of their power systems, maintain a relatively constant level of fuel consumption while driving, regardless of the vehicle's stop-and-go movement. They lack the ability to automatically adjust energy consumption in response to the driving conditions. As a result, the energy consumption of internal combustion engine vehicles can be more than triple that of electric vehicles. This dynamic emphasizes the importance of technical factors, such as energy recovery systems, in influencing the performance and efficiency of electric vehicles (Pratico et al., 2020). Ruan and Song (2019) proposed a novel dual-motor two--speed direct drive powertrain for BEVs that significantly enhances motor efficiency and extends the driving range. Their design strategically divides a single motor setup into two units, each equipped with fixed gear ratios optimized for varying driving conditions. This approach is fundamentally geared toward maximizing operational efficiency across typical driving scenarios.

3.3.4. Transmission

The transmission in BEVs is crucial for optimizing energy efficiency and enhancing performance by effectively translating electric motor power into motion (Tian et al., 2023). BEVs can incorporate various transmission types, such as single-speed and two-speed gear drives, along with advanced continuously variable transmissions (CVTs) such as half toroidal (HT), full toroidal (FT), and infinitely variable transmissions (IVTs). These systems, as emphasized by Bottiglione et al. (2014), adjust speed ratios to match the electric motor's efficiency map, which can significantly enhance energy efficiency and extend the driving range.

Drivetrain configurations such as front-wheel drive (FWD), Rear-wheel drive (RWD), and all-wheel drive (AWD) also play pivotal roles in vehicle dynamics and cost effectiveness. FWD systems are economical and suitable for urban driving but may struggle with handling under high-speed or high-torque conditions (Zhou et al., 2023). The RWD offers improved driving dynamics, which are ideal for performance cars, although it may have traction issues in adverse conditions (Heydrich et al., 2024). AWD provides excellent control and traction and is suitable for both high-performance and challenging terrains but at the cost of increased weight and increased expenses (Ruan et al., 2023). Thus, the choice of transmission and drivetrain is vital in BEVs, influencing not only their technical performance but also their overall vehicle efficiency and suitability for different environments. This strategic selection ensures that BEVs meet various driving needs while maximizing their operational effectiveness (Robinette, 2023).

3.3.5. Onboard charger

The integration of an OBC is crucial in BEVs, which are primarily responsible for converting an external AC from the electrical grid into a DC that can directly charge the vehicle's battery pack (Khaligh and D'Antonio, 2019). This process not only ensures effective charging of the battery but also helps extend its lifespan. According to standards set by the society of automotive engineers (SAE), OBCs are classified into three levels on the basis of their charging power: level 1 chargers offer a peak power of 3.7 kW and are suitable for home use and slower charging needs; level 2 chargers provide up to 22 kW of power, which is ideal for faster charging in residential and commercial applications; and level 3 chargers utilize three-phase AC power, with capacities ranging from 22 to 43.5 kW, which are primarily used in commercial settings and rapid charging stations (Pradhan et al., 2023). Khaligh and D'Antonio et al. (2019) conducted a comprehensive review of the utilization, standards, and categorization of OBCs for electric vehicles globally. Their research also explored potential solutions for high-power OBCs in anticipated usage scenarios, evaluating accessible metrics for various proposed solutions.

3.3.6. DC–DC converter

In BEVs, DC–DC converters are pivotal for adjusting voltage levels between the high-voltage main battery pack and lower voltage systems such as lighting and entertainment systems. These converters are categorized into boost, buck, and buck-boost types, each serving different voltage conversion needs (Turksoy et al., 2020). Additionally, they are classified on the basis of electrical isolation into isolated and nonisolated converters. Nonisolated converters, such as traditional and interleaved boost converters, are preferred for their simplicity and cost-effectiveness in low-to medium-voltage applications (Venugopal et al., 2023), whereas isolated converters, such as full-bridge converters, are chosen for their ability to provide electrical isolation and handle higher voltage gains efficiently (ElMenshawy and Massoud, 2020).

Different DC–DC converter topologies are tailored to varying operational principles and power levels. For high-power applications (above 10 kW), the multi-device interleaved bidirectional DC-DC converter (MDIBC) is optimal, offering low ripple, reduced electromagnetic interference, and high efficiency (Chakraborty et al., 2019). For lower power needs (below 10 kW), converters such as the sinusoidal amplitude converter (SAC) and Z-source DC-DC converter (ZVSC) are beneficial because of their soft-switching capabilities and noise reduction ability (Khan and Agrawal, 2023). In fast charging applications, technologies such as the Vienna Rectifier and Multi-Interleaved Step-Down Converters ensure high efficiency and effective control (Chakraborty et al., 2019). The advancement of wide bandgap semiconductor (WBGS) technology further enhances power density, reduces costs, and extends the lifespan of power electronics in BEVs (Chakraborty et al., 2019).

3.3.7. DC fast charger

In this study, the DCFC is analyzed as an external component of a BEV, which is specifically designed to convert AC to DC and rapidly charge the vehicle's high-voltage battery (Mateen et al., 2023). DCFCs provide significantly more power than standard household chargers do, enabling them to quickly charge a vehicle's battery to 80%, thereby increasing convenience by reducing charging time (Feng and Khan, 2024). By bypassing the vehicle's internal charger, DCFCs minimize energy conversion losses and improve charging efficiency (Mahmud et al., 2023).

The key components of a DCFC system include an AC to DC converter, a control system, a cooling system, and a user interface (Sawant and Zambare, 2024). The AC-to-DC converter is crucial for effective power conversion, whereas the control system regulates current and voltage for safe and efficient charging and communication with the vehicle. The cooling system prevents overheating, ensuring operational safety, and the user interface facilitates user interaction, allowing monitoring of charging status and management of payments (Xu et al., 2023).

Technological advancements in DCFCs, such as the adoption of wide bandgap semiconductors such as silicon carbide (SiC) (Xu et al., 2023) and gallium nitride (GaN) (De Seram et al., 2023), increase the conversion efficiency and reduce the charger size. Multiport designs and intelligent management systems for remote monitoring further improve functionality and encourage the broader adoption of electric vehicles (Bajpai et al., 2024). Importantly, in rapid charging scenarios, the high-power levels required are typically managed by the integral AC–DC conversion units within DCFCs, which provide significantly higher power than that available from household electrical sources and on-board chargers, thereby facilitating a faster charging process (Husain et al., 2021).

3.3.8. Diversified charging solution

In addition to standard and fast charging, BEVs are supported by several innovative charging technologies designed to increase convenience and integrate with broader energy systems. Wireless charging is one such technology, where vehicles are charged via electromagnetic fields generated by a transmitter in the ground and a receiver in the vehicle, allowing for cable-free charging while parked (Manivannan et al., 2023). Battery swap stations offer another alternative, providing a way to exchange a depleted battery for a fully charged battery within minutes, akin to refueling a conventional car, which is particularly useful for drivers in hurry or commercial vehicles that cannot afford long downtimes (Tarar et al., 2023).

V2G technology is another advanced concept where BEVs can contribute to grid stability by returning electricity to the network, especially during peak demand times or when there is surplus renewable energy (Straub et al., 2023). This system not only supports the electrical grid but also potentially allows vehicle owners to gain financial benefits through smart energy management.

Additionally, solar-powered charging is gaining traction, where solar panels are used either to directly charge the vehicle's battery or to power charging stations (Satheesan and Thankappan Nair, 2023). Some BEVs are even equipped with built-in solar panels that provide supplementary power, thereby extending the range and reducing the dependency on traditional charging infrastructure. These diverse technologies collectively expand the utility and appeal of BEVs, promoting their integration into a sustainable and energy-efficient transportation future.

4. Integrative analysis

This section explores how various factors identified from the literature affect the performance of BEVs. Factors are categorized into environmental, technological, behavioral, and economic domains to analyze their specific impacts and interactions. The determining factors are categorized on the basis of their primary focus in the literature into environmental, technological, behavioral, and economic factors. This classification guides a detailed analysis of how each category affects BEV performance metrics. Case studies are also used to demonstrate the real-world effects of these factors on BEVs.

The decision to use this categorization rather than alternatives such as scenario-based approaches stems from several advantages. This classification scheme is broad and versatile and applicable across diverse studies, enhancing the adaptability and relevance of our research. This approach allows for clear identification of causal relationships and provides a thorough examination of how each factor influences BEV performance. Additionally, this method can be easily updated to reflect new research or technological changes, ensuring that the study remains current. It also facilitates the effective communication of findings and supports the systematic management of complex data, ensuring accurate and reliable analyses. This framework provides a robust basis for policymakers and industry stakeholders, helping them make informed decisions and implement effective strategies.

While the determinants have been categorized on the basis of analysis, it is essential to recognize that the factors influencing the performance of BEVs are multidimensional and complex (Philipsen et al., 2019). Technological advancement remains the core driver of performance improvements (Conway et al., 2021). However, other categories of determinants, such as environmental (Al-Wreikat et al., 2021) and behavioral (Günther et al., 2019; Neumann et al., 2015) factors, can also play significant roles. These factors may either act as primary factors or surface-level elements or interact synergistically with technological factors (Loganathan et al., 2021).

For example, the study by Agrawal et al. (2016) sheds light on how technical and behavioral determinants intertwine within the context of traffic networks to affect the performance and route choice behaviors of BEVs. Technical factors directly influence operational characteristics such as energy consumption rates and the efficiency of regenerative braking systems, which are crucial for determining viable route options. Conversely, behavioral factors, which are influenced by drivers' perceptions of vehicle performance and economic considerations such as range anxiety and energy costs, serve as surface-level elements that ultimately impact route decisions (Neubauer and Wood, 2014). This interplay between technical determinants and behavioral responses provides valuable insights for traffic planners and policymakers to enhance the integration and optimization of BEVs in modern traffic systems (Donkers et al., 2020).

On the basis of the categorization logic established earlier in the text, all the articles that underwent an in-depth review were labeled. These labels identify the various determinant categories and both major and minor performance classes involved. On the basis of these labeled results, a statistical analysis was conducted, and Fig. 7, a heatmap, was created to display the frequency of discussions in the literature regarding the determinants that affect BEV performance and their relationship with performance outcomes. This not only highlights hot topics but also reveals areas where discussion is lacking.

For instance, technological factors are the most frequently discussed determinants across all categories. In particular, the impact of technological factors on efficiency is the most extensively studied scenario. Following this, the influence of environmental factors on emissions has also received significant attention. However, although behavioral factors have been explored in terms of efficiency and emissions, both behavioral and economic policy determinants are relatively underdiscussed across all performance categories. This analysis not only helps us understand current trends and focal points in the research field but also highlights areas that may require more attention in future studies. For detailed statistical results and citation annotations, please refer to Table A1 in Appendix.

4.1. Environmental determinants

The performance and environmental impact of BEVs are significantly influenced by a range of environmental determinants. These factors not only dictate the operational efficiency and sustainability of BEVs but also play crucial roles in shaping broader strategies for their integration into automotive markets. This section reorganizes and synthesizes the research findings to provide a comprehensive perspective and insights into how environmental factors influence BEV performance.

4.1.1. Climate and regional environmental conditions

The influence of regional climate variations on BEV performance is profound. Yuksel and Michalek (2015) reported that, compared with milder climates such as the Pacific coast, colder regions such as the upper Midwest in USA have increased energy consumption and a reduced range of BEVs. Neubauer and Wood (2014) further highlighted that high temperatures accelerate battery degradation, necessitating robust cooling systems, whereas cold climates primarily challenge the efficiency of cabin heating systems. Wei et al. (2022) added that in colder seasons, the energy consumption rate (ECR) of BEVs increases by 39%, leading to a 30% reduction in the driving range, emphasizing the substantial impact of temperature extremes on electric vehicle performance. Under adverse weather conditions, studies indicate that the driving range can be reduced by up to 37.8% when the temperature decreases from 10–16 °C

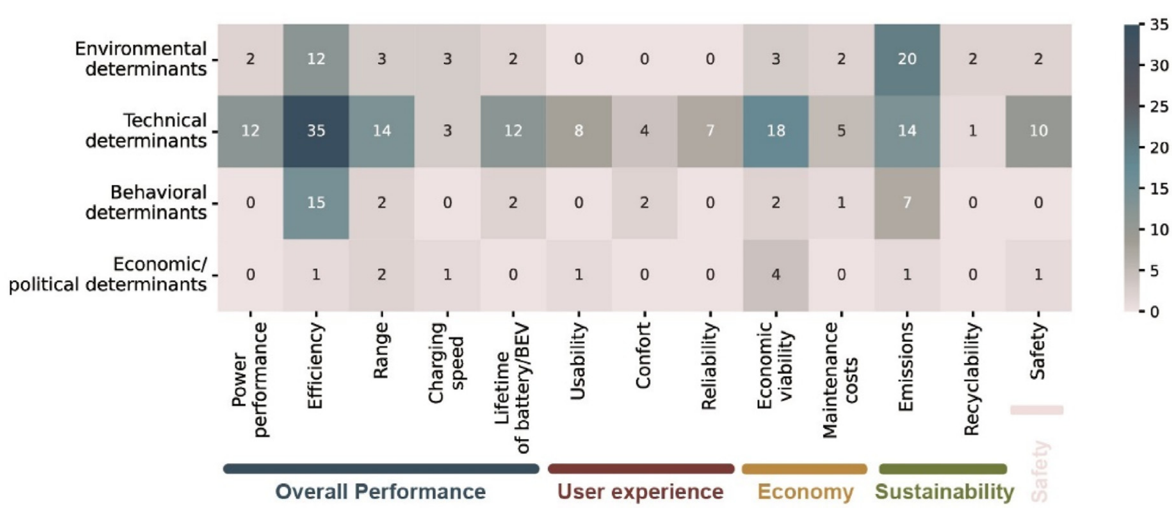

Fig. 7. Frequency analysis of BEV performance determinants in the literature.

to −6–0 °C (Rodrigues and Seixas, 2022). McGrath et al. (2022) analyzed the influence of environmental factors on double deck battery electric buses in four UK cities and demonstrated that variations in ambient temperature and geographical location significantly affect energy consumption, operational costs, and carbon emissions, with the bus range decreasing by up to 26% over the lifespan.

The performance of BEVs is significantly influenced by environmental conditions such as road grade, travel speed, and traffic conditions. Barco et al. (2017) discussed how these factors affect a vehicle's acceleration and deceleration rates, which in turn impact power consumption. The longitudinal dynamics equations of motion they use consider aerodynamic drag, rolling resistance, and gravitational forces on hilly terrains, illustrating how varied environmental conditions can directly affect the energy consumption of BEVs. Jonas et al. (2022) illustrated how traffic conditions can lead to additional energy consumption, emphasizing the benefits of choosing less congested routes and times for travel. In urban settings, the stop-and-go traffic and the distance to the vehicle ahead also influence BEV performance, as these affect the vehicle's aerodynamic drag and energy efficiency (Su and Chen, 2022). Mamarikas et al. (2022) reported that urban traffic strategies such as speed limitations can increase the energy efficiency of BEVs, whereas congestion mitigation measures provide significant benefits, demonstrating how traffic interventions can distinctly influence vehicle performance across different types of engines. Compared with traditional diesel buses, BEBs exhibit superior acceleration and deceleration capabilities; however, their performance is significantly influenced by the design of the driving cycles and changes in the road gradient (Tong and Ng, 2023). Technical factors such as the design of the power system and adjustments to the driving environment play crucial roles in the operational efficiency and adaptability of BEBs (Tong and Ng, 2023). Additionally, it is important to consider the emission of particulate matter from tires and road wear, which varies according to the terrain over which the vehicle travels. This aspect of environmental impact, often overlooked, can be significant, especially in areas with rough or uneven road surfaces where increased friction leads to higher emissions of these particles (Gieré and Dietze, 2022).

4.1.2. Energy supply chain cleanliness and the renewable energy transition

The source of electricity used to charge BEVs plays a pivotal role in determining their overall environmental impact. Studies by Tamayao et al. (2015) and Yuan et al. (2015) illustrated that regions relying on cleaner energy sources or renewable energy exhibit significantly lower lifecycle emissions for BEVs. In contrast, regions that are dependent on coal for electricity generation face higher emissions. This is supported by Ke et al. (2017), who noted improvements in BEV efficiency in Beijing with an increase in renewable energy in its electricity mix. Bauer et al. (2015), Tran et al. (2012), and Campanari et al. (2009) reported that the cleanliness of the energy supply chain is crucial for minimizing greenhouse gas emissions throughout the lifecycle of BEVs. Furthermore, the impact of the energy supply chain on BEV emissions/cost extends beyond the simple calculation of grid carbon intensity. This process likely involves factors such as marginal grid energy (Thomas, 2012) and charging times (Li et al., 2023b). Essentially, the priority of electricity supply varies by generation type, and BEV charging may not always utilize cleaner energy, especially during peak demand times when fewer clean power sources are more frequently used (Huber et al., 2021).

Wang et al. (2020) added that the lifecycle water usage for BEVs in China is 50% higher than that in USA, largely because of a greater reliance on hydropower in China. This finding emphasizes the importance of transitioning to solar and wind energy, which can not only improve the energy and water efficiency in BEV production but also support sustainable development in the electric vehicle sector.

Koroma et al. (2022) demonstrated that transitioning to a higher proportion of renewable energy sources in the electricity mix can significantly mitigate the climate change impact of BEVs, resulting in a 9.4% reduction in climate impact. This transition not only reduces greenhouse gas emissions but also enhances the market presence of BEVs, as highlighted by Choi et al. (2018), who suggest that a renewable-oriented electricity generation mix strengthens the environmental credentials of BEVs. Kawamoto et al. (2019) suggested that BEVs can achieve lower life cycle emissions in regions where the electricity grid relies less on coal and more on renewable energy sources.

4.2. Technical determinants

The performance of BEVs is significantly influenced by various technical factors, including the optimization of powertrain components, advanced energy management systems, and enhancements in thermal management systems. This section provides a detailed analysis of these technical aspects, demonstrating their crucial roles in improving BEV performance and efficiency.

4.2.1. Battery and powertrain technologies

The key technological advancements and their impacts on the performance of BEVs cover battery technology, power systems, battery lifecycle management, and the associated environmental and economic effects. The optimization of battery technology, including improvements in cell and pack design and the use of thicker electrodes, is crucial for increasing energy density and reducing costs, as noted by Sakti et al. (2015). Basma et al. (2022) proposed a comprehensive framework for battery sizing in BEBs that takes into account various operational conditions and charging infrastructure needs, and they demonstrated through a case study that urban buses often have unnecessarily large batteries for rare extreme weather conditions. This approach not only optimizes battery sizes on the basis of actual energy consumption but also provides insights that are crucial for efficiently planning public transit network electrification. Effective BMSs are essential for extending battery life and enhancing efficiency through optimized charging strategies and thermal management, as highlighted by Neubauer et al. (2012) and Neubauer and Wood (2014). Additionally, rapid charging technologies not only accelerate the charging process but also may extend battery life and usability under various climatic conditions (Neaimeh et al., 2017). Ager-Wick Ellingsen et al. (2022) reported that the environmental performance of BEBs is influenced by the choice of battery technology, size, and charging methods, with smaller battery packs and fast charging options such as lithium titanium oxide (LTO) showing benefits, whereas larger packs and plug-in solutions present challenges. The efficiency of power systems directly affects BEV performance; for example, advanced rotor designs can reduce mechanical losses and increase efficiency (Momen et al., 2016). Furthermore, the latest propulsion systems help reduce greenhouse gas emissions throughout a vehicle's lifecycle (Tagliaferri et al., 2016). Liu and Wang (2017) discussed the integration of advanced wireless power transmission technologies in electric vehicles, which allows for dynamic charging while driving, thus directly enhancing the driving range and charging speed. Battery aging is a complex phenomenon that affects the performance and range of electric vehicles through multiple factors (Lehtola and Zahedi, 2021). Accurately predicting battery health is crucial for enhancing vehicle efficiency and prolonging battery life, which is necessary to maintain vehicle performance (Zhang et al., 2023). Managing battery efficiency decay, such as through refurbishment techniques, is also key to significantly extending battery life, reducing replacement frequency, and easing the environmental burden of new battery production (Koroma et al., 2022). Advanced battery technologies may increase emissions during the manufacturing stage but significantly reduce greenhouse gas emissions throughout the entire lifecycle of BEVs (Tagliaferri et al., 2016). The structure and material choices of batteries, such as anode materials, play a critical role in lifecycle emissions and sustainability (Dunn et al., 2012). In terms of battery recycling and prerecycling technologies, employing techniques such as infrared (IR) measurement and gas chromatography–mass spectrometry (GC–MS) can greatly increase recycling efficiency and reduce the energy used in recycling processes (Pražanová et al., 2023).

Kim et al. (2016) discussed the benefits of different recycling processes at the end of the lithium-ion battery lifecycle, noting that direct physical recycling can reduce the energy consumption of battery material production by approximately 48% in a closed-loop system. Through these technological advancements and management strategies, BEV performance can be improved, battery life can be extended, and environmental impact can be reduced, all while increasing consumer confidence in BEV technologies. In addition to battery technology, other powertrain components in BEVs are crucial for enhancing vehicle performance. Researchers have focused on optimizing the topology of these components to achieve higher efficiency, stability, and safety. The safety of BEBs primarily hinges on technical factors such as battery design and management (Rodrigues and Seixas, 2022).

Traction inverters, for example, are vital because of their high power density and efficiency, which directly influence vehicle dynamics (Reimers et al., 2019). Researchers have innovated in the design of these inverters to allow them to deliver significant power within a compact space, which is crucial for reducing vehicle weight and conserving space, thus enhancing overall performance (Anwar et al., 2015; Goli et al., 2021; Poorfakhraei et al., 2021). High efficiency in inverters ensures minimal energy loss during power conversion, maintaining optimal vehicle operation. Similarly, advancements in DC–DC converters have been targeted by different researchers to increase their efficiency and reliability (Chakraborty et al., 2019). These converters are essential for maintaining stable voltage levels across various vehicle subsystems, ensuring efficient power management, especially in DCFC use (Hao et al., 2021; Jyotheeswara Reddy and Natarajan, 2018; Venugopal et al., 2023). Optimizing their topology has led to improved performance in terms of energy conversion efficiency and operational stability, which is crucial for the overall electrical system of BEVs and the range (Hao et al., 2021). Yang et al. (2022a) explored the enhancement of BEBs through a hybrid energy storage system that integrates batteries and supercapacitors, employing an energy control strategy to mitigate pulse currents from opportunity charging, thereby improving the battery lifespan and extending the range. Transmission systems in BEVs, though simpler than those in internal combustion vehicles, also benefit from research into their optimization (Gao et al., 2022). By refining the structural design and function of these systems, researchers aim to improve the energy transfer efficiency and enhance the drivetrain responsiveness (Ruan et al., 2016, 2018, 2019). This optimization directly impacts the acceleration, driving smoothness, and overall energy consumption of the vehicle (Du et al., 2021; Xue et al., 2020).

These efforts underscore a broader trend in BEV development, where the refinement of each component's topology through innovative research contributes significantly to vehicle efficiency, stability, and safety, thereby enhancing the user experience and environmental benefits.

4.2.2. Vehicle dynamics and operational efficiency

Optimized charging infrastructure and strategies are crucial for operational efficiency. The battery range optimization model (BROM) by Zhou et al. (2020) shows how tailored charging strategies can satisfy extensive travel demands. Additionally, the energy requirements of connected and automated vehicle subsystems need efficient management to optimize the overall energy and emissions footprint (Gawron et al., 2018). Advanced route optimization and energy consumption models can further address economic determinants, improving cost efficiency and market penetration (Wang et al., 2018a). Technological capabilities significantly shape the user experience. Familiarity with BEV range capabilities can alleviate range anxiety (Rauh et al., 2015), whereas advanced transmission systems improve driving comfort and reliability (Ruan et al., 2016).

Grunditz and Thiringer (2016) provided a comprehensive analysis of how vehicle size, weight, motor performance, and battery specifications affect energy consumption and performance metrics across different BEV categories. They emphasized that high-performance and sports BEVs typically exhibit superior power-to-weight ratios and battery performance, which are crucial for achieving outstanding speed and acceleration and are vital for overall vehicle performance. Additionally, Brendel et al. (2018) introduced a complex framework that integrates modules for energy demand prediction, battery charge scheduling, and vehicle selection. By performing discrete-event simulations with vehicle rental data, they demonstrated that these technical strategies not only improve charge scheduling but also significantly increase the efficiency and range of electric vehicles.

Beddows and Harrison (2021) and Rangaraju et al. (2015) discussed how regenerative braking and auxiliary energy systems not only reduce particulate emissions but also increase energy recovery, with auxiliary systems accounting for a significant portion of well-to-tank emissions. Yuan et al. (2015) explored the effects of the rolling resistance and aerodynamics on the driving range and emissions, indicating how these factors critically affect BEV performance. Additionally, Forrest et al. (2020) address the needs of heavy-duty BEVs, particularly the need for higher charging rates and expanded charging infrastructure to efficiently meet travel demands. Al Haddad et al. (2020) developed a genetic algorithm-based control strategy for heat pump systems in BEBs, which reduces energy consumption by 36% under both transient and steady-state conditions. This strategy significantly enhances the driving range of BEBs, especially in cold weather, by optimizing the system's performance coefficient.

4.2.3. Advanced communication, charging, energy management, and safety technologies

Research in the field of BEVs has significantly advanced the efficiency and cost-effectiveness of these systems. Wang et al. (2018a, 2018b) and Lu et al. (2019) focused on optimizing travel routes, energy consumption, and charging strategies, utilizing V2V communication to enhance regenerative braking. These technological enhancements not only increase energy efficiency but also improve the sustainability and cost effectiveness of BEVs by reducing emissions and decreasing ownership costs.

Although safety considerations in BEV discussions may receive less public visibility, they are nonetheless vital (Aalund et al., 2021; Xu et al., 2020). Topics such as structural integrity for crashworthiness and thermal management systems designed to prevent battery fires are consistently addressed by researchers and manufacturers, ensuring that safety remains a cornerstone of BEV development (Zhang et al., 2018). Gawron et al. (2018) reported challenges such as the increased weight and power requirements of connected and autonomous vehicle (CAV) subsystems, which can increase the overall energy and emission footprint by potentially increasing aerodynamic drag. In terms of environmental impact mitigation, Gryparis et al. (2020) and Ke et al. (2017) emphasized the significant role of emission controls at power plants in reducing the indirect emissions associated with the electricity used for charging BEVs. These improvements contribute substantially to the overall sustainability of the electric vehicle ecosystem. Pei et al. (2024) demonstrated that the performance and cost efficiency of electric bus transit systems are significantly influenced by the type of charging infrastructure and operational parameters, such as the fleet size and bus route characteristics, with a focus on optimizing these factors to increase sustainability and economic viability.

Furthermore, the development of cutting-edge charging and energy storage technologies, such as wireless charging systems and advancements in battery energy density, is critical for the future progress of BEVs. Researchers such as Burd et al. (2021) and Mohamed et al. (2017) highlight that these technologies are essential not only for reducing battery costs but also for improving operational efficiency. By decreasing the reliance on high-cost materials, these advancements play a significant role in shaping the sustainability trajectory of BEVs, making them more accessible and environmentally friendly.

4.3. Behavioral determinants

Behavioral determinants play crucial roles in the performance and acceptance of BEVs. These factors not only influence energy consumption and emissions but also affect the user experience and vehicle choice.

4.3.1. Influence of driving behavior and route selection

The operational efficiency of BEVs is significantly affected by driving behavior and traffic conditions. Fiori et al. (2018) utilized real-time GPS data to analyze how different traffic scenarios affect BEV energy consumption. Their findings indicate that faster routes increase energy consumption, whereas congested and slower routes reduce energy consumption because of regenerative braking systems. However, this comes at the cost of longer trip durations and potential delays. Additionally, Álvarez Fernández (2018) emphasized that human driving patterns, including aggressive driving, significantly affect BEVs' GHG emissions and energy efficiency.

Driving behavior, particularly driver aggression, significantly impacts the energy consumption and utility of BEVs, as identified by Neubauer and Wood (2014). Such behaviors influence the battery temperature and increase energy consumption rates, underscoring the need to adapt BEV systems to various driving styles. Additionally, Liu and Wang (2017) emphasized the role of user preferences in route selection, which affects the practicality of BEV charging infrastructure. Bi et al. (2019) further explored how optimal driving speeds, adjusted for seasonal temperature variations, can enhance BEV efficiency, indicating that behavioral adjustments in driving speeds on the basis of environmental conditions are crucial for optimizing BEV performance.

The study by Gawron et al. (2018) highlights how adopting driving behaviors such as eco-driving and platooning can lead to substantial reductions in energy consumption and greenhouse gas emissions, provided that these practices are effectively implemented. This finding demonstrates the significant impact that driving behavior and route selection have on the environmental footprint and efficiency of BEVs. Hasan et al. (2020) demonstrated that eco-driving behaviors, characterized by smoother velocity changes and controlled acceleration, significantly enhance the energy efficiency and performance of BEBs by optimizing energy management strategies and utilizing regenerative braking.

4.3.2. Impact of behavioral adaptation and experience

Behavioral adaptation to BEV technology is critical for enhancing vehicle performance. Neumann et al. (2015) reported that drivers transitioning from traditional vehicles to BEVs adapt to new eco-driving strategies within three months, which significantly improves energy efficiency and reduces range anxiety. Rauh et al. (2015) further support this finding by noting that experienced BEV drivers show less anxiety and a more positive evaluation of the vehicle's range than inexperienced drivers do. This suggests that familiarity with and comfort with BEV technology can mitigate some of the initial drawbacks perceived by new users. Günther et al. (2020) explored how the application of persuasive strategies, including feedback, gamification, and financial incentives, can profoundly influence the energy consumption behaviors of BEV users. These strategies encourage drivers to adopt more energy-efficient driving habits, showcasing how behavioral modifications, facilitated through engaging and rewarding interactions, can enhance the overall performance of BEVs without relying solely on technical advancements.

4.3.3. Charging infrastructure and consumer behavior

The availability and perception of charging infrastructure also play pivotal roles in shaping consumer behavior and vehicle performance. Neaimeh et al. (2017) and Nykvist et al. (2019) noted that fast charging options can alleviate range anxiety, potentially increasing daily driving distances and encouraging the adoption of BEVs. This behavioral change indirectly impacts the actual performance of BEVs as experienced by users. Van der Meer et al. (2018) highlighted the importance of optimizing charging strategies by considering behavioral patterns, such as the typical duration of workplace parking, to improve energy management effectiveness. Kostopoulos et al. (2020) emphasized the need to adopt optimal charging practices, specifically maintaining the battery's state of charge between 20% and 80%, to minimize losses and extend battery life, necessitating behavioral adjustments from users. Mohamed et al. (2017) analyzed how drivers respond to various charging rate scenarios influenced by psychological pricing and grid demand and suggested that aligning driver charging behaviors with grid capabilities and pricing strategies can optimize energy usage and cost efficiency. Additionally, Tamayao et al. (2015) highlighted that the timing of charging, whether immediate or delayed, can significantly impact emissions, with delayed charging often leading to higher emissions due to the increased proportion of coal-fired power at night. This underscores the environmental implications of charging behavior and the need for strategic planning in charging infrastructure to mitigate such impacts.

Pelletier et al. (2017) and Yang et al. (2019) focused on advancements in battery technology and charging infrastructure that have a direct impact on the practical aspects of BEV usage. Pelletier et al. (2017) discussed the relevance of empirical methods for developing capacity fade equations, which are crucial for understanding and mitigating battery degradation. Yang et al. (2019) introduced the asymmetric temperature modulation (ATM) method, which allows for rapid charging while maintaining high battery capacity, significantly surpassing the fast-charging targets set by the U.S. Department of Energy. These innovations not only improve the user experience by reducing charging times and extending battery life but also influence consumer behavior by making BEVs more appealing and practical.

4.4. Economic/political determinants

Economic and political determinants critically influence the performance and cost-effectiveness of BEVs. These factors determine financial support for BEV technologies, establish regulatory standards, and shape governmental incentives, all of which directly affect the development, operational costs, and consumer affordability of electric vehicles.

On the basis of a comprehensive review of the literature, it becomes evident that the impact of policy and economic factors on the performance of electric vehicles is challenging to define and correlate directly. This difficulty arises because the influence of these factors is neither straightforwardly linear nor precisely describable through conventional mathematical models. It is widely accepted from the literature that these factors predominantly affect the economic viability of electric vehicles. The nature of this impact can be dual, manifesting as either positive or negative, dependent on the characteristics of the policy or economic conditions and subject to changes over time and across different contexts. Consequently, the effects of policy and economic factors on electric vehicle performance involve multiple dimensions and interact with other variables in a nonlinear and complex manner, collectively shaping the final outcomes. Furthermore, there is a pressing need for more standardized scientific studies to elucidate the relationships involved, enhancing understanding and enabling more effective policy formulation.

4.4.1. Cost dynamics and market impact

The total cost of ownership (TCO) for consumers includes three main components: purchase cost, resale value, and operation cost, each of which can be further subdivided (Grube et al., 2021). For BEVs, the manufacturing cost primarily consists of the glider, drivetrain, and autonomous system, whereas the operation cost predominantly arises from fuel expenses and maintenance costs (Grube et al., 2021). As market conditions evolve and the costs associated with different processes and products in the supply chain change, the TCO of BEVs also fluctuates (Schwab et al., 2022; Zhou et al., 2023). Notably, the battery cost represents the largest single expenditure in the manufacture of BEVs. The cost of a battery depends on the types of essential materials used in its production and supply chains, reflecting the interplay between market factors and battery technology (Duffner et al., 2020).

The economic viability of BEVs can be measured through various cost calculations, including the TCO or the operational costs contained within it, which are of interest to consumers, manufacturers, and stakeholders throughout the supply chain. Considering the lifecycle of BEVs, different processes and supply chain segments have varying impacts on costs.

Ledna et al. (2022) noted that strategic investments in manufacturing technologies and future energy infrastructure are essential for reducing the lifecycle costs and emissions of BEVs. Huang and Kockelman (2020) analyzed how the profitability of EVCSs is critically dependent on the charging fees they impose. These fees directly influence the TCO for BEVs, affecting consumer adoption rates. Properly balancing these fees is essential for maintaining electric vehicle charging stations (EVCS) profitability while promoting broader BEV adoption. König et al. (2021) reported that the declining price of batteries, which currently constitute approximately one-third of the total vehicle cost, will drive down the overall cost of BEVs, making them comparable to ICEVs by 2030. This reduction in battery costs is pivotal, as it significantly influences the affordability and market competitiveness of BEVs. Ecer (2021) argues that more accessible pricing of BEVs could significantly increase their market penetration. BEBs face significant cost challenges, with purchase prices substantially higher than those of diesel buses, ranging from €350, 000 to €500,000 in Europe and $550,000 to $900,000 in USA, depending on battery capacity and location (Rodrigues and Seixas, 2022). These high costs are exacerbated by additional expenses for batteries, charging infrastructure, and necessary upgrades to existing facilities, alongside the need for substantial subsidies and incentives to offset initial investments.

4.4.2. Impact of financial incentives and cost reduction strategies

Financial incentives and cost reduction strategies typically manifest in various policy forms, which vary by country (geographical differences) and evolve over time (temporal differences). However, they can generally be summarized as aiming to reduce the costs of purchase and operation or to accelerate the construction of infrastructure. For instance, USA offers tax credits of up to $7,500 for the purchase of eligible new energy vehicles (Sheldon et al., 2023). Similarly, countries such as China and those in Europe reduce the purchase costs of electric vehicles through exemptions from purchase taxes, value-added taxes, or other forms of subsidies (Ji et al., 2022; Siebenhofer et al., 2021).

Economic incentives, especially subsidies, have been critical in making BEVs cost-competitive with ICEVs in China (Hao et al., 2014). As these subsidies are phased out, the sustained market viability of BEVs will increasingly depend on their inherent cost-effectiveness without reliance on government support. U.S. federal PEV subsidies have effectively increased electric vehicle adoption, with targeted incentives adapting over time to consumer and market changes (Sheldon et al., 2023). The $7,500 tax credit has notably increased PEV sales, although its impact varies by consumer income level (Sheldon et al., 2023).

Clinton and Steinberg (2019) explored the economic effects of state-level financial incentives on BEV adoption, emphasizing the significant impact of direct purchase rebates on increasing BEV registrations. Their analysis demonstrates that these rebates contribute to an approximately 8% increase in new BEV registrations for every thousand dollars of incentive, underscoring their effectiveness in promoting cleaner, energy-efficient transportation options. Yan (2018) analyzed the positive impact of tax incentives and cost reduction strategies on lowering the price and total ownership costs of BEVs. By reducing financial barriers through these incentives, BEVs become more accessible and economically feasible for a broader range of consumers. Ouyang et al. (2021) predicted that by 2025, small BEVs will achieve cost parity with ICEVs, highlighting the pivotal role of government incentives. They emphasized that robust policy support can effectively bridge the 31%–36% projected decrease in BEV prices between 2020 and 2030, thereby significantly influencing consumer adoption rates and the overall market trajectory for electric vehicles. Van der Meer et al. (2018) reported that an energy management system (EMS) could significantly reduce charging costs, influencing BEV adoption through lower operational costs.

4.4.3. Economic viability and production scales

The scale of production significantly impacts the economics of BEVs by enabling economies of scale, which reduce per-unit costs through bulk purchasing of materials, amortization of fixed costs, and enhanced production efficiencies (Burd et al., 2021; Zhou et al., 2023). Larger production scales also foster innovation and technology advancements, improving the efficiency and reducing the operational costs of BEVs (Zhou et al., 2023). Finally, increased production capacity enhances market competitiveness, enabling manufacturers to offer more competitive pricing and capture larger market shares.

Sakti et al. (2015) demonstrated that reaching production volumes of approximately 200–300 MWh annually is crucial for achieving economies of scale in BEV manufacturing, which stabilizes unit costs. However, they emphasized that further reductions in production costs, particularly for larger BEVs, largely depend on optimizing design features such as electrode thickness. By implementing these design changes, the cost per kWh can be significantly reduced, from $545 kWh^{-1} in smaller applications to $230 kWh^{-1} in larger BEV configurations, illustrating the profound impact of production scales combined with design optimization on cost efficiency. Nykvist et al. (2019) suggested that if battery pack costs drop to $150 per kWh, BEVs could compete in nearly half of the U.S. market segments. Ruan et al. (2016) assess the economic viability of multispeed transmissions in BEVs, concluding that they offer long-term savings through lower electricity consumption.

5. Discussion

The performance of BEVs is influenced by a myriad of factors ranging from environmental conditions to technological advancements, driving behaviors, and policy frameworks. A comprehensive understanding of these determinants is essential for enhancing the performance and sustainability of BEVs.

5.1. Environmental influences

1) **Temperature extremes**: BEVs, including BEBs, are notably sensitive to climatic conditions. Cold temperatures can reduce battery efficiency and diminish the driving range as the battery capacity decreases, and more energy is required for heating the vehicle. This is particularly significant in regions that experience severe winters where a decrease in temperature can lead to substantial reductions in battery performance. Conversely, high temperatures might accelerate battery degradation, adversely affecting vehicle longevity and performance. This is due to increased stress and potential thermal management issues that may arise during operation in hotter climates (Jaguemont et al., 2016; Yuksel and Michalek, 2015).
2) **Geographical terrain**: The performance of BEVs, including BEBs, also varies with geographic features such as road inclination and terrain roughness, which can significantly impact energy consumption rates. Hilly or mountainous terrains require more power for ascent, thereby reducing the overall range per charge cycle. Similarly, uneven or rough surfaces can increase the energy demand because of their lower rolling efficiency and higher mechanical resistance (Liu et al., 2017; Perger and Auer, 2020).
3) **Energy source**: The environmental benefits of operating BEVs are closely linked to the cleanliness of the electricity grid they utilize. In regions where electricity is generated from renewable sources such as wind, solar, or hydroelectric power, the positive impact on the environment is considerably enhanced. This results in lower net emissions and a smaller carbon footprint per vehicle. Additionally, hidden factors such as the conditions of the marginal grid and the

timing of charging play crucial roles. For example, charging BEVs during peak hours may lead to higher emissions if the marginal grid relies on nonrenewable energy sources. Conversely, charging during off-peak hours when renewable energy availability is greater can further reduce the environmental impact (Huber et al., 2021; Thomas, 2012; Wang et al., 2020).

5.2. Technological advancements

1) **Battery technology**: Innovations in battery technology, such as increased energy density and faster charging speeds, are critical for advancing the capabilities of both personal BEVs and BEBs. While improvements in fast charging technologies significantly increase convenience for personal BEVs, they are even more crucial for BEBs because of their larger battery capacities and the need for quick turnaround times in public transport schedules. Wireless charging, while beneficial for personal vehicles, could revolutionize how BEBs integrate into continuous public transit operations, potentially allowing for on-route charging without the need for long stops (Alamgir, 2017; Shafique et al., 2023).
2) **Powertrain efficiency**: Advances in electric motor and drive train technologies have increased the efficiency and performance of BEVs. For BEBs, the impact of these advancements is magnified because of the heavier loads and longer operational hours typical in public transport. Efficient traction inverters and optimized powertrain configurations not only enhance vehicle responsiveness but also significantly reduce energy consumption, which is paramount in maintaining the economic and environmental viability of BEBs over personal BEVs (Gao et al., 2022; Geiger and Bauer, 2023; Hao et al., 2021).
3) **Management systems and information communication**: Advances in electric motor and drive train technologies significantly enhance the efficiency and performance of BEVs, including BEBs. Efficient traction inverters, advanced motor designs, and optimized powertrain configurations not only improve vehicle responsiveness and drivability but also reduce energy losses, which extends the driving range and lowers operating costs. For BEBs, the integration of sophisticated energy and thermal management systems is essential to meet the rigorous operational demands and safety standards of public transportation. Additionally, V2V and vehicle-to-infrastructure (V2I) communications play crucial roles in improving the reliability and efficiency of BEBs by supporting better route management and schedule adherence, features that are particularly vital for public transit systems compared with personal BEVs (Chang et al., 2023; Lan et al., 2016; Satheesan and Thankappan Nair, 2023).
4) **Recycling technologies**: The end-of-life processing of BEVs presents significant environmental and economic challenges. These challenges are amplified in the case of BEBs because of their larger batteries and more complex systems. Effective recycling technologies and strategies are therefore critical for minimizing the ecological footprint and supporting the sustainability targets of public transport systems more than personal vehicle applications do (Pražanová et al., 2023; Rodrigues and Seixas, 2022).
5) **Charging infrastructure**: The design and operation of charging infrastructure must cater to the specific needs of both BEVs and BEBs. For personal BEVs, convenience and accessibility are key factors. However, for BEBs, the focus shifts toward high-capacity, fast-charging solutions that can be seamlessly integrated into bus depots and along routes to support continuous operation. This infrastructure must not only be robust but also capable of adapting to advancements in battery technology and the growing demands of urban transit systems, making it more complex than the infrastructure typically required for personal vehicles (Donkers et al., 2020; Rodrigues and Seixas, 2022; Xu et al., 2023).

5.3. Behavioral and operational factors

1) **Driving behavior**: The efficiency of BEVs is significantly influenced by driving habits. Behaviors such as frequent rapid acceleration and maintaining high speeds can lead to increased energy consumption, whereas the adoption of eco-driving techniques can considerably increase the overall vehicle range and reduce energy use. Eco-driving involves smoother accelerations, maintaining steady speeds, and optimizing the use of in-car energy-consuming features. Educational programs and real-time feedback systems can guide drivers to adopt these more efficient driving habits, thereby promoting a more energy-conservative driving culture. This not only extends the battery life but also contributes to the overall sustainability of BEV usage (Neubauer and Wood, 2014; Neumann et al., 2015).
2) **Charging behavior:** Charging behavior also plays a crucial role in the operational efficiency and longevity of BEVs. Optimal charging practices, such as avoiding frequent full charging cycles and instead maintaining the battery charge between 20% and 80%, can help preserve battery health and extend its lifespan. Additionally, timing the charging process during off-peak electricity hours can reduce charging costs and lessen the load on the power grid. Governments and utilities can encourage these practices by offering lower tariffs during off-peak hours and providing information on the best charging practices through educational campaigns (Patil et al., 2023; Rangaraju et al., 2015).
3) **Maintenance practices:** Regular maintenance and proper care significantly influence the operational efficiency and durability of BEVs. Unlike internal combustion engine vehicles, BEVs require less frequent traditional maintenance but do need regular checks of their electrical systems, battery health, and software updates. For BEBs, the emphasis on maintenance is even greater because of their continuous and demanding service schedules. Proactive maintenance ensures optimal performance and can prevent costly repairs. Educational outreach and service center initiatives can teach both personal BEV owners and BEB operators the importance of regular check-ups and how to maintain their vehicles properly, enhancing the driving experience and maximizing vehicle lifespan and reliability for both types of electric vehicles (Danilecki et al., 2023; McGrath et al., 2022).

5.4. Policy and economic support

1) **Regulatory support**: Policies and incentives are crucial for motivating both BEV adoption and technological advancement. Financial incentives, such as subsidies and tax rebates, make BEVs more affordable. For BEBs, specific incentives could include grants for public transit agencies to update fleets or build infrastructure that supports efficient operation. Stringent emission standards and regulations for battery manufacturing and recycling not only encourage cleaner production and sustainable practices for all BEVs but also support the large-scale integration of BEBs in public transport systems (Abdul Qadir et al., 2024; Du et al., 2019; Singh et al., 2021).
2) **Infrastructure enhancement:** Effective BEV adoption requires significant improvements in charging infrastructure. While expanding public charging stations benefits personal BEVs, BEBs need robust, high-capacity charging solutions strategically located at bus depots and key transit hubs. The integration of renewable energy sources in these infrastructures can enhance environmental benefits and make electric public transit more sustainable and appealing (Funke et al., 2019a; Mastoi et al., 2022; Rodrigues and Seixas, 2022).
3) **Technology and industry support:** Advancing BEV technology necessitates strong government support in research and development, particularly in batteries and drivetrain technologies. Policies encouraging partnerships among automakers, tech companies, and

universities can accelerate innovation and reduce costs. For BEBs, an additional focus on durable components and systems designed for high-use scenarios in public transportation can further strengthen the BEV market and support economic growth in this sector (Hao et al., 2024; Rissman et al., 2020).

4) **Educational and public engagement initiatives:** Public acceptance and knowledge of BEVs can be increased through educational campaigns and public engagement. Government-led initiatives should aim to educate consumers on the benefits of BEVs and organize public events such as expos and test drives to directly engage potential users, fostering a supportive culture for electric mobility (Broadbent et al., 2021; Huang et al., 2018).

In conclusion, the performance and sustainability of BEVs are influenced by a multidimensional interplay of technological, environmental, and behavioral factors. These determinants affect not only overall vehicle efficiency and longevity but also passenger comfort and safety. Importantly, the impacts of these factors are not linear; rather, the combined effect of multiple determinants often results in outcomes that are greater or lesser than the sum of individual influences. Therefore, there is a pressing need for more comprehensive evaluation systems and analytical research to explore these factors in depth. This will enhance transparency and facilitate better decision-making in the development and adoption of BEV technologies, ensuring that all stakeholders, including policymakers, manufacturers, and consumers, are well informed and collaboratively engaged in advancing the field of BEVs.

6. Conclusions and future research directions

The performance and sustainability of BEVs are influenced by a complex interplay of environmental, technological, behavioral, and political–economic determinants. This review systematically categorized and analyzed these factors to understand their impact across different operational scenarios. While the majority of the literature on BEV performance focuses predominantly on technological factors, which indeed play a leading role, studies addressing environmental and behavioral factors are less common. Discussions on political–economic factors are even rarer, possibly owing to their more straightforward impact processes. However, a comprehensive and intuitive evaluation system that addresses these determinants holistically is lacking, and research exploring the interdependencies among these factors is sparse, highlighting the complexity of the relationships between various elements and performance outcomes.

Technological advancements in battery and powertrain efficiency, coupled with environmentally conscious behaviors and supportive policy frameworks, are crucial for enhancing BEV performance. Moreover, geographical and climatic conditions significantly influence the operational efficiency of BEVs. Effective lifecycle management, including strategies for battery recycling and reuse, has emerged as essential for minimizing the ecological footprint of BEVs.

Addressing these diverse factors in a cohesive manner is imperative for stakeholders, including policymakers, manufacturers, and consumers, to foster the growth and acceptance of BEVs.

Given the gaps identified in the current literature and the complex interdependencies of the factors influencing BEV performance, future research should aim to do the following:

1) **Develop comprehensive evaluation models**: There is a need for more intuitive and comprehensive evaluation systems that integrate technological, environmental, behavioral, and political-economic factors. These models should facilitate the assessment of BEV performance in a holistic manner, considering all relevant determinants, including the distinct needs and operational contexts of BEBs, such as their higher usage rates and larger battery capacities.
2) **Explore interdependencies between determinants**: Future studies should delve deeper into the interrelationships among the various performance determinants. Understanding these interdependencies could lead to more effective strategies that leverage strengths and mitigate the weaknesses identified across different factors.
3) **Addressing environmental and behavioral research gaps**: While technological factors have been extensively studied, environmental and behavioral factors require more attention. Research should focus on how these factors influence BEV performance and user acceptance and how they can be optimized to enhance sustainability.
4) **Investigate political–economic influences**: Although political–economic factors have straightforward impacts, their detailed mechanisms and effects on BEV adoption and performance are less understood. Future research should explore how different policy frameworks, economic incentives, and regulations can be designed to support BEV deployment, with particular emphasis on the deployment of BEBs.
5) **Enhance lifecycle management strategies**: Further research is needed on effective lifecycle management for BEVs, particularly focusing on battery recycling and reuse. Studies should investigate innovative methods to improve the ecological footprint throughout the lifecycle of BEVs.
6) **Human-centric approaches**: Future studies should strive for greater transparency and adopt framework-oriented approaches that are human-centric. This focus will better understand and optimize the complex dynamics of BEV systems, ensuring their viability as a sustainable transportation solution.

By addressing these directions, future research can significantly contribute to optimizing the performance and reducing the environmental impact of BEVs, furthering their role as a sustainable mode of transportation.

CRediT authorship contribution statement

Fangjie Liu: Writing – original draft, Visualization, Validation, Resources, Methodology, Data curation, Conceptualization. **Muhammad Shafique:** Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Xiaowei Luo:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
Statistics of determinants and performance in the literature review

Ref.	Determinant				Performance												
					Overall performance					User experience			Economy		Sustainability		Safety
	Environmental determinants	Technical determinants	Behavioral determinants	Economic/ political determinants	Power performance	Efficiency	Range	Charging speed	Lifetime of battery/ BEV	Usability	Comfort	Reliability	Economic viability	Maintenance costs	Emissions	Recyclability	
Pei et al. (2024)	✓	✓											✓	✓	✓		
Teng et al. (2023)		✓										✓					
Tong and Ng (2023)	✓	✓			✓	✓											
Kang et al. (2023)		✓															✓
Koroma et al. (2022)	✓	✓				✓			✓						✓	✓	
Chakraborty et al. (2022)		✓					✓			✓					✓		
Yap et al. (2022)	✓	✓						✓							✓		✓
Abdul-Manan et al. (2022)	✓														✓		
Ager-Wick Ellingsen et al. (2022)		✓													✓		
Basma et al. (2022)		✓				✓											
Coban et al. (2022)		✓											✓				
Tang et al. (2022)	✓														✓		
Ahmed et al. (2021)		✓				✓											
Wei et al. (2022)	✓	✓				✓											
Mamarikas et al. (2022)			✓			✓											
McGrath et al. (2022)	✓						✓										
Oubelaid et al. (2022)		✓			✓												
Rodrigues and Seixas (2022)	✓	✓		✓		✓	✓						✓				✓
Rösch et al. (2023)		✓				✓											
Wang et al. (2022)			✓												✓		
Yang et al. (2022a)		✓					✓		✓								
Picatoste et al. (2022)		✓													✓		
Jonas et al. (2022)	✓					✓											
Beddows and Harrison (2021)		✓													✓		
Tang et al. (2021)		✓										✓					
Burd et al. (2021)		✓					✓						✓				
Ouyang et al. (2021)				✓									✓				
Huber et al. (2021)	✓							✓							✓		
Zhang et al. (2021)		✓															✓
Li et al. (2021)		✓															✓
Ahmed et al. (2021)		✓															✓
Yayan et al. (2021)		✓							✓								
Kuntz et al. (2021)		✓							✓								
Shelly et al. (2021)		✓					✓										
Wang et al. (2021)		✓								✓				✓			
Kurz et al. (2021)		✓													✓		
Sankaran and Venkatesan (2021)		✓					✓			✓							
Lamantia et al. (2021)		✓										✓					
Hao et al. (2020)	✓		✓			✓	✓										
Hasan et al. (2020)			✓			✓											
Kostopoulos et al. (2020)			✓			✓											
Petrauskienė et al. (2020)	✓														✓		
		✓					✓						✓				

(continued on next page)

Table A1 (*continued*)

Ref.	Determinant				Performance												
					Overall performance					User experience			Economy		Sustainability		Safety
	Environmental determinants	Technical determinants	Behavioral determinants	Economic/ political determinants	Power performance	Efficiency	Range	Charging speed	Lifetime of battery/ BEV	Usability	Comfort	Reliability	Economic viability	Maintenance costs	Emissions	Recyclability	
Löbberding et al. (2020)																	
Ambrose et al. (2020)		✓	✓												✓		
Al Haddad et al. (2020)		✓				✓											
Scorrano et al. (2020)	✓		✓										✓	✓			
He et al. (2020)		✓										✓					✓
Günther et al. (2020)			✓			✓											
Zheng et al. (2020)	✓														✓		
Figenbaum (2020)	✓							✓									
Koroma et al. (2020)	✓														✓		
Kleiner et al. (2019)		✓							✓								✓
Jenn et al. (2020)		✓													✓		
Sayed et al. (2020)		✓	✓			✓											
Dong et al. (2020)		✓								✓							
Chen and Rakha (2020)		✓			✓	✓											
Itoh et al. (2020)		✓				✓											
Rauh et al. (2020)			✓								✓						
Sankaran et al. (2020)		✓									✓						
Nykvist et al. (2019)				✓									✓				
Rupp et al. (2019)	✓		✓												✓		
Wu et al. (2019)	✓														✓		
Bi et al. (2019)		✓					✓										
Gao et al. (2019)		✓	✓			✓											
Ruan and Song (2019)		✓			✓	✓	✓						✓				
Lu et al. (2019)		✓				✓											
Bauer et al. (2019)		✓											✓				
Ruan et al. (2019)		✓			✓	✓			✓				✓				
Upadhyayula et al. (2019)		✓				✓									✓		
Sajadi-Alamdari et al. (2019)		✓					✓										
Baek and Chang (2019)	✓	✓			✓	✓											
Zhang and Zhuan (2019)		✓				✓					✓						✓
Wu et al. (2018)	✓		✓			✓									✓		
Van der Meer et al. (2018)		✓											✓	✓			
Gawron et al. (2018)		✓				✓									✓		
Choi et al. (2018)	✓														✓		
Álvarez Fernández (2018)	✓		✓												✓		
Peng et al. (2018)	✓														✓		
Safari (2018)		✓											✓				
Yan (2018)				✓									✓				
Ahmed et al. (2018)		✓							✓				✓				
Wang et al. (2018a)		✓				✓				✓			✓				
Wang et al. (2018b)		✓	✓			✓											
Luk et al. (2018)		✓													✓		
Eser et al. (2018)				✓											✓		
Ke et al. (2017)	✓					✓									✓		
Neaimeh et al. (2017)		✓					✓	✓		✓							
Mohamed et al. (2017)		✓								✓							

(*continued on next page*)

Table A1 (*continued*)

Ref.	Determinant				Performance												
					Overall performance					User experience			Economy		Sustainability		Safety
	Environmental determinants	Technical determinants	Behavioral determinants	Economic/ political determinants	Power performance	Efficiency	Range	Charging speed	Lifetime of battery/ BEV	Usability	Comfort	Reliability	Economic viability	Maintenance costs	Emissions	Recyclability	
Barco et al. (2017)		✓				✓			✓					✓			
Korta et al. (2017)		✓				✓											
Ruan et al. (2016)		✓			✓	✓							✓				
Tagliaferri et al. (2016)	✓														✓	✓	
Agrawal et al. (2016)			✓			✓											
Momen et al. (2016)		✓			✓	✓					✓	✓					
Arfa Grunditz and Thiringer (2016)			✓			✓											
Juergens et al. (2016)		✓				✓											
Liu et al. (2016)		✓				✓			✓					✓			
(Gopalakrishnan et al., 2017)		✓							✓								✓
Schönknecht et al. (2016)		✓											✓				
Barreras et al. (2016)		✓				✓	✓						✓				
Sergi et al. (2016)		✓				✓											
Tamayao et al. (2015)	✓														✓		
Rauh et al. (2015)			✓								✓						
Sakti et al. (2015)		✓											✓				
Rangaraju et al. (2015)	✓		✓			✓									✓		
Yuan et al. (2015)	✓	✓	✓			✓									✓		
Zhang et al. (2015)		✓		✓			✓	✓		✓							
Neumann et al. (2015)			✓			✓											
Li et al. (2015)		✓											✓				
Jurkovic et al. (2015)		✓				✓					✓						
Neubauer and Wood (2014)	✓		✓			✓			✓								
Bottiglione et al. (2014)		✓			✓	✓											
Rothgang et al. (2014)		✓			✓				✓								
Hegazy et al. (2013)		✓			✓	✓						✓					
Neubauer et al. (2012)		✓	✓				✓		✓				✓				
Roscher et al. (2012)		✓				✓											

References

Aalund, R., Diao, W., Kong, L., Pecht, M., 2021. Understanding the non-collision related battery safety risks in electric vehicles a case study in electric vehicle recalls and the LG chem battery. IEEE Access 9, 89527–89532.

Abdul Qadir, S., Ahmad, F., Mohsin, A.B., Al-Wahedi, A., Iqbal, A., Ali, A., 2024. Navigating the complex realities of electric vehicle adoption: a comprehensive study of government strategies, policies, and incentives. Energy Strategy Rev. 53, 101379.

Abdul-Manan, A.F.N., Gordillo Zavaleta, V., Agarwal, A.K., Kalghatgi, G., Amer, A.A., 2022. Electrifying passenger road transport in India requires near-term electricity grid decarbonisation. Nat. Commun. 13, 2095.

Ager-Wick Ellingsen, L., Jayne Thorne, R., Wind, J., Figenbaum, E., Romare, M., Nordelöf, A., 2022. Life cycle assessment of battery electric buses. Transport. Res. Transport Environ. 112, 103498.

Agoundedemba, M., Kim, C.K., Kim, H.G., 2023. Energy status in Africa: challenges, progress and sustainable pathways. Energies 16, 7708.

Agrawal, S., Zheng, H., Peeta, S., Kumar, A., 2016. Routing aspects of electric vehicle drivers and their effects on network performance. Transport. Res. Transport Environ. 46, 246–266.

Ahmed, I., Ahmad, I., Ahmed, S., Adil, H.M.M., 2021. Robust nonlinear control of battery electric vehicle charger in grid to vehicle applications. J. Energy Storage 42, 103039.

Ahmed, S., Trask, S.E., Dees, D.W., Nelson, P.A., Lu, W., Dunlop, A.R., et al., 2018. Cost of automotive lithium-ion batteries operating at high upper cutoff voltages. J. Power Sources 403, 56–65.

Aijaz, I., Ahmad, A., 2022. In: Agarwal, P., Mittal, M., Ahmed, J., Idrees, S.M. (Eds.), Electric Vehicles for Environmental Sustainability. Smart Technologies for Energy and Environmental Sustainability, Springer, Cham, pp. 131–145.

Al Haddad, R., Basma, H., Mansour, C., 2020. Genetic algorithm control strategy for heat pump system in battery electric buses. In: 2020 IEEE Vehicle Power and Propulsion Conference (VPPC), pp. 1–6.

Alamgir, M., 2017. Lithium has transformed vehicle technology: how trends in Li-ion battery technology have developed for vehicle electrification. IEEE Electrific. Mag. 5, 43–52.

Alanazi, F., 2023. Electric vehicles: benefits, challenges, and potential solutions for widespread adaptation. Appl. Sci. 13, 6016.

Allca-Pekarovic, A., Kollmeyer, P.J., Reimers, J., Mahvelatishamsabadi, P., Mirfakhrai, T., Naghshtabrizi, P., et al., 2024. Loss modeling and testing of 800-V DC bus IGBT and SiC traction inverter modules. IEEE Trans. Transp. Electrific. 10, 2923–2935.

Álvarez Fernández, R., 2018. A more realistic approach to electric vehicle contribution to greenhouse gas emissions in the city. J. Clean. Prod. 172, 949–959.

Al-Wreikat, Y., Serrano, C., Sodré, J.R., 2021. Driving behaviour and trip condition effects on the energy consumption of an electric vehicle under real-world driving. Appl. Energy 297, 117096.

Ambrose, H., Kendall, A., Lozano, M., Wachche, S., Fulton, L., 2020. Trends in life cycle greenhouse gas emissions of future light duty electric vehicles. Transp. Res. Part D Transp. Environ. 81, 102287.

Aminzadegan, S., Shahriari, M., Mehranfar, F., Abramović, B., 2022. Factors affecting the emission of pollutants in different types of transportation: a literature review. Energy Rep. 8, 2508–2529.
An, K., 2020. Battery electric bus infrastructure planning under demand uncertainty. Transport. Res. C Emerg. Technol. 111, 572–587.
Anwar, M., Hasan, S.M.N., Teimor, M., Korich, M., Hayes, M.B., 2015. Development of a power dense and environmentally robust traction power inverter for the second-generatio chevrolet VOLT extended-range EV. In: 2015 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 6006–6013.
Arfa Grunditz, E., Thiringer, T., 2016. Characterizing BEV powertrain energy consumption, efficiency, and range during official and drive cycles from Gothenburg, Sweden. IEEE Trans. Veh. Technol. 65, 3964–3980.
Aviles, J.E., Paniagua-Guerra, L.E., Ramos-Alvarado, B., 2023. Liquid-cooled heat sink design for a multilevel inverter switch with considerations for heat spreading and manufacturability. Appl. Therm. Eng. 219, 119588.
Baek, D., Chang, N., 2019. Runtime power management of battery electric vehicles for extended range with consideration of driving time. IEEE Trans. VLSI Syst 27, 549–559.
Bajpai, R.S., Srivastava, A., Singh, A., Kumar, S., 2024. Intelligent control of DC microgrid involving multiple renewables for fast charging control of electric vehicles. Elec. Power Compon. Syst. https://doi.org/10.1080/15325008.2024.2304149.
Barco, J., Guerra, A., Muñoz, L., Quijano, N., 2017. Optimal routing and scheduling of charge for electric vehicles: a case study. Math. Probl Eng. 2017, 8509783.
Barreras, J.V., Pinto, C., de Castro, R., Schaltz, E., Andreasen, S.J., Rasmussen, P.O., et al., 2016. Evaluation of a novel BEV concept based on fixed and swappable Li-ion battery packs. IEEE Trans. Ind. Appl. 52, 5073–5085.
Basma, H., Mansour, C., Haddad, M., Nemer, M., Stabat, P., 2022. Energy consumption and battery sizing for different types of electric bus service. Energy 239, 122454.
Bauer, C., Hofer, J., Althaus, H.J., Del Duce, A., Simons, A., 2015. The environmental performance of current and future passenger vehicles: life cycle assessment based on a novel scenario analysis framework. Appl. Energy 157, 871–883.
Bauer, G.S., Phadke, A., Greenblatt, J.B., Rajagopal, D., 2019. Electrifying urban ridesourcing fleets at no added cost through efficient use of charging infrastructure. Transport. Res. C Emerg. Technol. 105, 385–404.
Beddows, D.C.S., Harrison, R.M., 2021. PM10 and PM2.5 emission factors for non-exhaust particles from road vehicles: dependence upon vehicle mass and implications for battery electric vehicles. Atmos. Environ. 244, 117886.
Benoliel, P., Jenn, A., Tal, G., 2021. Examining energy uncertainty in battery bus deployments for transit agencies in California. Transport. Res. Transport Environ. 98, 102963.
Bi, J., Wang, Y., Sai, Q., Ding, C., 2019. Estimating remaining driving range of battery electric vehicles based on real-world data: a case study of Beijing, China. Energy 169, 833–843.
Blades, L.A.W., Matthews, T., McGrath, T.E., Early, J., Cunningham, G., Harris, A., 2024. Predicting energy consumption of zero emission buses using route feature selection methods. Transport. Res. Transport Environ. 130, 104158.
Bloomberg, 2024. Top China lithium firms look past profit slump and vow expansion. https://www.bloomberg.com/news/articles/2024-04-01/top-china-lithium-firms-look-past-profit-slump-and-vow-expansion.
Boretti, A., 2023. Battery energy storage in electric vehicles by 2030. Energy Storage 5, 383.
Bottiglione, F., De Pinto, S., Mantriota, G., Sorniotti, A., 2014. Energy consumption of a battery electric vehicle with infinitely variable transmission. Energies 7, 8317–8337.
Brendel, A.B., Lichtenberg, S., Brauer, B., Nastjuk, I., Kolbe, L.M., 2018. Improving electric vehicle utilization in carsharing: a framework and simulation of an e-carsharing vehicle utilization management system. Transp. Res. Part D Transp Environ. 64, 230–245.
Broadbent, G.H., Metternicht, G.I., Wiedmann, T.O., 2021. Increasing electric vehicle uptake by updating public policies to shift attitudes and perceptions: case study of New Zealand. Energies 14, 2920.
Burd, J.T.J., Moore, E.A., Ezzat, H., Kirchain, R., Roth, R., 2021. Improvements in electric vehicle battery technology influence vehicle lightweighting and material substitution decisions. Appl. Energy 283, 116269.
Campanari, S., Manzolini, G., Garcia de la Iglesia, F., 2009. Energy analysis of electric vehicles using batteries or fuel cells through well-to-wheel driving cycle simulations. J. Power Sources 186, 464–477.
Chakraborty, P., Parker, R., Hoque, T., Cruz, J., Du, L., Wang, S., et al., 2022. Addressing the range anxiety of battery electric vehicles with charging en route. Sci. Rep. 12, 5588.
Chakraborty, S., Vu, H.N., Hasan, M.M., Tran, D.D., El Baghdadi, M., Hegazy, O., 2019. DC-DC converter topologies for electric vehicles, plug-in hybrid electric vehicles and fast charging stations: state of the art and future trends. Energies 12, 1569.
Chang, C., Zhang, J., Zhang, K., Zhong, W., Peng, X., Li, S., et al., 2023. BEV-V2X: cooperative birds-eye-view fusion and grid occupancy prediction via V2X-based data sharing. IEEE Trans. Intell. Veh. 8, 4498–4514.
Chau, K.T., Chan, C.C., Liu, C., 2008. Overview of permanent-magnet brushless drives for electric and hybrid electric vehicles. IEEE Trans. Ind. Electron. 55, 2246–2257.
Chen, H., Rakha, H.A., 2020. Battery electric vehicle eco-cooperative adaptive cruise control in the vicinity of signalized intersections. Energies 13, 2433.
Cheng, Y., Ding, L., Zhao, T., Cui, S., 2024. Design and optimization of electric vehicle traction motor considering rotor topology and manufacturing uncertainty. IEEE Trans. Ind. Electron. 71, 5034–5044.
Choi, H., Shin, J., Woo, J., 2018. Effect of electricity generation mix on battery electric vehicle adoption and its environmental impact. Energy Pol. 121, 13–24.
Clinton, B.C., Steinberg, D.C., 2019. Providing the Spark: impact of financial incentives on battery electric vehicle adoption. J. Environ. Econ. Manag. 98, 102255.
Coban, H., Lewicki, W., Sendek-Matysiak, E., Łosiewicz, Z., Drożdż, W., Miśkiewicz, R., 2022. Electric vehicles and vehicle–grid interaction in the Turkish electricity system. Energies 15, 8218.
Conway, G., Joshi, A., Leach, F., García, A., Senecal, P.K., 2021. A review of current and future powertrain technologies and trends in 2020. Transport Eng. 5, 100080.
Danilecki, K., Smurawski, P., Urbanowicz, K., 2023. Optimization of car use time for different maintenance and repair scenarios based on life cycle assessment. Appl. Sci. 13, 9843.
De Seram, R., Golder, A., Williamson, S.S., 2023. Recent advancements in solid state transformer-based EV fast charging stations. In: 2023 IEEE 14th International Conference on Power Electronics and Drive Systems (PEDS), pp. 1–6.
Deng, J., Bae, C., Denlinger, A., Miller, T., 2020. Electric vehicles batteries: requirements and challenges. Joule 4, 511–515.
Dey, S., Sreenivasulu, A., Veerendra, G.T.N., Rao, K.V., Babu, P.S.S.A., 2022. Renewable energy present status and future potentials in India: an overview. Innov. Green. Dev. 1, 100006.
Dhameja, S., 2001. Electric Vehicle Battery Systems. Elsevier, Amsterdam, the Netherlands.
Dirks, N., Schiffer, M., Walther, G., 2022. On the integration of battery electric buses into urban bus networks. Transport. Res. C Emerg. Technol. 139, 103628.
Dong, J., Wu, X., Liu, C., Lin, Z., Hu, L., 2020. The impact of reliable range estimation on battery electric vehicle feasibility. Int. J. Sustain. Transp. 14, 833–842.
Donkers, A., Yang, D., Viktorović, M., 2020. Influence of driving style, infrastructure, weather and traffic on electric vehicle performance. Transport. Res. Transport Environ. 88, 102569.
Dottle, R., Politics, L.K.G., 2023. Climate disasters drain US emergency fund. Adding to Government Shutdown Risk. https://www.bloomberg.com/graphics/2023-fema-disaster-relief-fund-extreme-weather-climate-aid.
Du, J., Hu, L., Mao, J., Zhang, Y., 2021. Optimal vibration suppression modification method for high-speed helical gear transmission of battery electric vehicles under full working conditions. Machines 9, 226.
Du, J., Ouyang, M., Wu, X., Meng, X., Li, J., Li, F., et al., 2019. Technological direction prediction for battery electric bus under influence of China's new subsidy scheme. J. Clean. Prod. 222, 267–279.
Duffner, F., Wentker, M., Greenwood, M., Leker, J., 2020. Battery cost modeling: a review and directions for future research. Renew. Sustain. Energy Rev. 127, 109872.
Dunn, J.B., Gaines, L., Sullivan, J., Wang, M.Q., 2012. Impact of recycling on cradle-to-gate energy consumption and greenhouse gas emissions of automotive lithium-ion batteries. Environ. Sci. Technol. 46, 12704–12710.
Ecer, F., 2021. A consolidated MCDM framework for performance assessment of battery electric vehicles based on ranking strategies. Renew. Sustain. Energy Rev. 143, 110916.
ElMenshawy, M., Massoud, A., 2020. Modular isolated DC-DC converters for ultra-fast EV chargers: a generalized modeling and control approach. Energies 13, 2540.
Eser, P., Chokani, N., Abhari, R.S., 2018. Impacts of battery electric vehicles on renewable integration within the 2030 European power system. Int. J. Energy Res. 42, 4142–4156.
Evtimov, I., Ivanov, R., Stanchev, H., Kadikyanov, G., Staneva, G., Sapundzhiev, M., 2020. Energy efficiency and ecological impact of the vehicles. In: Lecture Notes in Networks and Systems, pp. 169–250.
Fan, E., Li, L., Wang, Z., Lin, J., Huang, Y., Yao, Y., et al., 2020. Sustainable recycling technology for Li-ion batteries and beyond: challenges and future prospects. Chem. Rev. 120, 7020–7063.
Faraz, A., Ambikapathy, A., Thangavel, S., Logavani, K., Arun Prasad, G., 2021. Battery electric vehicles (BEVs). In: Patel, N., Bhoi, A.K., Padmanaban, S., Holm-Nielsen, J.B. (Eds.), Electric Vehicles: Modern Technologies and Trends. Springer, Singapore, pp. 137–160.
Feng, J., Khan, A.M., 2024. Accelerating urban road transportation electrification: planning, technology, economic and implementation factors in converting gas stations into fast charging stations. Energy Syst. https://doi.org/10.1007/s12667-023-00638-4.
Ferrer, A.L.C., Thomé, A.M.T., 2023. Carbon emissions in transportation: a synthesis framework. Sustainability 15, 8475.
Ferris, N., 2023. COP28: EVs a bright spot but more needed in developing countries. Energy Monitor. https://www.energymonitor.ai/policy/international-treaties/evs-a-bright-spot-at-cop28-but-action-needed-in-developing-countries.
Fichtner, M., Edström, K., Ayerbe, E., Berecibar, M., Bhowmik, A., Castelli, I.E., et al., 2022. Rechargeable batteries of the future—the state of the art from a BATTERY 2030+ perspective. Adv. Energy Mater. 12, 2102904. https://doi.org/10.1002/aenm.202102904.
Figenbaum, E., 2020. Battery electric vehicle fast charging–evidence from the Norwegian market. World Electr. Veh. J. 11, 38.
Fiori, C., Ahn, K., Rakha, H.A., 2018. Optimum routing of battery electric vehicles: insights using empirical data and microsimulation. Transport. Res. Transport Environ. 64, 262–272.
Forrest, K., Mac Kinnon, M., Tarroja, B., Samuelsen, S., 2020. Estimating the technical feasibility of fuel cell and battery electric vehicles for the medium and heavy duty sectors in California. Appl. Energy 276, 115439.
Funke, S.Á., Plötz, P., Wietschel, M., 2019a. Invest in fast-charging infrastructure or in longer battery ranges? A cost-efficiency comparison for Germany. Appl. Energy 235, 888–899.
Funke, S.Á., Sprei, F., Gnann, T., Plötz, P., 2019b. How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison. Transport. Res. Transport Environ. 77, 224–242.

Ganesh, A.H., Xu, B., 2022. A review of reinforcement learning based energy management systems for electrified powertrains: progress, challenge, and potential solution. Renew. Sustain. Energy Rev. 154, 111833.
Gao, B., Meng, D., Shi, W., Cai, W., Dong, S., Zhang, Y., et al., 2022. Topology optimization and the evolution trends of two-speed transmission of EVs. Renew. Sustain. Energy Rev. 161, 112390.
Gao, Z., LaClair, T., Ou, S., Huff, S., Wu, G., Hao, P., et al., 2019. Evaluation of electric vehicle component performance over eco-driving cycles. Energy 172, 823–839.
Gao, Z., Lin, Z., LaClair, T.J., Liu, C., Li, J.M., Birky, A.K., et al., 2017. Battery capacity and recharging needs for electric buses in city transit service. Energy 122, 588–600.
Gao, Z., Xie, H., Yang, X., Zhang, L., Yu, H., Wang, W., et al., 2023. Electric vehicle lifecycle carbon emission reduction: a review. Carbon Neutralization 2, 528–550.
Gawron, J., Keoleian, G.A., De Kleine, R.D., Wallington, T.J., Kim, H.C., 2018. Life cycle assessment of connected and automated vehicles: sensing and computing subsystem and vehicle level effects. Environ. Sci. Technol. 52, 3249–3256.
Geiger, D., Bauer, C., 2023. Traction inverters - efficient by design. Atzelectronics Worldw 18, 50–55.
Gieré, R., Dietze, V., 2022. Tire-abrasion particles in the environment. In: Degradation of Elastomers in Practice, Experiments and Modeling, pp. 71–101.
Goli, C.S., Essakiappan, S., Sahu, P., Manjrekar, M., Shah, N., 2021. Review of recent trends in design of traction inverters for electric vehicle applications. In: 2021 IEEE 12th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), pp. 1–6.
Gopalakrishnan, R., Goutam, S., Miguel Oliveira, L., Timmermans, J.M., Omar, N., Messagie, M., et al., 2017. A comprehensive study on rechargeable energy storage technologies. J. Electrochem. Energy Convers. Storage. 13, 040801.
Grube, T., Kraus, S., Reul, J., Stolten, D., 2021. Passenger car cost development through 2050. Transport. Res. Transport Environ. 101, 103110.
Grunditz, E.A., Thiringer, T., 2016. Performance analysis of current BEVs based on a comprehensive review of specifications. IEEE Trans. Transp Electrific 2, 270–289.
Gryparis, E., Papadopoulos, P., Leligou, H.C., Psomopoulos, C.S., 2020. Electricity demand and carbon emission in power generation under high penetration of electric vehicles. A European Union perspective. Energy Rep. 6, 475–486.
Günther, M., Kacperski, C., Krems, J.F., 2020. Can electric vehicle drivers be persuaded to eco-drive? A field study of feedback, gamification and financial rewards in Germany. Energy Res. Social Sci. 63, 101407.
Günther, M., Rauh, N., Krems, J.F., 2019. How driving experience and consumption related information influences eco-driving with battery electric vehicles–Results from a field study. Transp. Res. Part F Traffic Psychol. Behav. 62, 435–450.
Guo, J., Li, Y., Pedersen, K., Stroe, D.I., 2021. Lithium-ion battery operation, degradation, and aging mechanism in electric vehicles: an overview. Energies 14, 5220.
Han, X., Lu, L., Zheng, Y., Feng, X., Li, Z., Li, J., et al., 2019. A review on the key issues of the lithium ion battery degradation among the whole life cycle. eTransportation 1, 100005.
Hao, H., Ou, X., Du, J., Wang, H., Ouyang, M., 2014. China's electric vehicle subsidy scheme: rationale and impacts. Energy Pol. 73, 722–732.
Hao, L., Namuduri, C., Duan, C., Gopalakrishnan, S., Bucknor, N., 2021. BEV range improvement using highly efficient downsized DC-DC converter. In: 2021 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 5210–5216.
Hao, X., Wang, H., Lin, Z., Ouyang, M., 2020. Seasonal effects on electric vehicle energy consumption and driving range: a case study on personal, taxi, and ridesharing vehicles. J. Clean. Prod. 249, 119403.
Hao, X., Wang, H., Zheng, Y., Lin, Y., Han, S., Zhong, R., et al., 2024. Toward carbon neutral road transport: development strategies and new R&D organizational paradigms. Automot. Innov. 7, 209–224.
Hasan, M.M., El Baghdadi, M., Hegazy, O., 2020. Energy management strategy in electric buses for public transport using ECO-driving. In: 2020 Fifteenth International Conference on Ecological Vehicles and Renewable Energies (EVER), pp. 1–8.
Haustein, S., Jensen, A.F., Cherchi, E., 2021. Battery electric vehicle adoption in Denmark and Sweden: recent changes, related factors and policy implications. Energy Pol. 149, 112096.
He, L., Ye, W., He, Z., Song, K., Shi, Q., 2020. A combining sliding mode control approach for electric motor anti-lock braking system of battery electric vehicle. Contr. Eng. Pract. 102, 104520.
Hegazy, O., Barrero, R., Van Mierlo, J., Lataire, P., Omar, N., Coosemans, T., 2013. An advanced power electronics interface for electric vehicles applications. IEEE Trans. Power Electron. 28, 5508–5521.
Heydrich, M., Mitsching, T., Gramstat, S., Lenz, M., Ivanov, V., 2024. Integrated Chassis Control for Energy-Efficient Operation of a 2WD Battery-Electric Vehicle with In-Wheel Propulsion, vol. 2550. SAE Technical Paper Series.
Huang, Y., Kockelman, K.M., 2020. Electric vehicle charging station locations: elastic demand, station congestion, and network equilibrium. Transport. Res. Transport Environ. 78, 102179.
Huang, Y., Ng, E.C.Y., Zhou, J.L., Surawski, N.C., Chan, E.F.C., Hong, G., 2018. Eco-driving technology for sustainable road transport: a review. Renew. Sustain. Energy Rev. 93, 596–609.
Huber, J., Lohmann, K., Schmidt, M., Weinhardt, C., 2021. Carbon efficient smart charging using forecasts of marginal emission factors. J. Clean. Prod. 284, 124766.
Husain, I., Ozpineci, B., Islam, M.S., Gurpinar, E., Su, G.J., Yu, W., et al., 2021. Electric drive technology trends, challenges, and opportunities for future electric vehicles. Proc. IEEE 109, 1039–1059.
Ibrahim, A., Jiang, F., 2021. The electric vehicle energy management: an overview of the energy system and related modeling and simulation. Renew. Sustain. Energy Rev. 144, 111049.
IEA, 2023. Electric vehicles. https://www.iea.org/energy-system/transport/electric-vehicles.
Itoh, K., Ishigaki, M., Kikuchi, N., Harada, T., Sugiyama, T., 2020. A single-stage rectifier with interleaved totem-pole PFC and dual active bridge (DAB) converter for PHEV/BEV on-board charger. In: 2020 IEEE Applied Power Electronics Conference and Exposition (APEC), pp. 1936–1941.
Jaguemont, J., Boulon, L., Dubé, Y., 2016. A comprehensive review of lithium-ion batteries used in hybrid and electric vehicles at cold temperatures. Appl. Energy 164, 99–114.
Jelodar, Y.J., Salari, O., Youssef, M.Z., Ebrahimi, J., Bakhshai, A., 2024. A novel control scheme for traction inverters in electric vehicles with an optimal efficiency across the entire speed range. IEEE Access 12, 25906–25916.
Jenn, A., Clark-Sutton, K., Gallaher, M., Petrusa, J., 2020. Environmental impacts of extreme fast charging. Environ. Res. Lett. 15, 094060.
Ji, Q., Wang, C., Fan, Y., 2022. Environmental and welfare effects of vehicle purchase tax: evidence from China. Energy Econ. 115, 106377.
Jonas, T., Hunter, C.D., Macht, G.A., 2022. Quantifying the impact of traffic on electric vehicle efficiency. World Electr. Veh. J. 13, 15.
Jones, B., Nguyen-Tien, V., Elliott, R.J.R., 2023. The electric vehicle revolution: critical material supply chains, trade and development. World Econ. 46, 2–26.
Jorge, S., Solsona, J.A., Busada, C.A., Tapia-Otaegui, G., Susperregui Burguete, A., Martínez Aguirre, M.I., 2024. Nonlinear controller allowing the use of a small-size DC-link capacitor in grid-feeding converters. IEEE Trans. Ind. Electron. 71, 2157–2166.
Juergens, J., Fricasse, A., Marengo, L., Gragger, J., De Gennaro, M., Ponick, B., 2016. Innovative design of an air cooled ferrite permanent magnet assisted synchronous reluctance machine for automotive traction application. In: 2016 XXII International Conference on Electrical Machines (ICEM), pp. 803–810.
Jurkovic, S., Rahman, K.M., Savagian, P.J., 2015. Design, optimization and development of electric machine for traction application in GM battery electric vehicle. In: 2015 IEEE International Electric Machines & Drives Conference (IEMDC), pp. 1814–1819.
Jyotheeswara Reddy, K., Natarajan, S., 2018. Energy sources and multi-input DC-DC converters used in hybrid electric vehicle applications–A review. Int. J Hydrog. Energy 43, 17387–17408.
Kang, S., Kwon, M., Choi, J.Y., Choi, S., 2023. Full-scale fire testing of battery electric vehicles. Appl. Energy 332, 120497.
Kapustin, A.V., Shchurov, N.I., 2023. An overview of main multilevel inverter topologies. Russ. Electr. Eng. 94, 334–339.
Kawamoto, R., Mochizuki, H., Moriguchi, Y., Nakano, T., Motohashi, M., Sakai, Y., et al., 2019. Estimation of CO2 emissions of internal combustion engine vehicle and battery electric vehicle using LCA. Sustainability 11, 2690.
Ke, W., Zhang, S., He, X., Wu, Y., Hao, J., 2017. Well-to-wheels energy consumption and emissions of electric vehicles: mid-term implications from real-world features and air pollution control progress. Appl. Energy 188, 367–377.
Khaligh, A., D'Antonio, M., 2019. Global trends in high-power on-board chargers for electric vehicles. IEEE Trans. Veh. Technol. 68, 3306–3324.
Khan, M.S., Agrawal, A., 2023. An overview of Bi-directional charging converter topologies for electric vehicles and fast charging stations analysis using neural network. In: 2023 International Conference on Computational Intelligence, Communication Technology and Networking (CICTN), pp. 219–224.
Kii, M., Isikawa, R., Kometani, Y., 2023. Toward a carbon neutral urban transportation system in Japan. IATSS Res. 47, 171–178.
Kim, H.C., Wallington, T.J., Arsenault, R., Bae, C., Ahn, S., Lee, J., 2016. Cradle-to-gate emissions from a commercial electric vehicle Li-ion battery: a comparative analysis. Environ. Sci. Technol. 50, 7715–7722.
Kleiner, J., Komsiyska, L., Elger, G., Endisch, C., 2019. Thermal modelling of a prismatic lithium-ion cell in a battery electric vehicle environment: influences of the experimental validation setup. Energies 13, 62.
König, A., Nicoletti, L., Schröder, D., Wolff, S., Waclaw, A., Lienkamp, M., 2021. An overview of parameter and cost for battery electric vehicles. World Electr. Veh. J. 12, 21.
Koroma, M.S., Brown, N., Cardellini, G., Messagie, M., 2020. Prospective environmental impacts of passenger cars under different energy and steel production scenarios. Energies 13, 6236.
Koroma, M.S., Costa, D., Philippot, M., Cardellini, G., Hosen, M.S., Coosemans, T., et al., 2022. Life cycle assessment of battery electric vehicles: implications of future electricity mix and different battery end-of-life management. Sci. Total Environ. 831, 154859.
Korta, P., Iyer, L.V., Lai, C., Mukherjee, K., Tjong, J., Kar, N.C., 2017. A novel hybrid approach towards drive-cycle based design and optimization of a fractional slot concentrated winding SPMSM for BEVs. In: 2017 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 2086–2092.
Kostopoulos, E.D., Spyropoulos, G.C., Kaldellis, J.K., 2020. Real-world study for the optimal charging of electric vehicles. Energy Rep. 6, 418–426.
Kuntz, P., Raccurt, O., Azaïs, P., Richter, K., Waldmann, T., Wohlfahrt-Mehrens, M., et al., 2021. Identification of degradation mechanisms by post-mortem analysis for high power and high energy commercial Li-ion cells after electric vehicle aging. Batteries 7, 48.
Kurz, L., Faryadras, M., Klugius, I., Reichert, F., Scheibe, A., Schmidt, M., et al., 2021. Global warming potential of a new waterjet-based recycling process for cathode materials of lithium-ion batteries. Batteries 7, 29.
Lamantia, M., Su, Z., Chen, P., 2021. Remaining driving range estimation framework for electric vehicles in platooning applications. In: 2021 American Control Conference (ACC), pp. 424–429.
Lan, C., Xu, J., Qiao, Y., Ma, Y., 2016. Thermal management for high power lithium-ion battery by minichannel aluminum tubes. Appl. Therm. Eng. 101, 284–292.

Ledna, C., Muratori, M., Brooker, A., Wood, E., Greene, D., 2022. How to support EV adoption: tradeoffs between charging infrastructure investments and vehicle subsidies in California. Energy Pol. 165, 112931.

Lehtola, T.A., Zahedi, A., 2021. Electric vehicle battery cell cycle aging in vehicle to grid operations: a review. IEEE J. Emerg. Sel. Topics Power Electron 9, 423–437.

Li, H., Hao, Y., Xie, C., Han, Y., Wang, Z.-R., 2023a. Emerging technologies and policies for carbon–neutral transportation. Int. J. Transp. Sci. Technol. 12, 329–334.

Li, J., Wang, G., Wang, X., Du, Y., 2023b. Smart charging strategy for electric vehicles based on marginal carbon emission factors and time-of-use price. Sustain. Cities Soc. 96, 104708.

Li, Q., Wu, L., Chen, T., Li, E., Hu, L., Wang, F., et al., 2021. Multi-objective optimization design of B-pillar and rocker sub-systems of battery electric vehicle. Struct. Multidiscip. Optim. 64, 3999–4023.

Li, Z., Chowdhury, M., Bhavsar, P., He, Y., 2015. Optimizing the performance of vehicle-to-grid (V2G) enabled battery electric vehicles through a smart charge scheduling model. Int. J. Automot. Technol. 16, 827–837.

Liu, F., Shafique, M., Luo, X., 2023. Literature review on life cycle assessment of transportation alternative fuels. Environ. Technol. Innov. 32, 103343.

Liu, F., Shafique, M., Luo, X., 2024. Quantifying delayed climate mitigation benefits in electric and hydrogen fuel cell vehicle deployment for sustainable mobility. Sustain. Prod. Consum. 49, 398–414.

Liu, H., Wang, D.Z.W., 2017. Locating multiple types of charging facilities for battery electric vehicles. Transp. Res. Part B Methodol. 103, 30–55.

Liu, K., Yamamoto, T., Morikawa, T., 2017. Impact of road gradient on energy consumption of electric vehicles. Transport. Res. Transport Environ. 54, 74–81.

Liu, T., Zou, Y., Liu, D., 2016. Energy management for battery electric vehicle with automated mechanical transmission. Int. J. Veh. Des. 70, 98.

Löbberding, H., Wessel, S., Offermanns, C., Kehrer, M., Rother, J., Heimes, H., et al., 2020. From cell to battery system in BEVs: analysis of system packing efficiency and cell types. World Electr. Veh. J. 11, 77.

Loganathan, M.K., Tan, C.M., Sultana, S., Hsieh, I.Y.L., Kumaraswamidhas, L.A., Rai, R.N., 2021. Parametric performance analysis of battery operated electric vehicle. In: 2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET), pp. 1–6.

Lu, C., Dong, J., Hu, L., 2019. Energy-efficient adaptive cruise control for electric connected and autonomous vehicles. IEEE Intell. Transport. Syst. Mag. 11, 42–55.

Luk, J.M., Kim, H.C., De Kleine, R.D., Wallington, T.J., MacLean, H.L., 2018. Greenhouse gas emission benefits of vehicle lightweighting: Monte Carlo probabalistic analysis of the multi material lightweight vehicle glider. Transport. Res. Transport Environ. 62, 1–10.

Mahmoudzadeh Andwari, A., Pesiridis, A., Rajoo, S., Martinez-Botas, R., Esfahanian, V., 2017. A review of Battery Electric Vehicle technology and readiness levels. Renew. Sustain. Energy Rev. 78, 414–430.

Mahmud, I., Medha, M.B., Hasanuzzaman, M., 2023. Global challenges of electric vehicle charging systems and its future prospects: a review. Res. Transp. Bus Manag. 49, 101011.

Mamarikas, S., Doulgeris, S., Samaras, Z., Ntziachristos, L., 2022. Traffic impacts on energy consumption of electric and conventional vehicles. Transport. Res. Transport Environ. 105, 103231.

Mandade, P., Weil, M., Baumann, M., Wei, Z., 2023. Environmental life cycle assessment of emerging solid-state batteries: a review. Chem. Eng. J. Adv. 13, 100439.

Manivannan, B., Kathirvelu, P., Balasubramanian, R., 2023. A review on wireless charging methods–The prospects for future charging of EV. Renew. Energy Focus 46, 68–87.

Martins, H., Henriques, C.O., Figueira, J.R., Silva, C.S., Costa, A.S., 2023. Assessing policy interventions to stimulate the transition of electric vehicle technology in the European Union. Soc. Econ. Plann. Sci. 87, 101505.

Massaro, M., Dumay, J., Guthrie, J., 2016. On the shoulders of giants: undertaking a structured literature review in accounting. Account Audit. Account. J. 29, 767–801.

Mastoi, M.S., Zhuang, S., Munir, H.M., Haris, M., Hassan, M., Usman, M., et al., 2022. An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends. Energy Rep. 8, 11504–11529.

Mateen, S., Amir, M., Haque, A., Bakhsh, F.I., 2023. Ultra-fast charging of electric vehicles: a review of power electronics converter, grid stability and optimal battery consideration in multi-energy systems. Sustain. Energy. Grids. Netw. 35, 101112.

Mayyas, A., Omar, M., Hayajneh, M., Mayyas, A.R., 2017. Vehicle's lightweight design vs. electrification from life cycle assessment perspective. J. Clean. Prod. 167, 687–701.

McGrath, T., Blades, L., Early, J., Harris, A., 2022. UK battery electric bus operation: examining battery degradation, carbon emissions and cost. Transp. Res. Part D Transp Environ. 109, 103373.

McKerracher, C., 2023. Battery bloat could backfire on electric vehicle manufacturers. https://about.bnef.com/blog/battery-bloat-could-backfire-on-electric-vehicle-manufacturers.

Mishra, S., Swain, S.C., Samantaray, R.K., 2021. A review on battery management system and its application in electric vehicle. In: 2021 International Conference on Advances in Computing and Communications (ICACC), pp. 1–6.

Mohamed, A.A.S., Lashway, C.R., Mohammed, O., 2017. Modeling and feasibility analysis of quasi-dynamic WPT system for EV applications. IEEE Trans. Transp. Electrific. 3, 343–353.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2010. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int. J. Surg. 8, 336–341.

Momen, F., Rahman, K., Son, Y., Savagian, P., 2016. Electrical propulsion system design of Chevrolet Bolt battery electric vehicle. In: 2016 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 1–8.

Neaimeh, M., Salisbury, S.D., Hill, G.A., Blythe, P.T., Scoffield, D.R., Francfort, J.E., 2017. Analysing the usage and evidencing the importance of fast chargers for the adoption of battery electric vehicles. Energy Pol. 108, 474–486.

Neubauer, J., Brooker, A., Wood, E., 2012. Sensitivity of battery electric vehicle economics to drive patterns, vehicle range, and charge strategies. J. Power Sources 209, 269–277.

Neubauer, J., Pesaran, A., Bae, C., Elder, R., Cunningham, B., 2014. Updating United States Advanced Battery Consortium and Department of Energy battery technology targets for battery electric vehicles. J. Power Sources 271, 614–621.

Neubauer, J., Wood, E., 2014. Thru-life impacts of driver aggression, climate, cabin thermal management, and battery thermal management on battery electric vehicle utility. J. Power Sources 259, 262–275.

Neumann, I., Franke, T., Cocron, P., Bühler, F., Krems, J.F., 2015. Eco-driving strategies in battery electric vehicle use–how do drivers adapt over time? IET Intell. Transp. Syst. 9, 746–753.

Ngo, H., Kumar, A., Mishra, S., 2020. Optimal positioning of dynamic wireless charging infrastructure in a road network for battery electric vehicles. Transp. Res. Part D Transp Environ. 85, 102385.

Nykvist, B., Sprei, F., Nilsson, M., 2019. Assessing the progress toward lower priced long range battery electric vehicles. Energy Pol. 124, 144–155.

Offer, G.J., Yufit, V., Howey, D.A., Wu, B., Brandon, N.P., 2012. Module design and fault diagnosis in electric vehicle batteries. J. Power Sources 206, 383–392.

Oubelaid, A., Taib, N., Nikolovski, S., Alharbi, T.E.A., Rekioua, T., Flah, A., et al., 2022. Intelligent speed control and performance investigation of a vector controlled electric vehicle considering driving cycles. Electronics 11, 1925.

Ouyang, D., Zhou, S., Ou, X., 2021. The total cost of electric vehicle ownership: a consumer-oriented study of China's post-subsidy era. Energy Pol. 149, 112023.

Patil, P., Kazemzadeh, K., Bansal, P., 2023. Integration of charging behavior into infrastructure planning and management of electric vehicles: a systematic review and framework. Sustain. Cities Soc. 88, 104265.

Paul, J., Lim, W.M., O'Cass, A., Hao, A.W., Bresciani, S., 2021. Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR). Int. J. Consum. Stud. 45, 1–16.

Pearre, N.S., Kempton, W., Guensler, R.L., Elango, V.V., 2011. Electric vehicles: how much range is required for a day's driving? Transport. Res. C Emerg. Technol. 19, 1171–1184.

Pei, M., Hu, Y., Han, W., Qu, X., Zou, C., 2024. Life-Cycle analysis of economic and environmental effects for electric bus transit systems. Transport. Res. Transport Environ. 131, 104205.

Pelletier, S., Jabali, O., Laporte, G., Veneroni, M., 2017. Battery degradation and behaviour for electric vehicles: review and numerical analyses of several models. Transp. Res. Part B Methodol. 103, 158–187.

Peng, T., Ou, X., Yan, X., 2018. Development and application of an electric vehicles life-cycle energy consumption and greenhouse gas emissions analysis model. Chem. Eng. Res. Des. 131, 699–708.

Perger, T., Auer, H., 2020. Energy efficient route planning for electric vehicles with special consideration of the topography and battery lifetime. Energy Effic 13, 1705–1726.

Petrauskienė, K., Skvarnavičiūtė, M., Dvarionienė, J., 2020. Comparative environmental life cycle assessment of electric and conventional vehicles in Lithuania. J. Clean. Prod. 246, 119042.

Philipsen, R., Brell, T., Biermann, H., Eickels, T., Brost, W., Ziefle, M., 2019. Should I stay or should I go? - influencing context factors for users' decisions to charge or refuel their vehicles. In: Advances in Intelligent Systems and Computing, pp. 573–584.

Picatoste, A., Justel, D., Mendoza, J.M.F., 2022. Circularity and life cycle environmental impact assessment of batteries for electric vehicles: Industrial challenges, best practices and research guidelines. Renew. Sustain. Energy Rev. 169, 112941.

Poorfakhraei, A., Narimani, M., Emadi, A., 2021. A review of modulation and control techniques for multilevel inverters in traction applications. IEEE Access 9, 24187–24204.

Pradhan, R., Keshmiri, N., Emadi, A., 2023. On-board chargers for high-voltage electric vehicle powertrains: future trends and challenges. IEEE Open J. Power Electron. 4, 189–207.

Pratico, F.G., Briante, P.G., Speranza, G., 2020. Acoustic impact of electric vehicles. In: 2020 IEEE 20th Mediterranean Electrotechnical Conference (MELECON), pp. 7–12.

Pražanová, A., Kočí, J., Míka, M.H., Pilnaj, D., Plachý, Z., Knap, V., 2023. Pre-recycling material analysis of NMC lithium-ion battery cells from electric vehicles. Crystals 13, 214.

Pucci, P., 2021. Spatial dimensions of electric mobility—scenarios for efficient and fair diffusion of electric vehicles in the Milan Urban Region. Cities 110, 103069.

Rangaraju, S., De Vroey, L., Messagie, M., Mertens, J., Van Mierlo, J., 2015. Impacts of electricity mix, charging profile, and driving behavior on the emissions performance of battery electric vehicles: a Belgian case study. Appl. Energy 148, 496–505.

Rauh, N., Franke, T., Krems, J.F., 2015. Understanding the impact of electric vehicle driving experience on range anxiety. Hum. Factors 57, 177–187.

Rauh, N., Günther, M., Krems, J.F., 2020. Positive influence of practical electric vehicle driving experience and range related knowledge on drivers' experienced range stress. Transp. Res. Part F Traffic Psychol Behav. 71, 182–197.

Reimers, J., Dorn-Gomba, L., Mak, C., Emadi, A., 2019. Automotive traction inverters: current status and future trends. IEEE Trans. Veh. Technol. 68, 3337–3350.

Rissman, J., Bataille, C., Masanet, E., Aden, N., Morrow, W.R., Zhou, N., et al., 2020. Technologies and policies to decarbonize global industry: review and assessment of mitigation drivers through 2070. Appl. Energy 266, 114848.

Robinette, D., 2023. Electric motor and transmission integration for light-duty electric vehicles: a 2023 benchmarking perspective and component sizing for a fleet approach. Vehicles 5, 1167–1195.

Rodrigues, A.L.P., Seixas, S.R.C., 2022. Battery-electric buses and their implementation barriers: analysis and prospects for sustainability. Sustain. Energy Technol. Assess. 51, 101896.
Rösch, T., Raghuraman, S., Sommer, M., Junk, C., Baumann, D., Sax, E., 2023. Multi-layer approach for energy consumption optimization in electric buses. In: 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), pp. 1–6.
Roscher, M.A., Leidholdt, W., Trepte, J., 2012. High efficiency energy management in BEV applications. Int. J. Electr. Power Energy Syst. 37, 126–130.
Rothgang, S., Baumhofer, T., Sauer, D.U., 2014. Diversion of aging of battery cells in automotive systems. In: 2014 IEEE Vehicle Power and Propulsion Conference (VPPC), pp. 1–6.
Ruan, J., Song, Q., 2019. A novel dual-motor two-speed direct drive battery electric vehicle drivetrain. IEEE Access 7, 54330–54342.
Ruan, J., Song, Q., Yang, W., 2019. The application of hybrid energy storage system with electrified continuously variable transmission in battery electric vehicle. Energy 183, 315–330.
Ruan, J., Walker, P., Zhang, N., 2018. Comparison of power consumption efficiency of CVT and multi-speed transmissions for electric vehicle. Int. J. Automot. Eng. 9, 268–275.
Ruan, J., Walker, P., Zhang, N., 2016. A comparative study energy consumption and costs of battery electric vehicle transmissions. Appl. Energy 165, 119–134.
Ruan, J., Wu, C., Cui, H., Li, W., Sauer, D.U., 2023. Delayed deep deterministic policy gradient-based energy management strategy for overall energy consumption optimization of dual motor electrified powertrain. IEEE Trans. Veh. Technol. 72, 11415–11427.
Rupp, M., Handschuh, N., Rieke, C., Kuperjans, I., 2019. Contribution of country-specific electricity mix and charging time to environmental impact of battery electric vehicles: a case study of electric buses in Germany. Appl. Energy 237, 618–634.
Safari, M., 2018. Battery electric vehicles: looking behind to move forward. Energy Pol. 115, 54–65.
Sajadi-Alamdari, S.A., Voos, H., Darouach, M., 2019. Nonlinear model predictive control for ecological driver assistance systems in electric vehicles. Robot. Auton. Syst. 112, 291–303.
Sakti, A., Michalek, J.J., Fuchs, E.R.H., Whitacre, J.F., 2015. A techno-economic analysis and optimization of Li-ion batteries for light-duty passenger vehicle electrification. J. Power Sources 273, 966–980.
Sankaran, G., Venkatesan, S., 2021. Standardization of electric vehicle battery pack geometry form factors for passenger car segments in India. J. Power Sources 502, 230008.
Sankaran, G., Venkatesan, S., Prabhahar, M., 2020. Range Anxiety on electric vehicles in India-Impact on customer and factors influencing range Anxiety. Mater. Today Proc. 33, 895–901.
Satheesan, J., Thankappan Nair, R., 2023. An adaptive energy management strategy for supercapacitor supported solar-powered electric vehicle charging station. Int. J. Emerg. Electr. Power Syst. 24, 705–716.
Sawant, V., Zambare, P., 2024. DC fast charging stations for electric vehicles: a review. Energy Convers. Econ. 5, 54–71.
Sayed, K., Kassem, A., Saleeb, H., Alghamdi, A.S., Abo-Khalil, A.G., 2020. Energy-saving of battery electric vehicle powertrain and efficiency improvement during different standard driving cycles. Sustainability 12, 10466.
Schlott, S., 2020. The routes to carbon-neutral freight transport. ATZ Worldw 122, 8–13.
Schönknecht, A., Babik, A., Rill, V., 2016. Electric powertrain system design of BEV and HEV applying a multi objective optimization methodology. Transp. Res. Procedia 14, 3611–3620.
Schwab, J., Sölch, C., Zöttl, G., 2022. Electric Vehicle Cost in 2035: the impact of market penetration and charging strategies. Energy Econ. 114, 106263.
Scorrano, M., Danielis, R., Giansoldati, M., 2020. Dissecting the total cost of ownership of fully electric cars in Italy: the impact of annual distance travelled, home charging and urban driving. Res. Transp. Econ. 80, 100799.
Sergi, F., Arista, A., Agnello, G., Ferraro, M., Andaloro, L., Antonucci, V., 2016. Characterization and comparison between lithium iron p hosphate and lithium-polymers batteries. J. Energy Storage 8, 235–243.
Shafique, M., Azam, A., Rafiq, M., Luo, X., 2022. Life cycle assessment of electric vehicles and internal combustion engine vehicles: a case study of Hong Kong. Res. Transp. Econ. 91, 101112.
Shafique, M., Akbar, A., Rafiq, M., Azam, A., Luo, X., 2023. Global material flow analysis of end-of-life of lithium nickel manganese cobalt oxide batteries from battery electric vehicles. Waste Manag. Res. 41, 376–388.
Sharma, S., Panwar, A.K., Tripathi, M.M., 2020. Storage technologies for electric vehicles. J. Traffic Transp. Eng. Engl. Ed. 7, 340–361.
Sheldon, T.L., Dua, R., 2019. Measuring the cost-effectiveness of electric vehicle subsidies. Energy Econ. 84, 104545.
Sheldon, T.L., Dua, R., Alharbi, O.A., 2023. Electric vehicle subsidies: time to accelerate or pump the brakes? Energy Econ. 120, 106641.
Shelly, T.J., Weibel, J.A., Ziviani, D., Groll, E.A., 2021. Comparative analysis of battery electric vehicle thermal management systems under long-range drive cycles. Appl. Therm. Eng. 198, 117506.
Shi, B., Ramones, A.I., Liu, Y., Wang, H., Li, Y., Pischinger, S., et al., 2023. A review of silicon carbide MOSFETs in electrified vehicles: application, challenges, and future development. IET Power Electron. 16, 2103–2120.
Shui, B., Shafique, M., Luo, X., 2024. Light-duty passenger vehicle electrification in China from 2021 to 2050 and associated greenhouse gas emissions: a dynamic fleet perspective. Transport. Res. Transport Environ. 130, 104199.
Siebenhofer, M., Ajanovic, A., Haas, R., 2021. How policies affect the dissemination of electric passenger cars worldwide. Energies 14, 2093.
Singh, V., Singh, V., Vaibhav, S., 2021. Analysis of electric vehicle trends, development and policies in India. Case Stud. Transp. Policy 9, 1180–1197.
Straub, F., Maier, O., Göhlich, D., Strunz, K., 2023. Sector coupling through vehicle to grid: a case study for electric vehicles and households in berlin, Germany. World Electr. Veh. J. 14, 77.
Su, Z., Chen, P., 2022. Cooperative eco-driving controller for battery electric vehicle platooning. IFAC-PapersOnLine 55, 205–210.
Sun, X., Luo, X., Zhang, Z., Meng, F., Yang, J., 2020. Life cycle assessment of lithium nickel cobalt manganese oxide (NCM) batteries for electric passenger vehicles. J. Clean. Prod. 273, 123006.
Tagliaferri, C., Evangelisti, S., Acconcia, F., Domenech, T., Ekins, P., Barletta, D., et al., 2016. Life cycle assessment of future electric and hybrid vehicles: a cradle-to-grave systems engineering approach. Chem. Eng. Res. Des. 112, 298–309.
Tamayao, M.A.M., Michalek, J.J., Hendrickson, C., Azevedo, I.M.L., 2015. Regional variability and uncertainty of electric vehicle life cycle CO_2 emissions across the United States. Environ. Sci. Technol. 49, 8844–8855.
Tang, B., Xu, Y., Wang, M., 2022. Life cycle assessment of battery electric and internal combustion engine vehicles considering the impact of electricity generation mix: a case study in China. Atmosphere 13, 252.
Tang, X., Guo, Q., Li, M., Wei, C., Pan, Z., Wang, Y., 2021. Performance analysis on liquid-cooled battery thermal management for electric vehicles based on machine learning. J. Power Sources 494, 229727.
Tarar, M.O., Hassan, N.U., Naqvi, I.H., Pecht, M., 2023. Techno-economic framework for electric vehicle battery swapping stations. IEEE Trans. Transp. Electrific. 9, 4458–4473.
Teng, S., Chen, L., Ai, Y., Zhou, Y., Zhe, X., Hu, X., 2023. Hierarchical interpretable imitation learning for end-to-end autonomous driving. IEEE Trans. Intell. Veh. 8, 673–683.
The European Green Deal, 2020. 2050 long-term strategy-European Commission. https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en.
Thomas, C.E., 2012. US marginal electricity grid mixes and EV greenhouse gasemissions. Int. J. Hydrog. Energy 37, 19231–19240.
Tian, Y., Wang, Z., Ji, X., Ma, L., Zhang, L., Hong, X., et al., 2023. A concept dual-motor powertrain for battery electric vehicles: principle, modeling and mode-shift. Mech. Mach. Theory 185, 105330.
Timilsina, L., Badr, P.R., Hoang, P.H., Ozkan, G., Papari, B., Edrington, C.S., 2023. Battery degradation in electric and hybrid electric vehicles: a survey study. IEEE Access 11, 42431–42462.
Tong, H.Y., Ng, K.W., 2023. Developing electric bus driving cycles with significant road gradient changes: a case study in Hong Kong. Sustain. Cities Soc. 98, 104819.
Tran, M., Banister, D., Bishop, J.D.K., McCulloch, M.D., 2012. Realizing the electric-vehicle revolution. Nat. Clim. Change 2, 328–333.
Turksoy, A., Teke, A., Alkaya, A., 2020. A comprehensive overview of the dc-dc converter-based battery charge balancing methods in electric vehicles. Renew. Sustain. Energy Rev. 133, 110274.
Upadhyayula, V.K.K., Parvatker, A.G., Baroth, A., Shanmugam, K., 2019. Lightweighting and electrification strategies for improving environmental performance of passenger cars in India by 2030: a critical perspective based on life cycle assessment. J. Clean. Prod. 209, 1604–1613.
Van der Meer, D., Chandra Mouli, G.R., Morales-Espana Mouli, G., Elizondo, L.R., Bauer, P., 2018. Energy management system with PV power forecast to optimally charge EVs at the workplace. IEEE Trans. Ind. Inf. 14, 311–320.
Venugopal, R., Chandrasekar, B., Savio, A.D., Narayanamoorthi, R., Aboras, K.M., Kotb, H., et al., 2023. Review on unidirectional non-isolated high gain DC–DC converters for EV sustainable DC fast charging applications. IEEE Access 11, 78299–78338.
Vijaya Sambhavi, Y., Ramachandran, V., 2023. A technical review of modern traction inverter systems used in electric vehicle application. Energy Rep. 10, 3882–3907.
Wang, H., Zhang, H., Zhao, L., Luo, Z., Hou, K., Du, X., et al., 2022. Real-world carbon emissions evaluation for prefabricated component transportation by battery electric vehicles. Energy Rep. 8, 8186–8199.
Wang, L., Shen, W., Kim, H.C., Wallington, T.J., Zhang, Q., Han, W., 2020. Life cycle water use of gasoline and electric light-duty vehicles in China. Resour. Conserv. Recycl. 154, 104628.
Wang, Y., Bi, J., Guan, W., Lu, C., Xie, D., 2021. Optimal charging strategy for intercity travels of battery electric vehicles. Transport. Res. Transport Environ. 96, 102870.
Wang, Y., Bi, J., Guan, W., Zhao, X., 2018a. Optimising route choices for the travelling and charging of battery electric vehicles by considering multiple objectives. Transport. Res. Transport Environ. 64, 246–261.
Wang, B., Hung, D.L.S., Zhong, J., Teh, K.Y., 2018b. Energy consumption analysis of different bev powertrain topologies by design optimization. Int. J. Automot. Technol. 19, 907–914.
Wei, H., He, C., Li, J., Zhao, L., 2022. Online estimation of driving range for battery electric vehicles based on SOC-segmented actual driving cycle. J. Energy Storage 49, 104091.
Wen, J., Zhao, D., Zhang, C., 2020. An overview of electricity powered vehicles: lithium-ion battery energy storage density and energy conversion efficiency. Renew. Energy 162, 1629–1648.
Woo, J., Magee, C.L., 2020. Forecasting the value of battery electric vehicles compared to internal combustion engine vehicles: the influence of driving range and battery technology. Int. J. Energy Res. 44, 6483–6501.
Wu, Z., Wang, C., Wolfram, P., Zhang, Y., Sun, X., Hertwich, E., 2019. Assessing electric vehicle policy with region-specific carbon footprints. Appl. Energy 256, 113923.
Wu, Z., Wang, M., Zheng, J., Sun, X., Zhao, M., Wang, X., 2018. Life cycle greenhouse gas emission reduction potential of battery electric vehicle. J. Clean. Prod. 190, 462–470.

Xu, J., Ma, J., Zhao, X., Chen, H., Xu, B., Wu, X., 2020. Detection technology for battery safety in electric vehicles: a review. Energies 13, 4636.
Xu, W., Rajendran, S., Guo, Z., Vetrivelan, A., Huang, A.Q., 2023. 13.8 kV/400 kW solid state transformer DC fast charger (SST-DCFC) based on 15kV SiC AC switch. In: 2023 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 905–912.
Xue, X., Guo, R., He Esq, J., Hong, Z., 2020. A Road Load Data Processing Method for Transmission Durability Optimization Development, vol. 1062. SAE Technical Paper Series.
Yan, S., 2018. The economic and environmental impacts of tax incentives for battery electric vehicles in Europe. Energy Pol. 123, 53–63.
Yang, J., Chen, F., 2021. How are social-psychological factors related to consumer preferences for plug-in electric vehicles? Case studies from two cities in China. Renew. Sustain. Energy Rev. 149, 111325.
Yang, X.G., Liu, T., Gao, Y., Ge, S., Leng, Y., Wang, D., et al., 2019. Asymmetric temperature modulation for extreme fast charging of lithium-ion batteries. Joule 3, 3002–3019.
Yang, Y., Wang, Z., Wang, S., Lin, N., 2022a. An investigation of opportunity charging with hybrid energy storage system on electric bus with two-speed transmission. Sustainability 14, 11918.
Yang, Z., Huang, H., Lin, F., 2022b. Sustainable electric vehicle batteries for a sustainable world: perspectives on battery cathodes, environment, supply chain, manufacturing, life cycle, and policy. Adv. Energy Mater. 12, 2200383.
Yap, K.Y., Chin, H.H., Klemeš, J.J., 2022. Solar Energy-Powered Battery Electric Vehicle charging stations: current development and future prospect review. Renew. Sustain. Energy Rev. 169, 112862.
Yayan, U., Arslan, A.T., Yucel, H., 2021. A novel method for SoH prediction of batteries based on stacked LSTM with quick charge data. Appl. Artif. Intell. 35, 421–439.
Young, K., Wang, C., Wang, L.Y., Strunz, K., 2012. Electric vehicle battery technologies. In: Electric Vehicle Integration into Modern Power Networks, pp. 15–56.
Yuan, X., Li, L., Gou, H., Dong, T., 2015. Energy and environmental impact of battery electric vehicle range in China. Appl. Energy 157, 75–84.
Yuksel, T., Michalek, J.J., 2015. Effects of regional temperature on electric vehicle efficiency, range, and emissions in the United States. Environ. Sci. Technol. 49, 3974–3980.
Zhang, J., Ning, L., Hao, Y., Sang, T., 2021. Topology optimization for crashworthiness and structural design of a battery electric vehicle. Int. J. Crashworthiness 26, 651–660.
Zhang, J., Zhang, L., Sun, F., Wang, Z., 2018. An overview on thermal safety issues of lithium-ion batteries for electric vehicle application. IEEE Access 6, 23848–23863.
Zhang, L., Shaffer, B., Brown, T., Scott Samuelsen, G., 2015. The optimization of DC fast charging deployment in California. Appl. Energy 157, 111–122.
Zhang, M., Yang, D., Du, J., Sun, H., Li, L., Wang, L., et al., 2023. A review of SOH prediction of Li-ion batteries based on data-driven algorithms. Energies 16, 3167.
Zhang, S., Zhuan, X., 2019. Study on adaptive cruise control strategy for battery electric vehicle. Math. Probl Eng. 2019, 7971594.
Zhao, X., Hu, H., Yuan, H., Chu, X., 2023. How does adoption of electric vehicles reduce carbon emissions? Evidence from China. Heliyon 9, e20296.
Zheng, Y., He, X., Wang, H., Wang, M., Zhang, S., Ma, D., et al., 2020. Well-to-wheels greenhouse gas and air pollutant emissions from battery electric vehicles in China. Mitig. Adapt. Strateg. Glob. Change 25, 355–370.
Zhou, W., Cleaver, C.J., Dunant, C.F., Allwood, J.M., Lin, J., 2023. Cost, range anxiety and future electricity supply: a review of how today's technology trends may influence the future uptake of BEVs. Renew. Sustain. Energy Rev. 173, 113074.
Zhou, Y., Wen, R., Wang, H., Cai, H., 2020. Optimal battery electric vehicles range: a study considering heterogeneous travel patterns, charging behaviors, and access to charging infrastructure. Energy 197, 116945.

Fangjie Liu obtained the B.S. degree in 2019 from Huazhong University of Science and Technology. She then completed a dual M.S. program, earning degrees from both Huazhong University of Science and Technology and École des Mines de Paris in 2022. She is currently pursuing the Ph.D. degree at City University of Hong Kong. Before joining City University of Hong Kong, she worked in the Energy Department of the United Nations Industrial Development Organization, where she assisted in compiling the "World Small Hydropower Development Report 2022".

Muhammad Shafique is currently a Lecturer (Assistant Professor) in the Department of Civil & Environmental Engineering, College of Engineering, Design and Physical Sciences at Brunel University London. He received the Ph.D. degree in 2021 in architecture and civil engineering from City University of Hong Kong and M.S. degree in 2018 in smart city and construction engineering from the University of Science and Technology, Republic of Korea. His research work spans life cycle assessment, circular economy, and scenario modeling to identify the environmental problems of emerging products and systems. By proactively understanding the environmental issues of technologies that are still under development, we can identify a number of optimal options and innovative solutions to avoid or reduce negative consequences. He works on interdisciplinary topics including sustainable transportation systems, sustainable construction, sustainable design of energy systems, advanced fuels, sustainable and smart materials, carbon-neutrality, net zero targets, energy, environment & economics nexus, and climate change adaptation. One of his core areas of work includes developing an integrated modeling approach based on life cycle assessment and circular economy for sustainable electromobility.

Xiaowei Luo holds the position of Associate Professor in the Department of Architecture and Civil Engineering at City University of Hong Kong. He earned the Ph.D. degree in 2013 in construction engineering and project management from the University of Texas at Austin, complemented by both M.S. and B.S. degrees from Tsinghua University in Beijing, China. His research primarily explores areas such as Building Information Modeling (BIM), Construction Safety Management, Construction Robotics, Human-Robot Collaboration, Digital Twins, Augmented and Virtual Reality (A&VR), Building Energy Management, and Life Cycle Assessment (LCA). He is a prolific author, having contributed numerous highly cited articles to journals, conference proceedings, and book chapters on these subjects. He has been awarded multiple research grants from various agencies, including the National Science Foundation of China, the Research Grant Council (HK), the Construction Industrial Council (CIC), the Shenzhen Innovation and Technology Council, etc. He serves as an Associate Editor for *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, and *Smart Construction.*