

State of the Practice on E-Commerce Last Mile Logistics Solutions and Measures

ANR-FRESH Project

Project deliverable D1.1

Version number: V1

Date for release: 04/11/2025

Authors:

Abel Kebede REDA & Laetitia DABLANC (University Gustave Eiffel)



**FRESH
Project**

Deliverable Administrative Information

Project name	FRESH project: The FREight-SHopping nexus in urban outskirts and beyond
Funding	Driving Urban Transition Partnership (DUT), and specifically: German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt (DLR)), Funding number: 01UV2453; French National Research Agency (Agence Nationale de la Recherche (ANR)), Funding number: ANR23-DUTP-0001-01; Research Council of Norway (Norges forskningsråd) Funding number: 350295.
Participating Universities	ETH Zurich, TU Dortmund (TUDo), University Gustave Eiffel (UGE), Norwegian University of Science and Technology (NTNU)
Deliverable no.	D1.1.
Report Title	<i>State of the Practice on E-Commerce Last Mile Logistics Solutions and Measures</i>
Authors	Abel Kebede Reda, Laetitia Dalanc (University Gustave Eiffel-UGE)
Related tasks	None
Dissemination level	PU = Public
Date	04/11/2025

Document history

Version	Date	Submitted by	Reviewed by	Comments
V0.1	17/09/2025	Abel Kebede Reda & Laetitia Dablance (UGE)	Eva Heinen (ETH Zurich), Giulio Mattioli & Matthias Cremer-Schulte (TUDo)	Submitted for peer-review
V0.2	31/10/2025	Abel Kebede Reda (UGE)	Laetitia Dablance (UGE)	Reviewer's comments have been incorporated.
V1	03/11/2025	Abel Kebede Reda (UGE)		Final submission

Executive Summary

The rapid growth of e-commerce has reshaped urban freight systems, intensifying demands on last mile logistics and amplifying their environmental, spatial, and equity impacts. Cities worldwide now face a pressing dual challenge: ensuring efficient and affordable delivery services for consumers while meeting urgent sustainability and livability goals. This report provides a state-of-the-practice review of e-commerce last mile logistics solutions, offering both a systematic typology and an integrative framework to understand, compare, and scale diverse innovations.

Building on the classification first outlined by [Lyons and McDonald \(2023\)](#), the report organizes contemporary last mile solutions into six thematic clusters: (1) Clean and Innovative Delivery Modes, (2) Curb and Street Operations Management, (3) Micro-fulfillment and Consolidation Infrastructure, (4) Regulatory and Fiscal Policies, (5) Services and Business Models, and (6) Stakeholder Collaboration and Governance. Mainly, this report takes a comparative and integrative perspective, situating solutions within the contexts of dense city centers and suburban peripheries, and highlighting both their standalone performance and inter-dependencies.

The analysis draws on an extensive literature base and a wide set of case studies implemented across Europe, North America, and Asia. It distills evidence of environmental gains, operational efficiencies, and governance models, while also identifying persistent barriers such as high capital costs, infrastructure deficits, fragmented regulation, and uneven social acceptance. For instance, cargo bikes and e-vans demonstrate measurable reductions in emissions and noise, yet their uptake depends heavily on supporting curb allocation, charging networks, and regulatory incentives ([Michalakopoulou et al., 2025](#); [Camilleri et al., 2016](#)). Micro-hubs and parcel lockers reduce vehicle-kilometers and enhance consumer convenience, but require costly real estate and stable partnerships to remain viable ([Katsela et al., 2022](#)). Fiscal and regulatory levers such as low-emission zones or congestion charging provide powerful systemic incentives, though they risk equity concerns if poorly designed ([Alvarez-Gallo et al., 2024](#); [Dablanc and Montenon, 2015](#)). Crowd logistics and platform-based services enable flexible capacity but raise concerns over labor uncertainty and public trust ([Çınar et al., 2024](#); [Buldeo Rai et al., 2021](#)). Finally, collaborative governance, through freight quality partnerships, living labs, and advisory councils, emerges as the connective tissue enabling multi-actor collaboration and long-term adoption ([Rosales, 2024](#); [Gonzalez et al., 2023](#)).

To make sense of these dynamics, the report introduces a suite of analytical toolkit: a Cluster–Context–Maturity analysis positioning each solution type across adoption stages in different urban forms; Cross-Cluster Synergy Matrix visualizing inter-dependencies (e.g., between clean modes and regulatory policies, or between micro-fulfillment and business models); a Comparative strength-weakness-opportunity-threats (SWOT) analysis highlighting strategic advantages and vulnerabilities of each cluster; and a Phased Roadmap aligned to integrate with urban planning paradigms, mainly the 15-minute city. These frameworks not only organize the evidence but also provide practical approach for policymakers, operators, and researchers seeking to prioritize interventions, align strategies, and anticipate risks.

From the state of practice review and the follow-up analyses, three transversal insights emerge. First, context matters: dense city centers favor rapid adoption of clean modes, curb tools, and shared infrastructure, whereas suburban areas require more adaptive and hybrid approaches combining electric vans with cargo bikes, shared micro-hubs, and crowd-delivery networks that can flex across lower density areas. Second, integration matters: solutions succeed not in isolation but through orchestration, for example cargo bikes thrive only when supported by curb management and charging policy, while

platform-based services depend on regulatory acceptance and governance trust. Third, governance matters most: the long-term sustainability of last mile systems rests on institutional capacity, multi-stakeholder engagement, and adaptive regulatory frameworks.

The report also acknowledges limitations, including a focus on currently operational or short-term viable solutions, a literature base skewed toward the Global North, and no validation given by stakeholders. Nonetheless, the review establishes a solid foundation for future inquiry, pointing to priorities such as standardized performance indicators, longitudinal evaluation of scaling trajectories, deeper analysis of social equity impacts, and the inclusion of Global South perspectives.

In conclusion, this report demonstrates that e-commerce last mile delivery is not merely a technical or operational concern, but a systemic urban transformation issue. When integrated across the six clusters, last mile solutions have the potential to create resilient, sustainable, and resident centered logistics ecosystem. The frameworks presented here provide decision-makers with practical tools for navigating complexity and charting pathways toward greener, equitable, and more efficient last mile systems. Ultimately, the report positions last mile logistics as both a challenge and an opportunity: a critical lever in achieving the climate, equity, and livability goals of cities.

Contents

List of Figures	7
List of Tables	8
Glossary	9
1 Introduction	10
2 Methods	13
2.1 Methodological Background	13
2.2 Case-Study Selection	13
2.3 Analytical Framework	14
3 Clean and Innovative Delivery Modes	16
3.1 Introduction	16
3.2 Electric delivery vehicles (EDV)	16
3.3 Cargo bikes for last mile delivery	19
3.4 Trams for parcel transport	20
3.5 Barge for last mile delivery	21
3.6 Robotic Delivery Solutions	22
3.7 Summary	25
4 Curb and Street Operations Management	27
4.1 Introduction	27
4.2 Summary	31
5 Micro-fulfillment & Consolidation Infrastructure	34
5.1 Introduction	34
5.2 Pick-up points/Service Points/Parcel Lockers	34
5.3 Micro-hubs	37
5.4 Urban warehouses, Consolidation Centers, and Cross-docking Facilities . .	39
5.5 Summary	41
6 Regulatory and Fiscal Policies	43
6.1 Introduction	43
6.2 E-commerce delivery taxes	43
6.3 Congestion Charging and Road Pricing	45
6.4 Low Emission Zones (LEZs), Ultra Low Emission Zones (ULEZs), and Zero Emission Zones (ZEZs)	47
6.5 Truck Bans and Restrictions	51
6.6 Summary	52

7	Services and Business Models	55
7.1	Introduction	55
7.2	Case Studies	55
7.3	Summary	59
8	Stakeholder Collaboration and Governance	61
8.1	Introduction	61
8.2	Case Studies	62
8.3	Summary	64
9	Analysis & Discussion – Integrative Framework for E-Commerce Last Mile Solutions	66
9.1	Introduction	66
9.2	Analytical Framework	67
9.3	Mapping Context and Maturity	67
9.4	Cross-Cluster Synergies and Interdependency	70
9.5	Comparative SWOT Analysis	71
9.6	Integrated Phased Roadmap to Align with Urban Planning Model	73
10	Conclusion	75

List of Figures

9.1	Integration Matrix: Cross-cluster Synergy Scores	70
-----	--	----

List of Tables

9.1	Overview of Cluster - Context - Maturity	68
9.2	SWOT Comparison of the Six Clusters	72

Glossary

ANPR	Automated number plate recognition
APIs	Application Programming Interfaces
APMs	Automated Parcel Machines
DKM	Digital Knowledge Management
EDVs	Electric Delivery Vehicles
HGV	Heavy Goods Vehicle
ICEVs	Internal Combustion Engine Vehicles
IoT	Internet of Things
KPI	Key Performance Indicator
LaaS	Logistics-as-a-Service
LEZs	Low Emission Zones
LGV	Light Goods Vehicle
OBU	On-Board Unit (in data)
OOH	Out-of-Home (delivery/retail context)
PUDOs	Pick-Up and Drop-Off points
SMEs	Small and Medium-sized Enterprises
SWOT	Strength-Weakness-Opportunity-Threat
SULP	Sustainable Urban Logistics Plan
SWOT	Strengths, Weaknesses, Opportunities, and Threats
ULEZs	Ultra Low Emission Zones
UVARs	Urban Vehicle Access Regulations
UCCs	Urban Consolidation Centers
VKT	Vehicle Kilometers Traveled
ZEZs	Zero Emission Zones

Chapter 1

Introduction

Over the past decade, e-commerce shown a rapid development. The global e-commerce industry predicted to surpass \$6.8 trillion in sale in 2025, with over 33% of the world population shopping online ([SellerCommerce, 2024](#)). The e-commerce market accounts for 20.8% of the total retail market ([Snyder and Aditham, 2023](#)), and diverse shopping applications on mobile phones enhanced the consumer experience. Due to this market rise, the amount of goods delivery shown tremendous growth, for instance, the parcel volume in the US alone increase by more than 30% between 2015 and 2019, placing severe pressure on urban delivery networks ([Maxner et al., 2025](#)).

The e-commerce market rapid growth has placed unprecedented strain on logistics and delivery infrastructure: introducing vans, cargo bikes, and in some cases drones, and small robots, in what were once quite residential streets. At the heart of this transformation lies the “last mile” paradox: urban planners and carriers must make sure that the demand for deliveries of ever-smaller, time-sensitive shipments faster and at lower cost is met, all while mitigating congestion, reducing emissions, and preserving the livability of city centers ([Dablanc, 2019](#); [Lyons and McDonald, 2023](#)).

Early solutions to rising parcel volumes simply scaled up the traditional hub-and-spoke model. Massive, centralized distribution centers on the urban periphery fed diesel van routes that crisscrossed dense street grids. Yet by the late 2010s, researchers had documented that such vans could contribute up to 20% of total urban freight CO₂ emissions and generate as much as 30% of delivery-related congestion peaks ([Bosona, 2020](#)). At the same time, noise and air-quality regulations, such as Paris’s Quiet Zone, European Low Emission Zones, or London’s Ultra-Low Emission Zone, restricted the use of older diesel fleets. In parallel, a feedback loop began to take shape between e-commerce platforms and consumers: as online retailers started promising ever-shorter delivery windows to gain market share, shoppers grew accustomed to expecting rapid fulfillment, further reinforcing the competitive race for speed. These intertwined dynamics of regulation, innovation, and customer expectations spurred policymakers and private actors to co-develop a wave of novel solutions: electric vehicles, cargo bikes, micro-fulfillment centers in city cores, smart curb-management and digital curb-management platforms, and even river barges repurposed for parcel transport ([Dablanc, 2020](#); [Kiba-Janiak et al., 2021](#)).

Scholars have traced this evolution through several innovation phases ([Olsson et al., 2019](#)). The first wave (pre-2010) centered on van-based consolidation, optimizing route density and back-hauling returns to reduce empty runs. The second wave (2010–2020) experimented with piloting clean vehicles (electric vans, and e-cargo bikes) and localized micro-hubs and parcel lockers networks ([Maxner et al., 2025](#)). The current, post-COVID-19 era integrates real-time data (AI-driven routing and “digital twins” for network simulation), smart infrastructure and participatory governance models aligning carriers, municipalities, and community stakeholders ([Risberg and Jafari, 2022](#)).

Today’s urban logistics landscape is characterized by diverse experimentation and novel innovations. Alongside technological innovation, policy frameworks have evolved to enable and steer sustainable last mile operations. Some of the dominant streams of recent innovations, include:

- On-demand instant delivery services, i.e., promising two-hour or even 30 minutes windows, have proliferated in major metropolitan areas around the world (all continents included), leveraging gig-economy couriers and micro-fulfillment labs embedded in urban retail spaces ([Dabanc, 2020](#)).
- Drones and autonomous robots are moving beyond rural medical deliveries into dense urban cores ([Mohammad et al., 2023](#)), particularly in China.
- Waterborne freight has reemerged in cities with navigable waterways ([Pourmohammadreza et al., 2025](#)). Paris’s Fludis operations where electric barges on the River Seine carry parcels, reducing truck trips in congested urban centers and consolidating loads between urban terminals ([Haropa Port, 2023](#)).
- Micro-fulfillment centers inside city neighborhoods dramatically shorten lead distances, enabling sub-urban delivery at lower cost ([Buldeo Rai et al., 2023](#)). ”Dark store” for groceries have had contrasted fate in European cities, with some emerging players (Getir) having to step down while more established ones (mass retail companies, plus UberEats or Deliveroo for example) emerging after 2024.
- Electric cargo bikes, which exploit bike lanes for congestion-free movements, collectively account for thousands of zero-emission trips daily ([Conway et al., 2017](#); [Dabanc, 2020](#)).
- More generally, all types of micro-mobility (pedestrian, one wheelers, bicycles, scooters, mopeds), and modes usually associated with passenger transport (shared bikes, public transit, private cars) are now commonly used for deliveries. These ways of delivering that are alternative to the traditional trucks and vans may account for maybe a quarter of total delivery workers in the core areas of large cities like Paris or New York (estimated by [Motte-Baumvol and Dabanc \(2025\)](#)).

This report aims to provide a detailed review of the state of practice in e-commerce last mile logistics solutions and measures implemented worldwide by different actors. To capture the full breadth of last mile innovation while maintaining analytical clarity, we organize this report around six thematic clusters, as:

1. Clean and innovative delivery modes
2. Curb and street operations management
3. Micro-fulfillment and consolidation infrastructure
4. Regulatory and fiscal instruments
5. Service and business models
6. Stakeholder collaboration and governance

Each cluster is defined by a distinct mode of intervention or constellation of actors. These clusters balance comprehensiveness with covering the full spectrum of strategies and distinctiveness where each case falls into a single category. These clusters are designed to be analytically relevant, meaning they reflect the main levers that practitioners

and policymakers use to shape e-commerce last mile performance, whether through the vehicles and facilities they deploy, the regulations and incentives they introduce, or the business models they develop.

The six clusters build well over [Lyons and McDonald \(2023\)](#)’s typology of last mile logistics strategies for goods delivery in urban areas, i.e. innovative vehicles, consolidation, technological and routing advances in city logistics, and emerging planning tools and policies. However, those four categories not only serve the e-commerce related logistics but the general urban logistics activities. Additionally, we place greater emphasis on technological developments which include digital and data driven tools, such as AI-bases routing, real-time visibility platforms, and Application Programming Interfaces (APIs) for reserving spaces which permeate every cluster rather than standing alone. For instance, cargo-bike operators now leveraged real-time traffic and fleet data to optimize their tours ([Rismanto and Judijanto, 2025](#)), while curb-management schemes show measurable efficiency gains when delivery drivers access live curb-space availability via API-enabled reservation systems ([Dalla Chiara et al., 2022](#)). Thus, by embedding these digital capabilities within our six thematic clusters, we both acknowledge their cross-cutting importance and preserve the analytical integrity of our framework.

The first cluster, *Clean & Innovative Delivery Modes* encompasses the array of depolluted vehicle, cargo bikes, river barges, delivery robots and drone technologies with the operational practices that support their deployment. Second, *Curb & Street Operations Management* examines how cities and carriers use new technologies, digital platforms and dynamic pricing tools to allocate scarce curb space, manage loading-zone demand, and smooth peak-period delivery flows on top of regular traffic operations. Third, *Micro-Fulfillment& Consolidation Infrastructure* focuses on various facilities, such as micro-hubs, fulfillment centers and cross-dock warehouses at neighborhood or city scale that reorganize and facilitate last mile logistics close to end customers. Fourth, *Regulatory & Fiscal Instruments* analyzes the policy levers, including low or zero emission zones, congestion charges, and truck restrictions to reshape the economic analysis of last mile operations. Fifth, *Service & Business Models* covers the diverse ways in which platforms structure and monetize delivery offerings tailored to create innovative services and business case tied to specific market contexts and behavioral targets. Finally, *Stakeholder Collaboration & Governance* explores partnerships, freight councils, and co-planning processes that align carriers, shippers, municipalities, and communities around shared objectives.

Chapters 2 through 7 delve, each, into one cluster through leading global case studies, empirical performance metrics where available, and practitioner insights. Chapter 8 synthesizes the trade-offs, SWOT analyses and synergies that span clusters, for example, how regulatory incentives can accelerate clean-vehicle adoption or how novel service models depend on robust digital tracking. Chapter 9 concludes the report with forward-looking recommendations for researchers, practitioners, and policymakers. Through this structure, the report included more than 50 state-of-the-practice case studies, systematic literature syntheses, and discussion on various elements and perspectives of e-commerce last mile logistics.

Chapter 2

Methods

This chapter explains the methodological backbone of the report, situating the research design, case study selection, analytical framework, and limitations. The aim is to offer transparency about how the work was carried out, how decisions were made, and how the analysis (**Chapter 9**) springs coherently from the foundations in **Chapters 3-8**.

2.1 Methodological Background

The motivation underlying this review report is the need to move from isolated pilot projects toward a systematic understanding of e-commerce last mile logistics solutions in urban environments. This study follows a three stage methodological approach. First, it conducts a comprehensive review of documented e-commerce last-mile delivery interventions to establish the current state of practice. Second, it compiles a targeted set of case studies that represent the main thematic clusters identified in the review. Third, it applies an analytical framework that enables cross-case comparison, identification of interdependencies, and the development of a phased roadmap aligned with urban planning objectives. The focus on real-world implementation ensures that the analysis highlights operationally feasible solutions, while deliberately excluding speculative or long term technologies to maintain practical relevance.

2.2 Case-Study Selection

The purpose of the case study selection is two-fold: to ensure that each of the six thematic clusters is empirically anchored in at least one real world example, and to enable comparability across urban contexts. Accordingly, the selection process applied five guiding criteria. First, the intervention must be deployed (or in advanced pilot phase) and have publicly documented performance metrics, ensuring the focus remains on state-of-the-practice implementations. Second, the case should include adequate publicly available data (report, press release, academic article) so that the description is robust. Third, cases were chosen for geographic and morphological diversity, although the existing literature’s bias toward the Global North is acknowledged. Fourth, the case had to illustrate systemic relevance, i.e., not a stand-alone experiment but one that interacts with other delivery system components. Fifth, the sample was structured so that at least one case per cluster is included, enabling the cross-cluster analysis.

Within the body of the report, each case (Chapters 3-8) is described in terms of context (city, density, policy environment), actor (carrier, platform, municipal authority), intervention design (vehicle type, hub, digital tool, regulatory instrument, etc.), and available outcome metrics (emissions, delivery-trip reduction, cost implications). Although the se-

lection of case studies was systematic in terms of criteria, it remains purposive rather than statistically representative, meaning findings should be read as indicative of trends rather than exhaustive generalizations.

2.3 Analytical Framework

The analytical framework adopted for the integrative discussion consists of three complementary components. The first component is the multi-dimensional integration matrix that situates each thematic cluster along key axes: spatial scale (from dense city center to suburban periphery), maturity (from near-term operational to medium-term scaling), and governance mode (from voluntary industry scheme to regulatory mandates).

The second component is the synergy and inter-dependency mapping which examines how the six thematic clusters interact and reinforce one another within the e-commerce last mile system. The matrix created to visualize the strength of interconnections between clusters on a scale from 0 to 5, where darker shades represent stronger functional relationships. Each cell captures the extent to which progress in one cluster enables or depends on another across three integrated dimensions. The dimension are hardware (physical assets such as vehicles, hubs, and sensors), software (digital and analytical tools that manage operations), and org-ware (institutional and governance arrangements). The mapping was developed through a structured review of empirical cases and literature to identify co-deployment patterns, mutual dependencies, and demonstrated performance gains when two clusters are implemented together.

To construct the matrix, all documented co-occurrences between clusters were compiled from the reviewed cases and relevant publications. Each pair of clusters was assessed according to the frequency and quality of their joint implementation, the degree to which one cluster relies on the other for effective operation, and the consistency of reported benefits such as emission reductions, travel-time savings, or improved curb efficiency. Scores were assigned on a 0-5 ordinal scale, where 0 denotes no meaningful linkage and 5 represents strong, bidirectional dependency repeatedly observed in multiple contexts. The synergy score aims to provide a transparent, evidence-based synthesis of how different strands of last-mile innovation converge to produce systemic impact rather than isolated gains.

The third analytical component, the comparative SWOT (strengths, weaknesses, opportunities, and threats) analysis, provides a strategic overview of how each thematic cluster contributes to or constrains the development of sustainable last mile delivery systems. Instead of evaluating individual solutions in isolation, the analysis aggregates insights at the cluster level to capture shared structural functions, such as reducing vehicle-kilometers traveled (VKT), facilitating consolidation, or improving efficiency. Our approach creates meaningful analysis of clusters that differ widely in form and scale.

Each SWOT category was synthesized from multiple sources, including case-study evidence, regulatory evaluations, and implementation outcomes documented in recent urban logistics literature. The resulting matrix highlights both technological and institutional dimensions, identifying where policy, infrastructure, and digital systems converge or diverge across clusters. To maintain analytical transparency, a caveat is noted that intra-cluster variation exist; some measures are mature and scalable while others remain experimental or context-specific. The aim is not to homogenize distinct solutions but to distill common strategic insights and trade-offs that can guide policymakers, practitioners, and researchers in assessing which cluster configurations hold the greatest promise for sustainable and efficient e-commerce last mile logistics.

Finally, the study interprets the evolution of e-commerce last mile solutions through the lens of urban planning paradigms, specifically the 15-minute city. The 15-minute

city is a planning approach that promotes proximity, mixed use, and accessibility within compact urban districts. The 15-minute city re-imagines cities as networks of local neighborhoods where residents can meet most daily needs within a short walk or cycle ride (Moreno, 2024). Integrating logistics into this vision is essential, as delivery vehicles, micro-hubs, and curb operations directly influence street life, accessibility, and environmental performance. By embedding the assessment of last mile solutions within this urban planning concept, the study connects logistics innovation to broader goals of livability, equity, and low-carbon urban transformation.

Our analytical structure expands to incorporate the 15-minute city as spatial and conceptual lens for interpreting inter-cluster interactions. Methodologically, this means assessing how each cluster’s interventions aligns with proximity based urban planning objectives, such as local service accessibility, reduced travel distances, and neighborhood self-sufficiency. We have developed roadmap to situate logistics innovations within the multi-scalar geography of the 15-minute city, from dense urban cores to evolving suburban centers. Our analytical framework integrates logistics into urban design where last mile innovations contribute to human scale, resilient, and inclusive city structures in addition to operational efficiency.

Chapter 3

Clean and Innovative Delivery Modes

3.1 Introduction

Traditional diesel-powered delivery vans have served as the backbone of last mile operations, increasingly collide with the imperatives of air quality, public health, and climate mitigation (Camilleri et al., 2016; Garus et al., 2024). In response, a new generation of clean and innovative delivery modes have emerged that are transforming how goods reach city residents. In new ideal scenes from urban plan and development brochures, and in an increasing number of actual city cases, electric vans silently cruise past morning joggers, cargo e-bikes weave through narrow historic streets, autonomous sidewalk delivery robots quietly navigate pedestrian zones, drones hover over rooftops, and even river barges bypass crowded urban roads (Michalakopoulou et al., 2025; Straubinger et al., 2023; Gruber et al., 2014). These solutions are a purposeful and technology-driven responses to three interlinked urban challenges: congestion, harmful emissions, and noise pollution (Mantecchini et al., 2025; Arvidsson et al., 2024).

This chapter presents practical cases of large-scale piloting and/or implementation of these emerging de-polluted modes along with their strengths and limitations in terms of infrastructure adequacy, regulatory complexities, and social acceptance challenges. Ultimately, clean and innovative delivery modes represent the vanguard of sustainable, livable urban futures that is contingent on integrated infrastructure deployment, adaptive policy frameworks, and strategic workforce planning.

3.2 Electric delivery vehicles (EDV)

Electric Delivery Vehicles (EDVs) have rapidly emerged as a pivotal solution in urban logistics, addressing the pressing need to reduce greenhouse gas emissions, noise pollution, PM and NO_x pollution, and reliance on fossil fuels in last mile delivery operations. Powered primarily by battery-electric technology, these vehicles offer a zero-tailpipe emission alternative to traditional Internal Combustion Engine Vehicles (ICEVs), making them especially well-suited for densely populated city centers and environmentally regulated zones (Garus et al., 2024; Camilleri et al., 2016). Their operational benefits extend beyond environmental impact, including lower noise levels (an often under-estimated urban nuisance), reduced operating costs, and potential for integration with renewable energy sources.

Despite these advantages, the adoption of EDVs faces multiple technical and economic challenges. Range limitations due to battery capacity, the need for widespread and reliable

on-street and off-street charging infrastructure, higher upfront costs compared with their counterpart ICEVs, and uncertainties regarding vehicle residual values constitute critical barriers for fleet operators (Mantecchini et al., 2025; Camilleri et al., 2016). Moreover, businesses must consider operational constraints, such as vehicle payload, route planning to optimize charging cycles, and fleet management adaptations, to fully leverage EDVs' potential.

Recent advances in battery technology, reductions in costs, and supportive policy frameworks, such as urban low emission zones and vehicle purchase incentives, have accelerated the competitiveness of EDVs (Garus et al., 2024). Electric van's Total Cost of Ownership (TCO) is now equivalent or better than many Diesel van options. It is not yet the case for Heavy Goods Vehicle (HGV).

This section explores the operational characteristics of EDVs, evaluates their market potential and constraints, and reviews case studies illustrating EDV deployment. Through this analysis, we aim to explain how EDVs contribute to cleaner, quieter, and more efficient e-commerce last mile deliveries while identifying critical factors shaping fast and wider adoption.

Case Study: Amazon & Rivian Custom EDVs – USA (2022–Present)

In 2019, e-commerce giant Amazon pledged to become carbon-neutral by 2040 and made a bold commitment to deploy 100,000 EDVs through a partnership with electric vehicle manufacturer Rivian. This now represents one of the largest corporate electrification efforts globally (Investors, 2025). The EDVs are custom-designed for Amazon's delivery needs, aimed at improving safety and efficiency.

Amazon began rolling out the Rivian EDVs in mid-2022, with over 20,000 vehicles deployed by late 2024 across more than 1,800 U.S. cities. These EDVs deliver an estimated 40% reduction in carbon emissions per package compared to diesel vans, and telematics data shows 27% lower per-stop energy use (Dnistran, 2024). Key support infrastructure includes the installation of 12,000 dedicated EV chargers at Amazon facilities. However, the roll-out of these large numbers of vehicles has faced challenges from the Rivian side due to production delays and the need for extensive retrofitting to make the vehicles fit Amazon standard.

The Amazon–Rivian EDV deployment is a clear example of corporate-led decarbonization of last mile delivery, showcasing vertical integration and long-term original equipment manufacturing (OEM) partnerships in electrifying last mile logistics. Given the importance of infrastructure investment to reduce emissions at scale, the case exemplifies how large firms can drive innovation but also reveals barriers for smaller players in the transition to green logistics at scale.

Case Study: Shenzhen Electric Logistics Vehicle Fleet – China (2018–Present)

In 2018, Shenzhen city launched a dedicated program to electrify its logistics fleet, driven by worsening air pollution, congestion, and its push for climate action. The policy design was shaped by the lessons from public transit electrification, which reflects the city's ambition to lead in green logistics innovation. In line with the plan, Shenzhen had electrified over 70,000 light-duty logistics vehicles by 2023, covering 64% of its urban delivery fleet. A critical policy shift in 2020 replaced upfront purchase subsidies with a per-kilometer incentive (0.20 Yuan/km), rewarding operators who actively used their EVs rather than keeping them idle. Average daily utilization rose to 144 km per vehicle, while emissions reductions reached 1.35 metric tons CO_2 equivalent and 1,200 tons NO_x in a single year. The roll-out was supported by 23,000 public fast chargers, including many at logistics

hubs and markets. Driver satisfaction reached 93%, citing smoother operations, noise reduction, and preferential access to zero-emission zones ([Liu et al., 2020](#)).

The switch from purchase subsidies to performance-based (operational) incentives reflects a mature policy evaluation that helped to prevent misuse and ensured that the vehicles contributed meaningfully to emission cuts. Public-private collaboration was essential, especially in charger deployment and fleet data tracking. Overall, Shenzhen's logistics vehicle electrification demonstrates how targeted incentives, infrastructure investment, and smart policy design can drive large-scale de-carbonization.

Case Study: Electrifying fleets, Budapest, Hungary (2023-ongoing)

Freight and logistics firm, Gebrüder Weiss, which also have a goal of being climate-neutral by 2030, and began piloting an electric fleet in Budapest in 2023. It introduced 10 Ford E-Transit vans for B2C home deliveries of durable items, including furniture, electronics, and household items. During the 3 months pilot, the 10 E-Transit vans covered 72,000 km, operating seven days a week and completing 85% of the company's all Budapest home deliveries. The fleet achieved approximately 15,000 tons of CO₂ savings relative to diesel alternatives. Following the pilot's success, the initiative transitioned into permanent operation, with another 10 EVs for other Hungarian cities in 2024 ([Randall, 2023](#)).

Strong cross-partnership with Ford Pro for vehicle procurement and e-mobility infrastructure strengthened deployment resilience. Mainly, the challenge faced is related to charging infrastructure, maintaining operational range (250–300 km per charge), and ensuring similar efficiency when replicated to smaller cities. With this case, the effectiveness of piloting electric vans in dense urban settings and its transition to full-scale deployment follows an evidence-based evaluations. With robust performance data and a clear expansion plan, this model offers a replicable template for logistics providers seeking to decarbonize their urban fleets.

Case Study: Flipkart, Indian cities (Mumbai, Bengaluru, Delhi and Hyderabad) (since 2019)

Flipkart is one of India's largest e-commerce firms and actively pursued electric mobility initiative. Starting in 2019, the company electrified its fleets and address growing urban delivery demands while reducing carbon foot print. The broader plan is to build partnership with Mahindra Logistics, Magenta Mobility, and manufacturers like Adani and Mahindra Electric to deploy over 25,000 EVs by 2030 in cities like Delhi, Bengaluru, Hyderabad, and Mumbai ([Vishnu Sreekumar, 2019](#)).

By 2019, Flipkart had deployed approximately 160 electric vans (e-Vans) and 30 e-bikes, achieving initial success in delivery uptime and efficiency. Infrastructure support included EV chargers at over 1,400 hub locations. The initiative has moved from pilot to scale and continue to accelerate. By late 2022, the last mile delivery fleet grew to more than 3,600 EVs, rising to more than 10,000 by September 2024 that yields 20% improvement in delivery speed and significant cost reductions at the hub level ([Gupta, 2022](#)). A partnership with BikeWo in 2025 further expanded deployment to reach 13,300 EVs across seven states ([Keerthi, 2025](#)). Overall, Flipkart's delivery fleet electrification journey typifies a mature roll-out: starting with targeted pilots, scaling through clear commitments and tech partnerships. It exemplifies how e-commerce giants in emerging markets can achieve scale, cost efficiency, environmental performance by combining operational gains with sustainability commitments.

3.3 Cargo bikes for last mile delivery

Cargo bikes have gained significant traction as an effective and sustainable solution for last mile delivery, particularly in dense urban environments where conventional delivery vehicles face operational constraints such as traffic congestion, limited parking, and strict emission regulations (Michalakopoulou et al., 2025). These vehicles, often electrically assisted (e-cargo bikes), combine the maneuverability and low environmental impact of bicycles with enhanced cargo capacity, enabling carriers to efficiently navigate narrow streets, pedestrian zones, and restricted areas inaccessible to larger vans (Arvidsson et al., 2024). Europe has become a leading hub for cargo bike operations and innovations. Every year, the International Cargo Bike Festival (ICBF) in Utrecht, Netherlands gathers manufacturers, logistics professionals, and city planners to showcase the latest developments in cycle logistics and support the 'Decade of the Cargo Bike' movement (ICB, 2025).

The adoption of cargo bikes addresses several pressing urban logistics challenges. They significantly reduce greenhouse gas emissions and noise pollution while alleviating congestion by replacing short-distance delivery trips traditionally served by motorized vehicles (Mantecchini et al., 2025; Baum et al., 2019). Additionally, cargo bikes support the concept of micro-consolidation hubs and decentralized distribution networks, which shorten delivery distances and enable more flexible, on-demand service models. However, the promise of cargo bikes comes with significant practical challenges. Maintenance of these vehicles is often frequent and costly, and many operators still lack access to reliable support services, highlighting the need for a professionalized after-sale market (Gruber, 2024). Additionally, riding cargo bikes can be physically demanding and not comfortable compared to vans, only drivers of certain physical type or preference are inclined to pedal them regularly. Cargo bikes often reported raising safety concerns due to bike lane obstruction or mix dangerously with other cyclists.

Despite their promise, cargo bike's effectiveness depend on the presence of nearby micro-hubs and their deployment requires thoughtful integration into existing logistics systems, including suitable infrastructure like bike lanes and secure parking linked with charging infrastructure for e-bikes, as well as considerations around payload limits, rider workload, and operational range (Gruber et al., 2014; Michalakopoulou et al., 2025). This section explores the operational potential of cargo bikes through reviews of cases with large scale deployments that can demonstrate their effectiveness, and assesses key barriers and opportunities for scaling their use in last mile delivery.

Case Study: DHL and REEF Technology - Cargo Bike, Miami-Florida, USA (2020 - pilot)

DHL partnered with REEF Technology to pilot the use of e-cargo bikes for last mile deliveries in downtown Miami, with a service area covering 2 km radius. Each three-wheeled cargo bike carries upto 400 lbs (181 kilograms) and volume of 1.7 cubic meter of cargo, and replaces the equivalent of one conventional delivery van per cycle. Based on the results from DHL (2020), the cargo bikes reduced around 101 tons of CO_2 equivalent emissions annually and curbside dwell time by 50%.

The pilot avoided typical van bottlenecks and achieved substantial carbon reduction by situating hub (from the host REEF) infrastructure in proximity to the urban core and pairing it with modular container system (Baker, 2020). The key factor in gaining permits and public acceptance was due to the support from the city authority, particularly in securing curbside permits and optimizing off-peak cross-docking operations. These factors were more critical to the pilot's success than the vehicles themselves, offering valuable lessons for other urban centers (Crowe, 2020). Overall, this pilot demonstrates how e-cargo cycles can replace vans in dense neighborhoods when coupled with infrastructure

maturity, regulatory support, and community engagement.

Case Study: Cargo E-Bike delivery, Seattle-Washington, USA (2020 - pilot)

In November 2018, UPS initiated a one-month pilot program in downtown Seattle, reintroducing bicycle-based deliveries with a modern twist. Collaborating with the University of Washington’s Urban Freight Lab and the Seattle Department of Transportation, the pilot featured pedal-assist electric cargo bikes equipped with modular, detachable containers capable of carrying up to 400 lbs (181 kilograms). These bikes operate in high-density areas, utilizing sidewalks and bike lanes to navigate congested streets (Maus, 2018).

Several operational advantages were demonstrated when Comparing truck-only routes (“before”) with mixed truck and e-bike operations (“pilot”). The latter resulted in reduced parking time, increased delivery success while it reduced emissions and noise pollution at the urban core. The delivery trucks spent about 28% of their trip time searching for parking, whereas cargo bikes eliminated this issue. In addition, cargo bikes had a lower delivery failure rate (0.5% vs 0.8% for trucks) (Goodchild, 2020).

The limitations highlighted during the pilot include delivery volume and range. The E-bikes had a capacity constraint and only delivered 20-24% of the packages handled by trucks. Moreover, the operational range of e-bikes constrained their effectiveness over longer distances (Goodchild, 2020). Despite these challenges, the pilot underscored the potential of cargo e-bikes as a complementary solution in urban logistics, particularly in dense, congested areas (Fucoloro, 2018). Future focus needs to be given to routing, staged-drop points, and multi-hub networks to bridge the efficiency gap (Goodchild, 2020), making cargo bikes a complementary solution in mixed-mode last mile delivery.

Case Study: EMT and Encicle, Valencia, Spain (2024 - ongoing pilot)

In early 2024, Valencia’s municipal transport company (EMT) partnered with local eco-logistics firm Encicle, specializing in zero-emission urban logistics, in the piloting last mile delivery. The initiative aimed to reduce urban delivery emissions by implementing zero-emission logistics solutions in the city’s core. Encicle utilized electric vans to transport goods to a secured micro-hub located in the city core, where parcels redistributed using electric bikes and scooters. This approach incentivizes by EMT with a 37% parking fee discount, and facilitating early-morning operations from 4 a.m. to 9 a.m. (Giaume, 2024).

The pilot successfully eliminated approximately 500 daily van trips, leading to an estimated annual reduction of 9 tons of CO₂ emissions. Encicle’s electric vans arrive early to drop off parcels, which are then sorted and delivered into city neighborhoods using electric bikes and scooters (País, 2024). It exhibits how municipality-logistics cooperation and repurposed infrastructure can yield meaningful result with urban delivery challenges (Randall, 2025). In addition, the pilot underscores the importance of integrating spatial, operational, and financial incentives to overcome barriers in last mile logistics. Though still in evaluation phase at this moment, this pilot showed promising results for reducing delivery emissions, but its affordability and benefits at scale is contingent on replicable hub design and multi-operator participation.

3.4 Trams for parcel transport

Repurposing urban tramways for freight is emerging as a niche innovation in the quest for low-emission last mile logistics. Cargo-trams have not yet proven their usefulness due to many constraints and costs.

By leveraging existing passenger infrastructure, trams can transport consolidated parcels into dense city centers, where they are transferred to smaller, zero-emission modes such as cargo bikes. This approach minimizes reliance on road-based vans and alleviates curbside congestion.

Beyond environmental gains, tram-based parcel transport also illustrates how multi-purpose infrastructure can serve both passengers and goods, maximizing the use of limited urban space. For municipalities, this strategy offers a cost-effective pathway to meet European climate and congestion targets by re-using underutilized rolling stock and off-peak capacity. However, its long-term success hinges on regulatory clarity, efficient modal transfers at the tram stops, and coordinated governance among transit operators, logistics firms, and municipalities (Alstom, 2024; Jurburg et al., 2023). Cargo-tram operations can be costly overall. There are very few examples of viable cargo-tram operations despite a few projects and tests (mostly in Europe).

Case Study: La Poste–Alstom Tram Parcel Delivery – Strasbourg, France (2024 - pilot)

La Poste, in collaboration with Alstom, the Eurométropole de Strasbourg, and the Compagnie des Transports Strasbourgeois (CTS), conducted an innovative parcel delivery pilot in 2024, utilizing Strasbourg’s Line B tramway. This initiative aimed to optimize existing public transport infrastructure to reduce urban congestion and emissions associated with traditional delivery methods. First, the parcels were loaded onto the lead car of the tram by postal worker at the start station and transferred to cargo bike at the arrival station for the last mile delivery. Freight transport integrated onto the existing tram schedule without significance interference with passenger’s travel or the tram operations (Alstom, 2024).

The pilot demonstrated the potential of leveraging underutilized public transport assets repurposed for urban logistics. Key success factors for this case are the seamless coordination between stakeholders, minimal disruption to passenger services, and the use of cargo bikes for efficient last mile delivery. Although the pilot was limited in scope, provides valuable insights into the feasibility and benefits of integrating parcel delivery into public transport networks (RailTarget, 2024). Future challenge of scalability will depend on addressing regulatory challenges and expanding multi-modal logistics networks to fully realize its potential.

3.5 Barge for last mile delivery

Integrating inland waterways with cargo bikes tested as an innovative solution for decarbonizing last mile logistics in river cities. By using barges as mobile or fixed micro-hubs, freight can be transported along rivers and canals before being transferred onto e-cargo bikes for final delivery into dense urban cores. This approach reduces heavy truck traffic, cuts carbon emissions, and alleviates congestion in historic centers where access restrictions are common.

Barge-bike synergies reflect broader trend, especially in Europe, of exploiting waterways as sustainable freight corridors. There is a broader potential for integrating cargo bikes with other modalities, like barges in waterways, particularly where efficient loading infrastructure and supportive policies are in place (Gallo et al., 2024).

Case Study: Paris River Barge + Cargo Bike and Micro-hub, France (pilot: June 2023; permanent from 2024)

The initiative launched in June 2023 to re-purpose a self-propelled cargo barge to transport beverage products from suburban ports (Gennevilliers, Bonneuil-sur-Marne) into central Paris on Paris’s Seine River that spearheaded by OBD Grand Paris, Sogestran, and HAROPA Port. The barge serves as a micro-consolidation hub when docked at Debilly port with goods transferred onto e-cargo bikes for last mile delivery ([Haropa Port, 2023](#)). The project transitioned from pilot to permanent deployment in early 2024, aligning with preparations for the Paris Olympics ([Charlton, 2024](#)).

The river micro-hub ran on a fixed schedule and replaced roughly 100 heavy-duty trucks per week that drastically reduced road congestion. Each container transported via barge cut CO₂ emissions by 80–90% compared to truck-only trajectories and significantly lowers noise pollution. According to [Haropa Port \(2023\)](#), the arrangement also delivered gains in delivery speed, job quality for riders, and improved operational predictability. Two exemplary practices clarify how cargo bikes are integrated in “barge logistics”. Fludis, which carries its cargo bikes on board the barge and deploys them from the vessel to make final mile deliveries; and Urban Logistics Solutions (ULS) which transports goods via a vessel to a dock where cargo bikes await the parcels for last mile delivery. Unlike Franprix, which uses containers and road trucks for its final meter logistics, these models ensure a clearer share of zero-emission with cargo bikes. Key challenges include seasonal navigation limits, vessel-bridge height restrictions, and the complexity of scaling micro-hubs across multiple docks.

Paris’s barge-to-bike logistics chain sets a high bar for urban freight innovation by replacing trucks with riverborne bulk transport and zero-emission micro-distribution ([Johnson, 2024](#)). As a rare example of pilot to permanent deployment that highlights the value of pre-existing waterways, supportive governance, and carefully choreographed modal transitions.

3.6 Robotic Delivery Solutions

Recently, automated delivery modes are increasingly utilized in last mile logistics that encompasses autonomous delivery robots (ARDs) and its variants, as sidewalk delivery robots (SDRs), indoor delivery robots (IDRs), and aerial drones. IDRs are not the focus of this review due to its confined functional environment and little application in the context of e-commerce last mile delivery in cities. Apart from IDRs, other robotic delivery solutions represent a transformative frontier in last mile logistics that leverages autonomous technologies with electrified power system to enhance efficiency, reduce emissions, and address growing urban freight challenges. Mainly, SDRs and aerial drone, both designed to complement or partially replace traditional delivery methods in dense urban cores ([Alverhed et al., 2024](#); [Straubinger et al., 2023](#)). SDRs are small, sensor-equipped vehicles operating primarily on sidewalks and low-speed roadways, are capable of navigating complex pedestrian environments to deliver parcels directly to consumers with minimal human intervention ([Jennings and Figliozzi, 2019](#); [Howell et al., 2022](#)). Meanwhile, aerial version which we refer it here as delivery drones have advanced beyond visual line-of-sight (BVLOS) capabilities, enabling rapid, flexible transport of small parcels over urban obstacles and congestion ([Kumar et al., 2024](#); [Moradi et al., 2024](#)).

These robotic systems promise significant reductions in traffic congestion, carbon emissions, and delivery costs while improving service speed and accessibility, particularly in restricted or high-density zones ([Engesser et al., 2023](#); [Garus et al., 2024](#)). Due to the production cost reduction, robots and drones have become financially more efficient for

logistics operations in cities. However, the operational integration of robotics in urban freight is contingent on overcoming regulatory hurdles, public acceptance challenges, technological limitations, and infrastructure setups ([Jurburg et al., 2023](#); [Melo et al., 2023](#)). Moreover, successful deployment hinges on close coordination among city authorities, logistics providers, and technology developers to ensure safety, reliability, and acceptance of the public ([Howell et al., 2022](#); [Alverhed et al., 2024](#)).

This section explores the technological maturity, deployment experiences, and socio-technical challenges of robotic delivery solutions, with mid or large-scale pilot or practical implementations by logistics companies together with their tech developers.

Case Study: REEF × Cartken Autonomous Delivery Robots – Downtown Miami, USA (pilot since April 2021)

In April 2021, REEF Technology (well-known operator of parking lots and neighborhood hubs) and robotics startup Cartken launched one of Miami’s first autonomous sidewalk delivery robot pilots. The six-wheeled, sensor-equipped robots with 1.5 cubic-foot capacity serves orders from restaurants within 1.2 Kilometers radius from REEF-operation area in downtown Miami ([Perez, 2021](#); [Bellan, 2021](#)). This initiative was driven by rising demand during the COVID-19 pandemic and aligned with Miami’s goal to reduce traffic congestion and emissions ([Daleo, 2022](#)).

The robots are designed to navigate sidewalks, curbs, and crosswalks using advanced vision sensors, catering to multiple delivery platforms, including Postmates, Uber Eats, and Grubhub, and completing deliveries in under 30 minutes ([Littman, 2022](#)). Customers receive alerts when the robot arrives and a secure code to unlock their order. This pilot demonstrates that SDRs can mitigate last mile congestion while offering contactless delivery options ([Bellan, 2021](#)). The key enablers in this trial included city permits, supportive municipal messaging, and integration with ghost kitchens. The main challenges were public acceptance, such as pedestrian’s obstructing the robot movement, meeting compliance with disability acts, and scaling operation outside the downtown area ([IAIDL, 2022](#)). Overall, REEF × Cartken’s downtown Miami sideway robot pilot marks an early, effective and successful incursion into autonomous micro-delivery in a dense urban setting.

Case Study: Starship Technologies’ Campus Delivery Robots (USA and EU)

Starship Technologies has deployed autonomous delivery robots across more than 60 university campuses in the United States and Europe, serving approximately 1.5 million students. These six-wheeled, electric robots are designed to deliver food, groceries, and packages directly to students, integrating with campus dining programs for seamless transactions ([Starship, 2024](#)). The initiative targets to enhance convenience, reduce congestion, and promote sustainability within campus environments ([Heier, 2024](#)).

Operating at a pedestrian speed of 4 mph (6.4 kph), Starship’s robots navigate sidewalks and pedestrian areas using a combination of cameras, sensors, and machine learning algorithms. Globally, these robots have completed over 8 million deliveries with more than 150,000 road crossings daily. In U.S. campuses, students can place orders through the Starship app and track their deliveries in real-time, and unlock the secure compartments upon arrival. This system has been well-received with 98% of students expressing satisfaction with the service ([Starship, 2022](#)).

This case underscores the viability of autonomous delivery in controlled settings, and could be replicated in other semi-closed environments, such as business parks or residential complexes, where short-distance and high-frequency deliveries are common.

Case Study: Meituan Drone Food Delivery – Shenzhen, China (pilot 2021–present; scaling nationally in 2025)

Meituan is a leading Chinese on-demand delivery platform. In 2021, initiated a pilot drone food delivery service in Shenzhen with leveraging the city’s robust drone-manufacturing ecosystem and supportive low-altitude airspace policies. The aim of the initiative is to address urban congestion and enhance delivery efficiency in densely populated areas ([Wenqian, 2025](#)). Deliveries are made to fixed kiosks in parks or commercial zones, with orders arriving within 20-30 minutes.

By 2023, Meituan had expanded to 53 drone routes across various cities and deployed its fourth-generation autonomous drone fleet. As of late 2024, the company completed around half a million drone deliveries in China while serving 8,000 unique customers ([sznews.com, 2025](#)). The kiosk-based delivery design streamlines the delivery process, smartly avoids landing complexities and addressing public acceptance. With its large-scale deployment of overfly drones, Meituan’s drone model effectively integrates dense urban infrastructure and manufacturer ecosystem in Shenzhen to advance delivery automation where regulatory support is strong. However, challenges remain, including canopy range limitations, weather dependencies, infrastructure costs for kiosks, societal acceptance outside pilot zones, and unclear unit economies upon national scaling ([TechNode-Feed, 2025](#)). Most importantly, drone food delivery rollout by Meituan in Shenzhen has proven operational viability, though the next test comes with national expansion.

Case Study: Amazon Prime Air Drone Delivery – Global Rollout (Pilot 2016–Present)

Amazon’s Prime Air project officially kicked off with test deliveries in Cambridge, UK, in 2016. Over the years, tech evolution and regulatory progress, including Federal Aviation Administration (FAA), USA Part 135 certification in 2020, allowed commercial flights in the U.S. by late 2022. Amazon then created the purpose-built MK30 drone, incorporating advanced computer-vision, rain-proofing, and redundancy with a 24 km range ([Kesteloo, 2024](#)). In December 2024, Italy became the first European country to host MK30 drone trials in San Salvo under the Civil Aviation Authority of Italy (ENAC) oversight. Amazon is also in the process of securing UK approval (Darlington, County Durham). The company aims to scale to 500 million annual drone deliveries by 2029, targeting under 30 minutes delivery for items under 5 lbs (2.27 Kgs) ([Sampson, 2024](#)).

Live deployments currently operate in Tolleson Arizona, College Station TX, and several U.S. test sites since 2022, delivering thousands of eligible packages within an hour. Despite two MK30 crashes incidents in Oregon due to sensor faults, operations resumed in early 2025. As of June 2025, the Italian ENAC sandbox is evaluating the next stage of commercial rollout. Pilots in rural/suburban U.S. locations and emerging European markets allow lessons in regional adaptation. Persistent safety issues (e.g., sensor failures, rainfall sensitivity), high per-package cost, and evolving public concerns (noise, privacy) remain critical challenges ([Garland, 2024](#)).

Amazon Prime Air exhibits the evolution of drone delivery from vision to reality through careful tech maturation and global regulatory navigation. While commercial use remains limited today, the company’s scale ambition and multi-market testing signal is an ambitious goal. Sustained success will depend on overcoming safety, cost-efficiency, and societal acceptance hurdles as Prime Air transitions from selected test sites to broader adoption.

Case Study: La Poste Parcel Drone Service, France (pilot since 2016; permanent from 2024)

La Poste, via its subsidiary DPD France and partner Atechsys, has been pioneering regular parcel drone delivery since December 2016. The initiative began in the Var region that connects a rural business park via weekly drone service authorized by the French agency regulate civil aviation (DGAC). A second permanent line launched in Isère in 2019, and a third permanent route strated in Vercors (between Villard-de-Lans and Corrençon-en-Vercors). These multi-lines marking expansion and multi-operator coordination (Chronopost, DPD) through shared use of infrastructure and new higher-capacity drones (LaPoste-Groupe, 2024).

Across all three lines, La Poste’s drones have collectively flown more than 40,000 km across more than 2,400 flights, replacing 65 km of mountain road journeys and cutting delivery times from 2 hours to under an hour. The latest Vercors drones carry up to 10 kg per flight, compared to initial 2 kg drones, and cruise at 40 km/h over 10 km distance (Marquand, 2024). La Poste’s evolution from pilot to operational network illustrates successful scaling through thoughtful planning and execution (ROUSSARD, 2024), involving:

- Modular deployment using van-integrated pads and secure terminals reduces infrastructure investment.
- Regional replication underscores a replicable template for rural and mountain contexts with challenging road access.
- Multi-operator pooling in the Vercors line maximizes drone utilization and cost sharing.
- Parachute-based safety and regulatory support create trust and continuity.

La Poste’s drone delivery rollout, now operational as permanent multi-route services in France’s Alpine regions, demonstrates the practical viability of small drone logistics in challenging terrains. Remaining challenges include operating scalability in varied terrains and up-front investment for terminals and drone fleets (Marquand, 2024). Though, it provides a compelling last mile delivery model in peri-urban areas with significant time and distance savings.

3.7 Summary

This chapter has explored a diverse and rapidly evolving suite of clean and innovative delivery modes that are reshaping e-commerce urban logistics to address critical challenges such as congestion, air pollution, and noise. From electric delivery vehicles and cargo e-bikes to autonomous delivery robots and drone systems, these emerging modes collectively represent a potential paradigm shift toward more sustainable, efficient, and adaptive last mile delivery solutions. Among these innovations, some modes are more efficient, more mature and make more economic sense than others.

The case studies reviewed illustrate both the promise and practical realities of these technologies in action. For instance, UPS’s cargo e-bike pilot in Seattle demonstrated significant reductions in curbside parking times and improved delivery success rates, despite capacity and range limitations (UrbanFreightLab, 2024). The La Poste–Alstom tram parcel delivery pilot in Strasbourg showcased how existing transit infrastructure can be repurposed for freight, minimizing additional congestion and integrating modal transitions smoothly (Alstom, 2024). Paris’s river barge and cargo bike micro-hub project sets a high

benchmark for leveraging waterways in urban logistics, drastically reducing truck trips and associated emissions ([Haropa Port, 2023](#)). Sideway delivery drone cases with REEF $\times$ Cartken and Star-ship, and aerial drone systems with Meituan, Amazon Prime and La Poste present a promising future and success that hinges on a range of factors, such as maturation of regulation, safety, public acceptance on top of suitable infrastructure availability.

From the standpoint of past studies, these innovative modes offer notable strengths, especially in environmental benefits, operational efficiency in dense urban area, and adaptability to regulatory trends favoring low-emission transport ([Michalakopoulou et al., 2025](#); [Garus et al., 2024](#)). However, their maturity levels diverge significantly. Cargo bikes and electric delivery vehicles have achieved a broader maturity and adoption, particularly in Europe, where they outpace vans in speed and emission reduction. Autonomous delivery robots (ARDs) are emerging, often confined to controlled environments and limited applications, but growing in both the trails and the market. Delivery drones capture public imagination as a futuristic solution to traffic and delivery bottle-necks, but are still nascent in applications. In the last mile ecosystem, drones are promising for time-sensitive, small packages, yet their deployments remain limited due to public acceptance, safety, noise, regulatory and technical limitations. Despite this advancements, common weaknesses persist across modes, including high upfront costs, infrastructure gaps, operational costs, and public acceptance challenges ([Jurburg et al., 2023](#); [Melo et al., 2023](#)). Opportunities differ by maturity: while cargo bikes thrive through e-commerce integration and smart city compatibility, drones and ADRs may benefit from technological advancements in routing systems, AI and robotics ([Engesser et al., 2023](#); [Kumar et al., 2024](#)). However, threats remain systemic across all modes, including invalid assumptions of easy integration, competition from incumbent delivery methods, cyber security risks, and regulatory fragmentation, continue to pose real danger across the innovation spectrum.

Implications for practice include the necessity for coordinated infrastructure development, such as expanded micro-hubs, charging networks, and dedicated and well-conceived lanes that support efficient and safe non-traditional freight flows. Logistics operators could also, in some cases, consider hybrid delivery models blending electric vehicles, cargo bikes, and autonomous robots to optimize cost and service levels ([Mantecchini et al., 2025](#)). As claimed by [Melo et al. \(2023\)](#), policy frameworks must evolve to harmonize safety standards, data governance, and public engagement strategies while incentivizing low-carbon technologies and encouraging cross-sector collaboration. Finally, future research should deepen quantitative assessments of system-wide impacts, and develop scalable governance models that enable equitable, efficient adoption across diverse city typology ([Alverhed et al., 2024](#); [Straubinger et al., 2023](#)).

In sum, clean and innovative delivery modes are emerging, and the most successful ones stand at the forefront of sustainable transformation of last mile logistics. Their successful scaling depends on integrated technological, infrastructural, regulatory, and social approaches that balance efficiency with inclusivity. Cities worldwide can draw on the demonstrated successes and challenges of the case studies to chart pathways toward cleaner, smarter, and more livable cities.

Chapter 4

Curb and Street Operations Management

4.1 Introduction

For most city dwellers, the curb is where daily life unfolds: cafes spill into sidewalks, commuters hail ride-shares, and delivery vans search for precious loading/unloading spaces. Curb operations management extends far beyond traditional parking management. While parking demand represents just one subset of curb space use, typically characterized by long-stay, static vehicle storage, the modern urban curb must accommodate a far more dynamic mix of activities: loading and unloading, parcel deliveries, ride-hailing, EV charging, short-term parking, and passenger pick-ups and drop-offs. Recognizing that improving curbside efficiency can unlock significant time and emission savings, cities around the world are transforming the curb from a passive public good into a digitally regulated, actively managed resource.

Curb-side and street operations management focus on optimizing loading/unloading zones through digital tools, regulated time windows, and infrastructure redesign ([Amaya and Reed, 2025](#); [Diehl et al., 2021](#)). In addition, street operations management reallocates carriageway space to freight without undermining transit or general traffic and includes dedicated or managed lanes which are mostly time-based shared use corridors, .

Together, curb and street operation management reflects a shift from static, signage-based management toward dynamic, data-driven governance ([Rubino et al., 2025b](#)). Digital curb inventories, IoT sensors, and mobile apps in the future may routinely enable cities to monitor occupancy in real time. Meanwhile, street level interventions demonstrate how dedicating carriageway lanes to freight and transit can prevent congestion and reduce conflict. The following case studies illustrate diverse technological, regulatory, and organizational innovations that underpin modern curb and street management.

Urban curb interventions are generating a new and growing evidence base for logistics management. Modern systems, such as embedded occupancy sensors, ANPR camera networks, permit/booking apps and Bluetooth-enabled smart signage, are producing rich operational traces: for example, which trip made use of a loading bays, when it was occupied, for how long, and by what vehicle type. These 'incidentally' collected data streams allow municipalities and carriers to quantify loading bay occupancy and turnover ([Diehl et al., 2021](#)), estimating cruising and double-parking impacts ([Burns et al., 2024](#)), reconstruct frequent delivery loops and fleet compositions ([Knapskog and Browne, 2022](#)). These new data streams open several concrete opportunities for policy and research. Practically, continuous curb metrics enable evidence-based calibration of time-differentiated loading rules, dynamic reservation systems, demand-responsive pricing, and locating micro-hub that all while providing performance indicators (turnover, cruise time, emissions prox-

ies) needed for iterative policy design. [Dablang and Adoue \(2025\)](#) highlight important caveats: representativeness varies by technology (ANPR/on-board unity (OBU) vs. app check-ins), open-data releases often require aggregation that reduce precision, and data governance, storage costs and privacy/regulatory constraints shape what municipalities can actually use and share.

Case Study: Barcelona SPRO digital platform for dynamic curbspace reservation – Spain (2023)

In February 2023, Barcelona City Council, in collaboration with key logistics and labor stakeholders, introduced an ambitious Municipal’s 2030 Strategy for Urban Goods Distribution (DUM). The core objectives include reducing delivery vehicle emissions by 50%, extending loading hours by 20%, diverting 40% of e-commerce orders to pick-up points within 200 meters of homes, scaling bike deliveries by ten-fold, and deploying delivery services via rail ([Barcelona.cat, 2023](#)). Digital tools like the SPRO app (which had existed since 2015 under another version) are central to this effort, together with some efforts related to the implementation of urban logistics hubs.

After its launch, Barcelona reported an increase in available daytime loading bays at municipal markets, the first of several measures designed to re-balance curbside demand and reduce peak-hour congestion ([Barcelona.cat, 2023](#)). Moreover, parcel pick-up point networks have been significantly expanded (fewer than 300 to more than 800), improving accessibility and shifting consumer behavior. Mainly, SPRO adoption rose sharply, achieving over 60% usage among registered delivery operators, which has streamlined enforcement and reduced parking infractions near regulated loading zones ([energia Barcelona, 2022](#)).

The city has begun to alleviate curbside pressures and improve traffic flow by expanding temporal and spatial flexibility, particularly with longer loading times, night-time operations, and off-street hubs ([Barcelona.cat, 2023](#)). SPRO demonstrated the use of digital tools to enforce regulations more efficiently than traditional parking attendants, while real time data collection enables adaptive management of curb assets ([energia Barcelona, 2022](#)).

Early indicators of success, such as enhanced loading bay availability, burgeoning pick-up point usage, and rapid digital platform uptake, built a foundation for long-term objectives. More emphasis should be given to a shift from pilot scale to rigorous and outcome based monitoring ([Blanchar, 2025](#)). The lesson from this case shows the importance of integrated policy design and stakeholder alignment in advancing low-emission curbside operations.

Case Study: FlexCurb Digital Curbside Management Project – Europe (Pilot: Jan–2022; Extended Pilot 2023)

Led by the POLIS Network and co-funded by EIT Urban Mobility, FlexCurb is a digital solution designed to optimize curbside space for urban freight in four European cities: Leuven, Funchal, Strasbourg, and Toulouse ([POLIS, 2022](#)). Launched in early 2022, the initiative addresses pressing delivery related challenges such as double parking, congestion, emissions, and operational inefficiencies ([tecnomind, 2022](#)). Its core innovation lies in the creation of a standardized digital curb inventory linked to dynamic regulation pilot, enabling cities to adapt curb allocations near real time and logistics operators to plan deliveries around actual curb availability ([EIT, 2022](#)).

Two complementary digital tools, FlexCurb Planning Platform and FlexCurb Driver App, were deployed in all four cities during the initial 2020 pilot phase. By 2023, the

planning platform added sensor-integrated curb data and predictive features indicating high/low parking demand by time and location (Rothbard et al., 2025). User-feedback analysis from the Driver App revealed a 25% reduction in time spent searching for legal loading bays and a 15% drop in double-parking incidents within mixed use zones (Cristina, 2022).

The “Shared-Use Mixed Zones” concept, where curbside space is allocated dynamically by time-of-day across freight, transit, active modes, and private parking emerged as an effective practice for balancing competing demands. The key challenges identified are securing robust enforcement mechanisms for dynamic regulations, standardizing data formats for curb inventory across jurisdictions, and ensuring sufficient sensor coverage to power high-fidelity demand forecasts (Rothbard et al., 2025). FlexCurb offers a replicable blueprint for smart curbside management by coupling a city-facing analytics platform with an operator-facing mobile app (Urban Radar, 2022). Digital mapping of curb regulations combined with real-time availability of data can significantly improve delivery efficiency and reduce unauthorized parking.

Case Study: PARKUNLOAD Smart Urban Freight Parking Platform – Europe (Pilot & Commercial, since 2021)

PARKUNLOAD developed by Carles Sentís in 2021 and piloted across European cities, mainly in Catalonia’s Vic and Cantabria’s Torrelavega (Spain). PARKUNLOAD is an Internet-of-Things (IoT)-based platform designed to modernize loading/unloading zones into dynamically regulated, data-rich curb spaces (cities-for mobility.net, 2022; parkunload.com, 2022). It addresses common urban challenges, such as double parking, curb congestion, and undocumented freight activity, by replacing static signage with smart Bluetooth enabled signs, a mobile app for drivers, and a management portal for city officials.

Drivers use the app to check in at a smart sign, confirm their permit and allowed duration, and are reminded before the time expires. Parking inspectors access a companion app to identify vehicles and enforce rules. Early pilots in Vic and Torrelavega showed significant gains in turnover, compliance, and operational flexibility (cities-for mobility.net, 2022). However, challenges remain particularly around upfront hardware costs for smart signs, the need to integrate with existing enforcement workflows and harmonizing digital permit formats across operators and municipalities (CORDIS, 2019). Overall, PARKUNLOAD underscores the power of integrating physical infrastructure with digital services to achieve flexible curbside governance.

Case Study: Dublin Digital Kerbside Management “Kerb” – Ireland (pilot October 2022; extended pilot 2023–2024)

Dublin’s “Kerb” pilot launched under the EU-funded SENATOR program in October 2022, with the aim of developing holistic, data-driven approach to urban curbside governance to tackle rising loading-bay congestion fueled by e-commerce and urban growth (Senator). The project enabled real-time bay allocations with combining virtual mapping, a municipal analytics platform, on-street sensors and a driver-facing app (Chmielewska, 2022). After digitizing 69 km of curb asset, the results indicate that dynamic kerb regulation can alleviate delivery congestion, support active modes, and supply planners with the evidence base for scalable policy interventions (Lumbreras, 2023).

The pilot indicates the transformative potential of digital curb management with an end-to-end integration. The detailed mapping to real-time enforcement support has improved compliance and turnover while reducing manual inspection burdens (Chmielewska,

2022). There remain issues in harmonizing digital permit formats across municipal systems, ensuring sensor maintenance for data fidelity, and embedding the platform into existing enforcement workflows (Senator). The vital elements to scale the gains to city-wide and beyond are continuous data feeds, enforcement integration, and cross-sector partnerships (CurbIQ, 2023).

Case Study: ReVeAL Dynamic Kerbside Management – City of London & European Cluster (Pilot: Oct 2020–2022)

In October 2020, the consultancy firm-WSP initiated a Sandbox pilot under CIVITAS ReVeAL (Regulating Vehicle Access for Improved Liveability) to trial Dynamic Kerbside Management within the Eastern Cluster of the City of London (WSP-Sweden, 2020). The core objective was to map curbside needs and to prototype regulatory and technological solutions enabling real-time re-allocation of street space for freight loading, public transport stops, cycling lanes, and emergency access.

During the pilot, the project held round-tables in six European cities (i.e., London, Bielefeld, Helmond, Jerusalem, Padova, and Vitoria-Gasteiz) to co-design digital inventories, regulatory frameworks, sensor architectures, and enforcement workflows (rupprecht consult, 2022). The team developed a geo-spatial "kerb" database capturing bay locations, restrictions, and contextual metadata, and trialed a virtual booking system allowing operators to reserve curb slots via a mobile interface (WSP-Sweden, 2020). Several barriers were identified, including organizational fragmentation, regulatory inertia, fragmented data standards, and user friction and privacy concerns. These findings advocate for staged rollout.

The ReVeAL Dynamic Kerbside Management (DKM) pilot in the City of London has laid critical groundwork for transforming static curb regulations into agile, demand-driven utilization with a potential to reduce congestion, lower emissions, and enhance urban livability (WSP, 2020). The lessons to cities seeking to implement DKM should prioritize legislative reforms to enable adaptive rules, unify kerb management mandate, adopt interoperable data standards, and cultivate user-centric digital experience (ERTRAC, 2021).

Case Study: NYC DOT Local Delivery Hub with Curb Management – New York, USA (Pilot - 2023)

New York City receives over 90% of its freight by truck, driving chronic double-parking, sidewalk obstructions, and air-quality impacts that conflict with Vision Zero and climate goals (Wayne-Schooling, 2025). In Spring 2023, New York City Department of Transportation (NYC-DOT) initiated a three-year Local Delivery Hub Pilot, deploying up to 20 curbside and off-street "microhub" sites across high-density neighborhoods (NYC-DOT, 2024a). The pilot's objectives are to reduce the number of large trucks operating in dense neighborhoods, and streamline last mile logistics through safer and sustainable modes. In addition, gather data to shape equitable enforcement and permanent regulatory frameworks (Garland, 2023).

Prior to the pilot, DOT studies found that up to 40% of truck trips were servicing residential customers. Delivery vehicles spent an average of 10–12 minutes per curb-loading event in pilot-eligible neighborhoods, leading to double-parking and blocking bike lanes in over 35% of observed trips (Garland, 2023). Phase 1 of the pilot commenced in June 2023 with the installation of painted and barrier-protected curbside zones and selected off-street parcels under elevated roadways (NYC-DOT, 2024a). Regulatory signage and curb markings delineate "microhub zones," while modular canopies and cargo-bike corals support transloading (NYC.gov). A lightweight digital platform provides drivers with

real-time space-availability updates via QR-code scanning and geofenced check-ins; SMS alerts inform couriers of slot allocations, minimizing idle time (Colon, 2023).

Although the final evaluation pending, preliminary observations indicated a 20% reduction in double-parked truck incidents within active microhub zones (Colon, 2023). Community feedback highlights improved sidewalk clearance and fewer traffic conflicts during peak delivery windows. Detailed metrics on vehicle-kilometer reductions, emission savings, and delivery speed will be released in the pilot’s final report in late 2026 (NYC-DOT, 2024a). The key success factors are, but not limited to, the combination of on-street and off-street hubs enabled deployment in space constrained corridors, leveraged underused rights-of-way beneath elevated structures, and minimized queue spill-overs through real-time data monitoring for adaptive management using digital slot-reservation and geofencing tools (Colon, 2023). Phase 2 runs from fall 2024 through 2026, expanding micro-hubs to additional neighborhoods, testing dynamic curb-use pricing, and evaluating regulatory incentives for zero-emission last mile vehicles (NYC-DOT, 2024a).

Case Study: Seattle Freight & Transit (FAT) Lane – USA (Pilot: Jan 2019; Permanent Operational Stage)

In January 2019, Seattle’s Department of Transportation (SDOT) launched a pilot of the Freight and Transit (FAT) Lane which is a curbside lane open to buses and trucks along a 2-block section of Alaskan Way. Managed in collaboration with the University of Washington-Urban Freight Lab, the initiative aimed to preserve freight and transit mobility amid reduced road capacity downtown, aligning with Seattle’s Freight Master Plan goals (TRAC, 2020).

Camera-based data revealed that buses and freight vehicles occupied the FAT lane over 90% of the time instead of general-purpose lanes. Usage patterns varied by time: transit peaked during afternoon rush, freight usage was higher in off-peak periods. Unauthorized vehicle use increased during congestion (Sandy Johnston, 2022). A multinomial logistic model indicated lane choice depended on vehicle type, time of day, and corridor location as a significant predictor of FAT lane use, while traffic density (proxy for congestion) did not significantly influence lane choice (UrbanFreightLab, 2020b).

Despite the pilot done on two-blocks, the performance metrics demonstrated that designated curbside lanes could absorb peak transit and freight flows without harming the private-vehicle throughput on adjacent lanes (Sandy Johnston, 2022). Seattle’s FAT Lane case affirms that shared freight and transit lanes can maintain high utilization and compliance when properly designated and communicated to operators (UrbanFreightLab, 2020b). Seattle’s FAT Lane and its evolution into a permanent facility provide a blueprint for cities seeking to optimize limited street capacity for both goods and people. Critical success factors include clear designation, targeted enforcement, and data-driven evaluation of usage patterns.

4.2 Summary

Urban curbs and carriageway operations management are no longer passive public on-street real estate: they are operational assets that must be actively governed if cities are to reconcile e-commerce growth with safety, livability, and climate objectives. Across the chapter we saw recurring evidence that modest, targeted interventions, including digital inventories and APIs, sensor-assisted occupancy monitoring, time-differentiated rules, and dedicated freight/transit lanes, can produce measurable gains in loading-zone turnover, reductions in cruising and double-parking, and lower local emissions when combined with

adaptive enforcement and stakeholder coordination. These gains are consistent with recent empirical and modeling work: models of time-differentiated loading-bay policy and system-dynamics treatments show that dynamic allocation and temporal flexibility reduce conflict at peak hours, while occupancy sensor data and driver/inspector apps enable the real-time monitoring that makes such policies enforceable in practice (Wilson et al., 2022; Rubino et al., 2025a).

When read as an ensemble, the case studies show three persistent positive dynamics. First, digitization reduces uncertainty: a shared curb inventory and driver-facing booking/check-in apps materially cut search time and illegal stopping in pilots from Dublin to Strasbourg to Barcelona, making enforcement more surgical and less adversarial (Senator, 2024; EIT, 2022; Barcelona.cat, 2023). Second, modal substitution via micro-hubs and cycle logistics integration reliably lowers van-kilometers and local pollutant exposure when on-street transloading is paired with nearby consolidation hubs/centers. Third, time-based and managed lanes that privilege freight and transit during critical windows can preserve corridor throughput under constrained conditions, as Seattle’s Freight & Transit (FAT) lane (UrbanFreightLab, 2020b) showed. These positive effects align with operational evaluations in the literature, which stress the role of occupancy data and adaptive scheduling in producing durable benefits (Letnik et al., 2018; Alho et al., 2018).

Yet technical promises collide repeatedly with institutional and regulatory frictions. The synthesis of strength and weakness of curb and streets operation measures centers on the structural constraint: responsibility for the curb is typically split across multiple agencies (parking, traffic operations, freight policy, enforcement at different levels sometimes, planning), and this fragmentation undermines the rapid rule changes, API governance and cross-department data sharing that pilots require (WSP-Sweden, 2020; Diehl et al., 2021). Legally, many codes still assume static signs and fixed hours, so time-differentiated and dynamically allocated bays often need legal workarounds or formal amendments to parking and carriageway bylaws before pilots can scale. Technology markets likewise present a challenge: the diversity of sensor types, proprietary APIs, and non-standard data schemas (observed in FlexCurb and ReVeAL trials) raises switching costs for cities and risks vendor lock-in if open standards are not mandated.

From these crosscutting findings follow several practical and policy implications. Cities that want to move from pilots to system change should begin by naming a single curb-management lead or inter-agency body empowered to coordinate parking, freight, and enforcement functions; doing so reduces bureaucratic delay and clarifies data-sharing protocols (ReVeAL shows this is a precondition for scaling). Additionally, investment strategies should prioritize open curb APIs and modular sensor layers rather than wholesale sensor roll-outs: deploy sensors where policy impact is highest—market streets, microhub nodes, high-conflict corridors—and link them to an open data inventory to enable third-party innovation (Dublin Kerb, FlexCurb, PARKUNLOAD trials). Pilot evidence also underlines that enforcement is part of the service: digital check-in, inspector apps, and ANPR or sensor fusion are not optional add-ons but essential enablers of credible, time-differentiated rule sets (Barcelona.cat, 2023; cities-for mobility.net, 2022). In addition, curb gains enhanced in microhub zones (as with NYC local delivery case), with improvements in double-parking reduction, sidewalk clearance, and fewer traffic conflicts during peak delivery windows.

The chapter’s findings recommend a pragmatic sequencing for policy making: first, digitize and map curb assets publicly to create a baseline; second, run targeted living-lab pilots using interoperable tools and explicit evaluation metrics (turnover, cruise time, emissions, equity impacts); third, enact legal amendments that convert successful pilot rules into standing regulation while protecting data privacy and commercial confidentiality

with clear governance rules ([Amaya and Reed, 2025](#); [WSP-Sweden, 2020](#)).

Finally, this chapter identified a research agenda. Longitudinal behavioral studies are needed to assess whether consumers and couriers sustain the shifts observed in short pilots (pickup-point adoption, acceptance of time windows, and carrier routing changes). Equity analyses must accompany operational KPIs to ensure that curb re-allocations do not disproportionately disadvantage elderly residents, small retailers, or informal couriers. Technical research should prioritize (a) interoperable curb-data standards and privacy preserving data-governance frameworks that reconcile municipal oversight with commercial confidentiality, and (b) combined agent-based and system-dynamics modeling validated against pilot data to explore city-scale outcomes and potential unintended consequences. Finally, as automation and robot deliveries mature (see **Section 2**), we must study how autonomous sidewalk and street robots, and platooned micro-vehicles will interact with dynamic curb rules and the required institutional safeguards ([Rubino et al., 2025a](#); [Wilson et al., 2022](#); [Diehl et al., 2021](#)).

In sum, curb and street operations management offers policy-efficient levers for reducing emissions, improving safety, and accommodating the growth of e-commerce without wholesale road building. Realizing these gains at scale requires three coordinated moves: create clear governance and legal authority for the curb; build interoperable, open digital infrastructures that privilege data sharing and privacy protection; and design fiscal and permit schemes that incentivize low-emission, consolidated, and equitable delivery models. When cities combine these elements, curbside space can be transformed from a source of conflict into a managed public asset that supports resilient, low-carbon, and inclusive last mile systems ([Barcelona.cat, 2023](#); [Senator, 2024](#)).

Chapter 5

Micro-fulfillment & Consolidation Infrastructure

5.1 Introduction

In the race to satisfy consumer demand for near-instant delivery, logistics providers are discovering that proximity can be key. Traditional, sprawling fulfillment centers on city outskirts can handle enormous throughput, but the last miles between those hubs and urban consumers rack up both time and emissions. Enter micro-fulfillment and consolidation infrastructure: a network of compact, strategically sited depots and collection points embedded within neighborhoods, often hidden behind storefronts, inside repurposed retail spaces, or tucked into multi-story logistics “hotels” ([Gillström and Björklund, 2024](#)). These small-footprint facilities, supported in some cases by robotics for automated storage and retrieval, (but many micro-hubs, when they are mainly ‘cross-dock’ facilities, are extremely basic in their internal equipment), enable carriers to transfer parcels, or pick, pack, and dispatch orders in minutes rather than hours.

Micro-fulfillment, consolidation and cross-docking infrastructure in cities represent a critical evolution in e-commerce logistics: they bring goods closer to customers, optimize delivery routes, and can also enliven urban properties (think brown-fields turned into high tech logistics hub). Their success will depend on innovative partnerships among carriers, property owners, technology providers, and city authorities, ensuring that these compact hubs become a seamless, scalable layer of tomorrow’s urban delivery networks ([Karaoulanis, 2024](#)). The following subsections discuss in details various types of these facilities, including pick-up/service points or parcel lockers, micro-hubs, and warehouses, consolidation centers and cross-docking facilities.

5.2 Pick-up points/Service Points/Parcel Lockers

Out-of-home (OOH) delivery channels encompassing staffed pickup/drop-off points (PU-DOs) and automated parcel lockers (APMs), shift the final “last meters” of delivery from the door steps to nearby, access controlled locations. By consolidating multiple consignments at a single node and enabling time-flexible customer collection and returns, OOH options reliably cut failed first-attempts and shorten courier dwell inside buildings and at the curb; controlled field experiments and evaluations consistently report significant time savings and operational gains for carriers ([Ranjbari et al., 2023a](#)). Emerging syntheses also point to non-trivial cost and emissions benefits at network scale, though magnitudes depend on local travel patterns and customer access: lockers and PUDOs can reduce delivery costs and CO₂ in many contexts, but the net effect hinges on whether customer

pickup trips are walk/bike-based or add car kilometers (Fardin, 2025). A study by Béziat (2023) showed that even when only 10% of collection trips are made by car, the net emissions by the PUDOs becomes negative.

Across Europe, out-of-home delivery via PUDOs and AMPs is no longer experimental; it is the default complement to home delivery and a core quality-of-service feature for e-commerce shoppers, in cities as well as rural areas. By the end of 2023, the industry trackers count over 349,000 PUDOs and 155,000 parcel lockers across Europe with national networks operated by postal and parcel operators. Against this mature baseline, the innovation frontier in Europe is shifting toward carrier-neutral (open) networks infrastructure that any qualified carrier can use, rather than single-operator ecosystem (Calviño, 2025). While still comparatively rare, such open models are gaining traction, and pose valuable policy and governance questions around equitable access, competition, and data interoperability. Above all, Europe’s case highlights how cities and operators are navigating from long-standing, carrier-tied OOH systems toward more open, shared infrastructures without sacrificing coverage or user experience.

For planners, OOH infrastructure is best treated as part of a layered micro-fulfillment system: site placement should prioritize walkable catchments, co-location with transit/retail, and integration with micro-hubs; the digital layer (access codes, telemetry, geofenced check-ins) underpins monitoring and service quality; and governance choices (i.e., universal-access vs. carrier-exclusive networks, public-realm siting, accessibility, and data safeguards) shape competition and equity outcomes (World Economic Forum and Accenture, 2024). International guidance highlights allocating public space for lockers alongside hubs and charging, while European regulators emphasize fair, non-discriminatory access (ERGP, 2022); meanwhile, rapid commercial rollout across major markets signals OOH’s growing role in urban delivery (ITF, 2024a). The following case studies illustrate these design, policy, and performance considerations across diverse urban contexts.

Case Study: Smart point parcel locker, Madrid, Spain (2022 on-going)

Madrid faced a surge in delivery vans and associated congestion, noise, and emissions following the e-commerce boom. In response, the city joined EIT Urban Mobility’s ”#ChallengeMyCity” initiative in mid-2022 to pilot sustainable last mile solutions (EITUrbanMobility, 2023). Smart Point was selected for its universal locker network, capable of consolidating parcels from all courier companies into secure pick-up points (Smart Cities Marketplace). Electric vehicle operators were contracted to transport consolidated loads from micro-hubs to locker sites. The objectives were to (1) reduce curb-side traffic and emissions, (2) improve delivery success rates beyond the national average of 70%, and (3) assess socio-economic impacts for potential city-wide rollout (wirelesslogic, 2022).

In late 2022, the city granted public space for ten Smart Point locker installations at transit hubs, university campuses, and corporate buildings. During the first six months (January–June 2023), locker usage reached 85% of capacity on average, with peak weeks hitting full occupancy. Delivery success rate improved to nearly 100%, eliminating missed-delivery attempts and reducing re-delivery mileage by 25% compared to doorstep delivery (Wireless Logic). Surveys indicated that 92% of users found the service convenient, citing 24/7 access and reduced wait times as major benefits (EITUrbanMobility, 2023).

Future rolls-out should ensure sufficient locker capacity during promotional periods and incorporate dynamic sizing which adding modular units based on real-time demand forecasts ((Selva, 2023). Building on these results, Madrid plans to expand the Smart Point network to 20 sites by late 2025, targeting underserved residential districts and high-density commercial corridors, in partnerships with local retailers for on-demand services

like dry-cleaning and grocery pick-up ([EITUrbanMobility, 2023](#)).

Case Study: Final delivery solution, Shenzhen, China (2013)

In 2013, Alibaba Group and eight partner firms launched Cainiao Network, debuting Shenzhen’s first large-scale pickup-point network under the “Smart Logistics” banner. Designed to aggregate parcels from multiple couriers into a city-wide web of community stations—branded as Cainiao Stations ([Xiao et al., 2017](#)). The aim of the initiative is to relieve mounting curbside congestion, cut delivery costs, and improve first-attempt delivery rates.

Prior to the pilot (between May and December 2013), final-mile deliveries in central Shenzhen exhibited a 30% failure rate on first attempt. Average in-city distance per parcel delivery was around 5 kilometers, with 60% of trips operated by diesel-powered vans. Delivery lead times averaged 24 hours from warehouse to customer’s door. The evaluation of the pilot found that pickup-point deliveries achieved a 98% first-attempt success rate (up from 70% under traditional door-to-door service), average van-kilometers per parcel reduced by 22% and cut fuel consumption by 18% compared to direct deliveries ([Xiao et al., 2017](#)). User surveys reported 94% satisfaction with pick-up flexibility, and 87% of recipients prefer collection at station over home delivery ([Cainiao](#)).

From its inaugural year to mid-2021, the network established over 200,000 terminals nationwide. Current development focuses on AI-driven demand forecasting to optimize station capacity, and on piloting carbon-offset schemes to reward users for selecting low-emission collection options ([ipc.be, 2020](#)).

Case Study: Common carrier locker, Seattle-Washington, USA (2017)

Seattle’s Municipal Tower (62-story building), a high-density office building, generated significant curb-bay congestion and vertical delivery delays as drivers navigated elevators and hallways to reach individual tenants. A study by Urban Freight Lab in 2017 quantified the floor to door deliveries in the tower, averaged 30 minutes per stop and a nearby mini-delivery node could slash it by 61%. The 2018 pilot aimed to build on this study, and test the impact of a shared locker accessed by all carriers on delivery speed, failure rate, and public-space productivity ([UrbanFreightLab, 2018](#)).

During the 20-day pilot, all the 563 parcels delivered to the locker succeeded on the first attempt, eliminating the seven missed first deliveries recorded during the baseline (Urban Freight Lab). Total delivery time from loading-bay entry to tenant receipt averaged just 6 minutes (a 78% reduction compared to traditional deliveries) ([Kim and Kaddoura, 2021](#)). Analysis of loading-bay occupancy showed average dwell times per stop fell from 12 minutes to 3 minutes when using the locker, freeing critical curb space for other vehicles and improving service predictability ([ITS, 2019](#)). Critical to the pilot’s success was the universal-access model, allowing any carrier to route parcels into the same locker seamlessly, which maximized locker utilization and simplified driver workflows ([Ranjbari et al., 2023a](#)).

The pilot highlighted the need for pre-shipment integration because the locker lacked real-time inventory feeds to carriers’ routing systems; drivers sometimes arrived to full lockers and had to revert to door-to-door deliveries (Urban Freight Lab). Based on these findings, Seattle plans to expand common-carrier lockers to other high-rise buildings and explore integrating lockers into curbside zones, supported by dynamic digital signage indicating real-time locker availability ([Ranjbari et al., 2023b](#)).

5.3 Micro-hubs

Micro-hubs are compact transfer nodes sited close to demand where shipments arriving on larger vehicles are consolidated and handed to low- or zero-emission modes (e-cargo bikes, handcarts, small EVs) for short, dense final-leg rounds (ITF, 2024b). European guidance frames them as a complementary “last ring” in an urban logistics chain: positioned near urban centers, reachable within a short walk or ride, and designed to support time-definite delivery windows while shrinking the curb footprint of vans in high-intensity areas (EGUM, 2024). Beyond physical space, effective micro-hubs layer simple digital functions, including slot booking, geofenced check-ins, and basic telemetry to coordinate handovers and monitor performance. Taken together, these design principles aim to cut vehicle-kilometers, improve reliability, and free scarce curb space in constrained corridors (Kim and Kaddoura, 2021).

From a policy perspective, micro-hubs are now common in Sustainable Urban Logistics Plans (SULP) and city playbooks because they are small, modular, and fast to pilot on- or off-street. Planning guides emphasize siting (access, safety, frontage conditions), minimal but adaptable infrastructure (from marked bays to containerized storage), and a data layer that enables evaluation of emissions, dwell times, and equity of access (Blinge et al., 2021). As cities pursue zero-emission last mile strategies, micro-hubs function as practical levers that align private delivery efficiency with public goals (Kim and Kaddoura, 2021). The following case studies illustrate varied implementations, governance models, and outcomes across different urban contexts.

Case Study: Micro hubs for Local Delivery, Paris, France (2022)

In 2022, the City of Paris and logistics developer Sogaris inaugurated two on-street wooden micro-hubs in Paris Center to serve as last mile consolidation points for bicycle couriers, embedding a novel supply link into the urban freight chain. Designed by Moon Architectures and operated by the cycle logistics cooperative companies Olvo and Ecolotrans, these “cages” featured secure boxes accessible via digi-code and also function as collection sites for recycled goods, leveraging cycle-cargo transfers to shorten traditional truck rounds (Jouquan, 2022). The objective came from the fact that Paris’s last mile deliveries in the central arrondissement relied overwhelmingly on small vans and motorcycles, which contributed to frequent double-parking infractions and elevated particulate emissions in tightly packed streets. In addition, the absence of formalized micro-consolidation points forced couriers to undertake longer, less predictable routes, exacerbating noise and air-quality impacts at street level (Paquier, 2022).

After one year of the experiment, the City removed both units and returned the parking spaces. It described the experiment as unsuccessful and returned the curb space to general use (Ville de Paris, 2025). The city points to three primary factors for the failure. First, design and maintenance issue where the first unit at boulevard Beaumarchais suffered from waterproofing shortcomings, and other unit at Reaumur drew unauthorized waste deposits. Second, the test did not allow validation of any business model for such street-sited micro-hubs. Third, limited demonstrated value relative to costs and public space trade-offs. Therefore, neutral evaluation that distinguish between proof of concept volumes and scalable performance was not closed by this trial and considered a major gap (Lavorel, 2023).

Case Study: HALLO Hubs for Last Mile Delivery Solutions – Barcelona, Spain and Stockholm, Sweden (Pilot: 2021 – 2022)

Rapid growth in e-commerce deliveries threatened inner-city air quality and curb-space in both Barcelona and Stockholm. European Institute of Innovation & Technology (EIT) Urban Mobility program to fund HALLO as a Horizon 2020 demonstration project. Barcelona’s pilot targeted municipalities bordering the newly introduced limited emission zone (LEZ), aiming to divert conventional vans to six cargo-bike-fed micro-hubs and test two innovative cargo-bike box designs for mixed-carrier parcel aggregation (EIT, 2021). Concurrently, Stockholm’s demonstration focused on refrigerated-goods consolidation: a micro-hub equipped for chilled handling and a light electric delivery vehicle logistics (David, 2021).

The implementation, for both cases, is supported with digital infrastructure. In Barcelona, six micro-hubs were equipped with modular cargo-bike boxes that carriers used to deposit parcels between 8 AM and noon; afternoon cargo-bike runs then delivered to end users within a 3 km radius. In Stockholm, a temporary consolidation and distribution center housed chilled storage and a light electric van; carriers dropped off morning loads, which the EV then distributed along pre-planned routes (EIT, 2021).

Over the pilot year, Barcelona’s micro-hubs processed approximately 160,000 parcels and achieved a 25% reduction in total van-kilometers compared to door-to-door services (David, 2021). Cargo-bike utilization exceeded 65% of available slot capacity, and mean delivery time from hub to customer averaged under 45 minutes, matching consumer expectations for same-day service (EIT, 2021). Stockholm’s refrigerated micro-hub handled 12,000 parcels, cutting diesel-van equivalents by 30% and preventing an estimated 11 tonnes of CO₂ emissions through EV deployment (David, 2021). Stakeholder surveys in both cities reported over 90% satisfaction from carriers and recipients, citing improved predictability and reduced urban disturbance (Sochor et al., 2023).

Building on HALLO project’s successes, Barcelona plans to expand micro-hub coverage to 12 LEZ border sites by 2025, integrate dynamic pricing for peak-slot reservations, and link hub data to municipal smart-city dashboards (Mecatti, 2025). In Stockholm, the City is drafting regulations to incentivize cold-chain consolidation centers and exploring autonomous electric tricycles for last mile legs (Sochor et al., 2023).

Case Study: Neighborhood delivery hub, Seattle, USA (2020)

Facing rising greenhouse-gas emissions and curb-space congestion, Seattle’s DOT endorsed the pilot as part of its Transportation Electrification Blueprint, which aims for 30% of urban goods movements to be zero-emission by 2030 (UrbanFreightLab, 2020a). The Neighborhood Delivery Hub sought to demonstrate that a shared micro-hub could concentrate parcel volumes at a single node, enabling last mile legs to shift to low-emission cargo bikes and EVs.

Prior to the pilot, last mile deliveries in Uptown relied almost exclusively on diesel vans, traveling an average of 4.8 km per parcel within the pilot zone and occupying curb-loading bays for 12 minutes per stop. Moreover, missed first-attempt deliveries averaged 15% due to limited recipient availability and driver scheduling uncertainties, leading to repeated trips and compounding congestion (UrbanFreightLab, 2021).

Over 18 months, carriers transferred parcels at a central site where they were reloaded onto electric cargo trikes and small EVs for final distribution. The pilot reduced average vehicle-kilometers per parcel by 28%, cut tailpipe CO₂ emissions by 34%, and slashed delivery-site dwell times by over 50%, while earning 91% satisfaction from participating carriers and residents (UrbanFreightLab, 2021). The project’s universal-access micro-hub

model which is open to all carriers drove high consolidation rates from inception, while strategic placement in Seattle’s mixed-use uptown zone maximized last mile density. Real-time digital slot booking and geo-fencing minimized idle times and prevented curbside conflicts, and the use of electric-assist cargo trikes enabled agile navigation of dense urban streets (Urban Freight Lab). Lastly, the integration of robust sensor networks provided actionable data for dynamic operational adjustments (Nelson, 2023).

Some of the challenges observed, includes an early operation encountered occasional drop-off queue spillovers when carriers failed to adhere to reserved windows (Nelson, 2023), and temperature-sensitive and bulky loads occasionally exceeded cargo-trike capacity, indicating the importance of modular unloading zones for transfer to small EVs. Moreover, harmonizing the carrier IT systems with other layers to ensure real-time inventory sync and prevent over-booking of drop-off slots (Gunes et al., 2024).

5.4 Urban warehouses, Consolidation Centers, and Cross-docking Facilities

Upstream of micro-hubs, there are a spectrum of facilities, including urban warehouses, urban consolidation centers (UCCs), micro-fulfillment, and cross-dock facilities. These facilities synchronize inbound and outbound flows so parcels spend less time idle and more time moving toward customers. Cross-docking, in particular, transfers goods directly from inbound to outbound vehicles with minimal storage, a strategy shown to reduce handling and inventory costs and compress lead times (Van Belle et al., 2012). Micro-fulfillment pushes fast-moving inventory into smaller, demand-proximate sites to accelerate order assembly and delivery in space-constrained cities. The recent expansion and spatial reconfiguration of last mile facilities in major metropolitan areas reflect these logic: platforms serving e-commerce increasingly locate closer to consumers, though centrality varies with market size and operations (Fried and Goodchild, 2023).

For planners, the central questions are where such facilities fit in the urban fabric and under what rules. Market assessment and professional guidance point to trade-offs between throughput, land use, traffic impacts, labor, and neighborhood quality of life (BJH, 2025). As cities formalize freight strategies, warehouse, micro-fulfillment centers, and cross-docks provide a predictable upstream rhythm that micro-hubs depend on (WEF, 2020). The following case studies exhibits how different jurisdictions balance siting, design, and governance to capture efficiency gains while mitigating externalities.

Case Study: Amazon Logistics Infrastructure Expansion, New York, USA (Pilot 2021)

New York City’s booming online-shopping demand strained local distribution networks, creating curb-side congestion and protracted delivery cycles. The under-capacity of local sortation and fulfillment assets meant that parcel volumes routinely exceeded processing rates, causing intermittent surges in curb-side loading activity and spillover parking violations in residential neighborhoods (Buldeo Rai, 2023). Under pressure from rising customer expectations and municipal stakeholders, Amazon in early 2021 accelerated its footprint across the New York metropolitan area by inaugurating a new sortation facility in Maspeth, Queens; activating a rooftop-solar-equipped fulfillment center on Staten Island; and leasing a converted warehouse in Westchester County to bolster e-commerce throughput.

Anchoring sortation close to high-density delivery zones (Queens) unlocked rapid parcel redistribution, while leveraging under-utilized real estate (Maspeth municipal lot and

New Windsor warehouse) accelerated capacity gains without greenfield buildings (Clark, 2017). The integration of renewable power at Staten Island’s facility contributes to sustainable operations and slashed energy costs on fulfillment centers nationwide (About Amazon). The company is also exploring micro-fulfillment by deploying autonomous mobile robots within its New York City distribution centers to further condense processing times and reduce labor strain. Collectively, these investments aim to anchor fulfillment infrastructure ever closer to consumers — shortening delivery windows, cutting emissions, and embedding resilience into Amazon’s urban logistics network (Long, 2022).

Despite operational gains, employee-safety advocates reported rising injury rates at these and other U.S. warehouses, driven by intensified productivity targets and pandemic hiring surges (Business Insider). Furthermore, community groups in Maspeth raised concerns about increased truck volumes on narrow residential streets, prompted Amazon to fund traffic-calming measures and night-time delivery restrictions (Buldeo Rai, 2023). Collectively, these investments aim to anchor fulfillment infrastructure ever closer to consumers to shorten delivery windows, cutting emissions, and embedding resilience into urban logistics network.

Case Study: NOVELOG Urban Consolidation Center - Reggio Emilia, Italy (2022)

By 2017, Reggio Emilia’s city centre faced mounting curb-space conflicts and growing freight-related emissions as parcel volumes rose by over 20% year-on-year (Pession, 2020). Under the EU-funded CIVITAS NOVELOG program, Reggio Emilia established an Urban Consolidation Center (UCC) in spring 2018 to pilot off-peak freight aggregation and zero-emission last mile distribution by routing goods through a dedicated consolidation node. Prior to the consolidation scheme, daily urban freight operations in the pilot zone involved an average of 120 van movements, each operating at just 65% of capacity, and covering 4.2 kilometers per parcel which elevated pollution in the historic center (Pession, 2020).

In 2018, the pilot UCC opened in a 500 square-meters municipal warehouse near the railway freight yard, operating between 7 PM and 3 AM to receive incoming shipments (Zunder, 2018). Carriers pre-booked drop-off windows via an online interface, which displayed real-time bay availability. After arrival, consignments were sorted and palletized along four consolidation lanes before being loaded onto ten shared electric vans for deliveries between 6 AM and 10 AM. After 5 months of operation, the UCC had processed 48,000 parcels, consolidating 75% of participating carriers’ urban flows. Load factor rose from 65% to 76% and the number of morning delivery vehicles fell by 10%. Total vehicle-kilometers per parcel decreased by 19%, cutting aggregated CO₂ emissions by 7% versus the baseline scenario (Zunder, 2018). User feedback from both carriers and city officials rated the scheme “effective” in reducing curb-space conflicts and smoothing delivery windows.

Despite overall success, the pilot surfaced two main hurdles: inconsistent data reporting from smaller carriers led to occasional bay overbooking, and coordinating late-night UCC operations with municipal noise protocols (Teoh et al., 2018). On the strength of pilot results, Reggio Emilia has codified UCC provisions into its 2020 Sulp, earmarking three additional consolidation nodes by 2023 (Zunder, 2018). This pathway provides valuable model for fast, low-cost decarbonization of last mile logistics for mid-size cities like Reggio Emilia.

5.5 Summary

Across cities, three consistent lessons emerge. First, bringing consolidation closer to demand via micro-hubs, parcel lockers/PUDOs, and consolidation centers makes it possible to reliably reduce curb pressure and failed first-attempts while enabling low- and zero-emission last mile modes. These outcomes recur in municipal pilots and peer-reviewed evaluations when simple digital coordination (slot booking, geofenced check-ins) is layered onto modest physical infrastructure ([UrbanFreightLab, 2020a](#)). The policy and professional guidance now treat these assets as part of a "last ring" that complements upstream depots and cross-docks within Sulp (EGUM, 2024).

Second, well-sited micro-hubs are not stand-alone solutions, but their performance depends on upstream facilities that synchronize inbound/outbound flows, such as urban warehouses, micro-fulfillment centers, and cross-docking platforms that transfer loads with minimal storage to raise trailer/vehicle load factors and compress lead times. Current road maps and round tables (such as ALICE/POLIS; ITF-OECD) emphasize "pooling and bundling" and cross-dock practices as enabling conditions for city-scale decarbonization, and city plans increasingly codify these links through freight strategies and zoning reforms ([Blinge et al., 2021](#); [ITF, 2024b](#)).

The case studies illustrate the pattern in diverse contexts. Seattle's neighborhood hub and common-carrier locker pilots document large delivery time savings, zero missed first deliveries, and measurable emission benefits when consolidation is paired with right-sized vehicles. Although not successful, Paris's Sogaris "tactical" micro-hubs show an ultra-light, public realm approach that integrates cycle logistics and waste functions ([Jouquan, 2022](#)). In addition, HALLO pilots (Barcelona and Stockholm) validate small consolidation/distribution centers and temperature-controlled micro-hubs as feasible in EU regulatory settings ([EIT, 2021](#)). Together, these cases demonstrate that different urban fabrics admit different micro-infrastructure archetypes, provided the digital and governance layers are in place.

At the network scale, the rapid expansion and spatial reconfiguration of last mile facilities have materially reshaped flows in major metros, creating both throughput gains and externalities that planning instruments now seek to manage. New York's recent market assessments and rule-makings highlight the twin imperatives of capacity and community impact, while journalism and advocacy foreground labor, traffic and environmental-justice concerns around dense clusters of last mile sites. These debates point to siting, operating-window, and data-sharing levers that can align firm efficiency with neighborhood quality of life ([BJH, 2025](#)).

The SWOT analyses for micro-fulfillment and consolidation infrastructure becomes less ambiguous when UCCs and micro-hubs are treated separately. For UCCs, the strength is their potential to reduce vehicle entries and facilitate zero-emission transitions when volumes are high or participation is mandated; however, recurrent weaknesses include high fixed/operating costs and persistent difficulties attracting and retaining carriers, with many schemes proving financially unsustainable once subsidies end. Opportunities lie in receiver- or sector-led models and in layering value-added services to improve economics. The threats are dependence on public support and fragile business models that unravel when funding or anchor-tenants fall away. These patterns are well documents on various studies ([Allen et al., 2012](#); [Dreischerf and Buijs, 2022](#); [ITF, 2024b](#)).

By contrast, micro-hubs (small, proximity nodes) show strengths in low upfront non-recurring investment, fast deployment, and enables mode shift to cargo-bikes or EVs. Micro-hubs tend to be accepted better by carriers when single operator (proprietary) rather than shared due to their desire to control over processes, data, and risk. Mainly the strengths include proven reductions in curb conflicts, delivery times, and emissions when

consolidation is paired with appropriate modes and simple digital tools. The weaknesses include integration frictions (with carrier platform heterogeneity), limited public-realm space, and capacity bottlenecks under peak demand ([Blinge et al., 2021](#)). The opportunities lie in regulated micro-hubs, green loading/zero-emission zones, and universal-access lockers/PUDOs co-located with transit and retail to maximize walk-up retrieval. Evidence from multi-city case indicated that privately led hubs and value-added services underpin viability, large carriers have the strongest business case for e-cargo operations, and truly open/neutral micro-hubs remain promising but comparatively rare ([EIT Urban Mobility, 2020](#)). The threats include fragmented governance, uneven access across districts, and community push-back where last mile facilities cluster ([UrbanFreightLab, 2020a](#)). The patterns and the instruments to address those threats are recurrent across city guidance and program documentation.

The practical implication should focus on designing micro-hubs as data-ready assets (with simple reservation windows, occupancy/turnover telemetry), enforce universal access where feasible, and iterate siting based on observed catchments and walking access to minimize induced customer VKT ([EIT, 2021](#)). Lockers/PUDOs should be embedded in walkable and transit-rich locations, and paired with micro-hubs to stabilize carrier operations and enable time-definite windows; published pilots show that the reliability gains and reduced re-delivery loops more than justify these choices when demand densities are adequate ([UrbanFreightLab, 2018](#)).

Chapter 6

Regulatory and Fiscal Policies

6.1 Introduction

Urban logistics unfolds within a tapestry of municipal bylaws, national regulations, and fiscal incentives that shape carrier behavior and technology adoption. Over the past decade, city authorities have wielded regulatory and fiscal policies, including but not limited to congestion charges, low- and zero-emission zones (LEZs, ZEZs), delivery surcharges, and tiered road-pricing. While some of these measures are designed specifically to manage delivery activity or freight-related emissions, others including LEZs and ULEZs pursue broader urban objectives such as improving overall air quality, reducing noise, and safeguarding public health. Their impacts on last-mile logistics are therefore often direct, shaped by how cities adapt these wider environmental frameworks to the operational realities of delivery fleets. These measures serve dual purposes to internalize the social and environmental costs of last mile delivery: penalizing polluting or peak-hour traffic flows while generating revenues that can be reinvested into cleaner infrastructure or relief for small businesses.

This chapter explores how regulatory and fiscal instruments function as both "carrots and sticks" and "push-and-pull" levers that reward positive impact behaviors such as clean-fleet adoption and off-peak deliveries, while discouraging high emission or congesting activities through fees, restrictions, and zoning rules. Together, these instruments shape behavioral incentives and modal choices within urban logistics systems. We examine their operational design, real-world performance, and unintended consequences. The next subsections present different regulatory and fiscal policies with four subsections: (1) E-commerce delivery taxes, (2) Congestion charging and road pricing, (3) Low Emission Zones (LEZs), Ultra Low Emission Zones (ULEZs), and Zero Emission Zones (ZEZs), and (4) Truck bans and restrictions.

6.2 E-commerce delivery taxes

A handful of cities and states have tested taxing e-commerce delivery transactions to internalize curb-space, congestion, and wear-and-tear externalities from rapidly growing e-commerce flows. Policy designs vary from per-delivery fees hypothecated to "clean transport" and road maintenance funds to municipal levies that price the occupation of loading bays, yet they share common goals: correcting price signals in the last mile, nudging order consolidation, and creating a revenue stream for freight-supportive infrastructure ([McLean, 2024](#)). However, these taxes are not without controversy and debate which increasingly centers on distributional effects, compliance burden for SMEs, and earmarking of proceeds for lockers, micro-hubs, EV charging, and safety upgrades ([Minnesota-DOR, 2025](#)).

Case Study: Barcelona TREC (“Amazon Tax”) – Spain (2023)

Barcelona’s City Council enacted the Tax on Logistics Externalities Charge (TREC) on March 2023 as a novel fiscal instrument to address curb-space congestion and fiscal inequities between digital and brick-and-mortar retailers ([Jasmijn, 2023](#)). Under the ordinance, operators earning over €1 million annually from B2C parcel deliveries within the municipal boundary must pay a levy equal to 1.25% of those delivery revenues ([Blanchar, 2025](#)). This measure originally targeted 26 principal carriers—including Amazon, Correos Exprés, Seur, DHL, and UPS—that collectively represent approximately 62% of Barcelona’s parcel-delivery market. The legal justification derives from studies commissioned from Universidad Carlos III de Madrid and the University of Barcelona, which quantified the economic cost of constructing, maintaining, and regulating the city’s public delivery bays, thereby underpinning the charge’s defensibility ([Dablanç, 2023](#)).

Given that Barcelona’s levy targets curb occupation from home B2C deliveries, operators have signaled an operational pivot toward parcel lockers/PUDOs, which are explicitly out of scope of the tax, while continuing separate fleet-renewal plans driven by UVAR/LEZ requirements. At this stage, there are no audited, city-published statistics attributing specific percentage shifts in locker use or EV uptake to TREC. Moreover, the ordinance’s legal trajectory limits any definitive impact evaluation ([Congostrina](#)). Therefore, locker expansion can be a logical compliance strategy under the ordinance’s non-subjection for PUDOs, and EV adoption as a parallel trend shaped by other regulations, rather than a quantified TREC effect. Despite initial compliance, multiple major operators have mounted legal challenges to the levy’s applicability—arguing it unfairly singles out B2C activities—and Catalonia’s Superior Court of Justice provisionally suspended TREC in July 2024 pending judicial review ([CatalanNews, 2024](#)).

By tying exemptions to clean-vehicle deployment, Barcelona has accelerated electrification efforts, with medium-duty electric vans now comprising roughly 7% of liable fleets—up from 2% pre-TREC—according to industry estimations ([cities-today.com](#)). Early operator feedback indicates a 10–15% shift of last mile volumes toward locker networks—accounting for lower or zero charges—while clean-vehicle usage among liable fleets increased by an estimated 8% as carriers sought exemption status ([Carey, 2022](#)). Despite initial compliance, multiple major operators have mounted legal challenges to the levy’s applicability—arguing it unfairly singles out B2C activities—and Catalonia’s Superior Court of Justice provisionally suspended TREC in July 2024 pending judicial review ([CatalanNews, 2024](#)).

Barcelona’s TREC is an unprecedented approach to taxing last mile externalities by monetizing the use of public curb space and aligning fiscal policy with urban sustainability goals ([Edwards, 2022](#)). Early performance metrics suggest it is steering carriers toward locker-based deliveries and green fleets, though its long-term success hinges on legal clarity and robust compliance mechanisms ([CatalanNews, 2024](#)).

Case Study: Minnesota Retail Delivery Fee - Minnesota, USA (Permanent July, 2024)

In June 2023, Minnesota passed a bill that imposes a \$0.50 fee on each retail delivery transaction over \$100, starting July 1, 2024 ([Kristen Weeks, 2023](#)). The fee—dubbed the “road improvement and food delivery fee”—is designed to counter declining gas tax revenues due to increased EV usage and fund local road maintenance. To mitigate equity concerns, the law exempts retailers with annual sales under \$1 million, along with items such as medical supplies, food, baby products, and deliveries by restaurants ([Oxford, 2024](#)). Delivery platforms can choose to absorb the fee or pass it to consumers. State

projections estimate over \$60 to \$64 million annually directed to local governments for infrastructure upkeep (Van Oot, 2024).

Retailers are responsible for collecting or self-assessing the fee and must display it as a separate line item, and the delivery platforms may absorb the RDF or pass it through to consumers at checkout (Blair, 2024). The system provides advantages from the last mile perspective with order consolidation where it encourages retailers and consumers to bundle purchases reducing total number of delivery trips and vehicle-kilometer travel (Vertex, Inc). Moreover, carriers are updating route planning and load-consolidation strategies to minimize the number of fee-eligible transactions which improve vehicle utilization and cutting per-parcel delivery cost. However, the system creates a compliance burden particularly on small and medium e-commerce enterprises to navigate cross-state fee regimes (Sanders, 2025).

As legal challenges and political debates continue, Minnesota’s experience will offer valuable lessons for other jurisdictions considering similar fiscal tools in urban logistics policy. Minnesota’s RDF marks an innovative state-level approach to internalizing last mile delivery externalities, directly tying e-commerce delivery volumes to transportation funding needs.

6.3 Congestion Charging and Road Pricing

Congestion charging applies cordon, corridor, or network fees that vary by time, place, and sometimes vehicle class, and aligning private travel decisions with social costs (delay, emission, crash risks). Decades of evaluation shows consistent traffic and emission reductions, and measurable accessibility gains when revenues are recycled into public and active transport. Recent scholarship also clarifies distributional outcomes, noting that exposure to traffic externalities disproportionately burdens lower-income neighborhoods even as charge payments skew toward higher-income car users (Proost, 2018). Emerging systems are extending beyond fixed cordons to Global Navigation Satellite System (GNSS) enabled distance- and time-varying pricing that can differentiate by vehicle type (including freight trucks) and dynamically target speed or emission outcomes (Singichetti et al., 2021).

For freight and parcel delivery, charges typically raise the shadow price of peak-hour, city-center access, rewarding route consolidation, off-peak scheduling, and cleaner vans or cargo-bike substitution for the last kilometer. Model-based assessments suggest that coupling pricing with reliability-oriented service windows and micro-consolidation can reduce vehicle-kilometers while preserving delivery performance (Proost, 2018). Wherever these measures implemented, legally mandated reinvestment of net proceeds into bus priority, cycling networks, curb/kerb management, and freight loading zones can mitigate business impacts and produce enduring system benefits.

Case Study: London Congestion Charge & ULEZ

London introduced the Congestion Charge in 2003, as a flat daily fee applied to most vehicles, including cars, vans and lorries alike, to drive within the central zone during charging hours (between 07:00 and 18:30 on weekdays). That design decision, maintained after extensive consultation and industry debate, meant freight vehicles paid the same headline rate as private cars, with discounts and exemptions kept narrow (TfL, 2007). The charge is £15 in 2025 (penalty £17.50) and failure to pay triggers a Penalty Charge Notice of £180 (reduced to £90 if paid within 14 days) (TfL, 2025a).

In its first year, chargeable entries fell 30%, with vans and lorries down 13%, and vehicle-kilometers across Greater London declined 11% from 2000 to 2012 (Furnas, 2024).

Delivery firms responded by re-optimizing routes, consolidating loads, and increasingly substituting light EVs and cargo bikes which is now supported by TfL’s Cargo Bike Action Plan and 2024 operational guidance ([TfL, 2023](#)).

Case Study: Milan Area C

Milan’s Area C traces its origins to the *Ecopass* scheme introduced in 2008, as a pollution-based access charge that applied only to the most polluting vehicle categories. Though not conceived as a pilot, Ecopass marked one of Europe’s earliest large-scale attempts to internalize vehicle emissions within a dense urban core, functioning in practice as an early form of Low Emission Zone (LEZ). Following a 2011 public referendum and a shift in city administration, the measure was transformed in 2012 into Area C: an 8.2 km² congestion charge applicable to all vehicles entering the central zone, with exemptions for hybrid and electric commercial vehicles. Operating on weekdays (07:30–19:30) at €5 per entry and enforced through 43 camera gates, the policy reduced total vehicle entries by about 28% and on-street parking demand by 10%. Freight transits declined at an average annual rate of 4% between 2021 and 2023, while the share of electric delivery vehicles rose from 2.5 to 5.9% ([Oppici, 2024](#)). Revenues have been reinvested in public transport and micro-hub development, and the exemption structure continues to incentivize Euro 6 and electric van adoption alongside cargo-bike and parcel lockers networks ([City of Milan, 2023](#)).

Case Study: Stockholm Congestion Tax

Stockholm’s seven-month trial (from January to July 2006) applied a cordon tax during peak hours using ANPR and DSRC transponders, achieving a 20–25% reduction in crossings and raising SEK 399 million with 96% compliance ([Börjesson, 2018](#)). Following a referendum, the tax was made permanent on 1 Aug 2007, with phased price adjustments and exemptions for Euro 6 and alternative-fuel vehicles; the measure continues to smooth peak-period traffic, encourage off-peak delivery schedules, and motivate fleet upgrades to meet stricter emission standards ([Eliasson, 2014](#)).

Case Study: Oslo Toll Ring

Oslo’s three concentric toll rings, introduced in the 1990s and modernized under the AutoPASS system, charge NOK 28 per point (NOK 34 in rush hours), with electric vehicles paying half and heavy-vehicle surcharges for gross vehicle weights (GVWs) more than 3.5 tons ([visitoslo, 2024](#)). The “Oslo Package 2” levy adds NOK 2 for public-transport funding, and heavy-vehicle tolls were restructured into congestion-sensitive rates in 2017, resulting in zero-emission trucks using the ring more frequently than their fleet share and prompting distributors to register EVs in outlying counties for operational advantage ([klimaoslo.no, 2024](#)).

Case Study: Singapore Electronic Road Pricing (ERP)

The pioneering shift of Singapore from its 1975 pilot Area Licensing Scheme (ALS) to the fully automated Electronic Road Pricing (ERP) system launched in 1998, and its ongoing ERP 2.0 upgrade slated for completion by 2025. ERP dynamically tailors tolls by corridor, time of day, and vehicle classification, including distinct freight tiers for light and heavy goods vehicles, thereby incentivizing e-commerce delivery operators to optimize routing, consolidate loads, and adopt off-peak schedules.

Operational data show ALS cut peak-hour traffic by 45% and crashes by 25%, with ERP further reducing volumes by 15%, all while preserving speeds of 20–30 km/h in

the CBD and 45–65 km/h on expressways Environmental Defense Fund ([Theseira, 2020](#)). The SGD 200 million rollout has been repaid via annual net revenues of SGD 40–50 million, funding road maintenance, capacity expansion, and low-emission vehicle support (Environmental Defense Fund). Looking ahead, GNSS-based distance charging promises even finer alignment of costs with actual road use, positioning Singapore’s ERP as a global benchmark for regulatory pricing coupled to last mile logistics efficiency ([OneMonitoring, 2025](#)).

Impacts on Last Mile Logistics

Congestion charging schemes in London, Milan, Stockholm, and Oslo have achieved traffic reductions of 15–34%, and the Singapore case achieved more than 45%, generated dedicated funding for sustainable mobility, and driven significant shifts in e-commerce last mile logistics through fleet electrification, delivery rescheduling, and micro-hub deployment ([Furnas, 2024](#)). In London, the Central Charging Zone and Ultra Low Emission Zone together reduced daily chargeable vehicles by roughly 30% and cut vans and lorries by 13%, prompting carriers to consolidate loads, adopt zero-emission vans, and leverage cargo-bike networks ([TfL, 2007](#)). Whereas, Milan’s Area C cut inner-city entries by over 34% in its first year, accelerated hybrid and electric van uptake through exemptions, and funded micro-hubs that feed final-mile e-cargo bike services ([Ambiente, 2015](#)). Stockholm’s congestion tax trial in 2006 delivered a 20–25% drop in crossings—made permanent in 2007—and continues to incentivize off-peak scheduling and Euro 6 fleet modernization ([Eliasson, 2014](#)). Oslo’s toll ring structure, with discounts for electric vehicles and peak-hour surcharges, has seen zero-emission heavy goods vehicles pass more frequently than their fleet share, driving e-truck adoption among major distributors ([klimaoslo.no, 2024](#)). Finally, Singapore’s tiered ERP model exemplifies a mature, adaptive road-pricing framework that tightly integrates toll policy with freight management by differentiating charges by vehicle class, location, and time.

Overall, congestion charging schemes support fleet electrification and upgrading, delivery rescheduling, micro-consolidation hubs, and route optimization with real time telematics. While fostering innovation and opportunities, such as enabling cities to obtain urban logistics data, varying charging schemes across cities, but introduce administrative overhead for multi-region carriers, necessitating integrated IT systems to manage exemptions, self-reporting, and invoice reconciliation ([Proost, 2018](#); [OneMonitoring, 2025](#)).

6.4 Low Emission Zones (LEZs), Ultra Low Emission Zones (ULEZs), and Zero Emission Zones (ZEZs)

LEZs/ULEZs policies restrict or price access for higher-emitting vehicles using Euro-class or equivalent standards; ZEZs go further by admitting only zero-emission vans and trucks. As a family of Urban Vehicle Access Regulations (UVARs), these instruments now span hundreds of European cities and are increasingly codified in national frameworks, with clear documentation portals to improve business compliance ([EU-Mobility, 2022](#)). Evidence from independent evaluations points to sustained reductions in NO₂ and PM, accelerated fleet renewal toward Euro 6 and battery-electric vans, and a complementary shift to micro-hubs and cargo bikes inside dense cores ([urbanaccess.eu, 2022](#)).

According to [Phan \(2025\)](#) comparative review of 37 representative European LEZs within a wider census of 315 zones as of April 2024, three patterns stand out: first, the vast majority of zones remain intra-urban and HGV-focused, with access predicated on Euro standards and increasingly enforced by automatic number-plate recognition (ANPR). Al-

though some European countries, such as Germany and France, restrict the use of ANPR cameras for the purpose of enforcement due to privacy rules. Second, despite two decades of expansion, recent growth has slowed and diversified (with notable repeals and strong national contrasts) producing heterogeneous rule sets (coverage, hours, penalties, and phasing) that raise compliance complexity for carriers. Final and third point, where access thresholds and enforcement are stringent and predictable, LEZs effectively reconfigure last-mile operations by accelerating fleet renewal, shifting flows toward micro-consolidation at perimeters, and pushing receivers to accommodate off-peak deliveries.

Overall in relation to emission zones, several countries are standardizing signage, data sharing, and phased compliance schedules, while the Netherlands has enabled municipalities to designate logistics ZEZs from January 2025 (polluting vans and trucks prohibited inside defined zones) (RVO, 2025). For e-commerce carriers, adaptation strategies include pre-positioning inventory at the zone edge, investing in shared charging, and leveraging exemption/grace-period rules to stage fleet renewal that is often supported by scrappage grants and targeted finance.

Case Study: London LEZ & ULEZ, England

In 2008, London introduced its LEZ for heavy-goods vehicles (HGVs) over 12 tonnes, expanding coverage in July 2008 to all HGVs above 3.5 tons, buses, and coaches and phasing in Euro IV and Euro VI standards by January 2012 to achieve up to 50% reductions in PM and 65% in NO_x emissions. In 2019, the Ultra Low Emission Zone replaced the T-Charge (Toxicity Charge), extending to cars, vans, and motorbikes with a £12.50 daily fee for non-compliant petrol and diesel vehicles and operating 24 hours a day across the central charging zone (TfL, 2025b). Independent evaluations attribute a 21% drop in NO_2 levels and 74,000 fewer high-emitting vehicles per day to the lorry LEZ and ULEZ, while logistics providers accelerated investment in electric and hybrid vans which is supported by TfL scrappage grants and financing programs to avoid recurring charges (C40-Cities, 2019).

Case Study: Paris Metropolitan Low Emission Zone (Zone à Faibles Émissions-ZFE), France

Effective July 2019, the Métropole du Grand Paris (Greater Paris government) established its Low Emission Zone- ZFE within the A86 highway ring, but its early phase was modest and only partially enforced with weekday restrictions (08:00–20:00) initially targeting *Crit’Air 5 and unclassified vehicles* (France-ServicePublic, 2024). A large share of older diesel vans and trucks still compliant, and a ZFE day-pass has allowed otherwise restricted vehicles to circulate a set number of days per year; together contributing to weak near-term logistics effects.

Paris tightened to Crit’Air 4 on June 2021, and retained the Crit’Air 3 step by January 2025. After national relaxations lifted the obligation for many other agglomerations, the overall trajectory has been marked by postponements and political recalibration, underscoring limited deterrence in the absence of robust automated enforcement (Mandard, 2024). Early Paris’s threshold and patchy controls produce gradual and uneven fleet renewal rather than rapid change. In addition, Dablanc (2025b) adds that logistics flow data remain scarce and delayed, further complicating targeted mitigation (urban micro-hubs, loading space, night delivery) that would pair the ZFE with freight-supportive measures.

Case Study: Sofia LEZ, Bulgaria

On December 2023, Sofia became the first Eastern European city to launch an LEZ, banning Euro 1 vehicles within its “small ring” under a phased schedule that will extend restrictions to Euro 2 by December 2024 and Euro 3 by December 2028, enforced year-round in winter months and monitored via eco-stickers ([Zlatin Dubarinov and Janev, 2023](#)). Early studies estimate that pre-2005, diesel cars are about 30% of the local fleet and account for over 56% of NO_x and 85% of PM emissions, prompting logistics firms to retrofit or replace aged vans and pilot micro-hub transshipment onto e-cargo bikes for central-zone deliveries ([novinite, 2023](#)).

Case Study: Copenhagen & Frederiksberg ZEZ, Denmark

Empowered by February 2024 parliamentary agreement, Copenhagen and Frederiksberg launched a continuous ZEZ for vans (less than 3.5 tons) and small trucks in March 2024, banning all petrol and diesel models via ANPR enforcement and promoting zero-emission uptake through scrappage grants, reduced parking fees, and preferential electricity tariffs under Denmark’s 2020 Green Transportation Deal. Municipal reports indicate clean-fleet adoption rates above 58% within the first year, as carriers pre-ordered electric vans to secure unrestricted access and avoid fines ([VolvoTrucks, 2025](#)).

Case Study: Rotterdam ZEZ, Netherlands

Following the 2019 national Climate Agreement, Rotterdam’s Roadmap for Zero Emission City Logistics (ZECL) targets a freight-only ZEZ on key corridors, on most notably the s-Gravendijkwal starting January 2025, mandating that all new trucks and vans registered after that date be zero-emission and retrofitting major depots with high-capacity chargers ([RVO, 2025](#)). The ZECL covenant, signed by the city, logistics firms, and industry bodies, forecasts up to 23,000 electric-van entries per weekday and is supported by local business engagement events to prepare small operators ([North Sea, 2025](#)).

Case Study: Seoul Green Transport Zone, South Korea

In December 2019, Seoul instituted its Green Transport Zone, banning Grade 5 (pre-Euro 4) diesel vehicles from central corridors and targeting a 2050 phase-out of all diesel traffic, enforced at 45 entry points via remote-sensing cameras ([Sandra Wappelhorst, 2022](#)). The zone delivered a 16% reduction in PM_{2.5} and a 9% drop in NO_x during its first year, prompting fleet operators to upgrade to cleaner vehicles and pilot battery-electric light-duty trucks for urban deliveries ([Yanocha et al., 2023](#)).

Cast Study: Beijing Zero Emission Freight Zone, China

Under a 2024 pilot, Beijing plans to introduce a Zero Emission Freight Zone (ZEFZ) within the Second Ring Road, banning internal-combustion light-duty trucks and allowing only zero-emission models which is planned for full roll-out by 2025 under a conservative scenario, complemented by differential access hours and access certificates to mitigate freight impacts ([Chen, 2024](#)). Early scenario analyses project that the ZEFZ could redirect 90% of less than 4.5 tons freight trips to battery-electric vehicles by 2025, reducing urban logistics emissions by up to 60% ([Jin and Chu, 2023](#)).

Impacts on Last Mile Logistics

Across LEZ, ULEZ, and ZEZ regimes in Europe and parallel initiatives worldwide, e-commerce carriers have restructured their last mile operations around four principal strategies: fleet electrification, micro-hub consolidation with cargo bikes, temporal delivery shifts, and data-driven compliance management.

Serious logistics impacts from LEZs and ZEZs only materialize when enforcement is both automated and predictable. Cities that pair clear threshold with ANPR camera networks see higher compliance and measurable fleet renewal. Brussels, for example, monitor LEZs with 363 cameras, enabling systematic identification of non-compliance vehicles and consistent penalties (UIT, 2024). In contrast, many European cities still rely on stickers, manual patrols, or fragmented databases, resulting in administrative frictions for carriers operating across borders (EGU, 2024). This uneven enforcement is often not simply a technical shortfall but a consequence of rigid national or regional legislative frameworks that restrict the use of ANPR data for environmental enforcement, typically citing data protection or privacy constraints. From a policy perspective, this highlights the need for harmonized, privacy-compliant regulations that allow automated monitoring and cross-border data sharing, as preconditions for achieving equitable and effective LEZ and ZEZ implementation across Europe.

Several implications can be made on utilizing emission zones for effective change on the behavior of logistics operation. First, strict access rules and toll exemptions for low- and zero-emission vehicles have helped make battery-electric van ownership economically compelling. Industry analyses show that electric vans can achieve up to 20% lower total cost of ownership than diesel equivalents over vehicle life-cycles thanks to reduced energy and maintenance costs which carriers leverage to offset upfront capital outlays (Kin and Quak, 2025). Moreover, ongoing EU proposals to exempt zero-emission heavy trucks from road tolls will further reinforce the business case for electrification, prompting large operators to accelerate fleet renewals (Edwards, 2025).

Second, micro-hubs sited at LEZ/ZEZ perimeters enable e-commerce firms to transship bulk loads onto cargo bikes and small EVs for the final mile, slashing inner-zone van travel by up to 52% per hub and cutting carbon footprints by over 50% (C40-Cities, 2024). Pilot programs, such as the HALLO micro-hub network in Barcelona, demonstrate that strategic hub placement can yield annual municipal savings of over USD 240 million in congestion and pollution costs, while improving delivery speed and flexibility (Sochor et al., 2023).

Third, high peak-hour cordon charges and time-based access bans have driven carriers to reschedule deliveries into off-peak windows, smoothing urban traffic flows and trimming per-parcel surcharges and parking fines by up to 75% (UK Haulier). Case studies from London’s ULEZ and New York’s Off-Hour Delivery program reveal that overnight or early-morning dispatches can shorten average stop times by nearly 50% and reduce route delays by over 40% (C40-Cities, 2024).

Finally, the integration of GNSS-based enforcement with telematics-driven route-optimization platforms has become indispensable for compliance and operational efficiency. By fusing real-time location data with emissions-zone boundaries, carriers can dynamically reroute to avoid fines—achieving up to a 12% reduction in route lengths, while centralized digital portals simplify multi-zone reporting and sticker management, mitigating administrative burdens (Sochor et al., 2023). However, fragmented sticker schemes and evolving standards highlight the ongoing need for harmonized, user-friendly compliance tools to sustain legal resilience and minimize operational complexity (Yang and Hyland, 2024).

6.5 Truck Bans and Restrictions

Time-of-day, weight-class, and area-specific truck restrictions are long-standing tools to protect sensitive urban areas, smooth peak demand, and reduce exposure to noise and emissions. Typical designs prohibit heavier goods vehicles during morning peaks in congested corridors, require permits for 3.5 to 7.5 tons trucks entries to historic centers, or designate pedestrian priority districts with delivery windows for light commercial vehicles (urbanaccess.eu, 2021). These measures reliably shift logistics toward right-sized fleets, curbside discipline, and off-hour deliveries. It also creates operational incentives for micro-hubs at perimeter locations that feed cargo bikes and small EVs for the last mile delivery.

Due to enforcement and clarity matter, cities increasingly publish rules and guides, stickers, and boundary datasets through national access points, and some pair restrictions with incentive programs to help businesses re-time deliveries. Outside Europe, large metro areas deploy similar instruments. Mexico City, for example, restricts morning peak access for heavier trucks and sets tailored rules in its Centro Histórico ([de México, 2015](#)). These illustrating convergence in global practice even as legal frameworks differ. For e-commerce, the combined effect is a re-optimization of delivery networks around vehicle class, timing, and facility location.

Case Study: Bucharest, Romania

Bucharest’s concentric Zone A (city core) and Zone B (surrounding ring) restrict vehicles over 5 tonnes from unauthorized entry without daily permits, enforced Monday–Friday from 7 a.m. to 7 p.m. (urbanaccess.eu, 2020). The permit system, which carries administrative fees and application procedures, deters out-of-city HGVs while exempting lighter delivery vans, prompting e-commerce carriers to pre-consolidate shipments at logistics centers along the ring road and transloading into lighter electric vans for final-mile transits into the historic center. This adjustment occurs against the backdrop of Romania’s rapidly expanding e-commerce market which is valued at over €6.5 billion in 2023, where efficient urban distribution is crucial to sustaining growth and customer service ([Nistor and Zadobrischi, 2024](#)).

Case Study: Mexico City, Mexico

In Mexico City, a morning rush-hour bans on trucks exceeding 5 tons along key corridors, typically from 06:00 to 10:00 AM, was introduced to reduce peak-period congestion and NO_x emissions. Studies show carriers responded by situating consolidation centers just outside restricted areas, deploying smaller vehicles for early deliveries, and diversifying routes to alternate arterial roads while optimizing schedules to fit permitted windows ([Lyons et al., 2017](#)).

Case Study: New York City Off-Hour Delivery (OHD) Program, USA

Originating as a pilot in 2002 in partnership with Rensselaer Polytechnic Institute and formalized in the 2010 Delivering Green plan, New York City’s Off-Hour Delivery (OHD) initiative rewards freight receivers and certified “Trusted Vendors” for shifting truck deliveries from peak daytime (7 AM – 6 PM) to off-peak nighttime hours (7 PM – 6 AM) ([Trottenberg, 2017](#)). Early trials demonstrated a 50% increase in delivery speeds and a

75% reduction in parking fines for participating businesses, translating into annual economic efficiencies valued at an estimated \$150–200 million.

The off-hour program is back on as of 2024 and has enrolled 27 businesses across 1,120 locations, with a goal of extending off-hour deliveries to 5,000 sites by 2040 that potentially shifts 62,000 daily truck trips away from peak periods and is backed by a \$6 million CMAQ-funded incentive pool supporting low-noise equipment and facility retrofits (NYC-DOT, 2024b). This enduring multi-stakeholder model underscores the power of time-based restrictions combined with financial and reputational incentives to drive sustainable freight operations in dense urban environments.

Impacts on Last Mile Logistics

The cumulative effect of these truck restrictions has been a rapid pivot toward fleet electrification. Comparative life-cycle analyses reveal that battery-electric vans can deliver up to a 20% reduction in total cost of ownership versus diesel models, owing to lower energy and maintenance expenses, encouraging major parcel carriers to accelerate electric-vehicle procurement (Anand, 2025).

Simultaneously, micro-hub networks at restriction boundaries have proliferated. A study by Kim and Kaddoura (2021) highlighted that transferring bulk shipments at micro-hubs and completing the final mile via cargo bikes or small EVs can slash inner-zone driving distances by over 50%, reduce noise from delivery vehicles by 8% and carbon footprints by more than half.

Moreover, temporal delivery shifts have smoothed urban traffic flows. U.S. DOT research indicates that moving deliveries to overnight or early-morning slots can cut average stop times by nearly 50% and reduce parking fines by up to 75%, enhancing route reliability and lowering per-parcel fees (US-DOT, 2025).

Finally, the integration of digital compliance and telematics has become indispensable. In Europe, the revised UVAR Regulation (EU 2022/670) mandates open access to standardized zone boundary and enforcement data via National Access Points, enabling carriers' telematics platforms to dynamically reroute around restricted areas, achieving up to a 12% reduction in route lengths, and streamlining multi-zone permit and sticker management through centralized digital portals. However, ongoing fragmentation of local sticker schemes underscores the need for harmonized, user-friendly compliance tools to sustain legal resilience and operational efficiency (EU-Mobility, 2022).

6.6 Summary

In this chapter, regulatory instruments show that pricing, access, and emission zones are key instruments when it is clear, enforced, and paired with reinvestment. Cordon and network charges have reliably reduced traffic and emissions while improving reliability. London's congestion charging and ULEZ regime cut the number of polluting vehicles in the zone by around 60% after expansion and drove measurable NO₂ reductions citywide (TfL, 2025b), illustrating the scale of change achievable when financial signals and enforcements are aligned. Road pricing also evolved. Singapore's ERP 2.0 upgrade replaces gantries with GNSS-based units, enabling distance- and time-sensitive charging that can differentiate by corridor and vehicle class, a direction that promises more granular management of freight externalities (OneMonitoring, 2025). At the same time, planning practice reminds us that institutions must catch up. For instance, in the United States, fewer than half of large cities have even begun to integrate last mile logistics into their sustainability plans, and only about a third of those committing resources to act (Maxner et al., 2025).

Access standards such as LEZs/ULEZs and their variant ZEZs have accelerated fleet renewal, encouraged micro-hubs and cargo bikes, and clarified compliance pathways where national frameworks exist (e.g., the Netherlands’ zero-emission city logistics road-map). Independent evaluations link these zones to sustained air-quality gains as operators retire older diesels and adopt Euro 6 and electric vans (Rotterdam ZECL); structured road-maps further de-risk investment for carriers by setting phased, predictable milestones (City of Rotterdam, 2020). Yet the same measures bring coordination and compliance burdens, particularly for SMEs, underscoring the need for standardized UVAR data, clear grace periods, and support for shared charging (City of Rotterdam, 2019). Moreover, complementary strategies, such as consolidation centers, protected loading space, night deliveries, and support for SMEs, are repeatedly flagged as essential to make LEZs both effective and socially durable (Alvarez-Gallo et al., 2024). In parallel, truck bans and time-of-day restrictions continue to push operations toward right-sized vehicles and off-peak windows. Latin American practice offers a useful counterpoint, with Mexico City’s peak-hour limits on heavier trucks (and tighter Centro Histórico rules) prompting micro-hub siting at the edge of restricted corridors and more systematic re-timing of deliveries (Ciudad de México, 2021).

Fiscal tools that target the last mile are emerging as complementary levers. State-level retail delivery fees (e.g., Minnesota’s US\$0.50 per qualifying order) create a modest, dedicated revenue stream while nudging order consolidation; their design reveals how exemptions, invoice-level itemization, and small-seller thresholds can temper regressivity and ease of compliance (Minnesota-DOR, 2025). Municipal curb-space levies, like Barcelona’s “TREC” applied to large B2C operators, are more novel and politically salient. It explicitly prices the management costs of thousands of delivery bays but can face legal scrutiny about taxpayer of record, subcontracting chains, and evidence of proportionality, as shown by the provisional suspension in 2024 (CatalanNews, 2024). The policy lesson is less about any single instrument than about institutional capacity: robust legal bases, transparent methodologies, and clear liability assignment are prerequisites for durable fiscal regulation. In short, pricing the last mile is as much behavioral economics as it is infrastructure finance (Barker and Brau, 2020).

The strength and weakness of these tools is instructive. On the strength side, the measures enhance environmental performance and urban livability, unlock efficiency via route consolidation and off-peak operations, and finance public transport, cycling, loading zones, and charging at scale (Mayor of London, 2023). On the weaker side, they demand capital from both the public sector (enforcement, data systems) and private operators (fleet renewal, facilities), impose coordination costs across municipalities, and can trigger unintended consequences (e.g., boundary effects, displacement to un-tolled corridors) if designs are not regionally harmonized (City of Rotterdam, 2019). Social acceptability improves when revenues are credibly recycled into visible mobility benefits and when small firms receive transition support; conversely, opaque fee design or unclear exemptions erode trust and compliance (Minnesota-DOR, 2025).

Beyond congestion and emission reduction outcomes, these schemes provide opportunities for regular and free data on urban logistics. The enforcement technologies produce continuous, zero marginal cost streams on vehicle standards, dwell times, curb turnover, spatial delivery intensity, etc. These data are incidental and generated as a by-product of operating the rules themselves, and cities can turn them into regular indicators for policy calibration and research without paying for bespoke surveys (Dablanc and Adoue, 2025).

Three implications stand out when considering practice. First, build delivery networks around micro-consolidation and right-sized vehicles at zone edges due to the evidence base shows micro-hubs can halve inner-zone driving and associated emissions while maintaining service speed (Kim and Kaddoura, 2021). Second, make off-peak a default operating

strategy: New York City’s Off-Hour Delivery program demonstrates sustained reductions in stop times, operational costs, and parking fines once receivers and carriers are coordinated under a “Trusted Vendor” model ([Holguin-Veras et al., 2018](#)). Third, treat digital compliance as core infrastructure: integrate GNSS/ANPR zone boundaries and rule sets into fleet telematics to enable dynamic rerouting and automated reporting across multiple jurisdictions ([OneMonitoring, 2025](#)).

The durability of policy hinges on credible reinvestment, interoperable data, and tailored transition pathways. In line with this consideration, the research priorities include longitudinal causal evaluations that isolate effects on freight VKT, reliability, and emissions across instrument combinations. Moreover, institutional studies on compliance architectures (self-report versus automated sensing) that minimize burden while preserving privacy and accuracy. Overall, regulatory and fiscal policy is now a strategic lever in e-commerce last mile logistics. Cities that combine clear rules, fair prices, smart data, and visible reinvestment are seeing cleaner air, more reliable streets, and healthier delivery ecosystems and at the same time laying the groundwork for next-generation, zero-emission freight.

Chapter 7

Services and Business Models

7.1 Introduction

Beyond hardware and policy, the engine of last mile innovation is increasingly fueled by novel service architectures and business models that reconfigure how consumers receive goods—and how carriers capture value. Traditional parcel delivery, governed by fixed routes and rigid service-level agreements, is giving way to a diverse options: crowd-delivery as a micro-market place that employs local residents and part-time couriers (Amazon Flex app for example); scheduled consolidation services (for e.g., like Amazon Day) aggregate disparate orders into single weekly drops; gig-economy platforms match on-demand drivers to e-commerce retailers; and hybrid click-and-collect models blend online ordering with neighborhood pick-up lockers or retail partners. Each model seeks to re-balance key trade-offs that are speed, cost, carbon footprint, and customer convenience, while carving out new revenue streams in an ever-competitive logistics landscape. However, the gig-economy overlooks persistent labor and legal risks. Many platforms formally classify drivers as independent contractors while exerting substantial control through apps and metrics, a pattern flagged by the ILO and challenged in national court (e.g., Spain) ([O'Mahony, 2023](#)).

The service architecture matter in this case because they change who capture value, and how sustainability and convenience trade-offs are resolved. A study by ([Buldeo Rai et al., 2021](#)) showed that price and convenience still dominate many customers' choices, even as distinct first innovator segment value flexibility, community-oriented delivery and interest in subscription services. At the same time, crowdsourced and gig-enabled options introduce important operational and behavioral constraints, including acceptance probabilities, compensation design and driver availability, which are now explicit decision variables in routing and assignment algorithms ([Alnaggar et al., 2021](#)). Moreover, financial viability (cost structure, revenue streams and value-added services) is the getting factor for scaling last mile delivery pilots into lasting business models.

This chapter explores service and business model innovations, examining how they align consumer behavior, workforce incentives, and carrier economics to create more efficient, sustainable, and user-centric last mile logistics systems.

7.2 Case Studies

Case Study: Veho Gig Delivery Platform (USA, since 2018)

Founded in Boulder, Colorado in 2018, Veho is a last mile delivery platform that primarily serves e-commerce retailers via a gig-based driver network. Unlike typical gig-based food delivery, Veho partners directly with brands and fulfillment centers. It combines

human-driven deliveries with real-time customer communications to enhance reliability and convenience. By 2022, Veho had expanded into over 25 U.S. markets and tripled one-day deliveries for brands like ThredUp and Saks Fifth Avenue (Veho, 2025).

Crucial to Veho's success is its customer-centric communication suite: automated texts at pickup, arrival, and exception events, plus a staffed support line ready to intervene. Retailers credit this transparency with slashing delivery related refunds by 71% and boosting customer lifetime value by over 40% (Veho, 2025). A joint study by Incisiv and Veho further reported a 15.3% uplift in net promoter score among participating brands, attributing gains to the premium delivery experience. However, the model faces operational headwinds at scale (Incisiv, 2024).

The gig element of Veho's models, perhaps, also raised grounded operational and labor concerns, including drivers report app crashes, long or poorly remunerated routes, unpaid "prep" time, and misdeliveries discussed in community forums and review sites, and rapid geographic expansion can be exacerbated these problems until local driver pools and facilities stabilize (Garland, 2025). Finally, road safety implication of instant, on-demand delivery are non trivial, with elevated crash risk and risky riding behaviors.

Case Study: Platform-Delivery surveys in Paris (France, 2016-2026)

The Logistics City Chair (University Gustave Eiffel) has run a sustained program of field surveys of platform delivery couriers in Paris and the inner suburbs (waves in 2016, 2018, 2020, 2021, 2022 and follow-ups planned in October 2025 and 2026). These longitudinal face-to-face questionnaires document how courier profiles, vehicle use, earnings, safety exposure, and employment status evolve in dense European city like Paris (Dablanc et al., 2022).

Couriers are predominantly young (but not so young, averaging end of their twenties) and male. Originally (2016, 2018), there was a large share of students (2016) which worked platform delivery as temporary or supplemental income rather than a long-term profession. Full time jobs are the norm, with migrants increasingly employed. The surveys also indicated mixed employment status and raising concerns about misclassifications and income volatility (Aguilera et al., 2022). In addition, long working days (six-seven days when active and often work 9+ hours on delivery days) and precarious earnings (reported in the €1,000–€1,500 range before charges) (?).

Motorized two-wheelers are central in Paris platform delivery, but not legally permitted for goods use in France. In 2021-2022, there was a huge use of shared e-bikes by riders, also showing evolving patterns (a decline in bicycle uses over 2016-2021 in some samples) with implications for both safety and modal policy. Accident risk is also high and many riders adopt risky behavior (e.g., riding in restricted areas or using non-compliant equipment) to meet incentives (Dablanc, 2025a).

Different implications can be made to each stakeholder. For platforms and retailers, the surveys are a reminder that algorithmic incentives, pay schemes and assignment logic directly shape not only operational performance but legal and reputational risk. For cities, the evidence argues for integrated regulation that combines road-safety enforcement, clearer rules on vehicle eligibility, and data sharing obligations so traffic regulations and curb management can be effectively enforced (?). Overall, durable business models for last mile services require explicit attention to labor conditions, safety, and regulatory interoperability .

Case Study: Amazon Day Scheduled/Consolidated Shipping Service (USA, Since 2019)

Amazon introduced "Amazon Day" in June 2019, a premium feature available to Prime members that offers customers the option to consolidate all eligible purchases into a single weekly delivery on a day of their choice. Rather than dispatching orders immediately, Amazon Day batches them at regional sortation centers and sends a consolidated shipment on the chosen day, aligning with the company's *Shipment Zero* ambition to achieve net-zero carbon across all shipments by 2030 (Austin, 2019). By empowering users to choose weekly delivery windows (e.g., Monday or Friday), Amazon Day aligns with rising consumer demand for sustainability and predictability in deliveries. It exists alongside other last mile innovations like same-day delivery hubs and real-time routing systems.

A survey by Waddell (2023) found that nearly 40% of interviewed Prime users chose it to cut down on packaging waste and delivery frequency. However, about 25% reported that time-sensitive items sometimes shipped separately, undermining full consolidation. In addition, 22% of third-party sold items bypass Amazon Day and ship immediately, leading to unexpected separate deliveries. The model transforms on-demand retail or ultra-fast shipping into weekly, batched model. Even if the delivery becomes slower to the premium members, it reduces delivery frequency and carbon footprint without dismantling its overall high-speed promises.

Case Study: La Ruche Qui Dit Oui! Crowd Delivery & Micro-Marketplace (Since 2010)

Founded in 2010 in Toulouse, France, La Ruche Qui Dit Oui! (LRQDO) is an innovative crowd-delivery micro-marketplace connecting local farmers, community hosts, and urban consumers through weekly "Assemblies" (Ruches) across Europe. Customers pre-order fresh produce online, while local hosts independently organize weekly pop-up pick-up points in cafés, schools, or community centers. LRQDO represents a crowd-delivery micro-marketplace at the intersection of e-commerce, local food systems, and community logistics. By combining online ordering, local pick-up points, and optional home delivery, it balances convenience, scale, and sustainability (Goldapple, 2020).

As of 2021, LRQDO supports over 10,000 producers, 1,000 Assemblies, and served 80,000 monthly active customers across France, Belgium, Germany, Italy, Spain, and the UK (Cipio-Partners, 2021). Producers retain approximately 80% of their sales revenue, and the host (Ruche manager) earns an 8% commission, while the platform's fee (covering technology, marketing, and support) constitutes the remaining 12% (Atlas of the Future). Assembly hosts operate as micro-entrepreneurs, each managing local logistics, marketing, and customer engagement. This distributed governance contrasts with centralized courier networks and fosters local resilience. LRQDO platform function in proximity commerce and distributed entrepreneurship offers a blueprint for integrating social value into the last mile logistics.

Case Study: Delivery Solutions: SaaS Platform for Retail Gig Delivery (USA/UK/Canada/EU/AUS, Since 2018)

Delivery Solutions labeled as Software-as-a-Service (SaaS) platform tailored to enterprise retailers, launched in Plano, Texas by entrepreneurs Arshaad Mirza and Manil Uppal in 2018. Their vision was to supply a turnkey "last-mile orchestration" toolkit which encompassing same-day delivery, curbside pickup, buy-online-pick-up-in-store (BOPIS), and reverse logistics that are all accessed via a single API rather than piecemeal integra-

tions ([Delivery Solutions, 2025](#)). It's like renting a service, not buying a product. The provider hosts, maintains, secures, and updates the software on their servers, delivering functionality through a web browser or app.

By 2021, *Delivery Solutions* had processed over \$660 million in orders for marquee clients including Walmart (via its GoLocal last mile service), Sephora, Abercrombie & Fitch, ShopRite, and Total Wine & More across North America, the U.K., Europe, Canada, and Australia ([PYMNTS, 2022](#)). Within two years of launch, the platform rolled out curbside-drop functionality, real-time tracking dashboards, and reverse-logistics workflows. In May 2022, United Parcel Service (UPS) acquired *Delivery Solutions* to deepen its omnichannel capabilities, retaining the brand as a subsidiary and embedding its orchestration engine into UPS's Carrier-independent network ([Straight, 2022](#)).

Delivery Solutions furnished retailers with a full suite of logistics controls, including fleet selection, routing parameters, and branded tracking, while still tapping into gig, carrier, or in-house fleets as needed. Its integration with UPS's global network offers retailers deeper geographic coverage and the ability to blend with UPS's legacy services with on-demand, gig-enabled options. However, questions emerge with the rise of gig and crowdsourced couriers around employment status, pay transparency, and liability.

Case Study: GREEN-LOG: Logistics-as-a-Service (LaaS) Platform for Interconnected City Logistics & Automated Delivery (Europe, 2023–2026)

GREEN-LOG is a Horizon Europe and CIVITAS Initiative co-founded project, coordinated by the POLIS Network, that began in early 2023 and will run through mid-2026. The project is a cross-sector initiative developing a Logistics-as-a-Service (LaaS) platform to optimize e-commerce last-mile delivery across Europe.

The project gathers diverse actors—from city agencies, carriers, tech providers, to researchers—within five Living Lab environments: Athens, Barcelona, Flanders (Ghent/Leuven/ Mechelen), Oxfordshire, and Ispra. The platform integrates digital twins, smart contracts, and real-time APIs to orchestrate autonomous vehicles, delivery droids, cargo-bike micro-consolidation, and multi-modal parcel flows via public transit, all governed by dynamic city-logistics data spaces ([GREEN-LOG, 2023](#)).

GREEN-LOG's consumer-facing marketplace went live in mid-2023, enabling real-time booking of green delivery services with cargo bikes, autonomous droids (Yape), and transit-integrated routes with dynamic pricing tied to actual transport costs. Some of the outputs obtained are ([CIVITAS, 2025](#)):

- Flanders: A regional LaaS platform links policies and private delivery operations in Ghent, Leuven, Mechelen.
- Ispra: Rolled out autonomous droids (Yape) and cargo bike (Measy) delivery flows controlled via booking and fleet systems.
- Athens & Oxfordshire: Initial data share reports show 35% fewer kilometers driven, 26% less travel time, and 12% fewer stops in Athens; Oxfordshire reported 87 kg CO₂ reduction per day from mobile hubs; Flanders saw daily tour reduction of 47%.

Pilot results across diverse urban contexts confirm that integrated, data-driven LaaS can reduce vehicle kilometers, emissions, and delivery times by 20–50%, validating the model's environmental and economic promise. Across all sites, GREEN-LOG partners co-developed governance frameworks and data-sharing policies ensuring stakeholder transparency and privacy. On the other hand, scaling beyond living labs hinges on aligning

data governance, overcoming interoperability among legacy systems, and securing public-private investment. Policy harmonization at city and regional levels emerges as a critical enabler ([Giaume, 2025](#)).

7.3 Summary

This chapter explained the case that the last mile has shifted from a set of discrete operational problems to a multidimensional service design and business model challenge where technology, labor arrangements, customer segments, and municipal governance jointly determine what scales and what survives. Empirical cases in this chapter, from marketplace and LaaS pilots (GREEN-LOG) to enterprise SaaS orchestration (Delivery Solutions/UPS), hybrid gig platforms (Veho), scheduled consolidation (Amazon Day), and community micro-marketplaces (La Ruche), collectively illustrate that digital orchestration and modular service bundles are now the dominant pattern shaping e-commerce fulfillment.

Across pilots and commercial deployments we observe three repeatable operational benefits when platforms are designed to coordinate modes, actors and data: (1) measurable reductions in vehicle kilometers, tours and CO₂ in well-designed living-lab settings (GREEN-LOG pilots reported large vehicle kilometers and tour savings), (2) clear unit-cost and service improvements when retailers use orchestration layers or dedicated SaaS tools (Delivery Solutions/UPS and Veho case evidence), and (3) concrete customer-facing gains from consolidation or scheduled delivery (Amazon Day) and from proximate micro-hubs or assemblies (La Ruche’s hybrid pick-up/home delivery). These operational gains, however, are fragile without matched demand uptake and robust cost-recovery models ([Kiba-Janiak et al., 2024](#)).

Important constraints arise from labor, governance, and behavioral limits. Crowd-sourced/gig options deliver flexibility and surge capacity but create uncertainty in supply (acceptance probabilities), requiring incentive-aware assignment algorithms and compensation design to avoid service failures ([Krier et al., 2022](#)). Moreover, labor and legal risks related to delivery platforms deserves a strong attention as well explained with the Paris case in Section 6.2, on top of road safety implication with crash risk and riding behavior. At the same time, shared-fleet dynamics (e.g., delivery riders using public bike-share systems) surface distributional and regulatory tensions that cities must manage to avoid implicitly subsidizing commercial activity through public infrastructure. These labor and governance tensions are central to any credible last mile business model.

From the customer perspective the economics of demand matter. Price and speed remain primary driver of consumer choices, but a non-trivial first innovator or environmentally minded segment values community-based, subscription or LaaS offerings and can be targeted to build initial scale for greener services. Business model design therefore requires segmentation aware pricing and value propositions that reconcile customers’ low willingness-to-pay for green options with city and societal externalities. The bottom line is to design a revenue mechanism that internalize those externalities, without it many pilots will remain niche.

For practice and platform design, we can draw two main implications. First, firms should invest in orchestration layers (LaaS / SaaS) that make hybrid fleets and multi-modal systems that are both contractible and measurable: the UPS–Delivery Solutions acquisition and Veho’s AI route stacks show how orchestration lowers friction for retailers while enabling blended carrier mixes. Operational tooling must include compensation-aware assignment, real-time exception handling, and API-level openness for carrier neutrality where that is commercially valuable ([Veho, 2025](#)). second, to capture the social and environmental value that many customers demand, providers should couple demand

shaping (e.g., subscription discounts, Amazon Day style incentives) with transparent impact metrics and optionality (Speed vs sustainability) so users can trade between them without losing trust. Overall, cities must move beyond ad-hoc regulation and adopt data governance, procurement, and co-investment strategies that enable multi-actor platforms to form while protecting public goods (bike share fleets, curb space, data privacy).

Services and business models are the gatekeepers that convert technical innovations into urban outcomes. When orchestration, fair labor practice, demand segmentation, and municipal governance align, the last mile can become dramatically more efficient and less polluting. When any one of those elements is weak (unstable driver supply, unclear revenue model, or absent data governance) where the gains evaporate. The cases and evidences in this chapter provide both the shift and the cautionary tales of services and business models.

Chapter 8

Stakeholder Collaboration and Governance

8.1 Introduction

A lasting transformation in e-commerce last mile delivery is no longer solely a technical problem of routing and vehicle choice, it is a multi-actor governance challenge in which public authorities, carriers, platforms or technology providers, and communities align their goals, resources, and incentives. Recent scenario and stakeholder studies show that the direction and pace of the transition towards sustainable last mile systems depend heavily on local authority capacity and the quality of public-private dialogue, even as private operators remain central to service delivery ([Gonzalez et al., 2023](#); [Plazier et al., 2024](#)). The cluster of *Stakeholder Collaboration and Governance* encompasses the formal and informal frameworks that convene these actors, such as, Freight Quality Partnerships, voluntary certification schemes, pre-commercial procurement trials, and living-lab environments. An instructive example is UK's Fleet Operator Recognition Scheme (FORS), a voluntary accreditation for fleet operators that promote safety, environmental performance and operational best practice. Recently, FORS function as a practical governance lever where public purchases explicitly reward higher accreditation tiers (Bronze, Silver, Gold) in tendering and permitting decisions ([TfL, 2024](#)).

Governance mechanisms provide the scaffolding for co-creation as they establish shared data platforms, coordinate pilot deployments, negotiate regulatory designs, and translate promising experiments into enduring policies. In this chapter, we examined two interlinked themes. First, the modes and instruments that authorities use ranging from Freight Quality Partnerships and pre-commercial procurement and voluntary certification, and the ways these shape incentives for carriers and technology suppliers. Second, the network dynamics among stakeholders, including trust, commitment, proximity and reciprocity that determine whether cooperation endures beyond pilot grants and yields measurable environmental or service gains. Together these strands provide a practical framework for policymakers and practitioners to align e-commerce delivery performance with urban livability and climate goals.

8.2 Case Studies

Case Study: Sustainable Urban Logistics Plan (SULP) & Stakeholder Platform (Antwerp, Belgium - Since 2023)

Antwerp has pursued a city-scale Sustainable Urban Logistics Plan (SULP) that treats stakeholder engagement as a primary governance instrument. SULP and the city's ongoing "Slim naar Antwerpen" platform combine formal planning, EU project networks and an active public-private stakeholder forum to align municipal departments, port actors, carriers, property owners and research partners around a 2030 logistics vision ([ARRIVAL platform, 2023](#)).

The SULP/platform approach directly shapes e-commerce operations by; (a) offering shared route guidance and curb rules that reduce route ambiguity for parcel carriers (SCALE-UP), (b) issuing KPI-linked pilot funding that de-risk experiments (micro-hubs, cargo-bike fleets) for last mile operators, and (c) creating a single municipal "interface" to expedite permits and street space experiments that e-commerce firms require for quick scaling ([SlimNaar, 2024](#)). These arrangements lower transaction costs for carriers and accelerate iteration between pilots and formal policy that reinforce trust and shared data use. This aligns with recent finding by [Mucowska \(2024\)](#) on the centrality of trust, proximity and repeated interaction in sustaining green last mile collaborations.

Antwerp demonstrates a pragmatic, multi-actor governance model for e-commerce last mile transactions: combine a formal SULP with an active stakeholder platform, tie pilots to simple KPI funding, and make operational tools (route planners, incentive platforms) public ([SlimNaar, 2024](#)). Some of the risks are pilot fragmentation without a clear scale-up pathways, the administrative burden on SMEs to respond to KPI calls, and the potential mismatch between region-scale logistics and street-level rules ([CIVITAS, 2023a](#)). Having a neutral organizer to liaise between the local authority and private actors helped to build trust between partners ([CIVITAS, 2023b](#)).

Case Study: Clean-Fleet Certification Schemes – Rotterdam, Netherlands (ECOSTARS since 2013; PIEK since 2018)

Rotterdam's voluntary dual-certification framework that combining the ECOSTARS emissions reduction scheme (since 2013) with the PIEK quiet-operations standard (since 2018). The program has mobilized over 550 local carriers to upgrade both their exhaust and acoustic performance ahead of the city's 2025 Zero-Emission City Logistics (ZECL) mandate. In April 2013, the Municipality of Rotterdam launched its local ECOSTARS program, offering Bronze, Silver, and Gold ratings to fleet operators based on comprehensive emissions reduction practices that range from eco-driving training to electrification road-maps and positioning the scheme within the city's broader clean-transport agenda ([City of Rotterdam, 2021](#)). Five years later, in 2018, Rotterdam formally incorporated the European PIEK noise protection standard into its certification portfolio, enabling fleets with PIEK-certified vehicles and equipment (≤ 60 dB(A) at 7.5 meters separation) to secure evening and nocturnal delivery permits under forthcoming ZECL access rules ([ICLEI, 2012](#)).

Between 2013 and 2021, ECOSTARS Rotterdam engaged 557 member firms and delivered over 170 one-on-one fleet consultations covering total cost of ownership analyses, grant application support, and eco-fleet transition planning, thereby guiding carriers toward higher recognition tiers and subsidy schemes. In line with the 2021 program renewal, two distinct tracks were established: ECOSTARS City, mandating fully electric fleets within the ZECL zone, and ECOSTARS Road, accommodating longer-haul vehicles

transitioning to clean fuels ([City of Rotterdam, 2021](#)).

E-commerce platforms and dark-store operators in Rotterdam have leveraged ECOSTARS consultancy to recalibrate delivery hubs and secure preferential loading slots, with total cost of ownership (TCO) analyses demonstrating up to 20% reductions in operating costs after electrifying van fleets ([Streng, 2023](#)). Simultaneously, PIEK-certified refrigerated and parcel carriers have unlocked pre-dawn and late-evening fulfillment windows, previously restricted by noise ordinances, by integrating geo-fencing telematics that automatically shift refrigeration units into quiet mode upon entering residential zones ([City of Rotterdam, 2021](#)). These schemes supported fleet preparation for the city's upcoming mandatory Zero-Emission City Logistics (ZECL) zone scheduled for 2025.

Despite strong engagement among major operators, participation among smaller fleets remains uneven, largely due to limited capital and low awareness of certification pathways, while Bronze-level criteria intended as low-barrier entry points which risk delivering modest environmental gains unless complemented by deeper performance benchmarks and third-party verification ([City of Rotterdam, 2021](#)). The combination of ECOSTARS emissions ratings with PIEK certification has orchestrated a comprehensive, incentive-driven pathway for Rotterdam's e-commerce and cold-chain fleets in preparation to its 2025 ZECL zone.

Case Study: Freight Quality Partnerships FQP (UK, since early 2000s)

Freight Quality Partnerships (FQPs) formalized through the Department of Transport's (TfL) 2003 Good Practice Guides, and have become cornerstone forum for collaborative urban freight governance in the UK, convening local authorities and private operators to tackle access, loading, routing, and delivery issues in defined areas ([Allen et al., 2014](#)). By the mid-2010s, over fifty FQPs meeting happened, with two to four times annually to co-produce routeing maps, loading-bay signage, and pilot projects, yielding measurable reductions in delivery conflicts and empty running ([Lindholm and Browne, 2014](#)). As e-commerce deliveries surged with online food orders alone growing 7.5% in the UK in 2019, FQPs extended into micro-consolidation trials, cargo-bike logistics, and digital telematics to optimize last mile operations in noise and congestion sensitive neighborhoods ([Paddeu, 2022](#)).

The outputs of FQPs meetings fall into four categories, as explained in [Lindholm and Browne \(2014\)](#):

- Steering groups, sub-working groups, and joint charters to set shared objectives as collaboration frameworks.
- Information tools such as maps, routing guides, multilingual driver pamphlets, and interactive road maps to streamline deliveries.
- Regulatory interventions, such as loading bay time extensions, permit schemes, and kerbside management protocols to reduce conflicts and fines.
- Collaborate to launch pilot projects on urban consolidation centers, electric vehicle charging coordination, and micro-consolidation trials.

The rapid growth of online deliveries has driven FQPs to integrate e-commerce stakeholders, such as dark-store operators, digital platforms, and parcel carriers, into their governance structures ([Paddeu, 2022](#)). Through micro-consolidation schemes piloted in Bristol and other cities, FQPs have enabled cargo-bike last mile services from local hubs, cutting vehicle kilometers by 12% and noise impacts during peak times (Local Government

Association). Digital telematics trials coordinated via FQP working groups have allowed participating carriers to pre-book curbside slots, dynamically re-route vehicles around restrictions, and reduce empty mileage by 8% in consolidated urban sectors (Lindholm and Browne, 2014). By co-designing out-of-hours delivery windows and geo-fenced quiet zones, FQPs have helped e-commerce providers meet narrow delivery promises without exacerbating daytime congestion or noise complaints.

Despite the successes, FQPs face challenges in ensuring equitable participation and long-term impact. Smaller carriers frequently lack the capacity to engage, leading to under-representation and potential bias towards larger operators in planning outcomes. In addition, limited core funding constrains many FQPs to short-term projects, impeding the development of permanent infrastructure, such as consolidation centers or integrated digital platforms, that could deliver deeper efficiency gains (Paddeu, 2022). Similarly, the absence of standardized KPIs and shared data platforms hinders benchmarking across partnerships, making it difficult to aggregate performance metrics on emissions reduction, congestion relief, or service quality (Lindholm and Browne, 2014). Overall, FQP showcase an effective, bottom-up model for stakeholder collaboration, delivering a portfolio of infrastructure improvements, informational tools, and pilot innovations that enhance last mile logistics performance.

8.3 Summary

This chapter shows that effective governance for e-commerce last mile logistics depends on two mutually reinforcing elements: (1) the deliberate design of instruments and institutional roles that create credible incentives for carriers and technology suppliers, and (2) the quality of the multi-actor relationships that sustain cooperation beyond short pilots. Certification and recognition schemes (e.g., ECOSTARS) and performance standards (e.g., PIEK) create market signals and operational privileges that accelerate fleet upgrades, while bottom-up forums (e.g., Freight Quality Partnerships) deliver place-based problem-solving, local knowledge and low-barrier innovation testing. Together these instruments types lower the transaction costs of change and make it feasible for cities and firms to trial zero-emission and quiet delivery practices.

The case of Sulp with Antwerp’s experience highlights persistent governance risks and design rules. Without a modest, permanent secretariat and simple, SME friendly procurement procedures, pilot activity can remain fragmented and administratively heavy; cross-jurisdictional channels must be formalized so port scale flows and street levels rules cohere, and KPI calls must be calibrated to avoid discouraging smaller carriers from participating (CIVITAS, 2023a). By marrying strategy, procurement-style calls and operational tools, Antwerp converts advisory dialogue into predictable, measurable conditions for market actors to invest in low-impact last mile practices (EGUM, 2024).

The Rotterdam experience of combining ECOSTARS advisory pathways with PIEK acoustic certification and explicit linkage to a Zero-Emission City Logistics roadmap that illustrates how municipal leadership can convert voluntary incentives into preparatory investments by fleets, including refrigerated and parcel operators, ahead of mandatory restrictions (TDA, 2022). Evidence from program reporting shows substantial membership and consultation activity under ECOSTARS and concrete PIEK applications by cold-chain operators, which translated into operational access and quieter out-of-hours deliveries. However, these gains are conditional on active policy linkage, grant and advisory support, and visible benefits for participating firms (City of Rotterdam, 2021).

Freight Quality Partnerships in the UK demonstrate the complementary strength of collaborative forums: by convening shippers, haulers, local planners and community representatives, FQPs produce pragmatic outputs that directly improve e-commerce last mile

reliability in defined areas. These outputs include routing guides, curbside protocols and pilots for consolidation or cargo-bike services. The FQP model’s adaptability and low institutional friction make it an effective vehicle for co-design, but long-term impact is frustrated when funding is ad hoc, smaller carriers are under-represented, or KPIs and data platforms are missing (Lindholm and Browne, 2014).

A SWOT synthesis of *Stakeholder Collaboration and Governance* clarifies where to concentrate effort. The strength arises from flexible, low-cost convening platforms and market-facing certifications that mobilize private investment and manufacturer innovation. The weaknesses are mainly emanate from uneven participation (small carriers), reliance on voluntary uptake, and scarcity of standardized metrics to aggregate impact across pilots. The opportunities tied with voluntary schemes to public procurement, scale pilots through stakeholder platforms, such as living-labs, and harness pre-commercial procurement to bring SMEs and platforms into public service design. The threats are related to the risk that voluntary schemes lose relevance once regulation becomes mandatory unless they up-grade their rigor and inclusivity (Mucowska, 2024), and the potential for fragmented technical solutions to lock cities into incompatible systems.

Cities should adopt a portfolio approach that combines recognition schemes (to create market pull) with convening mechanisms (FQPs or FORS or equivalent) and targeted technical/financial assistance for small carriers. The actions of embedding certifications in municipal procurement and permitting (so ECOSTARS/PIEK performance yields preferential loading windows or tender advantages), and invest in small-firm outreach and pooled finance to avoid exclusionary outcomes. Operationally, converting the pilot outputs into modular, standards-based services (e.g., common curb-booking APIs, shared micro-hub guidelines) by inducing KPI’s so that these operations face predictable rules across neighborhoods.

The policy implication at national and regional authorities should recognize and resource the “soft infrastructure” of freight governance. These includes fund sustained coordination roles, require minimal reporting on standard KPIs for pilots, and mandate open data sharing arrangements as a condition of public funding for trials. For instance, link voluntary certification scheme to statutory urban vehicle access regulations (UVARs) so that early adopters capture regulatory certainty rather than being displaced when rules tighten. In addition, the research implications that are urgently needed are longitudinal, experimental studies that measure (i) emission and noise co-benefits, (ii) effects on service reliability and operating costs for carriers of different sizes.

Chapter 9

Analysis & Discussion – Integrative Framework for E-Commerce Last Mile Solutions

9.1 Introduction

Over the past decade, the last mile of e-commerce logistics has evolved from a narrowly defined challenge which was primarily about delivery vans navigating clogged urban streets, into a multifaceted ecosystem. Today's last mile reality is dominated by fleets of diesel vans, motorcycles, and a workforce often facing difficult conditions, especially in rapidly growing cities across India, South America and much of the Global South. At the same time, scattered but significant experiments in Europe, North America, and selected Asian mega cities are reshaping this landscape which spans electric fleets, micro-fulfillment hubs, digital curbside reservation platforms, smart fiscal policy tools, and collaborative governance mechanisms. This chapter serves as a pivotal synthesis, weaving together these threads into an integrated scheme that can guide systemic transformation.

Our analysis builds upon the state-of-the-practice review of e-commerce last mile logistics solutions or measures, and reinterprets the foundational framework of [Lyons and McDonald \(2023\)](#) into six thematic clusters as presented in the above sections of the report as: (i) Clean & Innovative Delivery Modes; (ii) Curb & Street Operations Management; (iii) Micro-Fulfillment & Consolidation Infrastructure; (iv) Regulatory & Fiscal Policies; (v) Services & Business Models; (vi) Stakeholder Collaboration & Governance.

Rather than isolating these solutions in silos, we examine their interconnections across two axes: *Urban context* to distinguish between densely packed city centers, transitional inner suburbs, and more sprawling outer suburbs, and *implementation horizon* that contrasts strategies immediately deployable with those requiring infrastructure or regulatory maturation. This systemic framing is grounded in academic precedent. [Olsson et al. \(2019\)](#) found an expansive yet fragmented landscape of themes with a broad review of articles, such as emerging technologies, operational optimization, supply chain models, performance measurement, and policy action, each are vital but seldom integrated. Meanwhile, global dialogues emphasize that consensus driven urban logistics requires holistic, scalable, and sustainable solutions ([World Economic Forum and Accenture, 2024](#)).

Fragmentation isn't merely a theoretical concern, but it actively undermines effectiveness. In logistics, for instance, disconnected systems and non-collaborative actors lead to repeated inefficiencies, higher operational costs, and compromised service quality. For example, deploying electric vans in isolation cannot deliver low-carbon gains if curbside access remains chaotic or if consumer demand patterns continue to drive fragmented, one-by-one deliveries. The challenge is not speed itself but rapid dispatch can in fact be

highly efficient if it is based on consolidated shipments and optimized tours. This chapter strives to expose those linkages by revealing how aligned policies, enabling governance, and technological interoperability can unlock true systemic value.

9.2 Analytical Framework

To ground our discussion, we propose a robust three layer framework, including spatial and temporal dimensions. These layers are *Enablers*, *Operational Solutions*, and *Outcomes*. The *Enablers* lie at the foundation layer and act as a structural levers that enables progress. Here, Regulatory & Fiscal Policies (such as low-emission zones, dynamic pricing, congestion charges) and Stakeholder Collaboration & Governance (public-private coalitions, freight partnerships, living labs) set possibilities in motion.

The *Operational Solutions* layer encompasses tangible delivery mechanisms: Clean & Innovative Delivery Modes (electric bikes, small EVs, drones), Curb & Street Operations Management (digital reservations platforms, smart signage), Micro-fulfillment & Consolidation Infrastructure (parcel lockers, micro-hubs, neighborhood dark stores), and Services & Business Models (aggregate deliveries, crowdsourcing, green delivery options). The *Outcomes* sit at the summit and provide the fruits of orchestration. We evaluate impact across environmental outcomes (emissions, noise, air quality), economic metrics (cost efficiency, time savings), social equity (accessibility, fair pricing), and resilience (redundancy, adaptability under stress). Therefore, each cluster have an outcome layer that linked directly to the respective impact.

The dual lenses are *Geographic* and *Temporal*. The *Geographic* lens distinguishes city centers that is intensely packed with delivery density and curbside constraints, from inner suburbs where mixed-use development allows experimentation, and outer suburbs which characterized by low density and longer routes. On the other hand, the *Temporal* lens differentiates short-term strategies, including those with pilots or proof of concept, micro-hubs or e-bike delivery as a medium-term innovations, and fully automated micro-fulfillment or aerial corridors, which require maturation in tech, policy, or public acceptance.

Our layered and lensed structure guides context and maturity mapping (**Table 9.1**). It clarifies where each strategy resides in terms of readiness and spatial fit. For instance, cargo bikes are increasingly viable in inner city districts, while drone deliveries may remain contingent on regulatory flexibility and airspace design. In relation to this, scholars and practitioners are increasingly advocating of systems thinking but not isolated pilots (Boysen et al., 2021), by which these systems are integrated, multi-stakeholder platforms where technology, policy, and infrastructure reinforce each other.

9.3 Mapping Context and Maturity

The thematic clusters chart e-commerce last mile logistics landscape, not only in terms of geographic relevance but also regarding readiness for implementation. The contexts and maturity of the clusters are presented with more details in **Table 9.1**. This mapping helps distinguish which strategies are ripe for immediate action, and which require deeper infrastructure, policy shifts, or ecosystems development before scaling effectively.

Table 9.1: Overview of Cluster - Context - Maturity

Cluster	Layer	Geographic Fit	Maturity (Horizon)	Governance Mode
Clean & Innovative Delivery Modes	Operational	City centers; adaptable to inner/outer suburbs	EV vans (short); e-cargo bikes & drones (medium)	Hybrid (voluntary + incentives/regulation)
Curb & Street Operations Management	Operational	City centers; extending to inner suburbs	Reservation apps (short); sensor/automation (medium)	Hybrid (policy + enforcement + platforms)
Micro-Fulfillment & Consolidation Infrastructure	Operational	Urban cores; growing in inner suburbs	Dark stores/lockers (short); automated micro-hubs (medium)	Hybrid (planning/zoning + partnerships)
Regulatory & Fiscal Policies	Enabler	All geographies	Congestion/LEZ fees (short); dynamic pricing (medium)	Regulatory
Services & Business Models	Operational	Universal relevance	Aggregation models (short); crowd-delivery (medium)	Market-driven (with policy guardrails)
Stakeholder Collaboration & Governance	Enabler	All contexts; vital for suburban diffusion	Living labs (short); institutional coalitions (medium)	Collaborative

With the *Clean & Innovative Delivery Modes*, urban cores are experiencing an electrified renaissance. Electric cargo bikes and tricycles, once niche, are increasingly integral to delivery fleets. For instance, DHL Group’s use of 6,100 e-bikes and 23,000 electric delivery vehicles in Germany has rendered half of its delivery zones carbon-neutral, saving roughly one million tons of CO₂ in a year (ITF, 2024a). E-commerce delivery set to raise emissions by 32% by 2030, electrification is both timely and urgent (Sax, 2024). In suburban areas, these clean modes are emerging but less pervasive, hindered by longer route and inadequate charging infrastructure. In addition, drones and autonomous robots or droids remain largely experimental, awaiting regulatory clarity and public acceptance.

In city centers, technology such as digital curb booking systems has demonstrated remarkable promise. With the pilot under FlexCurb project, such systems cut double parking by 15-20% and improved compliance among delivery drivers (Cristina, 2022). These developments reveal that, with policy support and enforcement, curb management can rapidly shift urban behavior. Similarly, inner suburbs are starting to embrace digital curb tools, while outer suburbs still rely largely on informal loading zones with limited enforcement or structured access.

Micro-fulfillment & Consolidation Infrastructure are growing and transforming in urban cores. Urban hubs and micro-fulfillment centers are becoming more common, especially in dense markets fueled by rapid commerce (Karaoulanis, 2024). Meanwhile, in suburban contexts, shared-use consolidation points and retrofit micro-hubs hold promise but await alignment with zoning regulations and commercial demand.

Regulatory & Fiscal Policies, policy frameworks, such as congestion charges and low-emission zones, are operational realities in many global cities, but are not futuristic. While, the next evolutions like dynamic curb pricing and tiered delivery fees remain limited, pending stakeholder consensus and technological acceptance (ITF, 2024a). Currently, regulatory policies span all geographies, but adaptability and sophistication vary as the urban core drivers encounter more direct policy levers than those in the outer rings.

Service & Business Models are becoming increasingly visible with aggregation models in city centers, these includes consolidated delivery waves and scheduled drop-offs. Crowd-delivery platforms continue to expand slowly, while still grappling with labor concerns. These models are inherently adaptable and friction-light, and effective where delivery density supports consolidation. In suburbs, service models still skew toward traditional single-trip deliveries, with consolidation yet to take significant root.

In dense urban centers, *Stakeholder Collaboration & Governance* is increasingly mature and structured. The mechanisms of forums like the UK’s Freight Quality Partnerships (FQPs) make local councils, logistics operators, and community actors convene to co-design delivery solutions tailored to specific neighborhoods (Allen et al., 2014). Complementing this are living labs, where public and private actors prototype and iteratively refine logistics practices using shared real-time data and infrastructure. These governance models are robust in city centers, where institutional capacity and stakeholder density support formal collaboration. In contrast, suburban zones remain nascent domains for such governance, often relying on ad-hoc dialogues or rare initiatives rather than sustained collaborations. This spatial disparity highlights a pressing need to replicate and adapt urban governance innovations in suburban contexts to ensure last mile strategies can scale equitably and institutionally.

In summary, each cluster demonstrates meaningful maturity within urban cores but more emerging status in suburban and peripheral zones. This spatial and temporal mapping lays a clear foundation for narrative exploration of synergy, equity, road mapping, and strategic integration in the subsections to follow in this chapter.

9.4 Cross-Cluster Synergies and Interdependency

Effective last mile logistics innovations are not developed in isolation but thrive through a web of well-coordinated interactions among diverse clusters, as captured with **Fig 9.1** developed by the authors. The synergy and interdependency assess how the solutions across the six thematic clusters interact within the last mile delivery ecosystem. The matrix depicts the strength of these relationships on a 0-5 scale, where darker shades represent stronger mutual reinforcement. Each score reflects evidence from real-world cases and literature, assessing how frequently two clusters are co-deployed, the extent to which they depend on one another for performance, and the quality of measurable results such as reductions in emissions, travel time, or vehicle kilometers.

The strongest ties exist between *Clean & Innovative Delivery Modes*, *Regulatory & Fiscal Policies*, and *Stakeholder Collaboration & Governance*, underscoring the catalytic role of governance and regulation in scaling low-emission vehicles. Regulatory frameworks, such as London’s ULEZ, establish both incentive and enforcement mechanisms that accelerate fleet electrification. Conversely, widespread uptake of cargo bikes provides tangible results that strengthen political and institutional support for expanding such zones.



Figure 9.1: Integration Matrix: Cross-cluster Synergy Scores

Similarly, *Micro-Fulfillment & Consolidation Infrastructure* and *Service & Business Models* form a second high-intensity pair. For instance, PARKUNLOAD Smart curb management platform (in Spain) enables reservation of loading bays and significantly increases cargo-bike delivery efficiency while cutting idle times and emissions. The synergy between clean delivery modes and curb management is emblematic of how inter-cluster coordination magnifies system performance.

Equally important is the dependency between micro-hubs and service models. The

neighborhood delivery hub in Seattle, USA illustrates this: operators consolidated deliveries through neighborhood hubs only by coordinating retail drop-off schedule; a fusion of infrastructure with service design, which cut both travel distances and environmental load.

The regulatory cluster serves as a catalyst. Low-emission zones in cities like London, Paris and Beijing created market incentives for fleet electrification, spurring both adoption of clean modes and the scaling of consolidation infrastructure (e.g., micro-fulfillment centers). These aren't standalone actions, they spark ripple effects across multiple clusters.

Central to enabling all these interactions is *Stakeholder Collaboration & Governance*. The cases with Sulp in Antwerp, ECOSTARS with the PIEK in Rotterdam, and FQP in London exemplifies a multi-actor governance model. The project emphasizes structured consultation, data sharing and collaboration to align urban logistics space with governance that enables cross-sector integration, planning, and enforcement.

The integration matrix in **Fig 9.1** also draws attention to underdeveloped connections, like that between service models and curb management, highlighting opportunities. Delivery platforms that schedule consolidated drop-offs gain real efficiency when paired with digital curb allocations, but many operate in silos, limiting potential gains. Moreover, without governance framework, even integrated technologies risk functioning in silos.

In essence, systemic efficiency is better when operational, regulatory, and governance cluster align, but not only on singular breakthroughs. Clear modes need digital curb systems to be effective; micro-hubs demand service schedules and shared platforms to optimize usage; policies must signal incentives across clusters, and governance must bring all together. When all these things go in orchestration, cities will be able to transform the last mile from a patchwork of pilots towards coherent, sustainable, and inclusive urban delivery ecosystems.

9.5 Comparative SWOT Analysis

To assess the strategic potential of innovations in e-commerce last mile logistics, the SWOT framework helps to stage them within their core strengths, persistent weakness, merging opportunities, and rising threats. The SWOT analysis of all clusters is given in **Table 9.2**, summarizing the cases and experiences listed in the previous chapters. Our earlier discussion and synthesized practice demonstrate that each cluster brings distinctive value, but also faces hurdles shaped by urban context, technological maturity, and policy alignment.

Table 9.2: SWOT Comparison of the Six Clusters

Cluster	Strengths	Weaknesses	Opportunities	Threats
Clean & Innovative Delivery Modes	Reduces tailpipe emissions and noise; high agility in dense cores (e.g., cargo bikes, small EVs).	High upfront costs; range/payload/weather constraints; effectiveness often depends on micro-hub proximity.	Declining battery costs; expanding public/semi-public charging; policy incentives accelerating modal shift.	Uneven charging access; grid capacity limits; fragmented regulations; rising urban space costs.
Curb & Street Operations Management	Cuts double-parking and search time; improves loading reliability via digital reservation and time-window controls.	Capital and operation & management costs (sensors, signs); complex cross-agency coordination; political sensitivities over reallocation.	API-based curb platforms and integration with routing/dispatch; data-driven compliance and pricing.	Pushback from legacy users; underfunded enforcement or maintenance can erode performance.
Micro-Fulfillment & Consolidation Infrastructure	Shorter last-mile loops; faster service; potential VKT and emissions reductions via local stock and lockers.	High real-estate and fit-out costs; limited stock keeping unit flexibility; throughput risk if demand is volatile.	Retail/ parking-space repurposing; shared-use hubs; automation/robotics to boost pick-pack efficiency.	Under-utilization if demand shifts; zoning and permitting delays; landlord and neighborhood opposition.
Regulatory & Fiscal Policies	Internalizes externalities (congestion, pollution); creates stable revenue streams for green infrastructure.	Risk of regressivity if poorly designed; administrative complexity; compliance burden for SMEs.	Dynamic/zone-based pricing; tiered incentives linked to emissions/performance; direct reinvestment in hubs and charging.	Political backlash or rollbacks; fragmented regional frameworks complicate multi-city operations.
Services & Business Models	Aggregation windows and scheduled delivery reduce trips; flexible capacity via crowdsourcing and platform orchestration.	Labor uncertainty in gig models; uneven consumer adoption where speed dominates preferences.	“Green-default” at checkout; loyalty nudges; retailer partnerships for coordinated consolidation.	Tighter labor regulation and rising costs; persistent instant-delivery expectations limiting consolidation uptake.
Stakeholder Collaboration & Governance	Living labs, Freight Partnerships, and co-design platforms build trust, context fit, and adaptive policy cycles.	Needs sustained funding and institutional embedding; complexity can slow decisions or dilute accountability.	Embed in planning (in case with SULPs); digital collaboration and data-sharing frameworks; replication across districts.	Weak governance or political turnover; uneven representation may skew benefits and stall scaling.

Each cluster within last mile logistics brings distinct strengths and forward-looking opportunities that, if aligned, could catalyze system-wide efficiency gains. *Clean Delivery Modes*, such as electric vans and cargo bikes, offer clear environmental benefits and urban agility, especially as battery technology improves and charging infrastructure expands. *Curb & Street Operations Management* streamlines street loading and parking, particularly when integrated with real-time APIs and reservation systems. *Micro-fulfillment Infrastructure* accelerates delivery by consolidating inventory near consumers, a trend gaining traction amid retail space re-purposing in cities. On the policy front, *Regulatory & Fiscal Policies* that appropriately price congestion or emissions can drive modal shifts and fund green infrastructure. Meanwhile, *Services & Business Models* that include aggregation and crowd-based delivery hold promising behavioral engagement potential, and *Stakeholder & Governance*, in the form of freight partnerships and living labs, fosters adaptive innovation and multi-actor trust.

Each cluster also faces significant headwinds that could undermine its impact if not addressed. Clean modes remain hindered by upfront costs and infrastructure deficits, while their effectiveness is closely tied to postage-like hub networks. Curb managements systems require complex coordination and capital, and may face public resistance. Micro-fulfillment sites struggle with high real estate costs and risk of under-utilization if demand wanes or zoning stalls rollout. Dynamic and equitable policy tools risk backlash or uneven implementation if misaligned with stakeholder needs. Service innovations, while flexible, are vulnerable to labor regulation and customer preferences for speed. Finally, governance structures like living labs demand sustained funding and may falter with political turnover or stakeholder fatigue. These weaknesses, especially in suburban areas with lower density and institutional strength may threaten the cohesive unfolding of the last mile transformation unless intentionally integrated.

9.6 Integrated Phased Roadmap to Align with Urban Planning Model

Realizing both a resilient e-commerce last mile system and the goals of 15-minute city requires a phased, context-sensitive implementation strategy. The strategy has to fuse logistics innovation with localized urban governance. We segment the phases with three steps as localized prototype, scaling and mainstreaming.

Phase 1: Building Localized Prototypes

The rollout begins at the neighborhood scale, ideally within compact, mixed-use districts where the ambitions of the 15-Minute City and last mile logistics converge. Pilots could deploy micro-fulfillment centers or lockers at the local retail zones, supported by cargo-bike routes and digital curb reservation tools for street-level access. These pilot projects function as living labs that brings together carriers, municipal planners, and local businesses to iteratively test logistics solutions to serve both delivery efficiency and neighborhood accessibility. Implementing these innovations within areas already prioritizing local proximity (such as districts where daily life is within a 15-minute walk or cycle) demonstrates how logistics can become embedded, rather than intrusive.

Phase 2: Scaling & Coordination

With neighborhood scale success in place, the next phase expands both delivery networks and urban infrastructure. Micro-hubs clusters link across multiple local, such as

15-minute neighborhoods, enabling inter-neighborhood consolidation and dynamic routing. Curb-management systems become proactive, offering real-time, digital system to reserve curbside space (for e.g., the use of APIs) across districts. Electrified micro fleets, like E-bikes or trikes, small EVs, serves as the connective tissue between micro-hubs and customers. Regulatory policies such as low-emission zones and dynamic pricing support these operations by channeling demand toward sustainable modes. In parallel, the governance structures formalize through sustainable action plans like SULPs and neighborhood coalitions, embedded within broader 15-minute city frameworks to ensure coordination and adaptability.

Phase 3: Mainstreaming Logistics within Urban Planning

Eventually, logistics infrastructure transforms from novelty to norm. The final phase institutionalizes logistics as part of urban design. New developments embed micro-fulfillment nodes become standard in new developments; curb-access becomes managed by integrated digital systems; delivery services default to consolidated and green options. A mature logistics network combines multiple modalities, ready to adapt to interruptions or shocks or surges in demand. Governance transitions from pilot to permanent structures such as local logistics councils, transparently monitoring metrics like delivery times, emissions, access equity, and network reliability, forming a fully integrated logistics layer in the 15-minute city.

Overall, the integration of logistics and neighborhood planning strengthens the 15-minute city's promise which is not just to bring services closer, but to make delivery itself neighborhood embedded. The Driving Urban Transitions (DUT) initiative underscore that the 15-minute city concept thrives when prototyped in co-creative settings with attention to real-time data, governance, and local specificity (Büttner et al., 2024). Marzolla et al. (2024) confirms that a successful 15-minute city structure, i.e., compact and walkable, correlate with reduced per-capita transport emissions. It underscores the environmental impact potential of integrated logistics and proximity design. Therefore, aligning the phased road map with the 15-Minute city paradigm make the logistics, not an external system tacked onto urban life, but an integral part and enable in how we live and move locally.

Chapter 10

Conclusion

This report has provided a comprehensive state-of-the-practice review of e-commerce last mile solutions, situating them within six thematic clusters: clean and innovative delivery modes; curb and street operations management; micro-fulfillment and consolidation infrastructure; regulatory and fiscal policies; services and business models; and stakeholder collaboration and governance. By structuring the analysis across these clusters, the report has moved beyond fragmented accounts of isolated implementation or pilot of solutions to offer a more systematic and comparative framework.

Our central aim was to examine environmentally sound and cost-effective solutions implemented in urban contexts, with a focus on practices that are operational today or in the near term. Unlike earlier reviews (e.g., [Lyons and McDonald \(2023\)](#)), this study foregrounds the integration of multiple solutions and their embedding within broader urban sustainability agendas. Rather than positioning last mile logistics as an additional technical layer, we argue that it is increasingly a core layer of urban design, policy, and governance.

Across clusters, the review highlighted a combination of distinct advantages and persistent vulnerabilities. Electric vans are rapidly scaling in many cities and can significantly reduce emission, but their adoption is still constrained by purchase costs and uneven availability of charging infrastructure ([Camilleri et al., 2016](#)). Cargo bikes offer flexible, low carbon option for dense urban cores, through their range and load capacity limit their use to short haul deliveries and favorable geographies ([Michalakopoulou et al., 2025](#)). Autonomous robots, by contrast, remain experimental, promising new forms of last mile automation but facing major hurdles in regulation, safety, and public acceptance. Curb and street management initiatives enhance urban efficiency and reduce double-parking, though they demand heavy coordination and sustained municipal investment ([UrbanFreightLab, 2020b](#)). Micro-fulfillment solutions, from parcel lockers to automated mini-warehouses, improve delivery speed and optimize proximity, but remain challenged by space scarcity and high capital requirements ([Karaoulanis, 2024](#)).

Regulatory and fiscal policies have emerged as powerful levers: low-emission zones, dynamic road pricing, and green rebates can internalize externalities while funding new infrastructure. Yet misalignment across governance levels often risks disproportionate impacts on smaller carriers or vulnerable consumers ([Alvarez-Gallo et al., 2024](#)). Meanwhile, innovative service and business models, such as crowd-shipping, LaaS platforms, and default green delivery options, show promise in scaling flexibility and behavioral nudges, but face labor challenges and, for some of them, consumer skepticism ([Çınar et al., 2024](#); [Buldeo Rai et al., 2021](#)). Finally, stakeholder collaboration and governance were identified as an important binding tissue of innovation. Evidence from freight quality partnerships in the UK, living labs in Europe, and collaborative data platforms shows that governance coalitions can be important for scaling and embedding last mile solutions ([Rosales, 2024](#);

Gonzalez et al., 2023).

Beyond these cluster-specific insights, two transversal findings stand out. First, context matters: dense city centers tend to support rapid adoption of clean modes, micro-hubs, and curb management, while suburban areas face slower, fragmented uptake due to sprawl and lower delivery densities. In addition, the context extends to countries and their cities. For instance, Alvarez-Gallo et al. (2024) indicated that the differences in infrastructure, socio-economic and logistical complexity play a major role when implementing demand specific strategies, such as LEZs. Second, synergies matter: solutions rarely succeed in isolation. Electric cargo bikes thrive when supported by curb allocation and charging, while crowd-shipping models require both regulatory acceptance and trusted governance structures to reach critical mass, as well as guaranteeing labor law enforcement.

To bring order to this complexity, the report introduced a suite of visual toolkits: the Cluster–Context–Maturity, which mapped adoption stages across urban forms; the Integration Matrix, which visualized synergy strengths between clusters; and the Comparative SWOT analysis, which distilled strategic positioning. Finally, a phased roadmap was aligned with the 15-minute city paradigm, illustrating how local pilots can evolve into fully embedded logistics ecosystems.

Together, these tools underscore the report’s central contribution: shifting from a fragmented catalog of innovations to a relational framework. The integrative perspective reveals not only what each solution achieves in isolation, but also how they co-evolve—whether through enabling regulations, supportive infrastructure, or collaborative governance. For researchers and practitioners alike, these tools provide a plan to navigate choices, prioritize interventions, and assess risks in complex urban environments.

Policy and Practice Implications

The review carries important implications for municipalities, operators, technology providers, and communities. For municipalities, the lesson is that regulatory and fiscal levers are among the most decisive instruments for shaping last mile systems. Local authorities that combine LEZs, congestion pricing, and targeted subsidies tend to accelerate uptake of clean modes and digital curb systems (Maxner et al., 2025). For operators and logistics firms, the findings point to the necessity of diversifying fleets, investing in micro-hubs, and integrating services into multi-modal ecosystems. For technology providers, API-driven curb booking, and LaaS platforms emerge as critical enablers, offering interoperability across clusters. For communities, the value lies in ensuring inclusivity in delivery systems must not exacerbate inequities, whether by shifting costs to low-income consumers or excluding peripheral neighborhoods.

The findings also align closely with broader urban agendas. Last mile solutions are no longer peripheral to sustainability debates, they are central to decarbonization, air quality, and livability goals. For embedding logistics within the 15-minute city framework, the road map illustrates how deliveries can be re-imagined as local services that strengthen neighborhood coherence rather than strain it (Büttner et al., 2024). The city of Paris’s experiment with urban logistics hotels and micro-hubs exemplify this integration, showing how proximity logistics can support both e-commerce efficiency and reduce emission from logistics activity (Reda, 2025). Internationally, such lessons are transferable, though always requiring adaptation to governance structures, urban morphology, and socio-economic context.

Limitations of the Report

It is important to acknowledge limitations. The review focused on state-of-the-practice solutions, specifically on those already implemented or operationally feasible in the short term. Speculative or long-horizon technologies, such as aerial drone mass deployment or physical internet (PI), were beyond scope. The review is also skewed toward Global North case studies, reflecting the availability of literature, empirical data, and more experience with piloting and implementing solutions/measures. Finally, no expert validation interviews were conducted, meaning that findings rely on literature and documented case outcomes rather than stakeholder perceptions. Planned follow-up studies are expected to address several of these gaps, these include targeted expert interviews and stakeholder validation workshops to triangulate findings and assess the practical transferability of the reviewed measures. These expansions will allow future publications to provide a more balanced and empirically grounded perspective on e-commerce last-mile solutions.

Future Research and Action Agenda

The report identifies several future priorities. More evidence is needed on the social impacts of new models, such as crowd-delivery or default green options, particularly regarding labor standards and consumer equity. Comparative evaluations would benefit from standardized performance indicators across clusters, enabling benchmarking of emissions, costs, and service reliability. Longitudinal studies are essential to track whether pilots persist once subsidies end or leadership changes.

A stronger Global South perspective is also needed, given rapidly growing e-commerce markets in Asia, Africa, and Latin America, where urban form and informality reshape feasibility of last mile solutions. Finally, integration with urban planning frameworks, such as zoning, sustainable urban mobility plans, and metropolitan freight strategies, remains a frontier for research and practice alike (Plazier et al., 2024; Mucowska, 2024).

In conclusion, e-commerce last mile delivery is not merely a logistical challenge. It is a systemic urban transformation issue, shaping congestion, emissions, public space, and equity. The six clusters reviewed here reveal both promising innovations and persistent vulnerabilities, but most importantly, they demonstrate the necessity of integration. Only by bridging across clean modes, curb management, micro-fulfillment, policy instruments, business models, and governance structures can cities design last mile ecosystems that are sustainable, resilient, and citizen-oriented.

The report thus provides both a state-of-the-practice snapshot and a strategic road map. Its integrative frameworks, spanning SWOTs analysis, cross-cluster synergy, and integrated phased road maps, offer decision-makers with practical tools for navigating complexity. For researchers, the report highlights evidence gaps and future agendas. For policymakers, they underline that last mile delivery is not an afterthought but a lever of urban futures. Ultimately, the convergence of these clusters points toward a greener, resilient, equitable, and more efficient last mile system that anchors e-commerce firmly within the sustainable city of tomorrow.

Acknowledgment

This project is funded through Driving Urban Transition Partnership (DUT), and specifically: German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt (DLR)), Funding number: 01UV2453; French National Research Agency (Agence Nationale de la Recherche (ANR)), Funding number: ANR23-DUTP-0001-01; Research Council of Norway (Norges forskningsråd) Funding number: 350295.

Bibliography

- Cargo bike action plan, 2023. URL <https://content.tfl.gov.uk/tfl-cargo-bike-action-plan-2023-acc.pdf>.
- Recommendations, best practices & possible actions on establishing and operating urban vehicle access regulations (personal mobility and freight), 2024. URL https://transport.ec.europa.eu/document/download/f7926735-a48b-4be3-b0a0-189420b8e0f8_en?filename=EGUM-Recommendations-UVAR.pdf. Endorsed by the EGUM Subgroup on UVARs and Parking on 28 Feb 2024.
- Low emission zones — key takeaways from the early adaptors, 2024. URL <https://cms.uitp.org/wp/wp-content/uploads/2024/03/Low-Emission-Zone-Key-takeaways-from-early-adaptors.pdf>. Official UITP knowledge brief; compiled with case studies and interviews.
- International Cargo Bike Festival, 2025. URL <https://cargobikefestival.com/>.
- Congestion charge, 2025a. URL <https://tfl.gov.uk/modes/driving/congestion-charge>.
- Anne Aguilera, Laetitia Dablanc, Camille Krier, and Nicolas Louvet. Platform-based food delivery in Paris before and during the pandemic: Profile, motivations and mobility patterns of couriers. 14(1):45, 2022. ISSN 1866-8887. doi: 10.1186/s12544-022-00569-8. URL <https://doi.org/10.1186/s12544-022-00569-8>.
- André Romano Alho, João de Abreu e Silva, Jorge Pinho de Sousa, and Edgar Blanco. Improving mobility by optimizing the number, location and usage of loading/unloading bays for urban freight vehicles. 61:3–18, 2018. ISSN 1361-9209. doi: 10.1016/j.trd.2017.05.014. URL <https://www.sciencedirect.com/science/article/pii/S1361920916303182>.
- Julian Allen, Michael Browne, Allan Woodburn, and Jacques Leonardi. The role of urban consolidation centres in sustainable freight transport. 32(4):473–490, 2012. doi: 10.1080/01441647.2012.688074. URL <https://doi.org/10.1080/01441647.2012.688074>.
- Julian Allen, Maja Piecyk, David Cebon, and Phil Greening. Department for transport – freight, logistics and the planning system: call for evidence, 2014. URL <https://www.csrf.ac.uk/wp-content/uploads/2023/10/SRF-response-to-DfT-logistics-planning-call-for-evidence-05-10-2023.pdf>.
- Aliaa Alnaggar, Fatma Gzara, and James H. Bookbinder. Crowdsourced delivery: A review of platforms and academic literature. 98:102139, 2021. ISSN 0305-0483. doi: 10.1016/j.omega.2019.102139. URL <https://www.sciencedirect.com/science/article/pii/S030504831930578X>.

- Alstom. Parcel delivery by tram in Strasbourg, an experiment to improve the flow of traffic in the city centre. <https://www.alstom.com/press-releases-news/2024/9/parcel-delivery-tram-strasbourg-experiment-improve-flow-traffic-city-centre>, 2024. [Accessed 28-01-2025].
- Sandra Milena Alvarez-Gallo, Jacobo Hernan Echavarria-Cuervo, and Julien Philippe Dominique Maheut. Analysis and strategies for urban freight logistics in a low emission zone. 2024. ISSN 2013-0953. doi: 10.3926/jiem.6902. URL <https://riunet.upv.es/handle/10251/211812>.
- Elin Alverhed, Simon Hellgren, Hanna Isaksson, Lisa Olsson, Hanna Palmqvist, and Jonas Flodén. Autonomous last-mile delivery robots: A literature review. 16(1):4, 2024. ISSN 1866-8887. doi: 10.1186/s12544-023-00629-7. URL <https://doi.org/10.1186/s12544-023-00629-7>.
- Johanna Amaya and Sara Reed. Space management policy for urban last-mile parking infrastructure: A demand-oriented approach. 200:104185, 2025. ISSN 1366-5545. doi: 10.1016/j.tre.2025.104185. URL <https://www.sciencedirect.com/science/article/pii/S1366554525002261>.
- Assessore Ambiente. Milan's Area C reduces traffic pollution and transforms the city center - C40 Cities. <https://www.c40.org/case-studies/milan-s-area-c-reduces-traffic-pollution-and-transforms-the-city-center/>, 2015. [Accessed 11-10-2024].
- Saurav Anand. EVs offer 15–20% cost advantage over diesel in logistics report/articleshow/121774395.cms, 2025. [Accessed 06-08-2025].
- ARRIVAL platform. BABLE - Use Case: Sustainable Urban Logistics Planning in Antwerp. <https://www.arrival-platform.eu/default/knowledge-hub/best-practices/best-practice/case-study-antwerp-sustainable-urban-logistics-planning.html>, 2023. [Accessed 02-03-2025].
- Niklas Arvidsson, Howard Twaddell Weir IV, and Tale Orving. Operational performance of light electric freight vehicles in the last mile: Two nordic case studies. 54(2):192–210, 2024. ISSN 0960-0035. doi: 10.1108/IJPDLM-02-2023-0079. URL <https://www.emerald.com/insight/content/doi/10.1108/IJPDLM-02-2023-0079/full/html>.
- Patrick Lucas Austin. Amazon's New 'Amazon Day' Feature Lets You Get All Your Packages at Once. <https://time.com/5541186/amazon-day/>, 2019. [Accessed 04-03-2025].
- Linda Baker. Today's pickup: Dhl, reef technology launch eco-friendly cargo bike pilot. https://www.freightwaves.com/news/todays-pickup-dhl-reef-technology-launch-eco-friendly-cargo-bike-pilot?utm_source=chatgpt.com, 2020. [Accessed 28-07-2024].
- Barcelona.cat. Strategy to halve emissions from delivery vehicles — Info Barcelona — Barcelona City Council. https://www.barcelona.cat/infobarcelona/en/tema/mobility-and-transport/strategy-to-halve-emissions-from-delivery-vehicles_1257063.html, 2023. [Accessed 20-11-2024].

Jordan M. Barker and Rebekah I. Brau. Shipping surcharges and LSQ: Pricing the last mile. 50(6):667–691, 2020. ISSN 0960-0035. doi: 10.1108/IJPDLM-09-2019-0292. URL <https://www.emerald.com/insight/content/doi/10.1108/ijpdlm-09-2019-0292/full/html>.

Leonard Baum, Tom Assmann, and Henning Strubelt. State of the art - automated micro-vehicles for urban logistics. *IFAC-PapersOnLine*, 52(13):2455–2462, 2019. ISSN 2405-8963. doi: 10.1016/j.ifacol.2019.11.575. URL <https://www.sciencedirect.com/science/article/pii/S2405896319315629>.

Rebecca Bellan. Google alum startup Cartken and REEF Technology launch Miami’s first delivery robots — TechCrunch — [techcrunch.com. https://techcrunch.com/2021/03/30/google-spinoff-cartken-and-reef-technologies-launch-miamis-first-delivery-robots/](https://techcrunch.com/2021/03/30/google-spinoff-cartken-and-reef-technologies-launch-miamis-first-delivery-robots/), 2021. [Accessed 05-08-2024].

BJH. Last-mile parcel delivery facilities: Market assessment, 2025. URL https://www.nyc.gov/assets/planning/downloads/pdf/our-work/plans/citywide/last-mile-facility-text-amendment/25DCP067Y_%20Last-Mile_Facilities_Market_Assessment_V1_03282025.pdf.

Adam Blair. Understanding Retail Delivery Fees and Their Impact on Sales Tax Compliance - Retail TouchPoints. <https://www.retailtouchpoints.com/features/executive-viewpoints/understanding-retail-delivery-fees-and-their-impact-on-sales-tax-compliance>, 2024. [Accessed 11-10-2024].

Clara Blanchar. Barcelona facilita la descarga nocturna de mercancías para reducir el tráfico de día. <https://elpais.com/espana/catalunya/2025-05-05/barcelona-facilita-la-descarga-nocturna-de-mercancias-para-reducir-el-trafico-de-di.html>, 2025. [Accessed 12-07-2025].

Magnus Blinge, Paola Cossu, Fernando Liesaistic, Giacomo Lozzi, Charlotte Migne, María Dolores Ortiz Sánchez, Hans Schurmans, Tim Sjouke, and Jos Streng. Guide for advancing towards zero-emission urban logistics by 2030., 2021.

Techane Bosona. Urban freight last mile logistics—challenges and opportunities to improve sustainability: A literature review. 12(21):8769, 2020. ISSN 2071-1050. doi: 10.3390/su12218769. URL <https://www.mdpi.com/2071-1050/12/21/8769>.

Nils Boysen, Stefan Fedtke, and Stefan Schwerdfeger. Last-mile delivery concepts: A survey from an operational research perspective. 43(1):1–58, 2021. ISSN 1436-6304. doi: 10.1007/s00291-020-00607-8. URL <https://doi.org/10.1007/s00291-020-00607-8>.

Heleen Buldeo Rai. Urban warehouses as good neighbors: Findings from a New York City case study. 19:100823, 2023. ISSN 2590-1982. doi: 10.1016/j.trip.2023.100823. URL <https://www.sciencedirect.com/science/article/pii/S2590198223000702>.

Heleen Buldeo Rai, Sara Verlinde, and Cathy Macharis. Who is interested in a crowd-sourced last mile? A segmentation of attitudinal profiles. 22:22–31, 2021. ISSN 2214-367X. doi: 10.1016/j.tbs.2020.08.004. URL <https://www.sciencedirect.com/science/article/pii/S2214367X20302039>.

- Heleen Buldeo Rai, Joséphine Mariquivoi, Matthieu Schorung, and Laetitia Dablang. Dark stores in the City of Light: Geographical and transportation impacts of ‘quick commerce’ in Paris. 100:101333, 2023. ISSN 07398859. doi: 10.1016/j.retrec.2023.101333. URL <https://linkinghub.elsevier.com/retrieve/pii/S0739885923000732>.
- Aaron J. Burns, Jeremy J. Michalek, and Constantine Samaras. Estimating the potential for optimized curb management to reduce delivery vehicle double parking, traffic congestion and energy consumption. 187:103574, 2024. ISSN 1366-5545. doi: 10.1016/j.tre.2024.103574. URL <https://www.sciencedirect.com/science/article/pii/S1366554524001650>.
- Adrien Béziat. DomirÉdo — Évaluation environnementale des modes de réception des colis. Slide deck, 2023. URL https://splott.univ-gustave-eiffel.fr/fileadmin/redaction/SPLOTT/archives_seminaire_SPLOTT/Beziat_2023_SPLOTT.pdf.
- Maria Börjesson. Long-Term Effects of the Swedish Congestion Charges, 2018. URL https://www.oecd.org/en/publications/long-term-effects-of-the-swedish-congestion-charges_d944f94b-en.html.
- B. Büttner, S. Seisenberger, B. McCormick, C. Silva, E. Papa, M. Cao, and J. F. Teixeira. Mapping of 15-minute City Practices Overview on strategies, policies and implementation in Europe and beyond, 2024. URL https://dutpartnership.eu/wp-content/uploads/2024/04/DUT_15-minute-City-Mapping_04-2024.pdf.
- C40-Cities. C40 Knowledge Community. <https://www.c40knowledgehub.org/s/article/How-road-pricing-is-transforming-London-and-what-your-city-can-learn>, 2019. [Accessed 04-12-2024].
- C40-Cities. The pioneers of zero-emission logistics in european cities. https://www.c40knowledgehub.org/s/article/The-pioneers-of-zero-emission-logistics-in-European-cities?language=en_US, 2024. [Accessed 10-07-2025].
- Cainiao. Cainiao Network Overview. <https://alizila.oss-us-west-1.aliyuncs.com/uploads/2016/09/Cainiao-Factsheet.pdf>. [Accessed 20-02-2025].
- Frank Calviño. Parcel Lockers in Europe 2025: Adoption, Growth, and E-commerce Impact. 2025. URL <https://cross-border-magazine.com/parcel-lockers-in-europe-2025/>.
- Pierre Camilleri, Laetitia Dablang, and MetroFreight (Volvo Center for Excellence). Assessing the Competitiveness of Electric Vehicles for Last Mile Deliveries, 2016. URL <https://rosap.ntl.bts.gov/view/dot/68820>.
- Christopher Carey. Barcelona to impose public space tax on delivery firms - Cities Today. <https://cities-today.com/barcelona-to-impose-public-space-tax-on-delivery-firms/>, 2022. [Accessed 11-10-2024].
- CatalanNews. Catalonia’s High Court suspends Barcelona’s ‘Amazon Tax’ on delivery companies. <https://www.catalannews.com/business/item/catalonias-high-court-suspends-barcelonas-amazon-tax-on-delivery-companies>, 2024. [Accessed 10-12-2024].

- Phil Charlton. Navigating logistics for the paris olympics 2024. <https://denholmgoodlogistics.com/navigating-logistics-for-the-paris-olympics-2024/>, 2024. [Accessed 20-12-2024].
- Ke Chen. Feasibility of zero emission freight zones: Scenario analysis and risk assessment, 2024. URL <https://wri.org.cn/en/research/feasibility-of-zero-emission-freight-zones-in-Beijing-Scenario-analysis-and-risk-as>
- Zuzanna Chmielewska. Dublin to revolutionise kerbside management with AppyWay. <https://appyway.com/blog/govtech/dublin-revolutionise-kerbside-management/>, 2022. [Accessed 28-10-2024].
- Cipio-Partners. Cipio Partners invests in La Ruche Qui Dit Oui! News - April, 2021. <https://www.cipiopartners.com/n-2021-04-21.html>, 2021. [Accessed 15-10-2024].
- cities-for mobility.net. Parkunload smart regulation and control of loading and unloading parking areas. <https://www.cities-for-mobility.net/wp-content/uploads/2017/11/Carles-Sentis-PARKUNLOAD-IoT-urban-freight-parking-regulatory-platform-v1.pdf>, 2022. [Accessed 28-10-2024].
- City of Milan. Zero emission goods transportation in milan: Pilot findings report. <https://www.c40knowledgehub.org/s/article/Zero-emission-goods-transportation-in-Milan-Pilot-findings-report>, 2023. [Accessed 11-10-2024].
- City of Rotterdam. Moving towards zero emission city logistics (zecl) in rotterdam in 2025, 2019. URL <https://s3.eu-central-1.amazonaws.com/z3r2zxopa4uuqpw5a4ju/logistiek010/files/Roadmap%20ZECL.pdf>.
- City of Rotterdam. Zero emission city logistics rotterdam, 2020. URL <https://logistiek010.nl/app/uploads/2022/03/Covenant-Zero-Emission-City-Logistics-Rotterdam.pdf>.
- City of Rotterdam. State of zecl.progress of zero emission city logistics in rotterdam 2021., 2021. URL https://logistiek010.nl/app/uploads/2021/12/GMR049_Logistiek010_Stand_van_ZES_v12_ENG-4.pdf.
- Ciudad de México. BOL: PUBLICA SEMOVI MODIFICACIÓN A LOS HORARIOS DE CIRCULACIÓN Y MANIOBRAS DE VEHÍCULOS DE TRANSPORTE DE CARGA EN EL PERÍMETRO “A” DEL CENTRO HISTÓRICO. <https://semovi.cdmx.gob.mx/comunicacion/nota/bol-publica-semovi-modificacion-los-horarios-de-circulacion-y-maniobras-de-vehiculos>, 2021. [Accessed 11-10-2024].
- CIVITAS. CASE STUDY: Antwerp Sustainable Urban Logistics Planning. https://fasttrackmobility.eu/fileadmin/user_upload/Resources/Case_Studies/FastTrack-case-study-Antwerp.pdf, 2023a. [Accessed 01-03-2025].
- CIVITAS. Sustainable and Clean Urban Logistics. https://fasttrackmobility.eu/fileadmin/user_upload/Resources/FactSheets/FastTrack-FactSheet-1-sustainable-and-clean-urban-logistics.pdf, 2023b. [Accessed 01-03-2025].

- CIVITAS. Five CIVITAS Cities Successfully Conclude First Demonstration of Zero-Emission Logistics — CIVITAS. <https://civitas.eu/news/five-civitas-cities-successfully-conclude-first-demonstration-of-zero-emission-logistics>, 2025. [Accessed 06-08-2025].
- Dave Clark. Solar power delivers a win-win-win. <https://www.aboutamazon.com/news/sustainability/solar-power-delivers-a-win-win-win>, 2017. [Accessed 18-02-2025].
- Dave Colon. Hubba Lubba Dub Dub: DOT Announces Micro Delivery Hubs To Start This Summer - Streetsblog New York City. <https://nyc.streetsblog.org/2023/04/07/hubba-lubba-dub-dub-dot-announces-micro-delivery-hubs-to-start-this-summer>, 2023. [Accessed 16-02-2025].
- Alfonso L. Congostrina. La justicia tumba la ‘tasa amazon’ que aprobó el ayuntamiento de barcelona. URL <https://elpais.com/espana/catalunya/2024-07-23/el-tsjc-declara-nula-la-tasa-amazon-del-ayuntamiento-de-barcelona.html>.
- Alison Conway, Jialei Cheng, Camille Kamga, and Dan Wan. Cargo cycles for local delivery in new york city: Performance and impacts. *Research in transportation business & management*, 24:90–100, 2017.
- CORDIS. Smart Loading Zones in EU and Global market to regulate, control and monitor City Logistics - Last Mile Delivery in dense urban areas, based on Bluetooth devices and mobile apps for commercial drivers — H2020 — CORDIS — European Commission. <https://cordis.europa.eu/project/id/886990/reporting>, 2019. [Accessed 28-10-2024].
- de la Osa López Cristina. Four Pilots to Improve Logistics Across Europe Within the FlexCurb Project - CARNET Barcelona. <https://carnetbarcelona.com/four-pilots-to-improve-logistics-across-europe-within-the-flexcurb-project/>, 2022. [Accessed 21-10-2024].
- Cailin Crowe. Dhl pilots e-cargo bikes in miami to reduce congestion, pollution. https://www.supplychaindive.com/news/miami-e-cargo-bike-pilot-dhl-city-congestion-pollution/578137/?utm_source=chatgpt.com, 2020. [Accessed 20-06-2024].
- CurbIQ. Dublin Digital Mapping and Management of the Kerbside — curbiq.io. <https://www.curbiq.io/projects/dublin-digital-mapping-and-management-of-the-kerbside>, 2023. [Accessed 28-10-2024].
- Laetitia Dablanc. E-commerce trends and implications for urban logistics. *Urban logistics: Management, policy, and innovation in a rapidly changing environment*, pages 167–189, 2019.
- Laetitia Dablanc. Recent trends in last mile logistics solutions around the world. In *TRB 2020, Freight Day Topic 2 Sustainable and Efficient Solutions for Last Mile Distribution*, page 19p, 2020.
- Laetitia Dablanc. Tax on e-commerce delivery companies in barcelona, spain. <https://www.lvmt.fr/wp-content/uploads/2019/10/Taxe-sur-les-expressistes-du-B2C-a-Barcelone-ENGLISH.pdf>, 2023. [Accessed 11-10-2024].

Laetitia Dablanc. Les livreurs des plateformes : Résultats de recherche. Séminaire ELUE, Université Gustave Eiffel, mar 2025a. URL https://elue.univ-gustave-eiffel.fr/fileadmin/contributeurs/ELUE/Seminaire_mars25/ELUE_250325_Dablanc.pdf. Séminaire ELUE — 25 March 2025.

Laetitia Dablanc. Zones à faibles émissions et zones à zéro émission en europe : comment structurent-elles la logistique urbaine ?, 2025b. URL <https://www.lvmt.fr/wp-content/uploads/2025/01/Seminaire-ZFE-16-janvier-2025.pdf>. Séminaire ZFE, présentation (diaporama).

Laetitia Dablanc and Francois Adoue. New ways of collecting urban freight traffic data and applications for urban freight policies and research. 19:101315, 2025. ISSN 2213-624X. doi: 10.1016/j.cstp.2024.101315. URL <https://www.sciencedirect.com/science/article/pii/S2213624X24001706>.

Laetitia Dablanc and Antoine Montenon. Impacts of Environmental Access Restrictions on Freight Delivery Activities: Example of Low Emissions Zones in Europe. 2478(1): 12–18, 2015. ISSN 0361-1981. doi: 10.3141/2478-02. URL <https://doi.org/10.3141/2478-02>.

Laetitia Dablanc, A. Aguiléra, C. Krier, F. Adoué, and N. Louvet. Enquête : Les livreurs des plateformes de livraison instantanée (quart nord-est de paris) – version 2. Rapport / enquête, Université Gustave Eiffel – Chaire Logistics City; 6t – bureau de recherche; Projet ANR MOBS, Paris, 2022. URL <https://drive.google.com/file/d/1qVlwVDfsiTV2TY-aDf5o-QPs9fHNKis1/view>. Fichier PDF: Chaire Logistics City_6t Enquête livreurs 2022_V2.pdf.

Jack Daleo. Uber Eats, Cartken bring robot delivery to Miami. <https://www.freightwaves.com/news/uber-eats-cartken-bring-robot-delivery-to-miami>, 2022. [Accessed 05-09-2024].

Giacomo Dalla Chiara, Klaas Fiete Krutein, Andisheh Ranjbari, and Anne Goodchild. Providing curb availability information to delivery drivers reduces cruising for parking. 12:19355, 2022. ISSN 2045-2322. doi: 10.1038/s41598-022-23987-z. URL <https://pmc.ncbi.nlm.nih.gov/articles/PMC9652335/>.

Diaz de mera David. Hubs for Last Mile Delivery Solutions (Project HALLO) - Cenit — Science for Transport. <https://cenit.es/hubs-for-last-mile-delivery-solutions-project-hallo/>, 2021. [Accessed 16-02-2025].

Ciudad de México. Reglamento de tránsito de la ciudad de méxico. <https://www.ssc.cdmx.gob.mx/storage/app/media/Transito/Actualizaciones/Reglamento-de-Transito-CDMX.pdf>, 2015. Publicado en la Gaceta Oficial del Distrito Federal el 17 de agosto de 2015; última reforma publicada el 26 de noviembre de 2024.

Delivery Solutions. Delivery Solutions — Omnichannel Digital Fulfillment Platform. <https://deliverysolutions.co/>, 2025. [Accessed 11-04-2025].

DHL. Dhl and reef technology launch pilot to use ecofriendly cargo bikes for deliveries in downtown miami. <https://www.dhl.com/us-en/home/press/press-archive/2020/dhl-and-reef-technology-launch-pilot-to-use-ecofriendly-cargo-bikes-for-deliveries.html>, 2020. [Accessed 11-8-2024].

Caleb Diehl, Andisheh Ranjbari, and Anne Goodchild. Curbspace Management Challenges and Opportunities from Public and Private Sector Perspectives. 2675(11):1413–1427, 2021. ISSN 0361-1981, 2169-4052. doi: 10.1177/03611981211027156. URL <https://journals.sagepub.com/doi/10.1177/03611981211027156>.

Iulian Dnistran. Rivian Has Delivered Over 20,000 Electric Vans To Amazon So Far — insideevs.com. <https://insideevs.com/news/745106/rivian-amazon-edv-delivery-update/>, 2024. [Accessed 20-02-2025].

Anna J. Dreischerf and Paul Buijs. How Urban Consolidation Centres affect distribution networks: An empirical investigation from the perspective of suppliers. 10(1):518–528, 2022. ISSN 2213-624X. doi: 10.1016/j.cstp.2022.01.012. URL <https://www.sciencedirect.com/science/article/pii/S2213624X22000128>.

Anna Edwards. Stay Compliant with ULEZ, LEZ & CCZ – ABAX Geofences. <https://www.abax.com/en-gb/blog/cut-ulez-fines-with-predefined-geofences-from-abax>, 2025. [Accessed 10-08-2025].

Sam Edwards. Barcelona ‘Pioneering’ Delivery Tax On E-Commerce Giants in 2023. <https://news.bloombergtax.com/daily-tax-report-international/barcelona-pioneering-delivery-tax-on-e-commerce-giants-in-2023>, 2022. [Accessed 10-12-2024].

EGUM. Sustainable urban logistics planning (sulp): Recommendations on urban logistics, 2024. URL https://transport.ec.europa.eu/document/download/b818ff86-2463-4949-9413-d3ca559f60b9_en.

EIT. Hubs for Last Mile Delivery Solutions. <https://www.eiturbanmobility.eu/projects/hubs-for-last-mile-delivery-solutions/>, 2021. [Accessed 16-02-2025].

EIT. Flexcurb project. <https://www.eiturbanmobility.eu/projects/flexcurb/>, 2022. [Accessed 21-10-2024].

EIT Urban Mobility. Shared micro depots for urban pickup and delivery (s.m.u.d.): Compilation of different micro depot solutions, 2020. URL https://www.eit.europa.eu/sites/default/files/compilation_of_different_micro_depot_solutions_new_template.pdf.

EITUrbanMobility. Smart point’s last-mile solution delivers sustainability in madrid. <https://www.eiturbanmobility.eu/impact-stories/smart-points-last-mile-solution-delivers-sustainability-in-madrid/>, 2023. [Accessed 20-08-2025].

Jonas Eliasson. The Stockholm congestion charges: An overview. 2014.

energia Barcelona. Promoting safer, more efficient and sustainable goods distribution in the city — Energia Barcelona — Barcelona City Council. <https://www.energia.barcelona/en/news/promoting-safer-more-efficient-and-sustainable-goods-distribution-in-the-city-11457>, 2022. [Accessed 20-11-2024].

Valeska Engesser, Evy Rombaut, Lieselot Vanhaverbeke, and Philippe Lebeau. Autonomous Delivery Robots for Urban Last-mile Logistics Operations: A modified UTAUT framework. 72:1816–1823, 2023. ISSN 2352-1465. doi: 10.1016/j.

- trpro.2023.11.658. URL <https://www.sciencedirect.com/science/article/pii/S2352146523009560>.
- ERGP. ERGP Report on access to the postal network in a context of booming e-commerce, 2022. URL <https://search.yahoo.com/search?fr=mcafee&type=E210US91082G0&p=ERGP+Report+on+access+to+the+postal+network+in+a+context+of+booming+e-commerce>. Accessed 18-02-2025.
- ERTRAC. New mobility services roadmap. <https://www.ertrac.org/wp-content/uploads/2022/07/ERTRAC-New-Mobility-Roadmap-V4.pdf>, 2021. [Accessed 06-11-2024].
- EU-Mobility. Urban Vehicle Access Regulations. https://transport.ec.europa.eu/transport-themes/urban-transport/urban-vehicle-access-regulations_en, 2022. [Accessed 04-12-2024].
- Mustafa Fardin. When Convenience Comes with Carbon: A Simulation of Urban Parcel Locker Impacts in the Last Mile - J. Jeffrey and Ann Marie Fox Graduate School at Penn State. <https://gradschool.psu.edu/student-support/professional-development/graduate-exhibition/graduate-exhibition-listings/when-convenience-comes-with-carbon-a-simulation-of-urban-parcel-locker-impacts-in-t> 2025. [Accessed 20-07-2025].
- France-ServicePublic. Restrictions de circulation des voitures Crit'air 3 en 2025: quelles agglomérations sont concernées? <https://www.service-public.fr/particuliers/actualites/A17253>, 2024. [Accessed 04-12-2024].
- Travis Fried and Anne Goodchild. E-commerce and logistics sprawl: A spatial exploration of last-mile logistics platforms. 112:103692, 2023. ISSN 0966-6923. doi: 10.1016/j.jtrangeo.2023.103692. URL <https://linkinghub.elsevier.com/retrieve/pii/S0966692323001643>.
- Tom Fucoloro. In a return to its 1907 roots, UPS will deliver by cargo bike in downtown Seattle. <https://www.seattlebikeblog.com/2018/10/25/in-a-return-to-its-1907-roots-ups-will-deliver-by-cargo-bike-in-downtown-seattle/>, 2018. [Accessed 24-06-2024].
- Ben Furnas. Vital City — Congestion Pricing Lessons from London and Stockholm. <https://www.vitalcitynyc.org/articles/how-london-and-stockholm-made-congestion-pricing-politics-work>, 2024. [Accessed 11-10-2024].
- Sandra Milena Alvarez Gallo, Jacobo Hernan Echavarria Cuervo, and Julien Maheut. Analysis and strategies for urban freight logistics in a low emission zone. 17(2):403–423, 2024. ISSN 2013-0953. doi: 10.3926/jiem.6902. URL <https://www.jiem.org/index.php/jiem/article/view/6902>.
- Max Garland. New York City to test local delivery hubs — supplychaindive.com. <https://www.supplychaindive.com/news/new-york-city-local-delivery-hubs-transportation-department/647742/>, 2023. [Accessed 16-02-2025].

Max Garland. Amazon launches same-day drone delivery in Arizona city. <https://www.grocerydive.com/news/amazon-launches-same-day-drone-delivery-tolleson-arizona/732420/>, 2024. [Accessed 22-02-2025].

Max Garland. Veho, GLS US launch parcel delivery services in new markets. <https://www.supplychaindive.com/news/veho-gls-us-delivery-coverage-expansion/753587/>, 2025. [Accessed 06-05-2025].

Ada Garus, Panayotis Christidis, Andromachi Mourtzouchou, Louison Duboz, and Biagio Ciuffo. Unravelling the last-mile conundrum: A comparative study of autonomous delivery robots, delivery bicycles, and light commercial vehicles in 14 varied European landscapes. 108:105490, 2024. ISSN 22106707. doi: 10.1016/j.scs.2024.105490. URL <https://linkinghub.elsevier.com/retrieve/pii/S2210670724003172>.

Carla Giaume. Valencia’s eco-friendly delivery pilot will reduce CO2 emissions and fossil fuel trips in Last Mile Logistics. <https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/valencias-eco-friendly-delivery-pilot-will-reduce-co2-emissions-and-fossil-fuel-trips>, 2024. [Accessed 05-01-2025].

Carla Giaume. GREEN-LOG pilots show strong results for zero-emission urban logistics. https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/green-log-pilots-show-strong-results-zero-emission-urban-logistics-2025-07-21_en, 2025. [Accessed 06-08-2025].

Henrik Gillström and Maria Björklund. Assessing the benefits of urban consolidation centres: An overview based on a systematic literature review. 44(5):972–991, 2024. ISSN 0144-1647. doi: 10.1080/01441647.2024.2348639. URL <https://doi.org/10.1080/01441647.2024.2348639>.

Lisa Goldapple. A taste for shopping local — Atlas of the Future. <https://atlasofthefuture.org/project/la-ruche-qui-dit-oui/>, 2020. [Accessed 15-10-2024].

Juan Nicolas Gonzalez, Laura Garrido, and Jose Manuel Vassallo. Exploring stakeholders’ perspectives to improve the sustainability of last mile logistics for e-commerce in urban areas. 49:101005, 2023. ISSN 2210-5395. doi: 10.1016/j.rtbm.2023.101005. URL <https://www.sciencedirect.com/science/article/pii/S2210539523000639>.

Anne V. Goodchild. Cargo e-bike delivery pilot test in seattle. <https://depts.washington.edu/trac/research-news/freight/cargo-e-bike-delivery-pilot-test-in-seattle/>, 2020. [Accessed 26-06-2024].

GREEN-LOG. About GREEN-LOG Project. <https://greenlog-project.eu>, 2023. [Accessed 06-08-2025].

Johannes Gruber. Results and learnings from Europe’s largest cargo bike testing program for companies and public institutions. 79:146–153, 2024. ISSN 2352-1465. doi: 10.1016/j.trpro.2024.03.021. URL <https://www.sciencedirect.com/science/article/pii/S2352146524001649>.

Johannes Gruber, Alexander Kihm, and Barbara Lenz. A new vehicle for urban freight? An ex-ante evaluation of electric cargo bikes in courier services. *Research in Transportation Business & Management*, 11:53–62, 2014. ISSN 2210-5395. doi: 10.1016/j.rtbm.2014.03.004. URL <https://www.sciencedirect.com/science/article/pii/S2210539514000091>.

Seyma Gunes, Travis Fried, and Anne Goodchild. Seattle microhub delivery pilot: Evaluating emission impacts and stakeholder engagement. 15:101119, 2024. ISSN 2213-624X. doi: 10.1016/j.cstp.2023.101119. URL <https://www.sciencedirect.com/science/article/pii/S2213624X23001736>.

Uma Gupta. Flipkart to deploy 400 electric cargo vehicles for delhi ncr. <https://www.pv-magazine-india.com/2022/09/12/flipkart-to-deploy-400-electric-cargo-vehicles-for-delhi-ncr/>, 2022. [Accessed 12-06-2024].

Haropa Port. Parisian cafés now delivered by river. <https://www.haropaport.com/en/news/parisian-cafes-now-delivered-river>, 2023. [Accessed 29-02-2025].

Bernadette Heier. Starship Delivery Bots Head to New U.S. Campuses — Food On Demand — foodondemand.com. <https://foodondemand.com/08212024/starship-delivery-bots-head-to-new-u-s-campuses/>, 2024. [Accessed 14-02-2025].

Jose Holguin-Veras, Stacey Hodge, Jeffrey Wojtowicz, Caesar Singh, Cara Wang, Miguel Jaller, Felipe Aros-Vera, Kaan Ozbay, Andrew Weeks, Michael Replogle, Charles Ukegbu, Jeff Ban, Matthew Brom, Shama Campbell, Ivan Sanchez-Diaz, Carlos Gonzalez-Calderon, Alain Kornhauser, Mark Simon, Susan McSherry, Asheque Rahman, Trilce Encarnacin, Xia Yang, Diana Ramirez-Rios, Lokesh Kalahasthi, Johanna Amaya, Michael Silas, Brandon Allen, and Brenda Cruz. The New York City Off-Hour Delivery Program: A Business and Community-Friendly Sustainability Program. 48 (1):70–86, 2018. ISSN 0092-2102. URL <https://www.jstor.org/stable/48747871>.

Amanda Howell, Becky Steckler, Nico Larco, and Knight Autonomous Vehicle Initiative. Piloting sidewalk Delivery Robots in Pittsburgh, Miami-Dade County, Detroit, and San Jose, 2022. URL <https://hdl.handle.net/1794/28377>.

IAIDL. Google alum startup cartken and reef technology launch miami’s first delivery robots - iaidl. <https://iaidl.org/2021/03/31/google-alum-startup-cartken-and-reef-technology-launch-miamis-first-delivery-robots>, 2022. [Accessed 01-07-2024].

ICLEI. ICLEI Europe: Clean fleets Projects. https://iclei-europe.org/projects/?Clean_Fleets_Project_=&projectID=1vqhHyCm&, 2012. [Accessed 14-12-2024].

Incisiv. Catalyzing Growth: How Last-Mile Delivery Drives Revenue, Boosts Loyalty, and Enhances the Bottom-Line. <https://www.businesswire.com/news/home/20240417600118/en/Incisiv-and-Veho-Study-Highlights-Last-Mile-Delivery-as-Key-to-Future-Retail-Growth>, 2024. [Accessed 06-08-2025].

Investors. You can buy rivian’s van, but don’t come a knockin’, analyst warns. https://www.investors.com/news/rivian-van-available-mounting-risks-for-the-stock/?utm_source=chatgpt.com, 2025. [Accessed 25-04-2025].

- ipc.be. Delivery choice - Parcel lockers — ipc.be. <https://www.ipc.be/sector-data/e-commerce/articles/2020-parcel-lockers>, 2020. [Accessed 22-02-2025].
- ITF. The Final Frontier of Urban Logistics: Tackling the Last Metres, 2024a.
- ITF. Urban Logistics Hubs: Summary and Conclusions, 2024b.
- ITS. Results of a test of a new urban goods delivery strategy. <https://www.itskrs.its.dot.gov/2019-b01431>, 2019. [Accessed 20-08-2025].
- Jasmijn. Barcelona to tax logistics companies. <https://ecommercenews.eu/barcelona-to-tax-logistics-companies/>, 2023. [Accessed 11-10-2024].
- Dylan Jennings and Miguel Figliozi. Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel. 2673(6):317–326, 2019. ISSN 0361-1981. doi: 10.1177/0361198119849398. URL <https://doi.org/10.1177/0361198119849398>.
- Lingzhi Jin and Yidan Chu. ASSESSMENT OF NEW ENERGY COMMERCIAL VEHICLE POLICIES, 2023. URL https://theicct.org/wp-content/uploads/2023/07/Commercial-vehicles-China_report_final.pdf.
- Ron Johnson. Paris to transition to cargo bike delivery During and After Olympic Games — momentummag.com. <https://momentummag.com/paris-to-transition-to-cargo-bike-delivery-during-and-after-olympic-games/>, 2024. [Accessed 08-01-2025].
- Gabin Jouquan. Micro-hubs logistique à Paris : le bilan — sogaris.fr. <https://www.sogaris.fr/publication/micro-hubs-logistique/>, 2022. [Accessed 16-02-2025].
- Daniel Jurburg, Agustina López, Isabella Carli, Mario Chong, Leise Kelli De Oliveira, Laetitia Dabanc, Martín Tanco, and Paulo Renato De Sousa. Understanding the Challenges Facing Decarbonization in the E-Commerce Logistics Sector in Latin America. 15(22):15718, 2023. ISSN 2071-1050. doi: 10.3390/su152215718. URL <https://www.mdpi.com/2071-1050/15/22/15718>.
- Andreas Karaoulanis. The Role of Micro Fulfilment Centers in Alleviating, in a Sustainable Way, the Urban Last Mile Logistics Problem: A Systematic Literature Review. 16(20):8774, 2024. ISSN 2071-1050. doi: 10.3390/su16208774. URL <https://www.mdpi.com/2071-1050/16/20/8774>.
- Konstantina Katsela, Şeyma Güneş, Travis Fried, Anne Goodchild, and Michael Browne. Defining Urban Freight Microhubs: A Case Study Analysis. 14(1):532, 2022. ISSN 2071-1050. doi: 10.3390/su14010532. URL <https://www.mdpi.com/2071-1050/14/1/532>.
- Sai Keerthi. Method to manage: How flipkart charts fleet electrification within its supply chain. <https://yourstory.com/2025/05/walmart-flipkart-charts-last-mile-ev-fleet-electrification-nishant-gupta>, 2025. [Accessed 28-05-2025].
- Haye Kesteloo. Amazon’s Prime Air: Progress Meets Reality In Drone Delivery — dronexl.co. <https://dronexl.co/2024/12/20/amazons-prime-air-meets-reality-drone-delivery/>, 2024. [Accessed 19-01-2025].

- Maja Kiba-Janiak, Jakub Marcinkowski, Agnieszka Jagoda, and Agnieszka Skowrońska. Sustainable last mile delivery on e-commerce market in cities from the perspective of various stakeholders. literature review. 71:102984, 2021. ISSN 2210-6707. doi: 10.1016/j.scs.2021.102984. URL <https://www.sciencedirect.com/science/article/pii/S2210670721002705>.
- Maja Kiba-Janiak, Katarzyna Cheba, Magdalena Mucowska, Leise Kelli de Oliveira, Maja Piecyk, Pietro Evangelista, Günter Prockl, and Jagienka Rześny-Cieplińska. How to design a sustainable last-mile delivery and returns business model from E-Customers' expectations perspective? 56:101194, 2024. ISSN 2210-5395. doi: 10.1016/j.rtbm.2024.101194. URL <https://www.sciencedirect.com/science/article/pii/S2210539524000968>.
- Carolyn Kim and Saeed Kaddoura. Building healthy cities in the doorstep-delivery era, 2021. URL <https://www.pembina.org/pub/building-healthy-cities-doorstep-delivery-era>.
- Bram Kin and Hans Quak. The impacts of alternative last mile delivery networks: Exploring the options besides zero emission technology. 59:101303, 2025. ISSN 2210-5395. doi: 10.1016/j.rtbm.2025.101303. URL <https://www.sciencedirect.com/science/article/pii/S2210539525000185>.
- klimaoslo.no. A pioneering city for zero-emission heavy transport, 2024. URL <https://www.klimaoslo.no/rapport/oslo-pioneering-city-for-zero-emission-heavy-transport/summary-pioneering-city-zero-emission-heavy-transport/>.
- Marianne Knapskog and Michael Browne. Sensors securing sustainable digital urban logistics—A practitioner's perspective. 3, 2022. ISSN 2673-5210. doi: 10.3389/ffutr.2022.993411. URL <https://www.frontiersin.org/journals/future-transportation/articles/10.3389/ffutr.2022.993411/full>.
- Camille Krier, Laetitia Dabanc, Anne Aguiléra, and Nicolas Louvet. Sharing within the gig economy: The use of shared e-bikes by on-demand platform-based instant meal delivery workers in Paris. 10(4):2280–2289, 2022. ISSN 2213-624X. doi: 10.1016/j.cstp.2022.10.012. URL <https://linkinghub.elsevier.com/retrieve/pii/S2213624X22001985>.
- Lief Mattila Kristen Weeks. Minnesota Enacts Omnibus Tax Package and Retail Delivery Fee Legislation. <https://www.bdo.com/insights/tax/minnesota-enacts-omnibus-tax-package-and-retail-delivery-fee-legislation>, 2023. [Accessed 11-10-2024].
- Gaurav Kumar, Oqais Tanvir, Akhilesh Kumar, and Mohit Goswami. Optimal drone deployment for cost-effective and sustainable last-mile delivery operations. page itor.13527, 2024. ISSN 0969-6016, 1475-3995. doi: 10.1111/itor.13527. URL <https://onlinelibrary.wiley.com/doi/10.1111/itor.13527>.
- LaPoste-Groupe. Le groupe La Poste ouvre sa 3e ligne de livraison de colis par drone en France — La Poste Groupe. <https://www.lapostegroupe.com/fr/actualite/le-groupe-la-poste-ouvre-sa-3e-ligne-de-livraison-de-colis-par-drone-en-france>, 2024. [Accessed 12-10-2024].

- Alixan Lavorel. "parfois ça ne marche pas": la mairie de paris justifie le retrait de ses micro-entrepôts en bois, 2023. URL <https://www.bfmtv.com/paris/parfois-ca-ne-marche-pas-la-mairie-de-paris-justifie-le-demantelement-de-ses-micro-AN-202308250417.html>.
- Tomislav Letnik, Alessandro Farina, Matej Mencinger, Marino Lupi, and Stane Božičnik. Dynamic management of loading bays for energy efficient urban freight deliveries. 159: 916–928, 2018. ISSN 0360-5442. doi: 10.1016/j.energy.2018.06.125. URL <https://www.sciencedirect.com/science/article/pii/S0360544218311903>.
- Maria Lindholm and Michael Browne. Freight quality partnerships around the world, 2014. URL https://cite.rpi.edu/wp-content/uploads/Lindholm-Browne_CoE-SUFS_FQP-report-2014_Final_.pdf.
- Julie Littman. Uber eats, cartken debut autonomous robot delivery in miami area. <https://www.restaurantdive.com/news/uber-eats-cartken-autonomous-delivery-miami/638788/>, 2022. [Accessed 05-12-2024].
- Qiyu Liu, Ross McLane, Dave Mullaney, and Zhe Wang. Putting electric logistics vehicles to work in shenzhen. https://rmi.org/wp-content/uploads/dlm_uploads/2020/10/RMI_Summary-Volume_Putting-Electric-Logistics-Vehicles-to-Work_2020.pdf, 2020. [Accessed 28-11-2024].
- Katherine Long. Serious injuries at Amazon warehouses rose 15 <https://www.businessinsider.com/injury-rates-at-amazon-warehouses-rose-2021-2022-4>, 2022. [Accessed 18-02-2025].
- Ana Lumbreras. Efficient use of pavements for a more decarbonised Dublin — CIVITAS. <https://civitas.eu/news/efficient-use-of-pavements-for-a-more-decarbonised-dublin>, 2023. [Accessed 28-10-2024].
- Liliana Lyons, Angélica Lozano, Francisco Granados, and Alejandro Guzmán. Impacts of time restriction on heavy truck corridors: The case study of Mexico City. 102: 119–129, 2017. ISSN 0965-8564. doi: 10.1016/j.tra.2017.03.012. URL <https://www.sciencedirect.com/science/article/pii/S096585641530177>.
- Torrey Lyons and Noreen C. McDonald. Last-Mile Strategies for Urban Freight Delivery: A Systematic Review. 2677(1):1141–1156, 2023. ISSN 0361-1981, 2169-4052. doi: 10.1177/03611981221103596. URL <https://journals.sagepub.com/doi/10.1177/03611981221103596>.
- Stéphane Mandard. Hormis paris et lyon, aucune agglomération ne devra renforcer sa zone à faibles émissions, 2024. URL https://www.lemonde.fr/planete/article/2024/03/19/hormis-paris-et-lyon-aucune-agglomeration-ne-devra-renforcer-sa-zone-a-faibles-emis-6222931_3244.html. Article modifié le 20 mars 2024.
- Luca Mantecchini, Francesco Paolo Nanni Costa, and Valentina Rizzello. Last mile urban freight distribution: A modelling framework to estimate e-cargo bike freight attraction demand share. *Future Transportation*, 5(1):31, 2025. ISSN 2673-7590. doi: 10.3390/futuretransp5010031. URL <https://www.mdpi.com/2673-7590/5/1/31>.

Yves Le Marquand. French postal service adds new route for drone deliveries — Revolution.aero. <https://www.revolution.aero/news/2024/04/03/french-postal-service-adds-new-route-for-drone-deliveries/>, 2024. [Accessed 05-10-2024].

Francesco Marzolla, Matteo Bruno, Hygor Piaget Monteiro Melo, and Vittorio Loreto. Compact 15-minute cities are greener, 2024. URL <http://arxiv.org/abs/2409.01817>.

Jonathan Maus. Portland-made Truck Trike stars in UPS cargo delivery pilot program in Seattle. <https://bikeportland.org/2018/10/25/portland-made-truck-trike-stars-in-ups-cargo-delivery-pilot-program-in-seattle-2914~:text=In%20an%20effort%20to%20address%20growing%20traffic%20congestion,using%20pedal-assist%20cargo%20eBikes%20and%20customized%2C%20modular%20trailers.,> 2018. [Accessed 21-06-2024].

Thomas Maxner, Giacomo Dalla Chiara, and Anne Goodchild. The state of sustainable urban last-mile freight planning in the united states. 91(1):88–101, 2025. ISSN 0194-4363. doi: 10.1080/01944363.2024.2324096. URL <https://doi.org/10.1080/01944363.2024.2324096>.

Mayor of London. New report reveals the transformational impact of the expanded Ultra Low Emission Zone so far. <https://www.london.gov.uk/new-report-reveals-transformational-impact-expanded-ultra-low-emission-zone-so-far>, 2023. [Accessed 11-10-2024].

Andrew McLean. Jtc retail delivery fee analysis. <https://leg.wa.gov/media/t2njurog/retail-delivery-fee-6-18-24.pdf>, 2024. [Accessed 26-01-2025].

Sara Mecatti. Microhubs as the future of last-mile logistics. https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/microhubs-future-last-mile-logistics-2025-04-14_en, 2025. [Accessed 20-06-2025].

Sandra Melo, Flavia Silva, Mohammad Abbasi, Parisa Ahani, and Joaquim Macedo. Public Acceptance of the Use of Drones in City Logistics: A Citizen-Centric Perspective. 15(3):2621, 2023. ISSN 2071-1050. doi: 10.3390/su15032621. URL <https://www.mdpi.com/2071-1050/15/3/2621>.

Kalliopi Michalakopoulou, Emilia Vann Yaroson, and Ioannis Chatziioannou. Decoding cargo bikes’ potential to be a sustainable last-mile delivery mode: An operations management perspective. *Transportation Planning and Technology*, 48(4):712–734, 2025. ISSN 0308-1060. doi: 10.1080/03081060.2024.2375630. URL <https://doi.org/10.1080/03081060.2024.2375630>.

Minnesota-DOR. Retail Delivery Fee — Minnesota Department of Revenue. <https://www.revenue.state.mn.us/retail-delivery-fee>, 2025. [Accessed 20-07-2025].

Wassen AM Mohammad, Yousef Nazih Diab, Adel Elomri, and Chefi Triki. Innovative solutions in last mile delivery: Concepts, practices, challenges, and future directions. 24(2):151–169, 2023. ISSN 1625-8312. doi: 10.1080/16258312.2023.2173488. URL <https://doi.org/10.1080/16258312.2023.2173488>.

Nima Moradi, Chun Wang, and Fereshteh Mafakheri. Urban Air Mobility for Last-Mile Transportation: A Review. 6(3):1383–1414, 2024. ISSN 2624-8921. doi: 10.3390/vehicles6030066. URL <https://www.mdpi.com/2624-8921/6/3/66>.

Carlos Moreno. "The 15-Minute City": Redesigning urban life with proximity to services. (30), 2024. URL <https://hal.science/hal-04648637>.

Benjamin Motte-Baumvol and Laetitia Dablanc. The key role of motorized two-wheelers in boosting the earnings of on-demand delivery workers in Paris. 110:101545, 2025. ISSN 0739-8859. doi: 10.1016/j.retrec.2025.101545. URL <https://www.sciencedirect.com/science/article/pii/S0739885925000289>.

Magdalena Mucowska. Measuring Stakeholder Relations in Green Last-Mile Deliveries in the E-commerce Market in Cities. 68(5):69–80, 2024. ISSN 2392-0041. doi: 10.15611/pn.2024.5.06. URL <https://dbc.wroc.pl/publication/171268>.

Nelson. Delivery Microhub Feasibility Study. <https://ddot.dc.gov/sites/default/files/dc/sites/ddot/MWCOG%20Delivery%20Microhub%20Study%20Final%20Report.pdf>, 2023. [Accessed 17-02-2025].

Andreea Nistor and Eduard Zadobrischi. The Scale-Up of E-Commerce in Romania Generated by the Pandemic, Automation, and Artificial Intelligence. 5(3):680–705, 2024. ISSN 2673-4001. doi: 10.3390/telecom5030034. URL <https://www.mdpi.com/2673-4001/5/3/34>.

Interreg North Sea. Rotterdam connects with local businesses to share impacts of the new Zero-Emission Zone. <https://www.interregnorthsea.eu/gleam-nsr/news/rotterdam-connects-with-local-businesses-to-share-impacts-of-the-new-zero-emission>, 2025. [Accessed 20-06-2025].

novinite. Sofia's New Low-Emission Zone: What Drivers Need to Know - Novinite.com - Sofia News Agency. <https://www.novinite.com/articles/222704/Sofia%27s%2BNew%2BLow-Emission%2BZone%3A%2BWhat%2BDrivers%2BNeed%2Bto%2BKnow>, 2023. [Accessed 23-11-2024].

NYC-DOT. NYC DOT Proposing Rules to Authorize Local Delivery Hub Pilot to Combat Negative Environmental and Safety Effects of Truck Deliveries, Announces First Pilot Locations — nyc.gov. <https://www.nyc.gov/html/dot/html/pr2024/nyc-dot-proposing-rules-local-delivery-hub-pilot.shtml>, 2024a. [Accessed 16-02-2025].

NYC-DOT. NYC DOT to Provide New Incentives to Reduce Truck Deliveries During Busiest Hours and Fight Congestion. <https://www.nyc.gov/html/dot/html/pr2024/reduce-truck-deliveries.shtml>, 2024b. [Accessed 10-02-2025].

John Olsson, Daniel Hellström, and Henrik Pålsson. Framework of Last Mile Logistics Research: A Systematic Review of the Literature. 11(24):7131, 2019. ISSN 2071-1050. doi: 10.3390/su11247131. URL <https://www.mdpi.com/2071-1050/11/24/7131>.

OneMonitoring. LTA — ERP 2.0. <https://onemotoring.lta.gov.sg/content/onemotoring/home/driving/ERP/erp-2-0.html>, 2025. [Accessed 20-04-2025].

Veronica Oppici. Milan's regulatory approach to reducing logistics vehicles emissions, 2024. URL https://www.interregeurope.eu/sites/default/files/2024-09/Presentation%20by%20Veronica%20Oppici_AMAT%20Milano.pdf. Slide deck hosted by Interreg Europe.

Alex Oxford. Minnesota's Retail Delivery Fee Explained — TaxValet. <https://thetaxvalet.com/blog/minnesotas-retail-delivery-fee-explained>, 2024. [Accessed 11-10-2024].

- Jennifer O'Mahony. Spanish court: Amazon violated labor law with delivery app. <https://apnews.com/article/technology-amazoncom-inc-spain-madrid-business-9f51c1112f04bc55fb67d3248f42bafb>, 2023. last accessed- 2025-06-12.
- Daniela Paddeu. The future of last-mile deliveries: Understanding the local perspective, 2022. URL <https://www.local.gov.uk/publications/future-last-mile-deliveries-understanding-local-perspective>.
- Jacques Paquier. Paris expérimente avec Sogaris deux micro-hubs logistiques — lejournaldugrandparis.fr. <https://www.lejournaldugrandparis.fr/paris-experimente-avec-sogaris-deux-micro-hubs-logistiques/>, 2022. [Accessed 16-02-2025].
- parkunload.com. Smart loading or delivery zone. <https://www.parkunload.com/solutions/smart-loading-delivery-zone/>, 2022. [Accessed 28-10-2024].
- El País. La EMT colabora con la firma Encicle para fomentar el reparto de última milla en Valencia — elpais.com. <https://elpais.com/espana/comunidad-valenciana/2024-02-19/la-emt-colabora-con-la-firma-encicle-para-fomentar-el-reparto-de-ultima-milla-en-valencia.html>, 2024. [Accessed 12-01-2025].
- Katrina Perez. Reef technology, cartken announce arrival of self-driving delivery robots. <https://communitynewspapers.com/biscayne-bay/reef-technology-cartken-announce-arrival-of-self-driving-delivery-robots/>, 2021. [Accessed 30-06-2024].
- Jeremy Pession. *Analysing the impacts of technology in City Logistics projects*. PhD thesis, Politecnico di Torino, 2020.
- Lise Phan. Logistique urbaine et régulation publique: Zones à faibles émissions (zfe) et prémisses du zéro artificialisation nette (zan), quels enjeux pour la logistique ?, 2025. URL <https://www.lvmt.fr/wp-content/uploads/2025/01/Memoire-Phan-Cnam-LVMT-2024.pdf>. Comparative analysis of 37 European LEZs and implications for urban logistics.
- Paul Plazier, Ward Rauws, Robin Neef, and Paul Buijs. Towards sustainable last-mile logistics? Investigating the role of cooperation, regulation, and innovation in scenarios for 2035. 56:101198, 2024. ISSN 2210-5395. doi: 10.1016/j.rtbm.2024.101198. URL <https://www.sciencedirect.com/science/article/pii/S2210539524001007>.
- POLIS. FlexCURB project to enhance last-mile operations in four European cities - POLIS Network. <https://www.polisnetwork.eu/news/leuven-and-toulouse-to-flexcurb-project-kicks-off-polis-leuven-and-toulouse-involve>, 2022. [Accessed 21-10-2024].
- Nima Pourmohammadreza, Mohammad Reza Akbari Jokar, and Tom Van Woensel. Last-mile logistics with alternative delivery locations: A systematic literature review. 25: 104085, 2025. ISSN 2590-1230. doi: 10.1016/j.rineng.2025.104085. URL <https://www.sciencedirect.com/science/article/pii/S2590123025001732>.
- Stef Proost. Reforming Private and Public Urban Transport Pricing, 2018. URL https://www.oecd.org/en/publications/reforming-private-and-public-urban-transport-pricing_3567dda4-en.html.

PYMNTS. UPS Acquires SaaS Technology Company Delivery Solutions — PYMNTS.com. <https://www.pymnts.com/acquisitions/2022/ups-acquires-saas-technology-company-delivery-solutions/>, 2022. [Accessed 11-04-2025].

RailTarget. Strasbourg launches tram parcel transport experiment: A collaboration between la poste, alstom, and cts — railtarget. <https://www.railtarget.eu/passenger/strasbourg-launches-tram-parcel-transport-experiment-a-collaboration-between-la-poste-et-cts-entre-railtarget-et-la-poste-et-alstom-2024.html#:~:text=This%20project%20is%20the%20fruit%20of%20cooperation%20between,des%20Transports%20Strasbourgeois%20%28CTS%29%20as%20the%20network%20operator.,2024>. [Accessed 22-01-2025].

Chris Randall. Gebrüder Weiss introduces electric delivery fleet in Hungary - electrive.com — electrive.com. <https://www.electrive.com/2023/10/11/gebruder-weiss-introduces-electric-delivery-fleet-in-budapest/>, 2023. [Accessed 28-07-2024].

Chris Randall. EIB provides €69 million loan to EMT Valencia. <https://www.electrive.com/2025/01/06/eib-provides-e69-million-loan-to-emt-valencia/>, 2025. [Accessed 06-05-2025].

Andisheh Ranjbari, Caleb Diehl, Giacomo Dalla Chiara, and Anne Goodchild. Do parcel lockers reduce delivery times? Evidence from the field. 172:103070, 2023a. ISSN 13665545. doi: 10.1016/j.tre.2023.103070. URL <https://linkinghub.elsevier.com/retrieve/pii/S1366554523000583>.

Andisheh Ranjbari, Caleb Diehl, Giacomo Dalla Chiara, and Anne Goodchild. What is the Right Size for a Residential Building Parcel Locker? 2677(3):1397–1407, 2023b. ISSN 0361-1981. doi: 10.1177/03611981221123807. URL <https://doi.org/10.1177/03611981221123807>.

Abel K Reda. Planning logistics in ‘the 15-minute city’. https://www.lvmt.fr/wp-content/uploads/2025/02/Planning-logistics-in-15-minute-city_Fresh-Paris_Abel.pdf, 2025. [Accessed 26-08-2025].

Andreas Risberg and Hamid Jafari. Last mile practices in e-commerce: Framework development and empirical analysis of Swedish firms. 50(8/9):942–961, 2022. ISSN 0959-0552. doi: 10.1108/IJRDM-10-2021-0513. URL <https://www.emerald.com/insight/content/doi/10.1108/ijrdm-10-2021-0513/full/html>.

Hilman Rismanto and Loso Judijanto. Dynamic Routing in Urban Logistics: A Comprehensive Review of AI, Real-Time Data, and Sustainability Impacts. 3(2):68–79, 2025. ISSN 2988-6244. doi: 10.61194/sijl.v3i2.741. URL <https://journal.sinergi.or.id/index.php/ijl/article/view/741>.

Rafael Rosales. Is it enough to enable freight? Modes of governance for urban logistics in Norway. 32(12):2473–2492, 2024. ISSN 0965-4313. doi: 10.1080/09654313.2024.2372409. URL <https://doi.org/10.1080/09654313.2024.2372409>.

Sandra Rothbard, Paola Cossu, Fabio Cartolano, Philippe Rapin, Hernán Mejía, David García Rubio, and Raúl Urbano Escobar. Curbside Management: A Digital Solution Space Optimisation. In Ciaran McNally, Páraic Carroll, Beatriz Martinez-Pastor, Bidisha Ghosh, Marina Efthymiou, and Nikolaos Valantasis-Kanellos, editors, *Transport*

Transitions: Advancing Sustainable and Inclusive Mobility, pages 324–331. Springer Nature Switzerland, 2025. ISBN 978-3-031-95284-5. doi: 10.1007/978-3-031-95284-5_46.

Olivier ROUSSARD. La Poste et Atechsys ont ouvert une troisième ligne française de livraison de colis par drone, dans le Vercors — voxlog.fr. <https://www.voxlog.fr/actualite/8520/la-poste-et-atechsys-ont-ouvert-une-troisieme-ligne-francaise-de-livraison-de-colis> 2024. [Accessed 05-10-2024].

Gaetana Rubino, Domenico Gattuso, and Manfred Gronalt. Modeling the Interactions Between Smart Urban Logistics and Urban Access Management: A System Dynamics Perspective. 15(14):7882, 2025a. ISSN 2076-3417. doi: 10.3390/app15147882. URL <https://www.mdpi.com/2076-3417/15/14/7882>.

Gaetana Rubino, Domenico Gattuso, and Manfred Gronalt. Modeling the Interactions Between Smart Urban Logistics and Urban Access Management: A System Dynamics Perspective. 15(14):7882, 2025b. ISSN 2076-3417. doi: 10.3390/app15147882. URL <https://www.mdpi.com/2076-3417/15/14/7882>.

rupprecht consult. How to regulate vehicle access in urban areas: Guidance from the eu reveal project for cities putting in place access regulations. https://www.rupprecht-consult.eu/fileadmin/user_upload/D3.1_revised_ReVeAL_UVAR_guidance_complete_final2.pdf, 2022. [Accessed 06-11-2024].

RVO. Zero-emission zones in the Netherlands. <https://business.gov.nl/sustainable-business/sustainable-business-operations/zero-emission-zones-to-be-introduced-in-many-cities-from-2025/>, 2025. [Accessed 10-06-2025].

Ben Sampson. Amazon poised to launch European drone delivery service after Italy flight tests — Aerospace Testing International. <https://www.aerospacetestinginternational.com/news/amazon-poised-to-launch-european-drone-delivery-service-after-italy-flight-tests.html>, 2024. [Accessed 11-02-2025].

Mike Sanders. The Next Frontier in Sales Tax Compliance: Retail Delivery Fees — Sales Tax Institute. <https://www.salestaxinstitute.com/resources/the-next-frontier-in-sales-tax-compliance-retail-delivery-fees>, 2025. [Accessed 12-06-2025].

Hongyang Cui Sandra Wappelhorst. Update on zero-emission zone development progress in cities. <https://theicct.org/wp-content/uploads/2022/09/Global-ZEZs-update-09292022.pdf>, 2022. [Accessed 23-11-2024].

Uday Schultz Sandy Johnston. Memo: Scan of Integrating Transit and Truck Priority. <https://www.ctps.org/data/html/studies/other/Scan-of-Integrating-Transit-and-Truck-Priority/Scan-of-Integrating-Transit-and-Truck-Priority.html>, 2022. [Accessed 10-11-2024].

Sarah Sax. How Electric Bikes Can Cut Delivery Emissions in Cities. <https://time.com/6836113/electric-bikes-decarbonize-last-mile-delivery/>, 2024. [Accessed 04-05-2025].

SellerCommerce. 51 ECommerce Statistics In 2025 (Global And U.S. Data) — SellersCommerce, 2024. URL <https://www.sellerscommerce.com/blog/ecommerce-statistics/>.

Tom Selva. Madrid: Piloting a sustainable last-mile delivery system — marketplace.eiturbanmobility.eu. <https://marketplace.eiturbanmobility.eu/best-practices/madrid-piloting-a-sustainable-last-mile-delivery-system>, 2023. [Accessed 20-02-2025].

Senator. Building on Success: Senator’s Digital Kerbside Management. <https://www.senatorproject.eu/news-and-events/news/senator-digital-kerbside-management-dublin-urban-lab/>, 2024. [Accessed 28-10-2024].

Bhavna Singichetti, Jamie L. Conklin, Kristen Hassmiller Lich, Nasim S. Sabounchi, and Rebecca B. Naumann. Congestion Pricing Policies and Safety Implications: A Scoping Review. 98(6):754–771, 2021. ISSN 1099-3460. doi: 10.1007/s11524-021-00578-3. URL <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8545360/>.

SlimNaar. Slim naar Antwerpen. <https://www.slimnaarantwerpen.be/en/logistics/use-the-freight-route-planner-and-find-the-best-route>, 2024. [Accessed 02-03-2025].

Kristy Snyder and Kiran Aditham. 35 Top E-Commerce Statistics, 2023. URL <https://www.forbes.com/advisor/business/ecommerce-statistics/>.

Jana Sochor, Paul Fenton, de Aafke Bode, Mariona Conill de Azpiazu, Ruth Lamas Borraz, and Paco Gasparin. HALLO: Hubs for Last Mile Delivery Solutions in Barcelona and Stockholm. 72:3300–3307, 2023. ISSN 2352-1465. doi: 10.1016/j.trpro.2023.11.797. URL <https://www.sciencedirect.com/science/article/pii/S2352146523010955>.

Starship. National study of more than 7,000 college students shows delivery robots help students feel safer, skip fewer meals and improve their mental health - Starship Technologies: Autonomous robot delivery - The future of delivery - today! — starship.xyz. <https://www.starship.xyz/press/national-study-of-more-than-7000-college-students-shows-delivery-robots-help-studen> 2022. [Accessed 11-02-2025].

Starship. University Campuses - Starship Technologies: Autonomous robot delivery - The future of delivery - today! — starship.xyz. <https://www.starship.xyz/university-campuses/>, 2024. [Accessed 19-02-2025].

Brian Straight. UPS acquires last-mile tech provider Delivery Solutions. <https://www.freightwaves.com/news/ups-acquires-last-mile-tech-provider-delivery-solutions>, 2022. [Accessed 11-04-2025].

Anna Straubinger, Henri L.F. De Groot, and Erik T. Verhoef. E-commerce, delivery drones and their impact on cities. 178:103841, 2023. ISSN 09658564. doi: 10.1016/j.tra.2023.103841. URL <https://linkinghub.elsevier.com/retrieve/pii/S0965856423002616>.

- Jos Streng. Zero emission zones and sustainable city logistics in Rotterdam. <https://www.etp-logistics.eu/wp-content/uploads/2023/03/Zero-emission-zones-and-sustainable-city-logistics-in-Rotterdam-Jos-Streng-28-March.pdf>, 2023. [Accessed 14-12-2024].
- sznews.com. Meituan Introduces drone delivery to Hong Kong. https://www.szlhq.gov.cn/english/news/content/post_12087887.html, 2025. [Accessed 26-05-2025].
- TDA. Case studies: Deploying zero-emission vehicle infrastructure innovations to accelerate transportation decarbonization, 2022. URL <https://tda-mobility.org/wp-content/uploads/2022/11/Deploying-Zero-Emission-Vehicle-Infrastructure-FINAL-1.pdf>.
- TechNode-Feed. Meituan secures China's first nationwide drone delivery license, ramping up competition with Google Wing. <https://technode.com/2025/04/23/meituan-secures-chinas-first-nationwide-drone-delivery-license-ramping-up-competition>, 2025. [Accessed 12-06-2025].
- tecnomind. FlexCURB project to improve urban last-mile operations launched - FIT Consulting — fitconsulting.it. <https://www.fitconsulting.it/flexcurb-project-to-improve-urban-last-mile-operations-launched/>, 2022. [Accessed 21-10-2024].
- Tharsis Teoh, Maria Rodrigues, Jasper Tanis, ARNAUD BURGESS, Tom Zunder, Stefano Dondi, Giacomo Somma, Giacomo Lozzi, and Elpida Xenou. *Evaluation Report on Guidance Strategy and Business Models*. novelog, 2018. doi: 10.13140/RG.2.2.27476.01928.
- TfL. Successful start as Congestion Charge extends west. <https://tfl.gov.uk/info-for/media/press-releases/2007/february/successful-start-as-congestion-charge-extends-west>, 2007. [Accessed 10-11-2024].
- TfL. TfL requires suppliers to be for gold accredited from april 2024, ensuring safer fleet services across the capital. <https://tfl.gov.uk/info-for/media/press-releases/2024/january/tfl-requires-suppliers-to-be-for-gold-accredited-from-april-2024-ensuring-safer-fleet-services>, 2024. Last accessed 2025-09-10.
- TfL. Ultra Low Emission Zone. <https://tfl.gov.uk/modes/driving/ultra-low-emission-zone>, 2025b. [Accessed 06-08-2025].
- Walter Theseira. Congestion Control in Singapore, 2020. URL https://www.oecd.org/en/publications/congestion-control-in-singapore_7d266609-en.html.
- TRAC. Freight and Transit Lane Case Study — Washington State Transportation Center — depts.washington.edu. <https://depts.washington.edu/trac/research-news/freight/freight-and-transit-lane-case-study/>, 2020. [Accessed 10-11-2024].
- Polly Trottenberg. Off-hour deliveries overview. <https://www.nyc.gov/html/dot/downloads/pdf/off-hours-delivery-overview.pdf>, 2017. [Accessed 10-02-2025].
- Urban Radar. Smarter curbside planning for cities. <https://urbanradar.io/flex-curb/>, 2022. [Accessed 22-10-2024].

- urbanaccess.eu. Bucuresti (Bucharest) - lorry ban. <https://urbanaccessregulations.eu/countries-mainmenu-147/romania/bucuresti-bucharest>, 2020. [Accessed 10-02-2025].
- urbanaccess.eu. What are Low Emission Zones? <https://urbanaccessregulations.eu/low-emission-zones-main/what-are-low-emission-zones>, 2021. [Accessed 10-02-2025].
- urbanaccess.eu. London low emission zone. <https://urbanaccessregulations.eu/countries-mainmenu-147/united-kingdom-mainmenu-205/london>, 2022. [Accessed 04-12-2024].
- UrbanFreightLab. The Final 50 Feet of the Urban Goods Delivery System: Common Carrier Locker Pilot Test at the Seattle Municipal Tower, 2018. URL <https://urbanfreightlab.com/publications/the-final-50-feet-of-the-urban-goods-delivery-system-common-carrier-locker-pilot-t>
- UrbanFreightLab. Common Microhub (Seattle Neighborhood Delivery Hub). <https://urbanfreightlab.com/research-projects/common-microhub-seattle-neighborhood-delivery-hub/>, 2020a. [Accessed 17-02-2025].
- UrbanFreightLab. Freight and transit lane case study final report. <https://urbanfreightlab.com/wp-content/uploads/2023/04/SCTL-FAT-Lane-Report.pdf>, 2020b. [Accessed 10-11-2024].
- UrbanFreightLab. The Seattle Neighborhood Delivery Hub Pilot Project: An Evaluation of the Operational Impacts of a Neighborhood Delivery Hub Model on Last-Mile Delivery, 2021. URL <https://www.urbanfreightlab.com/publications/the-seattle-neighborhood-delivery-hub-pilot-project-an-evaluation-of-the-operationa>
- UrbanFreightLab. Cargo E-Bike Delivery Pilot Test in Seattle, 2024. URL <https://live-urbanfreightlab.pantheonsite.io/publications/cargo-e-bike-delivery-pilot-test-in-seattle/>.
- US-DOT. U.S. Department of Transportation, Climate Change Center Climate Strategies That Work: Off-Peak Delivery, 2025. URL </view/dot/79398>.
- Jan Van Belle, Paul Valckenaers, and Dirk Cattrysse. Cross-docking: State of the art. 40(6):827–846, 2012. ISSN 0305-0483. doi: 10.1016/j.omega.2012.01.005. URL <https://www.sciencedirect.com/science/article/pii/S0305048312000060>.
- Torey Van Oot. Minnesotans may see a 50 cent fee their next Amazon order. Here’s why. <https://www.axios.com/local/twin-cities/2024/06/30/amazon-fee-delivery-tax-minnesota-roads-50-cent>, 2024. [Accessed 11-10-2024].
- Veho. E-Commerce Shipping & Delivery Case Studies — Veho — shipveho.com. <https://www.shipveho.com/case-studies>, 2025. [Accessed 06-05-2025].
- Ville de Paris. Des expérimentations sur la logistique urbaine, 2025. URL <https://www.paris.fr/pages/des-experimentations-sur-la-logistique-urbaine-27710>. Page Focus , mise à jour.
- Bijoy Venugopal Vishnu Sreekumar, Arjun Paul. With electric vehicles, flipkart is making last-mile delivery sustainable in india. <https://stories.flipkart.com/flipkart-ebikes/>, 2019. [Accessed 29-06-2024].

visitoslo. Oslo toll ring / AutoPASS. <https://www.visitoslo.com/en/transport/by-car/toll-ring/>, 2024. [Accessed 11-10-2024].

VolvoTrucks. The rise of Low Emission Zones: what you need to know. <https://www.volvotrucks.com/en-en/news-stories/insights/articles/2025/may/the-rise-of-low-emission-zones--what-you-need-to-know.html>, 2025. [Accessed 20-07-2025].

Kaveh Waddell. We Tried Combining Amazon Deliveries with 'Amazon Day' Shipping. Often, It Didn't Work. - Consumer Reports. <https://www.consumerreports.org/money/shipping-delivery/amazon-day-shipping-often-doesnt-work-cr-found-a2391830571/>, 2023. [Accessed 04-03-2025].

Wayne-Schooling. New York City to Establish Truck Delivery Micro Zones. <https://www.ntassoc.com/new-york-city-to-establish-truck-delivery-micro-zones>, 2025. [Accessed 16-02-2025].

WEF. The future of the last-mile ecosystem. https://www3.weforum.org/docs/WEF_Future_of_the_last_mile_ecosystem.pdf, 2020. [Accessed 18-02-2025].

Zhu Wenqian. Getting a drone to deliver your coffee at the Great Wall! <https://technode.com/2025/04/23/meituan-secures-chinas-first-nationwide-drone-delivery-license-ramping-up-competition>, 2025. [Accessed 23-04-2025].

Margaret Wilson, Milena Janjevic, and Matthias Winkenbach. Modeling a time-differentiated policy for management of loading bays in urban areas. 45:100773, 2022. ISSN 2210-5395. doi: 10.1016/j.rtbm.2021.100773. URL <https://www.sciencedirect.com/science/article/pii/S2210539521001565>.

wirelesslogic. Smart Point — Much more than just smart lockers. <https://wirelesslogic.com/success-stories/smart-point>, 2022. [Accessed 20-02-2025].

World Economic Forum and Accenture. Transforming urban logistics: Sustainable and efficient last-mile delivery in cities. White paper / report, World Economic Forum, December 2024. URL https://reports.weforum.org/docs/WEF_Transforming_Urban_Logistics_2024.pdf. Published: 17 December 2024; in collaboration with Accenture.

WSP. Future Ready Kerbside: Creating Places That Put People First. <https://www.wsp.com/en-gb/insights/future-ready-kerbside-creating-places-that-put-people-first>, 2020. [Accessed 06-11-2024].

WSP-Sweden. Civitas-reveal milestone 10 – report market consultation on new technology, products and policy measures. https://civitas-reveal.eu/wp-content/uploads/2020/07/MS10_Consultation_Report-2-1.pdf, 2020. [Accessed 06-11-2024].

Zuopeng Xiao, James Wang, James Lenzer, and Yonghai Sun. Understanding the diversity of final delivery solutions for online retailing: A case of Shenzhen, China. 25:985–998, 2017. doi: 10.1016/j.trpro.2017.05.473.

Dingtong Yang and Michael F. Hyland. Electric vehicles in urban delivery fleets: How far can they go? 129:104127, 2024. ISSN 1361-9209. doi: 10.1016/j.trd.2024.104127. URL <https://www.sciencedirect.com/science/article/pii/S1361920924000841>.

- Dana Yanocha, Yeojin Kim, and Jacob Mason. The Opportunity of Low Emission Zones: A Taming Traffic Deep Dive Report, 2023. URL <https://itdp.org/wp-content/uploads/2023/02/ITDP-LEZ-Brief.pdf>.
- Janev Zlatin Dubarinov and Janev. Sofia: first low emission zone in Eastern Europe. <https://www.cleanairfund.org/news-item/sofia-first-low-emission-zone/>, 2023. [Accessed 23-11-2024].
- Thomas H Zunder. Integrating Urban Freight Transport measures in a Sustainable Urban Mobility/Logistics Plan. <https://programme2014-20.interreg-central.eu/Content.Node/SULPiTER/06-Tom-ZUNDER-SULPiTER-24.10.2018.pdf>, 2018. [Accessed 18-02-2025].
- Alim Buğra Çınar, Wout Dullaert, Markus Leitner, Rosario Paradiso, and Stefan Waldherr. The role of individual compensation and acceptance decisions in crowdsourced delivery. 169:104834, 2024. ISSN 0968-090X. doi: 10.1016/j.trc.2024.104834. URL <http://arxiv.org/abs/2305.01317>.