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Last-Mile Logistics under E-commerce Growth: Efficiency and Emissions

Abstract

Background: E-commerce growth has intensified last-mile logistics, a stage often described as the final leg from a distribution hub to the customer and frequently cited as a disproportionate share of total delivery cost. This review evaluates operational strategies that improve efficiency while reducing emissions, framing the problem as a coupled cost–carbon optimization. **Methods:** We synthesize work on last-mile delivery, consolidation, micro-fulfillment, electrification, and cargo-bike deployment, and propose a decision framework linking service promises to routing and fleet choices. **Results:** Interventions that combine consolidation with low-emission modes can reduce emissions without sacrificing service, but they require urban infrastructure and governance of delivery windows and pickup options.

Conclusions: Sustainable last-mile performance is achieved through network design (where to stock), operational control (how to route), and demand shaping (how customers choose speed and delivery format).

Keywords: last-mile delivery; e-commerce logistics; route optimization; micro-fulfillment; electrification; cargo bikes; emissions

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1. Introduction

In transportation and supply chain management, the last mile is the final segment that moves goods from a hub to the final destination. It is operationally challenging because deliveries are dispersed, routes are fragmented, and service expectations are high.

Two facts motivate research: last-mile activities can account for a large share of total logistics cost, and they can be emissions-intensive in dense urban areas. As e-commerce volumes rise, firms face a dual objective: protect service levels while bending the cost and carbon curves downward.

2. Materials and Methods

This review combines conceptual definitions of the last mile with evidence from practitioner and policy-oriented reports on emissions and operational levers. We focus on interventions that are scalable: consolidation strategies, pickup points, delivery windows, micro-fulfillment, routing optimization, and fleet decarbonization (electric vans and cargo bikes).We organize findings using a ‘cost–carbon frontier’ view: each intervention shifts the feasible set of outcomes, sometimes creating win–wins (lower cost and lower emissions) and sometimes forcing trade-offs.

3. Results

3.1. Efficiency levers. Route optimization, delivery density improvements, and micro-fulfillment can lower cost per drop and reduce failed deliveries. Consolidation through pickup points and scheduled delivery windows increases stop density and reduces vehicle-kilometers traveled.

3.2. Emissions levers. Electrification reduces tailpipe emissions, but it depends on charging infrastructure and electricity mix. Cargo bikes and e-bikes are particularly effective in dense areas where they avoid congestion and enable smaller, frequent rounds.

3.3. Integrated design. The strongest outcomes are achieved when network design (inventory positioning), operational control (routing and batching), and demand shaping (customer choice of speed and delivery format) are aligned.

4. Discussion

Last-mile sustainability is not only a technology problem. It is also a governance problem: service promises must be aligned with what is operationally and environmentally feasible. Ultra-fast delivery can increase trips and emissions unless countered by micro-fulfillment and consolidation.

Measurement should include emissions per parcel and per route, not only fleet-level totals. This supports fair comparisons between strategies and highlights the role of failed deliveries and returns.

5. Conclusions

Last-mile systems are best improved through coordinated interventions. Firms that invest only in fleet changes without redesigning routes and delivery formats may miss the largest efficiency gains.

Future research should quantify rebound effects (more orders due to faster delivery) and test policy levers such as curb access and urban consolidation centers.

Figures 1.

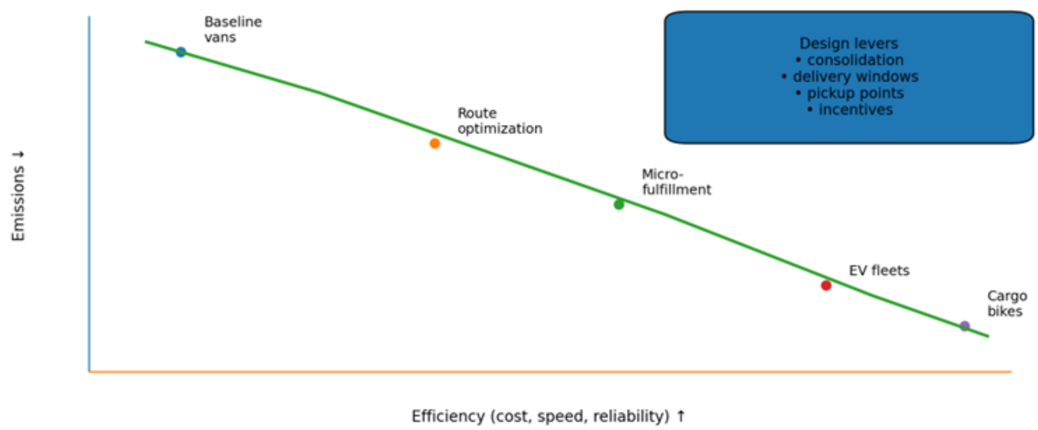

Figure 1. Efficiency–emissions frontier for last-mile interventions (conceptual).

Tables

Table 1. Last-mile interventions: expected operational and emissions effects.

Intervention	Mechanism	Efficiency effect	Emissions effect	Key constraint
Route optimization	Better sequencing and batching	Lower cost per stop	Lower VKT and emissions	Data quality; dynamic constraints
Micro-fulfillment	Closer inventory to demand	Faster delivery; fewer miles	Can reduce emissions	Real estate cost; inventory complexity
Pickup points	Consolidation of deliveries	Higher drop density	Lower emissions per parcel	Customer adoption; network coverage
Electric vans	Low-emission propulsion	Similar service capability	Lower tailpipe emissions	Charging and capex
Cargo e-bikes	Mode shift in dense cores	Faster in congestion	Very low emissions	Infrastructure; payload limits

Note: VKT = vehicle-kilometers traveled. Effects depend on city form, demand density, and service promises.

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