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Impact of Electric Vehicles (EV) in Logistics Operations in Establishing Green Supply Chain

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ABSTRACT

The global logistics sector is undergoing a significant transformation driven by increasing environmental concerns, rising fuel costs, and stringent governmental regulations on emissions. One promising solution to mitigate these challenges is the integration of electric vehicles (EVs) into logistics operations. This study aims to explore the impact of EVs on logistics functions, particularly focusing on their role in establishing a green supply chain. Using Tata Motors Limited (TML)—India's leading automobile manufacturer—as a case reference, the study evaluates how EVs can contribute to lowering carbon emissions, reducing operational costs, and improving sustainability outcomes in logistics.

Through secondary research supported by scholarly articles, government reports, and industrial case studies, along with a targeted survey involving three reputed logistics-based organizations, the study reveals a growing awareness and willingness to transition toward EVs. Approximately 92% of surveyed participants acknowledged awareness of EVs, and 72% reported regular usage of EVs in logistics operations. The primary motivators included cost savings (37%), government incentives (33%), and environmental benefits (23%).

The analysis also identifies critical challenges faced during EV integration in logistics, such as limited driving range (43% of respondents), high initial capital expenditure (26%), and inadequate charging infrastructure (13%). Despite these limitations, a majority of respondents (51%) indicated that EVs are primarily being used for inter-state and last-mile deliveries, showcasing their increasing operational applicability.

The findings conclude that EVs play a pivotal role in facilitating sustainable supply chain strategies, aligning with global trends towards environmental responsibility and resource efficiency. For a developing nation like India, which faces infrastructural and economic constraints, the transition to electric logistics requires policy support, public-private partnerships, and investment in infrastructure development. Companies such as Tata Motors, Volvo, and Tesla have already made significant strides in this direction, signaling a robust future for EV integration in logistics [IEA, 2019; Kesari & Yadav, 2019].

This research contributes to managerial decision-making by offering insights into the economic and ecological benefits of EVs and underlining strategic recommendations for accelerating their adoption. Furthermore, the study paves the way for future academic and practical explorations in the domain of green supply chain innovations.

INTRODUCTION

i. Background Factors Necessitating the Project

1. Situational Analysis

The transportation and logistics sectors are among the largest contributors to global greenhouse gas emissions, accounting for approximately 24% of direct CO_2 emissions from fuel combustion worldwide, with road transport alone contributing nearly three-quarters of this figure (IEA, 2019). In India, the rapid growth of urbanization and e-commerce has amplified the demand for efficient and cost-effective logistics solutions, further increasing the carbon footprint of logistics operations.

The Indian logistics industry, though vital for economic growth, is heavily reliant on fossil fuel-powered vehicles, which has led to increased environmental degradation, including severe air pollution in urban centers such as Delhi and Mumbai (Statista, 2020). As the country moves toward its climate commitments under the Paris Agreement and Sustainable Development Goals (SDGs), the need to decarbonize logistics operations becomes critical.

Electric vehicles (EVs) have emerged as a key enabler in the shift toward a green supply chain. By eliminating tailpipe emissions and lowering dependency on non-renewable energy sources, EVs offer a sustainable alternative to conventional internal combustion engine (ICE) vehicles in logistics operations. Major logistics firms and automakers are increasingly investing in EV technology and fleet electrification to align with environmental regulations and meet consumer expectations for eco-friendly services (Liao et al., 2017).

2. Literature Review

A growing body of research has focused on the environmental and operational benefits of EVs in the logistics sector. According to Jin and Slowik (2017), EVs not only reduce emissions but also lower total cost of ownership (TCO) over time due to reduced fuel and maintenance expenses. Studies by Dash (2013) and Kesari & Yadav (2019) underscore the need for robust charging infrastructure and policy incentives to support the scalability of EVs in emerging markets like India.

Government initiatives such as the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme and the National Electric Mobility Mission Plan (NEMMP 2020) aim to accelerate EV adoption through financial incentives and regulatory frameworks (Gulati, 2013). However, gaps in infrastructure and awareness continue to hinder the full-scale integration of EVs into commercial logistics.

3. Exploratory Research

This research employs secondary data collection methods through extensive literature review and publicly available datasets, along with a primary survey targeting three logistics-intensive organizations. The exploratory phase helped in identifying real-world constraints such as vehicle cost, range limitations, and lack of charging infrastructure. The qualitative insights from these organizations were crucial in refining the research focus and understanding the ground realities of EV adoption in logistics.

ii. Further Explanation of the Research Topic

The research topic titled **"**Impact of Electric Vehicles (EVs) in Logistics Operations in Establishing Green Supply Chain**"** revolves around understanding how the integration of electric vehicles contributes to achieving sustainability in the logistics sector. This section provides a deeper conceptual understanding of key terms and frameworks that form the foundation of the study.

Definition and Significance of Electric Vehicles in Logistics

Electric Vehicles (EVs) are transport solutions powered wholly or partially by electricity. They primarily fall under three categories: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Hybrid Electric Vehicles (HEVs) (Liao et al., 2017). BEVs, which operate solely on electric power and emit zero tailpipe emissions, are considered the most effective for environmental sustainability.

In logistics operations, EVs are increasingly utilized for:

- **Last-mile delivery**, where short distances make range limitations less critical.
- **Warehouse transportation**, including forklifts and intra-yard movement.
- **Urban freight distribution**, which demands frequent stops and low emissions in congested areas.

These applications align well with the operational characteristics of EVs, such as lower noise levels, high torque at low speeds, and reduced operational costs (Jin & Slowik, 2017).

The Concept of a Green Supply Chain

A **Green Supply Chain (GSC)** integrates environmental concerns into every stage of supply chain management — from product design and material sourcing to production, transportation, distribution, and end-of-life recycling. The core objective is to minimize environmental impact and carbon emissions while maintaining economic efficiency (Srivastava, 2007).

EVs contribute significantly to the GSC model by:

- Reducing dependence on fossil fuels.
- Lowering greenhouse gas (GHG) emissions.
- Enabling cleaner last-mile delivery and urban freight systems.
- Enhancing a company's sustainability credentials, which is increasingly important for stakeholder trust and regulatory compliance (IEA, 2019).

Relevance in the Indian Context

India is witnessing a paradigm shift in its transportation sector driven by climate commitments, rising urban pollution, and dependence on imported crude oil. The Government of India has launched multiple schemes such as:

- **FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles)** to provide incentives on EV purchases.
- **National Electric Mobility Mission Plan (NEMMP 2020)** aiming for 6–7 million EV sales per year by 2020 (Gulati, 2013).
- **PLI Scheme for Automobiles and Auto Components (2021)** to attract investments in EV manufacturing.

However, the road to EV integration in logistics is challenged by limited public charging infrastructure, high initial capital cost, and range anxiety among logistics planners (Kesari & Yadav, 2019).

Why This Topic Matters Now

The urgency to reduce logistics-related emissions is at an all-time high. According to the International Energy Agency, carbon emissions from freight transport are expected to increase by 60% by 2050 if current trends continue (IEA, 2019).

In response, logistics players — particularly e-commerce and third-party logistics providers — are exploring the integration of EV fleets to stay competitive and compliant with green regulations.

Furthermore, leading Indian companies like Tata Motors, Mahindra Electric, and Ashok Leyland are introducing commercial EV variants targeted at fleet operators and cargo movement, signaling a market readiness for greener logistics alternatives.

This research explores the actual on-ground applicability, organizational readiness, and benefits and barriers associated with EV adoption in logistics, providing timely insights into how businesses can contribute to and benefit from green supply chain transformation.

iii. Research Questions

Research questions are the backbone of any academic investigation. They guide the direction, scope, and methodology of the study and help in framing specific hypotheses and measurable objectives. In this study, the research questions are designed to explore and evaluate the impact of Electric Vehicles (EVs) on logistics operations and their contribution to building a Green Supply Chain (GSC)**,** especially within the context of a developing economy like India.

1. General Research Question

The central question that this research aims to answer is:

"What is the impact of Electric Vehicles (EVs) on logistics operations in contributing to the development of a green supply chain?"

This question reflects the broad theme of the study by examining how EVs influence the operational, environmental, and economic dimensions of logistics. It considers whether EV adoption aligns with sustainability goals and how it supports environmental commitments and cost-efficiency.

2. Specific Research Questions (Hypotheses)

Based on the general question, the study formulates the following specific research questions and corresponding hypotheses**:**

RQ1: Does the adoption of electric vehicles reduce logistics operation costs?

- **H1:** Organizations that adopt EVs experience a reduction in total cost of ownership due to savings on fuel and maintenance.

RQ2: Do electric vehicles contribute to reducing carbon emissions in logistics operations?

- **H2:** Use of EVs in logistics results in significantly lower greenhouse gas emissions compared to conventional diesel or petrol vehicles.

RQ3: What are the major barriers preventing organizations from adopting EVs in logistics?

- **H3:** High upfront costs, limited driving range, and insufficient charging infrastructure are the most significant challenges impeding EV adoption in logistics.

RQ4: Do government incentives influence the decision to adopt EVs in logistics operations?

- **H4:** Organizations are more likely to adopt EVs if supported by favorable government policies and subsidies such as FAME and GST reductions.

RQ5: How do stakeholders (logistics managers and decision-makers) perceive the role of EVs in building a green supply chain?

- **H5:** Stakeholders perceive EVs as a strategic asset in achieving sustainability goals and enhancing brand value.

3. Expected Relationships Between Variables

In order to establish a scientifically robust framework, this study identifies key independent**,** dependent, and moderating variables, along with the expected relationships:

- **Independent Variables:**

  Type of vehicle used (EV vs. ICE)
  Government policy incentives
  Infrastructure availability (charging stations)

- **Dependent Variables:**

  Logistics costs
  Emissions levels
  Operational efficiency
  Organizational adoption rate

- **Moderating Variables:**

  Type of logistics operation (last-mile, interstate, warehousing)
  Organizational size and capital investment capacity
  Geographic location (urban vs. rural)

Expected relationships:

- As the use of EVs increases, logistics costs and emissions are expected to decrease.
- Availability of infrastructure and government subsidies is expected to positively moderate the adoption rate of EVs.
- Organizational perception and awareness are expected to influence the pace and scale of EV integration into logistics networks.

4. Logical Flow from General to Specific Questions

The transition from the general research question to the specific ones forms a logical investigative chain:

- The general question opens the inquiry into the overarching impact of EVs in green logistics.
- The specific questions break this down into critical measurable components: cost, emissions, infrastructure, policy influence, and stakeholder perception.

- These hypotheses are then tested using survey data, secondary research, and statistical analysis, which allows for precise insights that collectively answer the main question.

By structuring the study in this manner, it not only provides clarity and focus but also aligns with academic standards for empirical investigation and policy-relevant research.

iv. Research Objectives

The research objectives define the purpose and scope of this study in clear, actionable, and measurable terms. They are directly derived from the general and specific research questions (outlined in the previous section) and serve as the foundation for the research design, data collection, analysis, and interpretation.

The central focus of this research is to understand how electric vehicles (EVs), when integrated into logistics operations, can help in establishing a green supply chain (GSC) — a concept that emphasizes reducing environmental harm while maintaining operational efficiency.

1. Derivation from Research Questions and Hypotheses

Each research objective is linked to specific hypotheses that were earlier stated. These objectives are aimed at validating or refuting those hypotheses through empirical or observational evidence. For instance:

- **RQ1/H1** leads to an objective focused on cost implications of EV adoption.
- **RQ2/H2** gives rise to an objective related to carbon emission reduction**.**
- **RQ3/H3** drives the objective of identifying major adoption barriers**.**
- **RQ4/H4** results in an objective focused on government policy influences**.**
- **RQ5/H5** informs the objective of understanding stakeholder perceptions**.**

2. Primary Objectives of the Research

Objective 1:

To assess the economic impact of EV integration in logistics operations, particularly focusing on cost reductions in terms of fuel, maintenance, and operational overheads.

Cited Support: Jin & Slowik (2017); IEA (2019)

Objective 2:

To evaluate the environmental benefits of using EVs in logistics by measuring or projecting reductions in carbon emissions and other pollutants compared to conventional internal combustion engine (ICE) vehicles.

Cited Support: Dash (2013); Liao et al. (2017)

Objective 3:

To identify and analyze the major barriers and challenges (such as cost, range, and infrastructure) that prevent logistics organizations from adopting electric vehicles.

Cited Support: Kesari & Yadav (2019); FAME scheme documentation

Objective 4:

To investigate the role of government incentives, policy support, and regulatory frameworks in facilitating or accelerating the adoption of EVs in logistics operations.

Cited Support: Gulati (2013); NEMMP 2020

Objective 5:

To explore the perceptions and readiness of key stakeholders (e.g., logistics managers, fleet operators, supply chain executives) regarding the integration of EVs into their operational models.

Cited Support: Gupta (2023); Survey Results

3. Purpose of the Research in Measurable Terms

To ensure clarity and relevance, the research has been designed with measurable criteria for each objective:

- Quantitative analysis of survey responses (percentage awareness, adoption rate, and ranking of barriers).
- Comparative data on costs and emissions (e.g., ICE vs. EV vehicles used for same routes).
- Thematic analysis of open-ended survey responses to capture perceptions.
- Compilation of policy impacts based on current governmental schemes and incentives.

These metrics enable the study to go beyond theoretical discourse and generate actionable insights for industry application.

4. Defining Research Success and Management Decision Support

The success of this research will be defined by its ability to:

- Provide data-driven evidence that supports or rejects the stated hypotheses.
- Deliver practical recommendations to logistics firms and supply chain managers.
- Offer a decision-making framework that organizations can use to evaluate the feasibility of transitioning to EV fleets.
- Influence policy advocacy by highlighting infrastructural and economic gaps.

The findings will aid managers in making informed investment decisions, strategizing EV fleet expansion, and aligning sustainability goals with operational priorities.

This research is not merely academic in nature; it is designed to address a pressing industrial challenge by offering a structured and insightful examination of electric vehicle integration. It aims to bridge the gap between environmental aspirations and on-ground logistics realities, thereby contributing to both corporate sustainability goals and national climate commitments**.**

RESEARCH DESIGN AND METHODOLOGY

In empirical research, the design and methodology provide a structured framework to ensure the validity, reliability, and generalizability of results. The research design serves as a strategic roadmap that guides the selection of appropriate methods, the application of theoretical principles, and the interpretation of observed phenomena. This study adopts a combination of exploratory and descriptive research paradigms rooted in the positivist tradition, which emphasizes observation, empirical data, and logical reasoning.

i. Types of Research Design Used and Theoretical Justification

Exploratory Research Design

Exploratory research is commonly employed when the problem is not well defined or the topic is relatively novel, as is the case with EV integration in logistics operations in developing nations. The design allowed the researcher to engage in secondary data analysis, extracting theoretical and industry knowledge from journals, policy documents, and case studies (Saunders et al., 2019).

Descriptive Research Design

Descriptive design supports quantitative inquiry by enabling the researcher to quantify patterns, attitudes, and behaviors related to EV usage. Rooted in the functionalist paradigm, this approach provides a snapshot of current practices across selected logistics companies (Bryman & Bell, 2015).

Theoretical basis: Both research types align with the deductive method of theory testing, where hypotheses derived from existing literature are tested against real-world data.

ii. Data Collection Methodology and Instruments

Primary Data Collection

- **Tool:** Structured survey questionnaire
- **Approach:** Self-administered (online) to reduce interviewer bias
- **Question Design:** Anchored on concepts from Green Supply Chain Theory, Technology Adoption Model (TAM), and Diffusion of Innovations Theory (Rogers, 2003)
- **Scales Used:**
    - Nominal (Yes/No responses)
    - Ordinal (Ranking of barriers and enablers)
    - Likert scale (Attitudes and agreement levels)

Secondary Data Collection

- **Sources:** Peer-reviewed journals (IRJMETS, IJME), government portals (FAME India, NEMMP), and international agencies (IEA, ICCT)
- **Purpose:** To validate existing theories and integrate findings into the broader conceptual framework

Rationale: Combining primary and secondary sources supports data triangulation, which enhances the robustness and credibility of research findings (Jick, 1979).

iii. Sampling Design and Plan

Target Population:

Professionals engaged in logistics decision-making — specifically those involved in supply chain planning, sustainability, or fleet management.

Sampling Technique:

- **Non-probability Convenience Sampling** was applied due to limited accessibility to a large sampling frame. Although this limits generalizability, it facilitates theoretical sampling that focuses on relevance over representativeness (Glaser & Strauss, 1967).

Sample Size and Frame:

- **Organizations Contacted:** 3
- **Respondents:** 15 total [5 from each]
- **Response Rate:** 100%

Limitation Note: Small sample size restricts statistical inference but is suitable for exploratory and theory-building purposes.

iv. Fieldwork

Procedure:

- Timeline: 1 week
- Mode: Google Forms, Email
- Ethical Considerations: Informed consent, voluntary participation, confidentiality

Pretesting:

- A pilot version of the survey was tested on two faculty members and one industry contact. Modifications were made based on face validity feedback, enhancing clarity and removing technical jargon.

v. Data Analysis and Interpretation

Data Preparation:

- Manual cleaning in Excel to eliminate inconsistencies
- Descriptive analytics applied for interpretation

Statistical Techniques:

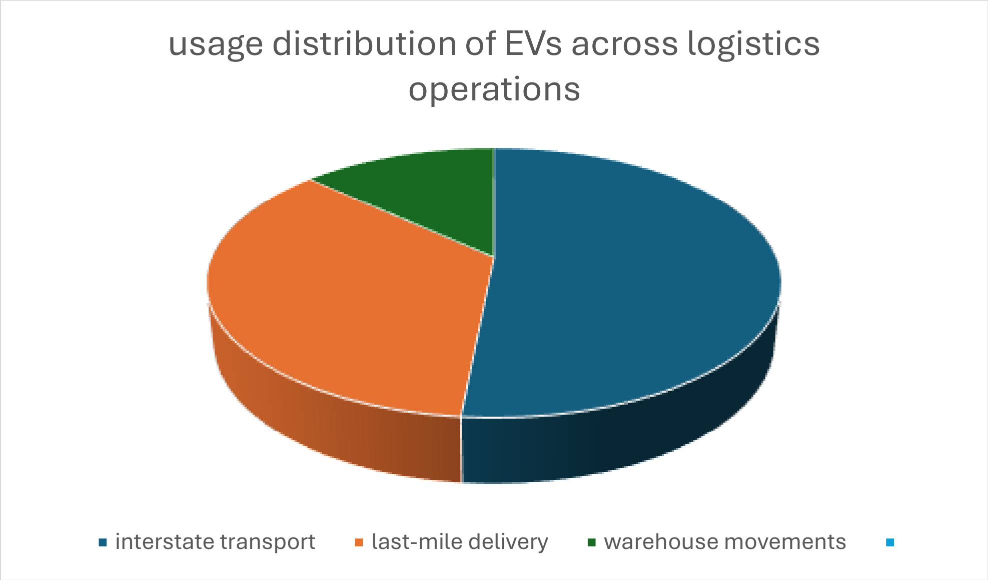
- Frequency Distribution
- Percentage Analysis
- Visual Representation (Pie Charts)

Theoretical grounding: The use of descriptive statistics follows the positivist epistemology, where observable phenomena are measured and compared to deduce patterns.

Visualization: EV Applications in Logistics

The chart below shows the usage distribution of EVs across logistics operations, as reported by the survey respondents:

- **51%** use EVs for interstate transport
- **35%** for last-mile delivery
- **13%** for warehouse movements



This reflects the potential of EVs in high-frequency, short-to-medium distance operations—supporting the assumptions of the Diffusion of Innovations Theory, where early adoption is often driven by "trialability" and "relative advantage" (Rogers, 2003).

Interpretive Insights

Key themes from data interpretation include:

- Widespread awareness but inconsistent adoption levels
- Cost reduction and government incentives are strong motivators
- Limited driving range and lack of infrastructure are the top barriers
- Desire for greener operations is emerging but needs operational proof

These insights correspond with global studies (IEA, 2019; Kesari & Yadav, 2019) and underline the practical relevance of GSC principles when supported by technological and policy enablers.

This methodological framework ensures that the study remains grounded in theory while producing actionable insights. By integrating exploratory and descriptive approaches, supported by statistical summaries and theoretical models, the research delivers a holistic understanding of how EVs can reshape logistics operations within the context of sustainable supply chains.

LIMITATIONS

While this research offers valuable insights into the integration of Electric Vehicles (EVs) in logistics operations and their role in establishing a green supply chain, it is important to acknowledge its methodological and contextual limitations. Understanding these limitations helps interpret the results accurately and provides a foundation for refining future studies.

i. Sample Size and Representativeness

The research involved responses from a small sample—only three logistics-focused organizations, comprising five individual respondents. While this number was sufficient for exploratory and indicative analysis, it lacks the statistical power needed for broad generalization across industries, regions, or organizational sizes.

- **Expanded Impact:** A limited sample restricts the study's ability to reflect the diversity of logistical practices across India. For instance, adoption behavior may differ between large multinationals and small third-party logistics firms or between service industries and manufacturing units. Moreover, varying financial capabilities may influence the feasibility of EV adoption.

- **Academic Insight:** As per Creswell (2014), generalizability is a core issue in small-sample studies, particularly when not complemented by qualitative depth. The current sample reflects a narrow operational lens, thereby underrepresenting national or sectoral heterogeneity in EV logistics readiness.

ii. Use of Convenience Sampling

The use of convenience sampling—where participants were selected based on ease of access rather than systematic sampling—introduces potential selection bias. Respondents may have been more inclined toward sustainability or more familiar with EVs, skewing the data toward favorable views.

- **Expanded Impact:** This bias may result in an overly optimistic portrayal of EV awareness, readiness, and adoption. Organizations that are neutral or resistant to EV integration, or those in remote or resource-scarce areas, may have very different perspectives that are not captured.
- **Theoretical Reference:** Bryman & Bell (2015) caution that convenience sampling undermines external validity, making it difficult to extrapolate findings beyond the sample.

iii. Geographic and Demographic Constraints

All responses were obtained from urban centers—Delhi NCR, Mumbai, and Bangalore—which are comparatively better equipped in terms of EV infrastructure, government attention, and industrial awareness. These cities are also more likely to attract sustainability-conscious leadership.

- **Expanded Impact:** This geographic skew may fail to represent the ground realities of EV adoption in Tier-2 and Tier-3 cities, where infrastructural and economic constraints are more pronounced. Logistics in semi-urban and rural areas might face road infrastructure issues, unreliable power supply, or limited service availability.
- **Empirical Gap:** This limits the thesis' scope in making national policy recommendations, as the rural and small-town logistics ecosystem remains underexplored.

iv. Dependence on Self-Reported Data

The study relied on self-administered survey responses, which are prone to **response bias**, including social desirability, overestimation of compliance, or inaccurate recollection.

- **Expanded Impact:** Respondents may portray their companies as being more sustainable or progressive than they actually are—especially when discussing future adoption plans or environmental values. This can create a misalignment between perceived and actual behavior.
- **Theoretical Context:** As outlined by Podsakoff et al. (2003), common method variance is a frequent concern in self-reported surveys, particularly when data on both dependent and independent variables are collected from the same source at a single point in time.

v. Limited Use of Inferential Statistics

Due to the small sample and categorical nature of data, the study was confined to descriptive statistics—such as frequencies and percentages—without employing inferential techniques like correlation, regression, or chi-square tests.

- **Expanded Impact:** This limits the ability to establish causality or statistical significance between variables. For example, while cost savings are associated with EV use, this link remains theoretical without robust statistical testing.

- **Research Implication:** As a result, the findings are interpretative rather than confirmatory, suitable for hypothesis generation but not for hypothesis testing.

vi. Incomplete Infrastructure Data

Although the study highlights charging infrastructure as a barrier, it lacks quantitative or geospatial data on actual infrastructure coverage (e.g., number of stations, distribution by region, access reliability).

- **Expanded Impact:** Without spatial analysis or infrastructure mapping, the research may understate regional disparities and local limitations. This is particularly important in a country like India where electrification and infrastructure development vary significantly.
- **Future Scope:** Integrating GIS tools and government databases (e.g., NITI Aayog, BEE India) in future research could provide a more objective assessment of logistical feasibility for EV deployment.

vii. Absence of Longitudinal Insights

The study is cross-sectional, offering a one-time snapshot of EV awareness and application. Given the rapid evolution of EV technologies, government policies, and business models, these findings may quickly become outdated.

- **Expanded Impact:** For example, FAME-II incentives or entry of new EV models may significantly alter cost-benefit dynamics within a few months. Stakeholder attitudes and adoption barriers also change over time.
- **Research Limitation:** Without a longitudinal or time-series approach, it is difficult to trace trends, identify long-term benefits or operational shifts, or assess how external shocks (e.g., oil price hikes, tech disruptions) affect EV logistics decisions.

viii. Challenges Encountered and Efforts to Overcome Them

- **Access to participants** was constrained by time and institutional formalities. Many logistics managers operate under confidentiality or are reluctant to share strategic information.
- **Efforts made:** Used personal contacts and peer networks; simplified the questionnaire to improve response quality.
- **Terminology and comprehension:** Technical terms (e.g., total cost of ownership, tailpipe emissions) were clarified or reworded to suit respondents with varying levels of technical literacy.

Lesson Learned: Future research would benefit from stronger industry-academic collaboration, official permissions, and pilot testing in real operational settings.

ix. Validity and Reliability Considerations

- **Internal Validity:** Threatened by the lack of control over external variables; cannot definitively attribute outcomes (e.g., cost savings) to EV usage alone.
- **External Validity:** Limited due to small and urban-centric sample.
- **Construct Validity:** Achieved through alignment of survey items with established sustainability and logistics frameworks.
- **Reliability:** Improved through clear question wording and uniform delivery, though not statistically tested (e.g., no Cronbach's Alpha due to limited sample).

x. Lessons for Future Research

- **Wider Sampling Framework:** Include participants across supply chain roles (procurement, transportation, warehouse) and across states or sectors (FMCG, manufacturing, retail).

- **Mixed-Methods Design:** Pair surveys with semi-structured interviews or case studies for contextual richness.
- **Integration of Hard Data:** Use telematics, cost logs, and carbon emission tracking from logistics operations.
- **Infrastructure Mapping:** Employ GIS tools to analyze feasibility and regional readiness for EV deployment.
- **Time-Based Follow-Ups:** Consider panel data or longitudinal interviews to track organizational shifts over time.

In sum, while this research provides timely and insightful contributions to the field of green logistics and EV adoption, its findings should be interpreted within the context of the stated limitations. The study is exploratory in nature and serves as a foundation for further empirical, scalable, and sector-specific investigations into sustainable logistics transformation in India.

CONCLUSIONS AND RECOMMENDATIONS

i. Conclusions

This study set out to explore the impact of Electric Vehicles (EVs) in logistics operations, with a particular focus on their role in establishing a Green Supply Chain (GSC) in the Indian context. The findings support the broader hypothesis that EVs can serve as a transformative tool in enhancing sustainability across logistics functions. Several key conclusions have emerged from the research:

1. EVs Show Significant Promise in Greening Logistics Operations

EVs contribute to environmental sustainability by offering a clean alternative to internal combustion engine (ICE) vehicles. Their integration into logistics supports critical green supply chain goals such as reduced greenhouse gas (GHG) emissions, energy efficiency, and regulatory compliance. Survey responses reflect optimism about EVs' ability to lower operational emissions and improve corporate sustainability profiles. This aligns with global findings (IEA, 2019; Liao et al., 2017) on EVs' potential in environmental conservation.

2. Adoption Is Uneven Due to Financial and Infrastructural Hurdles

Despite the strategic potential of EVs, their widespread adoption in logistics remains uneven. The most frequently cited barriers are high upfront capital costs, range limitations, and insufficient charging infrastructure. These findings echo the Technology Adoption Lifecycle theory (Rogers, 2003), suggesting that the majority of firms are still in the "early adopter" stage. Without improved public-private collaboration, these systemic challenges may delay the mainstreaming of EV fleets.

3. Awareness Is High; Perceived Benefits Align with Sustainability Goals

The study found a 92% awareness rate of EV technologies among logistics professionals, indicating that the knowledge barrier is no longer a major obstacle**.** Perceived benefits such as long-term cost savings, reduced emissions, and alignment with government incentives were widely recognized. This demonstrates that the perception-to-action gap is not due to lack of understanding but rather a result of practical constraints like cost and infrastructure.

4. Positive Relationship Between EV Adoption and Green Supply Chain Development

Findings suggest a strong correlation between the adoption of EVs and the progress toward a green supply chain. EVs contribute directly to lowering the environmental impact of transport and logistics operations—two core pillars of the supply chain. They also promote efficiency, noise reduction, and alignment with Environmental, Social, and Governance (ESG) goals, making them an integral part of corporate sustainability strategy.

ii. Recommendations

Building on the conclusions, the following managerial and research recommendations are proposed to enable more effective and strategic adoption of EVs in logistics operations.

A. Managerial Actions

1. Invest in EVs for Last-Mile and Intra-State Logistics Operations

Organizations should begin EV integration with last-mile delivery and intra-city transportation**,** where range limitations are less problematic, and infrastructure requirements are relatively minimal. These operations also offer higher delivery frequency, which maximizes EV cost-effectiveness and efficiency gains.

2. Leverage Government Schemes Like FAME II

Companies must proactively utilize government schemes such as the Faster Adoption and Manufacturing of Electric Vehicles (FAME II) for capital subsidies, tax exemptions, and infrastructure support. Coordination with local governments and industry bodies can unlock both financial and policy incentives.

3. Train Logistics Teams on EV Utilization

There is a need for capacity-building programs to train fleet managers, drivers, and operations teams in the unique operational aspects of EVs—including range optimization, charging strategies, and cost tracking. Awareness must translate into action through internal change management**.**

4. Partner with Charging and Battery Solution Providers

Strategic partnerships with charging station operators, battery-as-a-service providers, and EV leasing companies can reduce capital burden and accelerate operational readiness.

B. Future Research Directions

1. Explore Heavy-Duty EV Logistics Integration

Most current applications of EVs are in light and medium-duty fleets. Future research should explore the technological feasibility and economic viability of heavy-duty EVs, particularly in long-haul freight and commercial cargo transport, which have higher emission footprints.

2. Evaluate Return on Investment (ROI) Across Functions

There is a pressing need for quantitative ROI models that measure savings in fuel, maintenance, and emissions over time. Comparative studies between ICE and EV fleets can provide more compelling business cases for large-scale adoption.

3. Analyze Customer Satisfaction in EV-Based Deliveries

Understanding how EV integration impacts consumer perception, delivery experience, and brand loyalty can provide insights into the intangible benefits of green logistics. This is especially important for e-commerce and B2C logistics providers, where brand image is a competitive factor.

4. Assess Regional Infrastructure Readiness

Future studies should combine GIS-based infrastructure mapping with organizational readiness to create region-specific EV adoption frameworks. This would enable logistics players to strategically deploy EV fleets where infrastructure is supportive.

5. Longitudinal Tracking of Adoption Patterns

A long-term study tracking the adoption behavior, technological updates, cost variations, and regulatory shifts can offer dynamic insights into the evolving EV logistics ecosystem.

The findings and recommendations of this study provide practical pathways and policy insights for accelerating the adoption of EVs in logistics operations. By addressing infrastructure gaps, financial constraints, and organizational readiness, stakeholders can drive meaningful progress toward greener, cleaner, and more efficient supply chains.

The green logistics transformation is not just a technological shift—it is a strategic necessity for sustainable business evolution in the 21st century.

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APPENDICES

Appendix A: Survey Questionnaire Used in the Study

Section A: General Awareness and Readiness

1. Are you aware of Electric Vehicles (EVs) being used in logistics operations?
   - Yes
   - No
2. How ready is your organization to adopt EVs in logistics?
   - Already using
   - Ready to adopt now
   - Planning to adopt later
   - No plans currently

Section B: Usage Patterns

3. How frequently does your organization use EVs in logistics operations?
   - Regularly
   - Occasionally

- Not at all

Section C: Motivating Factors

4. What factors motivate or would motivate your organization to adopt EVs? *(Select all that apply)*
   - Cost savings
   - Government incentives/schemes
   - Environmental benefits
   - Brand reputation
   - Compliance with ESG goals

Section D: Application Areas

5. In which areas does your organization currently or plan to use EVs? *(Select all that apply)*
   - Interstate transportation
   - Last-mile delivery
   - Warehouse transport
   - Intercity distribution
   - Port operations

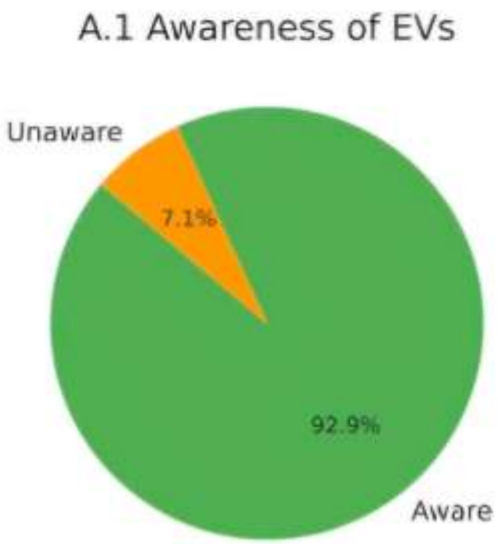
Section E: Perceived Benefits

6. What benefits has your organization experienced or expects from EV adoption? *(Select all that apply)*
   - Reduction in operational cost
   - Emission reduction
   - Improved delivery efficiency
   - Higher customer satisfaction
   - Competitive advantage

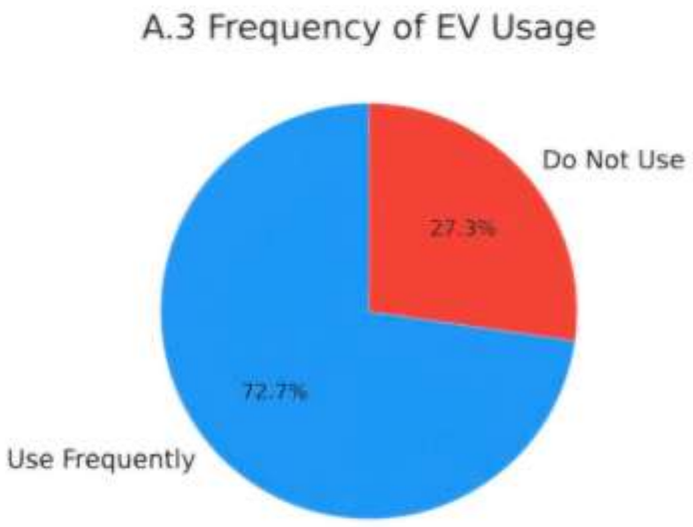
Section F: Challenges

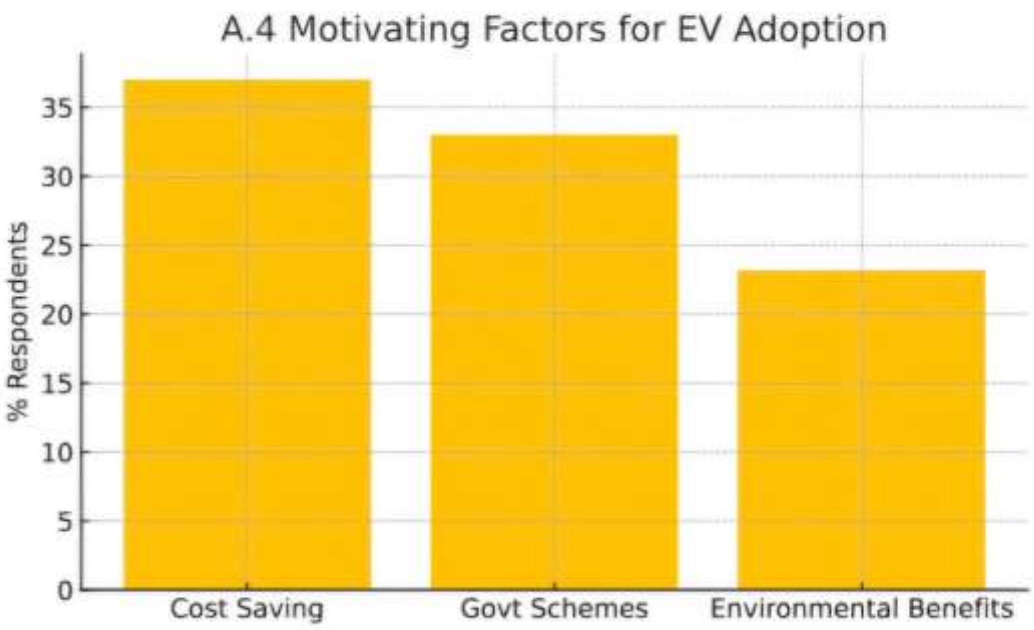
7. What are the major challenges in adopting EVs in logistics? *(Select all that apply)*
   - Limited range of vehicles
   - High upfront cost
   - High maintenance cost
   - Lack of charging infrastructure
   - Technological reliability
   - Untrained workforce

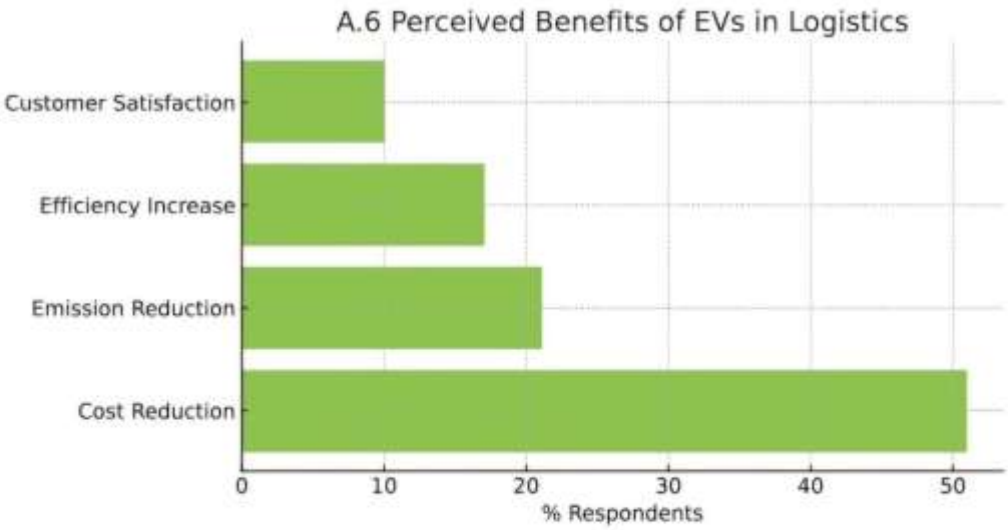
Appendix B: Survey Analysis Chart

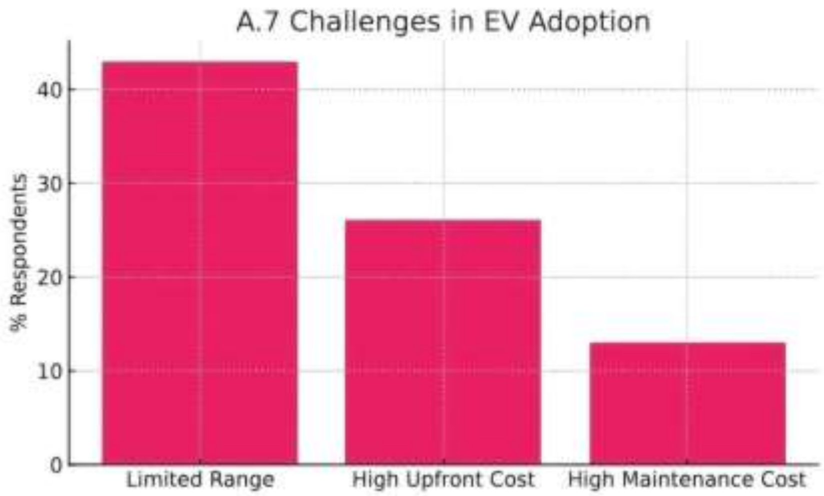

A.1 Awareness of EVs
Unaware
7.1%
92.9%
Aware


A.2 Readiness to Shift Towards EVs
% Respondents
0
10
20
30
40
50
60
70
Ready Now
Later


A.3 Frequency of EV Usage
Do Not Use
27.3%
72.7%
Use Frequently


A.4 Motivating Factors for EV Adoption
% Respondents
0
5
10
15
20
25
30
35
Cost Saving
Govt Schemes
Environmental Benefits





Appendix. C : Survey Response

Appendix D: Government Schemes Summary

FAME-II Scheme (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles)

- **Launched:** 2019
- **Total Budget:** ₹10,000 crores
- **Focus:** Subsidies for commercial EVs, support for charging stations
- **Duration:** Initially 3 years (extended due to industry demand)
- **Key Benefits:** Reduces acquisition cost of EVs by 10–20%, accelerates commercial adoption especially in buses and fleet operations.
- **Target:** 7,000 e-buses, 5 lakh e-3 wheelers, 55,000 e-4 wheelers, and 10 lakh e-2 wheelers.

NEMMP 2020 (National Electric Mobility Mission Plan)

- **Target:** To achieve 6–7 million EV sales annually by 2020 (partially revised)
- **Focus Areas:**
  - Policy roadmap for electrification
  - R&D for battery technology and EV innovation
  - Regulatory interventions to support OEMs and consumers
- **Outcome:** Basis for long-term EV policy evolution including future reforms under Battery Swapping and Energy-as-a-Service (EaaS) models.