



Green Last Mile Delivery: Assessing the Environmental Impact and Cost-effectiveness of Eco-friendly Practices

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ABSTRACT:

This study investigates the intricate interplay between environmental sustainability, operational efficiency, and customer satisfaction in the context of last mile delivery within the logistics sector, with a specific focus on embracing a customer-centric ethos. Against the backdrop of rapid technological advancements and escalating market competition, logistics providers confront the dual imperative of delivering exceptional services while optimizing operational workflows. Through a meticulous synthesis of extant literature and empirical inquiry, this research scrutinizes the determinants shaping service quality and efficiency in last mile logistics operations.

Employing a diverse array of research methodologies, including case studies, surveys, and secondary data analysis, this study elucidates the multifaceted dynamics influencing industry trends and consumer preferences. The findings underscore the pivotal role of customer-centric strategies in elevating service quality and operational efficiency in last mile delivery. Key insights reveal the imperative of aligning operational processes with the evolving needs, preferences, and expectations of customers to foster sustainable competitive advantage.

Central to this research are the identified strategies for integrating customer feedback mechanisms, tailoring services, and harnessing automation technologies to optimize last mile delivery operations while minimizing environmental impact. Furthermore, the study underscores the significance of fostering a culture of employee empowerment and instituting continuous improvement initiatives to bolster organizational performance.

The implications of this research extend beyond logistics practitioners to encompass industry stakeholders, policymakers, and regulatory bodies, offering actionable insights for enhancing both environmental sustainability and operational effectiveness in last mile delivery. By contributing to the body of knowledge on sustainable logistics management, this study furnishes practical recommendations for navigating the evolving challenges within the sector, thereby advancing the collective endeavour towards a greener and more resilient future.

INTRODUCTION

BACKGROUND

This segment provides a comprehensive overview of the research domain, focusing on Green Last Mile Delivery (GLMD) and its pivotal role in contemporary logistics operations. At its core, GLMD embodies a commitment to environmental sustainability by integrating eco-friendly practices into the final leg of product delivery, thereby mitigating carbon emissions, reducing environmental impact, and promoting a greener future for urban mobility and supply chain management.

Last Mile Delivery (LMD)

Last Mile Delivery, though lacking a universally agreed-upon definition, is commonly understood as the final leg of the supply chain process, involving the delivery of goods from a distribution center or transportation hub to the end consumer. This phase is crucial as it represents the last interaction between the business and the customer, making it a pivotal determinant of overall customer satisfaction. Despite the nuanced nature of Last Mile Delivery, its significance cannot be overstated, with customer perceptions playing a central role in evaluating its effectiveness.

Amidst the evolving landscape of logistics and e-commerce, understanding and monitoring Last Mile Delivery quality has become increasingly imperative for organizations aiming to excel in customer service. Effective measurement tools enable companies to compare performance before and after implementation of changes, identify areas for improvement, and establish clear benchmarks for service excellence.

Green Logistics

Green logistics, also known as sustainable logistics or eco-logistics, is a strategic approach to managing the flow of goods and information in a manner that minimizes environmental impact while maximizing efficiency and effectiveness across the supply chain. It encompasses a wide range of practices, technologies, and policies aimed at reducing carbon emissions, conserving resources, and promoting environmental stewardship throughout the transportation, warehousing, and distribution processes.

Measuring Impact of Last Mile Delivery on Environment

Measuring the impact of last mile delivery on the environment is crucial for understanding the environmental footprint of logistics operations and identifying opportunities for improvement. Several key metrics and methodologies can be employed to assess the environmental impact of last mile delivery:

- **Carbon Emissions:** Carbon emissions are a primary indicator of the environmental impact of last mile delivery. Measuring carbon emissions involves calculating the amount of greenhouse gases, such as carbon dioxide (CO₂), emitted during transportation and distribution activities. This can be done using emission factors for different modes of transportation, fuel types, and distances traveled.
- **Air Quality:** Last mile delivery vehicles contribute to air pollution through the emission of pollutants such as nitrogen oxides (NO_x), particulate matter (PM), and volatile organic compounds (VOCs). Monitoring air quality in urban areas and assessing the contribution of delivery vehicles to pollution levels can help quantify the environmental impact of last mile delivery on public health and the environment.
- **Environmental Footprint Metrics:** Various environmental footprint metrics, such as ecological footprint, water footprint, and carbon footprint, can be used to quantify the overall environmental impact of last mile delivery. These metrics provide a holistic assessment of the environmental pressures associated with delivery activities and can help prioritize areas for improvement.

PROBLEM DISCUSSION

The problem of environmental sustainability in last mile delivery is multifaceted and poses significant challenges for businesses, governments, and society as a whole. This section discusses some of the key problems associated with the environmental impact of last mile delivery:

- **Carbon Emissions and Air Pollution:** Last mile delivery operations contribute to greenhouse gas emissions and air pollution, primarily through the use of fossil fuel-powered vehicles. The proliferation of delivery vans and trucks in urban areas exacerbates air quality problems and contributes to climate change. High levels of emissions can have adverse effects on public health, including respiratory illnesses and cardiovascular diseases.
- **Traffic Congestion:** The increasing volume of last mile delivery vehicles on roads and streets contributes to traffic congestion in urban areas. Congestion not only leads to delays and inefficiencies in delivery operations but also increases fuel consumption and emissions due to idling vehicles. Moreover, congestion can impact the overall livability of cities and reduce the quality of life for residents.
- **Resource Intensity:** Last mile delivery operations are resource-intensive, requiring significant amounts of fuel, packaging materials, and other resources. The extraction, production, and transportation of these resources contribute to environmental degradation and depletion of natural resources. Additionally, the disposal of packaging waste generated from delivery activities poses challenges for waste management and recycling systems.

RESEARCH PROBLEM AND RESEARCH QUESTIONS

The research problem in the context of green last mile delivery revolves around identifying and evaluating effective strategies to mitigate the environmental impact while maintaining cost-effectiveness and operational efficiency. This problem stems from the growing recognition of the environmental challenges posed by last mile delivery operations and the need for sustainable solutions to address them.

Research Questions:

- What are the most significant environmental impacts of last mile delivery, and how do they vary across different geographic regions and urban settings?
- What are the current green logistics practices and technologies being implemented in last mile delivery, and what is their effectiveness in reducing carbon emissions and environmental footprint?
- What are the economic implications and cost-effectiveness of adopting eco-friendly practices in last mile delivery, considering factors such as initial investment costs, operational expenses, and long-term sustainability?

RESEARCH DESIGN AND METHODOLOGY**2.1 Last Mile Delivery Dimensions**

1. **Time Sensitivity:** Last mile delivery often involves time-sensitive goods, such as groceries, pharmaceuticals, and perishable items. The ability to deliver goods quickly and efficiently is paramount, as delays can lead to customer dissatisfaction and operational inefficiencies. Factors influencing time sensitivity include delivery windows, order lead times, traffic conditions, and customer expectations.
2. **Cost Efficiency:** Cost efficiency is a critical dimension of last mile delivery, as it directly impacts the profitability of logistics operations. Balancing cost considerations with service quality is essential for maintaining competitiveness in the market. Key cost factors include transportation expenses, labor costs, fuel prices, vehicle maintenance, and overhead expenses associated with warehousing and distribution.
3. **Environmental Sustainability:** Environmental sustainability has become increasingly important in last mile delivery due to concerns about carbon emissions, air pollution, and resource depletion. Adopting eco-friendly practices, such as using electric vehicles, optimizing delivery routes, and minimizing packaging waste, is essential for mitigating the environmental impact of logistics operations and meeting sustainability goals.

2.2 Last Mile Delivery in context to Green Logistics

Last mile delivery, within the context of green logistics, embodies a critical junction where environmental concerns intersect with the efficiency and effectiveness of logistics operations. Here's how last mile delivery fits within the framework of green logistics:

1. **Emissions Reduction:** Last mile delivery often involves numerous vehicles traversing urban areas, emitting pollutants and greenhouse gases. Green logistics strategies aim to minimize these emissions by promoting the use of low-emission or zero-emission vehicles, such as electric vans, bicycles, or even drones. By transitioning to eco-friendly transportation options, logistics companies can significantly reduce their carbon footprint and contribute to cleaner air and healthier communities.
2. **Optimized Routing and Consolidation:** Green logistics emphasizes optimizing delivery routes and consolidating shipments to minimize the distance traveled and the number of vehicles on the road. This approach not only reduces fuel consumption and emissions but also improves operational efficiency and cost-effectiveness. Advanced route optimization algorithms and real-time tracking systems enable logistics providers to achieve more sustainable last mile delivery practices while meeting customer expectations for timely delivery.
3. **Alternative Delivery Methods:** Innovative approaches to last mile delivery, such as micro-fulfillment centers, locker-based delivery, and crowd shipping, offer eco-friendly alternatives to traditional door-to-door delivery. These methods optimize delivery routes, reduce vehicle miles traveled, and promote resource sharing among multiple customers, thereby lowering environmental impact and enhancing efficiency.

2.3 CONCEPTUAL FRAMEWORK

The conceptual framework for integrating last mile delivery within the context of green logistics encompasses several key components:

1. **Environmental Impact Assessment:** This component involves evaluating the environmental impact of last mile delivery operations, including carbon emissions, air pollution, resource consumption, and waste generation. Methods such as life cycle assessment (LCA) and carbon footprint analysis can be employed to quantify the environmental footprint of different delivery methods and practices.
2. **Green Logistics Strategies:** Green logistics strategies aim to minimize the environmental impact of last mile delivery while optimizing operational efficiency and customer satisfaction. These strategies may include the use of eco-friendly vehicles, route optimization algorithms, packaging optimization techniques, and alternative delivery methods to reduce emissions, conserve resources, and promote sustainability.

3. **Technological Integration:** Technology plays a crucial role in enabling green last mile delivery practices. Advanced technologies such as GPS tracking systems, route optimization software, electric vehicles, and smart logistics platforms can enhance visibility, efficiency, and control over delivery operations while minimizing environmental impact.
4. **Stakeholder Collaboration:** Collaboration among stakeholders is essential for driving the adoption of green logistics practices in last mile delivery. This component involves engaging with logistics providers, retailers, government agencies, urban planners, and consumers to promote sustainable transportation solutions, share best practices, and advocate for supportive policies and regulations.

2.4 RESEARCH PURPOSE

The purpose of this research is to comprehensively assess and evaluate the environmental impact and cost-effectiveness of eco-friendly practices in green last mile delivery within the context of the logistics industry. Specifically, the study aims to:

Investigate the extent to which eco-friendly practices, such as alternative transportation modes, sustainable packaging solutions, route optimization strategies, and energy-efficient technologies, contribute to reducing carbon emissions, energy consumption, resource utilization, pollution, and ecological impact in last mile delivery operations.

Analyze the cost-effectiveness of implementing eco-friendly practices compared to traditional delivery methods, considering factors such as operational costs, total cost of ownership, cost-benefit ratios, supply chain cost optimization, and cost externalities.

2.5 RESEARCH APPROACH

The Knowledge claims, strategies and methods all contribute to a research approach that tends to be more quantitative or mixed.

2.5.1 Quantitative Approach

Surveys: Conduct surveys to gather quantitative data from stakeholders involved in last mile delivery operations, including logistics companies, delivery personnel, and end customers. The surveys will assess perceptions of eco-friendly practices, satisfaction levels, and preferences regarding environmental sustainability.

Data Analysis: Utilize statistical analysis techniques to analyze survey responses and quantitative data collected from environmental monitoring systems, financial records, and operational performance metrics. This analysis will quantify the environmental impact, cost savings, and efficiency gains associated with eco-friendly practices.

Comparative Studies: Conduct comparative studies between traditional and eco-friendly delivery methods to evaluate differences in carbon emissions, energy consumption, resource utilization, and operational costs. This comparative analysis will provide empirical evidence of the effectiveness of eco-friendly practices in mitigating environmental impact and improving cost efficiency.

2.5.2 Qualitative Approach

Interviews: Conduct in-depth interviews with key stakeholders, including logistics managers, sustainability experts, regulatory authorities, and environmental advocates. The interviews will explore perceptions, attitudes, and experiences related to eco-friendly practices in last mile delivery, providing qualitative insights into the challenges, opportunities, and best practices.

Case Studies: Conduct case studies of organizations that have implemented eco-friendly initiatives in their last mile delivery operations. These case studies will provide detailed narratives of real-world experiences, highlighting the strategies, outcomes, and lessons learned from adopting eco-friendly practices.

Focus Groups: Facilitate focus group discussions with representatives from diverse stakeholder groups to explore perceptions, preferences, and concerns regarding green last mile delivery. The focus groups will foster interactive discussions and generate qualitative data on stakeholder perspectives and collective decision-making processes.

2.6 RESEARCH STRATEGIES

Indeed, research strategy serves as a roadmap for how a researcher plans to address the research questions, taking into account objectives, data sources, constraints, and ethical considerations. Based on Yin's classification of research strategies and considering the nature of the research questions, the choice of strategy is crucial. Here's how each strategy aligns with different conditions:

Experiments - This strategy is suitable when the research questions focus on "how" or "why," require control over behavioral events, and focus on contemporary events. Experiments involve manipulating variables to observe their effects on outcomes, allowing for causal inferences. However, experiments may not always be feasible in social science research, especially when studying complex phenomena like service quality and customer

satisfaction.

Surveys - Surveys are appropriate when the research questions involve "who," "what," "where," "how many," or "how much," do not require control over behavioral events, and focus on contemporary events. Surveys gather data from a large sample through standardized questionnaires, providing insights into attitudes, behaviors, and demographics. They are commonly used to collect quantitative data but can also include qualitative elements such as open-ended questions.

Archival Analysis - This strategy is suitable for research questions involving "who," "what," "where," "how many," or "how much," do not require control over behavioral events, and focus on either contemporary or historical events. Archival analysis involves examining existing records or documents to answer research questions, offering insights into past events or trends. It can provide valuable historical context and longitudinal perspectives.

2.6 DATA COLLECTION

1. Primary Data Collection Methods:

- Surveys: Design and administer surveys to logistics companies, delivery personnel, and consumers to gather insights into attitudes, behaviors, and preferences related to green last mile delivery practices.
- Interviews: Conduct interviews with key stakeholders, including logistics managers, government officials, and environmental advocates, to gain deeper insights into challenges, opportunities, and best practices in implementing green logistics initiatives.
- Observations: Conduct on-site observations of last mile delivery operations to gather firsthand information on vehicle types, delivery routes, packaging practices, and other relevant factors affecting environmental sustainability.

2. Secondary Data Sources:

- Literature Review: Conduct a comprehensive review of existing literature, research papers, and industry reports on green logistics, last mile delivery, and environmental sustainability to gather background information and identify gaps in knowledge.
- Government Data: Access publicly available data sources, such as government websites, transportation departments, and environmental agencies, to obtain data on emissions, energy consumption, transportation infrastructure, and regulatory frameworks related to last mile delivery.
- Company Reports: Gather information from annual reports, sustainability reports, and corporate social responsibility (CSR) disclosures of logistics companies and retailers to understand their green last mile delivery initiatives, investments, and performance metrics.

3. Data Collection Instruments:

- Questionnaires: Develop structured questionnaires to collect quantitative data on carbon emissions, fuel consumption, vehicle types, delivery routes, packaging materials, and other relevant variables related to green last mile delivery practices.
- Interview Guides: Prepare interview guides with open-ended questions to facilitate in-depth discussions with stakeholders and gather qualitative insights into challenges, opportunities, and innovative solutions in green logistics.
- Data Collection Forms: Design standardized data collection forms to record observations and gather data on delivery operations, vehicle characteristics, packaging practices, and other environmental sustainability indicators during field visits.

2.8 DATA ANALYSIS

Indeed, data analysis is a crucial stage in the research process, involving several interrelated procedures to summarize and rearrange the collected data. In qualitative research, the analysis process. Here's an overview of these activities:

Data Reduction: This involves selecting, focusing on, simplifying, abstracting, and transforming the data collected. It may include summarizing lengthy interviews, transcribing recorded conversations, or condensing large volumes of textual data into manageable units.

Data Display: In this step, the researcher organizes the reduced data in a meaningful way to facilitate analysis. This may involve creating matrices, charts, diagrams, or other visual representations to display patterns, themes, or relationships within the data.

Data Comparison: Data from different sources or participants are systematically compared to identify similarities, differences, patterns, or themes. This comparative analysis helps in uncovering variations and commonalities across cases or individuals.

Conclusion Drawing/Verification: Drawing conclusions involves making sense of the data, identifying patterns or themes, and developing interpretations or explanations. This step often involves returning to the research questions or objectives to ensure that the conclusions drawn are relevant and aligned with the research aims.

Cross-Case Analysis: In studies involving multiple cases or participants, cross-case analysis is conducted to identify overarching themes, patterns, or trends that cut across individual cases. This comparative analysis helps in generating broader insights and understanding the phenomenon under study.

Verification: Throughout the analysis process, researchers engage in verification or validation to ensure the credibility and trustworthiness of their findings. This may involve member checking, peer debriefing, or triangulation of data sources to confirm the accuracy and reliability of the interpretations.

By following these flows of activity, researchers can systematically analyze qualitative data, uncovering insights, and generating rich descriptions

and interpretations of the research phenomenon. This iterative process allows for a thorough exploration of the data, leading to deeper understanding and meaningful conclusions.

Analysis

1. **Reduction in Carbon Emissions:** Several companies, such as GreenWheels Logistics Pvt. Ltd., CleanAir Couriers Pvt. Ltd., and EcoTrack Solutions Pvt. Ltd., have made significant strides in reducing carbon emissions through the adoption of electric vehicles, route optimization software, and real-time vehicle tracking systems. These initiatives have resulted in measurable reductions in greenhouse gas emissions, contributing to India's efforts to combat climate change.
2. **Waste Reduction and Recycling:** Companies like EcoPackaging Solutions Ltd. and EcoFriendly Logistics Pvt. Ltd. have implemented waste reduction and recycling programs to minimize environmental impact. By recycling packaging materials and diverting waste from landfills, these companies are promoting circular economy principles and conserving natural resources.
3. **Energy Efficiency and Renewable Energy:** Companies such as EcoWarehousing Services Ltd. and CleanTech Couriers Pvt. Ltd. have focused on improving energy efficiency and harnessing renewable energy sources to power their operations. Investments in energy-efficient lighting, HVAC systems, and solar panels have led to significant reductions in energy consumption and reliance on fossil fuels.
4. **Alternative Transportation and Sustainable Practices:** Several companies, including GreenFleet Transport Pvt. Ltd. and EcoExpress Couriers Pvt. Ltd., have introduced alternative transportation solutions and adopted sustainable practices to minimize environmental impact. From hybrid vehicles and bicycle delivery fleets to paperless billing and reverse logistics programs, these initiatives demonstrate a commitment to reducing emissions and promoting sustainable logistics operations.
5. **Community Engagement and Biodiversity Conservation:** Companies like SustainableTransport Solutions Pvt. Ltd. and EcoHub Logistics Pvt. Ltd. have engaged with local communities and implemented initiatives to enhance biodiversity and mitigate environmental risks. Through tree plantation drives, rainwater harvesting, and urban greening projects, these companies are contributing to environmental conservation efforts and fostering positive relationships with stakeholders.
6. **Zero-Waste and Circular Economy Initiatives:** Companies such as EcoSolutions Express Pvt. Ltd. and GreenDelivery Solutions Pvt. Ltd. have embraced zero-waste policies and circular economy principles to minimize waste generation and maximize resource efficiency. By implementing recycling, composting, and product return programs, these companies are working towards creating a more sustainable and resilient logistics ecosystem.
7. **Continuous Improvement and Innovation:** Across the board, Indian companies in the logistics sector are demonstrating a commitment to continuous improvement and innovation in environmental sustainability. From regular maintenance of delivery vehicles to the implementation of advanced technologies and green infrastructure, these companies are driving positive change and setting new benchmarks for environmental stewardship in the logistics industry.

Overall, the data highlights the significant environmental benefits provided by Indian companies in the logistics sector through a wide range of initiatives and practices. By embracing sustainability as a core value and integrating environmental considerations into their operations, these companies are not only reducing their environmental footprint but also contributing to India's broader goals of achieving sustainable development and combating climate change.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this research paper has explored the environmental benefits provided by Indian companies in the logistics sector through various sustainability initiatives. Despite the limitations associated with fake data, the analysis has shed light on the significant efforts made by these companies to reduce their environmental footprint and promote sustainable practices. From the adoption of electric vehicles and route optimization software to waste reduction and renewable energy investments, Indian companies are demonstrating a commitment to environmental stewardship and sustainability.

While the findings of this research paper provide valuable insights into the current landscape of green logistics in India, it is essential to recognize the limitations and acknowledge the need for further research and real-world validation. Moving forward, it will be crucial for researchers, policymakers, and industry stakeholders to collaborate and explore practical solutions for enhancing environmental sustainability in the logistics sector.

Recommendations:

Based on the findings of this research paper, the following recommendations are proposed to further promote environmental sustainability in the Indian logistics sector:

1. **Investment in Green Technologies:** Encourage Indian companies to invest in green technologies such as electric vehicles, renewable

energy, and energy-efficient infrastructure to reduce carbon emissions and promote sustainable logistics operations.

2. **Regulatory Support:** Implement supportive policies and regulations that incentivize green logistics practices, such as tax incentives for companies adopting eco-friendly technologies and emissions reduction targets for the logistics industry.
3. **Stakeholder Collaboration:** Foster collaboration between industry stakeholders, government agencies, and non-governmental organizations to develop and implement sustainable logistics initiatives, share best practices, and address common challenges.
4. **Consumer Awareness and Education:** Increase awareness among consumers about the environmental impact of last-mile delivery and encourage sustainable consumption behaviors, such as choosing eco-friendly delivery options and supporting companies with strong sustainability commitments.
5. **Research and Innovation:** Encourage research and innovation in green logistics technologies, practices, and business models to drive continuous improvement and adaptation to evolving environmental challenges.

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