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CHALLENGES AND LIMITATIONS OF ELECTRIC TRANSPORT SYSTEMS: ECONOMIC, ENVIRONMENTAL AND INFRASTRUCTURE PERSPECTIVES

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Annotation

This article examines the main challenges and limitations of electric transport systems from economic, environmental, and infrastructure perspectives. The study analyzes the high initial cost of electric vehicles, the uneven development of charging infrastructure, the growing pressure on power systems, and the environmental issues related to battery production, resource extraction, and end-of-life disposal. Particular attention is given to the contradiction between the environmental advantages of electric transport during operation and the hidden ecological costs that arise across the full life cycle. The article also considers infrastructure-related barriers, including insufficient charging coverage, long charging times, grid capacity constraints, and regional inequality in access to modern transport technologies. On this basis, the paper argues that the large-scale expansion of electric transport requires not only technological progress, but also integrated economic policy, sustainable energy planning, and effective battery management systems. The findings may be useful for researchers, policymakers, and practitioners working on sustainable mobility and transport modernization.

Keywords

electric transport systems, electric vehicles, charging infrastructure, battery lifecycle, environmental impact, economic barriers, grid capacity, sustainable mobility, transport decarbonization, infrastructure limitations.

1. Introduction

The global transportation sector is undergoing a major transformation driven by technological innovation and the need to reduce greenhouse gas emissions. Electric transport systems, including electric cars, buses, and rail systems, are increasingly promoted as sustainable alternatives to conventional fossil fuel–based transportation. Governments and international organizations support the development of electric mobility as part of broader strategies aimed at improving energy efficiency and reducing environmental impacts.

Electric vehicles (EVs) are often considered environmentally friendly because they produce lower emissions during operation and offer higher energy efficiency compared with internal combustion engine vehicles. As a result, many countries have introduced policies such as subsidies, tax incentives, and infrastructure development programs to encourage the adoption of electric transport technologies.

However, despite their potential benefits, the large-scale implementation of electric transport systems faces several important challenges. High production costs, limited battery lifespan, dependence on critical raw materials, and insufficient charging infrastructure remain significant barriers to widespread adoption. In addition, battery production and disposal may generate environmental impacts that partially offset the environmental advantages of electric vehicles.

Infrastructure development is another critical factor influencing the adoption of electric transport. Reliable and accessible charging networks are necessary to support the growing number of electric vehicles. In many regions, however, charging infrastructure remains limited

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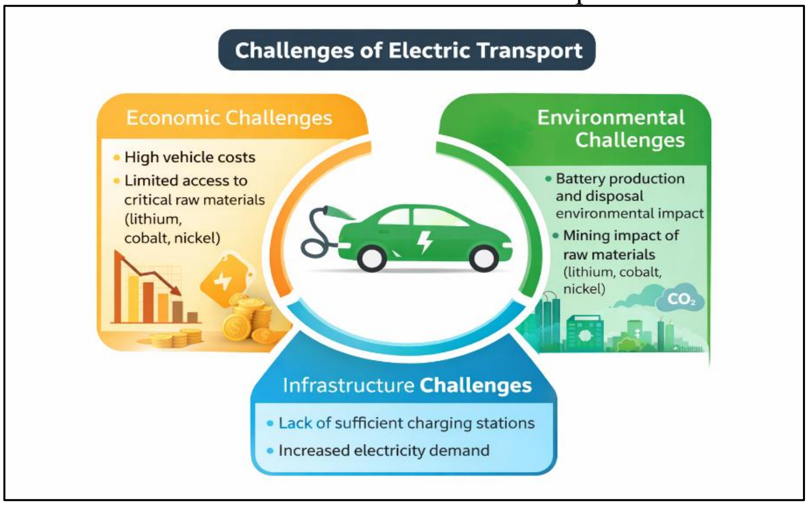
or unevenly distributed, which contributes to consumer concerns regarding vehicle range and charging availability.

Furthermore, the increasing number of electric vehicles may place additional pressure on electricity systems. Without the expansion of renewable energy sources and modernization of power grids, the environmental benefits of electric transport could be reduced.

This study aims to analyze the major challenges and limitations associated with electric transport systems. The research focuses on three key aspects: economic constraints, environmental impacts related to battery production and disposal, and infrastructural barriers associated with charging networks and energy systems. By examining these factors, the study provides a balanced assessment of the role of electric transport in the transition toward sustainable mobility.



2. Methods

This study employs a qualitative and analytical research approach to examine the key limitations and challenges associated with electric transport systems. The research is based on a comprehensive review of academic literature, international policy reports, and industry analyses related to electric mobility, battery technologies, and transport infrastructure.

First, a systematic literature review was conducted to identify the primary economic, environmental, and infrastructural issues associated with electric transport development. Scientific publications, international energy reports, and policy documents were analyzed in order to understand the current state of electric transport technologies and the barriers affecting their large-scale adoption.

Second, comparative analysis was applied to evaluate different dimensions of electric transport limitations. The study examines several critical aspects, including battery production processes, raw material supply chains, charging infrastructure availability, and the economic costs associated with electric vehicle manufacturing and infrastructure development. This analytical framework allows for the identification of major structural barriers that influence the efficiency and sustainability of electric transport systems.

Finally, synthesis and conceptual analysis were used to integrate the findings from the reviewed sources. This approach allows the study to present a comprehensive assessment of the challenges associated with electric transport systems and their implications for sustainable mobility strategies.

3. Results

One of the most significant barriers is the high cost of electric vehicle production. The manufacturing process of electric vehicles requires advanced technologies and expensive battery systems, which significantly increase production costs compared with conventional vehicles. According to recent market data, the average price of a battery electric vehicle remains around

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USD 40,000–45,000, while comparable internal combustion engine vehicles typically cost USD 30,000–32,000. Battery systems account for nearly 30–40% of total EV production costs. However, battery technology costs have gradually declined over time: the global average lithium-ion battery pack price fell to approximately USD 108 per kWh in 2025, representing an 8% decrease compared with 2024. Despite these improvements, electric vehicles remain more expensive than conventional vehicles in many markets.

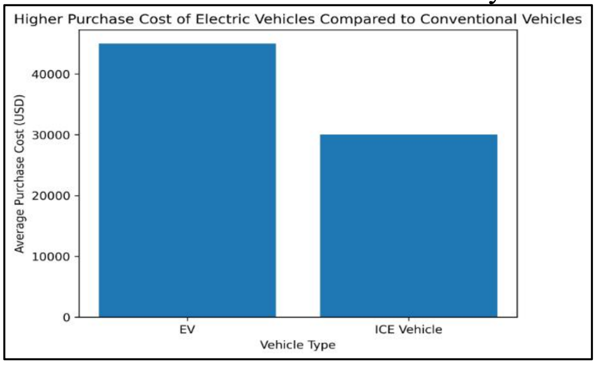

Figure 1. Higher Purchase Cost of Electric Vehicles Compared to Conventional Vehicles

Figure 1 illustrates the significant price difference between electric vehicles and conventional vehicles. Electric vehicles remain more expensive due primarily to the high cost of lithium-ion battery systems and advanced electronic components. This cost difference represents one of the most important barriers to the widespread adoption of electric transport, particularly in developing economies where purchasing power is lower.

Another important challenge relates to the supply chain of battery materials. Lithium-ion batteries depend on critical raw materials such as lithium, cobalt, and nickel. Global lithium production has increased rapidly due to growing EV demand, reaching roughly 180,000 tons in 2023–2024, and estimates suggest that production could exceed 200,000 tons in 2025. Approximately 47% of global lithium production is located in Australia, around 30% in Chile, and about 15% in China. These materials are geographically concentrated, which creates potential supply chain risks and geopolitical dependencies for electric vehicle manufacturers.

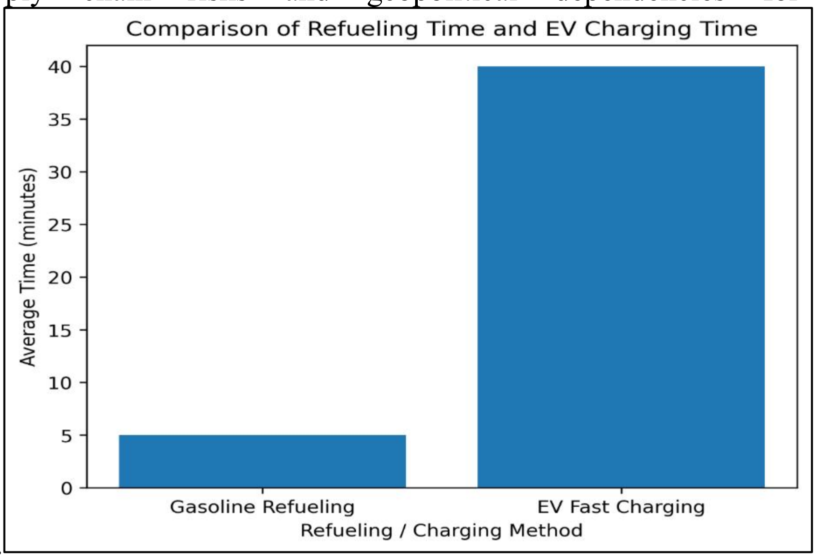

Figure 2. Comparison of Refueling Time and EV Charging Time

Figure 2 highlights the significant difference between traditional fuel refueling and electric vehicle charging times. While gasoline vehicles can be refueled within a few minutes, electric vehicles often require significantly longer charging periods. This limitation reduces the convenience of electric vehicles for long-distance travel and remains a critical challenge for widespread adoption.

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Environmental concerns associated with battery production and disposal also represent a major limitation. Although electric vehicles produce fewer emissions during operation, the production of batteries requires substantial energy consumption. Life-cycle studies indicate that the manufacturing of electric vehicles can generate approximately 10–12 tons of CO_2 emissions, compared with around 6–7 tons for conventional vehicles, largely due to battery production processes. In addition, the rapid growth of the EV market means that the number of used batteries will increase significantly in the coming years. By 2025, global EV battery demand is expected to exceed 950 GWh, creating additional pressure on recycling systems. However, recycling of lithium-ion batteries remains limited, with global recycling rates estimated at only 5–10%, highlighting the need for improved recycling technologies.

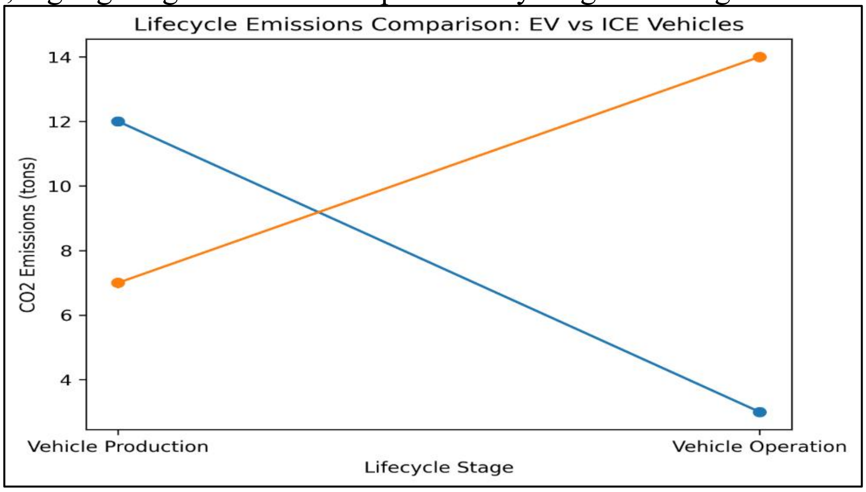

Figure 3. Lifecycle Emissions Comparison of Electric and Conventional Vehicles

Figure 3 demonstrates that electric vehicles tend to produce higher emissions during the production stage due to battery manufacturing processes. However, during the operational phase, electric vehicles generally produce lower emissions compared with conventional vehicles. This indicates that the environmental benefits of electric transport depend heavily on improvements in battery manufacturing and energy production systems.

Infrastructure limitations represent another key barrier to the widespread adoption of electric transport systems. Many regions still lack sufficient charging infrastructure to support large numbers of electric vehicles. By the end of 2024, the global number of public EV charging points exceeded 5 million, reflecting rapid growth in infrastructure deployment. Current projections indicate that the number of public charging stations could exceed 10 million worldwide by 2025 as governments and private companies continue expanding charging networks.

However, infrastructure distribution remains uneven, particularly between urban and rural areas. Charging time also remains a challenge: refueling a conventional vehicle typically takes 3–5 minutes, while fast-charging an electric vehicle often requires 30–40 minutes to reach 80% battery capacity.

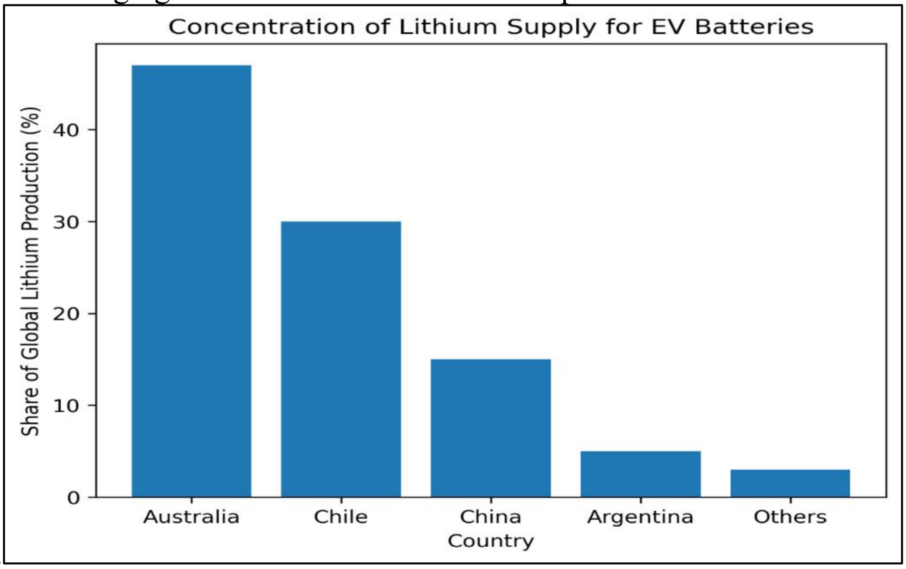

Figure 4. Global Lithium Supply Concentration

Figure 4 illustrates the strong geographic concentration of lithium production, which is a key material used in lithium-ion batteries. The concentration of production in a few countries creates potential supply risks and geopolitical dependencies. Such supply chain vulnerabilities may affect the long-term stability and scalability of electric vehicle manufacturing.

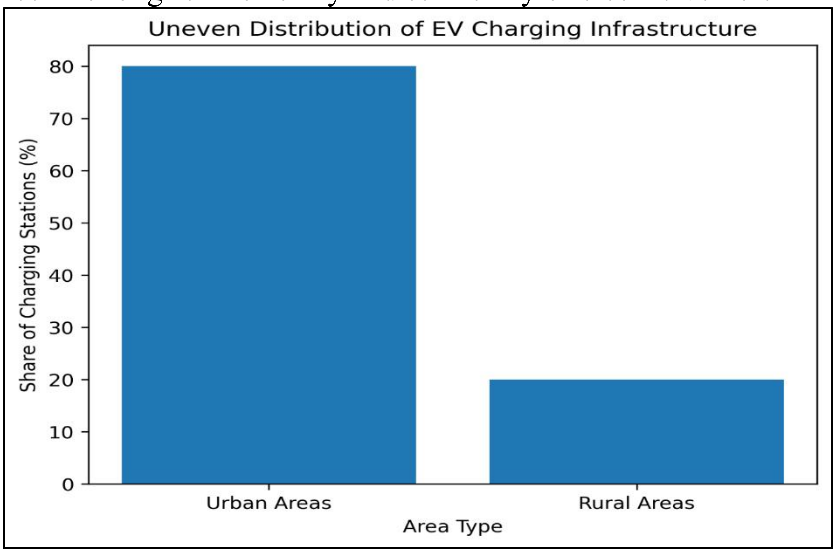

Figure 5. Uneven Distribution of EV Charging Infrastructure

Figure 5 demonstrates the uneven distribution of charging infrastructure between urban and rural areas. Charging stations are typically concentrated in urban regions where demand is higher and infrastructure investment is more profitable. This imbalance may limit the adoption of electric vehicles in rural areas and highlights the need for more balanced infrastructure development.

In addition, the increasing number of electric vehicles may place significant pressure on national electricity systems. Global EV sales exceeded 17 million vehicles in 2024, and projections suggest that sales may surpass 20 million vehicles in 2025, representing approximately one quarter of global new car sales.

Such rapid growth could substantially increase electricity demand in the transport sector and require significant upgrades to energy infrastructure.

4. Discussion

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The findings of this study highlight the complex nature of the transition toward electric transport systems. While electric mobility offers clear environmental advantages compared with traditional fossil fuel–based transportation, several structural challenges remain that must be addressed in order to ensure sustainable implementation.

Economic barriers remain one of the most significant obstacles to the widespread adoption of electric vehicles. Although battery prices have declined dramatically—from approximately USD 1,200 per kWh in 2010 to about USD 108 per kWh in 2025—electric vehicles are still more expensive than conventional vehicles in many markets. High purchase prices continue to limit EV accessibility, particularly in developing countries where income levels are lower and government subsidies may be limited.

Environmental concerns associated with battery production also raise important questions regarding the overall sustainability of electric transport systems. The extraction of critical minerals used in battery manufacturing can cause environmental degradation, high water consumption, and ecological damage in mining regions. Furthermore, the limited recycling of lithium-ion batteries may create long-term waste management challenges as the number of electric vehicles continues to grow.

Infrastructure development represents another critical component in the transition toward electric transport. The availability of reliable and accessible charging networks is essential for increasing consumer confidence in electric vehicles. However, despite rapid growth, infrastructure expansion often struggles to keep pace with EV adoption. Public charging stations have more than doubled since 2022, yet infrastructure remains unevenly distributed across regions.

Furthermore, the electrification of transport must be closely integrated with broader energy system transformations. If electricity used to power electric vehicles is generated primarily from fossil fuels, the environmental benefits of electrified mobility may be reduced. Therefore, the expansion of renewable energy systems and modernization of electricity grids should accompany the electrification of transport systems.

Overall, the transition toward electric mobility should be approached with a balanced perspective that recognizes both its potential benefits and its current limitations. Addressing these challenges will require continued technological innovation, expansion of charging infrastructure, improved battery recycling systems, and stronger integration between transport and energy policies.

5. Conclusion

Electric transport systems are widely promoted as an essential component of sustainable mobility and global decarbonization strategies. However, the findings of this study demonstrate that the transition toward electrified transport is associated with several significant economic, environmental, and infrastructural challenges. While electric vehicles offer advantages such as reduced operational emissions and improved energy efficiency, their large-scale adoption remains constrained by technological limitations, high production costs, and infrastructure requirements.

One of the most important challenges identified in this research is the economic cost associated with electric vehicle production and battery technologies. The reliance on lithium-ion batteries, which require rare and expensive raw materials, contributes to higher vehicle prices and creates supply chain dependencies. These factors may limit the accessibility of electric vehicles for consumers, particularly in developing economies where purchasing power and government subsidies are limited.

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Environmental considerations also play an important role in evaluating the sustainability of electric transport systems. Although electric vehicles produce fewer emissions during operation, the environmental impact of battery production and raw material extraction must also be considered. Mining activities associated with lithium, cobalt, and nickel extraction may lead to environmental degradation and increased energy consumption. Additionally, the disposal and recycling of used batteries present technological and environmental challenges that require further research and development.

Infrastructure limitations represent another key obstacle to the widespread adoption of electric transport. The successful integration of electric vehicles into transport systems depends heavily on the availability of reliable and accessible charging infrastructure. In many regions, charging networks remain insufficient or unevenly distributed, which can discourage potential users and slow the transition toward electric mobility.

Furthermore, the electrification of transportation may significantly increase electricity demand. Without adequate expansion of renewable energy sources and modernization of electricity grids, increased electricity consumption from electric vehicles could place pressure on national energy systems and reduce the overall environmental benefits of electrified transport.

Overall, the transition toward electric transport should be approached with a balanced and realistic perspective. While electric mobility represents an important technological innovation with significant environmental potential, addressing its economic, environmental, and infrastructural limitations is essential for ensuring sustainable implementation. Future research should focus on improving battery technologies, developing efficient recycling systems, and expanding charging infrastructure in order to support a more sustainable and accessible electric transport ecosystem.

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