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Regulatory Enablers and Stakeholders' Acceptance in Defining Eco-Friendly Vehicle Logistics Solutions for Rome

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Abstract

Urban freight generates a disproportionate share of urban externalities, yet the large-scale integration of eco-friendly vehicles (EFVs) remains limited. Barriers include high capital costs, inadequate charging/refuelling infrastructure, and fragmented governance frameworks. This article examines how regulatory structures and stakeholder alignment shape EFV adoption in Rome, analysing two pilot solutions: (i) a shared hub for electric and hydrogen freight vehicles, and (ii) a cargo-bike programme combining service-trip separation with reverse logistics. The methodological approach integrates a structured review of recent scholarship—organised in line with PRISMA guidance and enriched with bibliometric analysis—with empirical insights from five Living Lab workshops involving logistics providers, energy firms, technology suppliers, and industry associations. The findings highlight that progress depends less on technological capability than on policy mixes matched to stakeholder incentives. For the hub, decisive factors include siting, governance, and scale, while for cargo-bikes, reliability of dispatch, remuneration models, and certified training are critical. The study concludes that Rome's path to freight decarbonisation requires regulatory and financial packages continuously tailored to actors' operational priorities and behavioural responses.

Keywords: eco-friendly vehicles; city logistics; regulation; stakeholder acceptance; charging hub; cargo bike; living lab

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1. Introduction

Urban freight flows are a major driver of negative externalities. They account for about 25% of urban CO_2 emissions and nearly half of local pollutant emissions [1,2]. Beyond emissions, freight operations contribute significantly to congestion, noise, and competition for scarce curb space. These issues are especially acute in last-mile deliveries, which have grown rapidly with e-commerce. Eco-friendly vehicles (EFVs)—including battery-electric vans, hydrogen fuel-cell trucks, and cargo-bikes—are widely regarded as a central pathway to reduce the environmental footprint of freight. They deliver measurable gains in air quality and noise reduction, with potential benefits for public health and

urban liveability. However, the transition from conventional diesel fleets to EFVs has been slower than technological progress alone would suggest. High upfront capital expenditure, uneven refuelling and recharging availability, grid capacity and siting constraints, and uncertainty about long-term technological viability all discourage adoption. In addition, regulatory frameworks remain fragmented, often designed for passenger mobility rather than for freight, and insufficiently coordinated across agencies to support freight-specific requirements [3]. The interplay between technology readiness, infrastructure deployment, and governance design thus remains a critical barrier to scale-up.

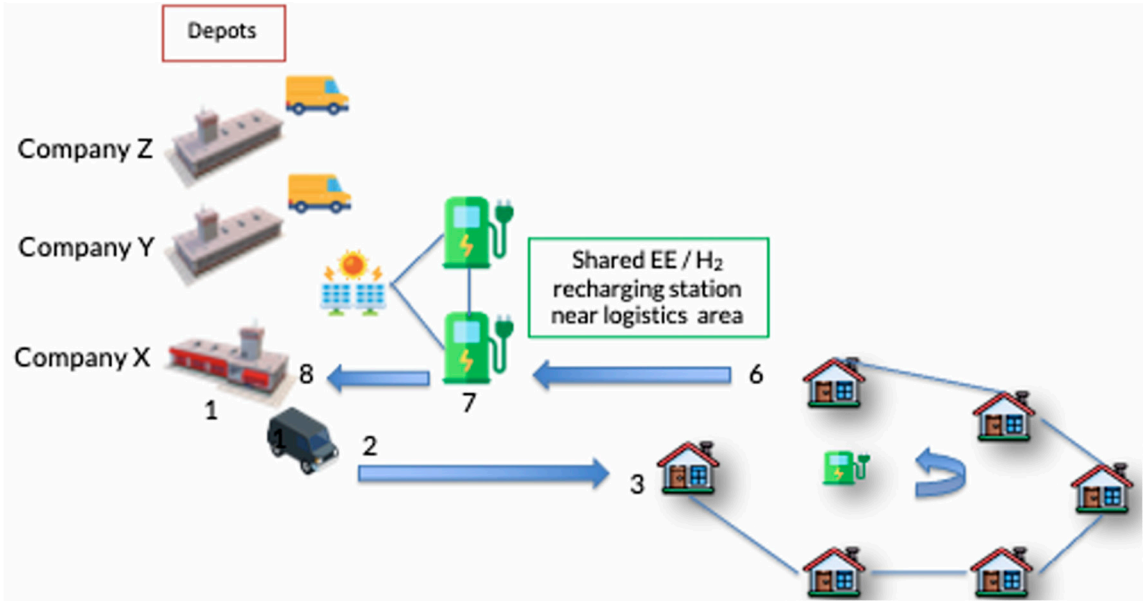
EFVs' adoption cannot be explained by technology alone. Decisions by logistics operators, manufacturers, consumers, and public authorities determine whether EFVs are integrated into daily operations. Operators evaluate vehicle choice through a total cost of ownership (TCO) lens that includes acquisition costs, maintenance, energy expenses, and productivity effects. Manufacturers weigh platform investments against anticipated demand signals and regulatory pressure. Consumers evaluate delivery services based on cost, reliability, and convenience. Public authorities must design and enforce policies within budgetary and institutional constraints [4]. The heterogeneity of these perspectives implies that effective governance must align multiple incentives, manage transaction costs, and anticipate behavioural responses—treating "acceptance" not as a residual barrier but as a strategic resource that can be built and steered over time.

The academic literature highlights that EFV deployment depends on multi-layered policy mixes rather than single interventions. Six regulatory domains appear consistently. First, access and zoning rules—such as low- or zero-emission zones (LEZs/ZEZs) and delivery time-window restrictions—provide strong compliance signals but may create equity challenges for small operators [5]. Second, fiscal and economic measures, including purchase subsidies, differentiated tolling, and favourable tax regimes, help reduce the cost gap between conventional and electric fleets [6]. Third, operational requirements, such as consolidation centres, minimum load-factor thresholds, and curb-space management, translate regulatory intent into day-to-day logistics decisions [7,8]. Fourth, smart-city and technology-oriented instruments leverage digitalisation—parking allocation systems, real-time traffic monitoring, and data-interoperability standards—to improve efficiency [5,9]. Fifth, environmental standards (e.g., Euro 6/7) and noise regulations steer industry investment towards cleaner technologies. Finally, collaborative governance mechanisms, including public–private partnerships (PPPs), create shared responsibility for infrastructure investment and risk management [10–13]. Taken together, the evidence suggests that carefully sequenced, cross-domain policy packages outperform isolated measures—particularly when access rules, fiscal incentives, and data-interoperability mandates are co-designed with infrastructure planning.

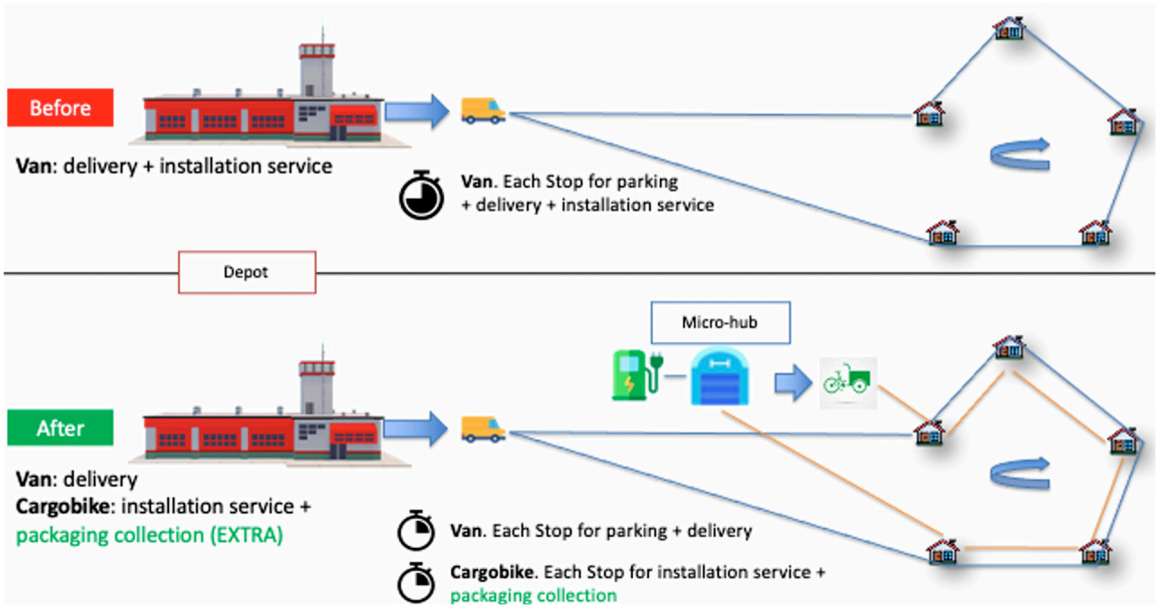
A second strand of literature examines stakeholder acceptance. Four actor groups dominate: policymakers, logistics operators, vehicle manufacturers, and consumers. Acceptance is increasingly conceptualised as an enabling governance resource, not simply a barrier. Yet misaligned incentives among these groups generate transaction costs and delay adoption. Policymakers focus on enforceability and fiscal neutrality; operators require cost parity and predictable performance; manufacturers demand stable demand signals to de-risk long-term platform development; and consumers only value "green" delivery options when service quality and price remain competitive [14–18]. Analytical models—ranging from discrete choice modelling to agent-based simulations—have begun to quantify these trade-offs, but comparable, context-rich empirical evidence on how specific regulatory levers shape actors' choices remains limited.

Rome offers a compelling testbed for studying these dynamics. The city faces persistent overlaps between passenger and freight peaks, fragmented governance structures, and

complex land-use constraints. Infrastructure provision is complicated by limited available space, multi-agency permitting, and uneven grid capacity across districts. Within this context, the PULSe project has co-developed two solutions. The first is a shared charging and refuelling hub for electric and hydrogen freight vehicles (Figure 1a). Its success depends on siting in areas with adequate grid connections, establishing neutral governance structures, and matching capacity with fleet demand profiles. The second is a cargo-bike scheme that separates service trips from delivery and integrates reverse logistics (Figure 1b). Its feasibility depends on digital dispatch platforms, remuneration models for riders, and certified training for handling diverse goods. Both solutions were shaped through stakeholder engagement, reflecting the city's operational realities and the literature's emphasis on multi-actor coordination.



(**a**)



(**b**)

Figure 1. (**a**) Graphic representation of Solution 1; (**b**) Graphic representation of Solution 2.

This study responds to convergent gaps identified in the review. First, it examines how the interaction between regulatory design and stakeholder acceptance conditions

EFV adoption in practice, moving beyond descriptive catalogues of measures to focus on how specific instruments map onto actors' incentive structures. Second, it identifies which regulatory and financial levers carry the greatest weight when translating the two Rome solutions from design into deployment. Then, the guiding research questions are: (RQ1) How do regulatory frameworks and stakeholder acceptance affect EFV uptake? and (RQ2) Which regulatory and financial instruments are most effective in catalysing the implementation of the two Rome-based solutions, considering stakeholder priorities? Addressing these questions advances the debate from general aspirations to implementable pathways, offering policy-relevant evidence for scaling eco-friendly freight solutions in complex urban contexts.

Methodologically, the paper combines a systematic literature review, conducted according to established reporting standards and complemented by bibliometric analysis, with empirical insights from a sequence of Living-Lab workshops involving logistics operators, energy providers, technology firms, and associations (details in Sections 2–4). This mixed approach is designed to bridge the persistent gap between generic policy menus and the operational thresholds that determine feasibility in practice. While the empirical base is necessarily bound to Rome and two solution archetypes, the analysis explicitly distinguishes context-specific constraints (e.g., local land-use and grid conditions) from more generalisable design principles (e.g., neutral governance, tariff setting, and dispatch reliability), thereby supporting cautious transferability to other cities.

This research's central scope is on identifying the regulatory and acceptance conditions that practitioners deem non-negotiable for implementation, rather than on estimating full welfare impacts ex ante. The discussion thus foregrounds sequencing of instruments, governance models, and behavioural thresholds (e.g., handover reliability and hub utilisation) that, if met, can unlock durable EFV uptake in everyday operations. Subsequent work will extend the empirical base and quantify trade-offs, but the present contribution is to articulate, with evidence from both the literature and stakeholders, how policy packages can be assembled to align heterogeneous incentives in the Rome context and beyond.

2. Materials and Methods

This research follows a two-phase methodological design. The first phase involved a structured review of the scientific literature to identify regulatory and stakeholder-related drivers of eco-friendly vehicle (EFV) adoption. The second phase complemented this with empirical validation through a series of Living Lab workshops held in Rome. The combination ensures that theoretical insights from the literature are tested and contextualised in real-world operational settings. An overview of the methodological approach is presented in Figure 2.

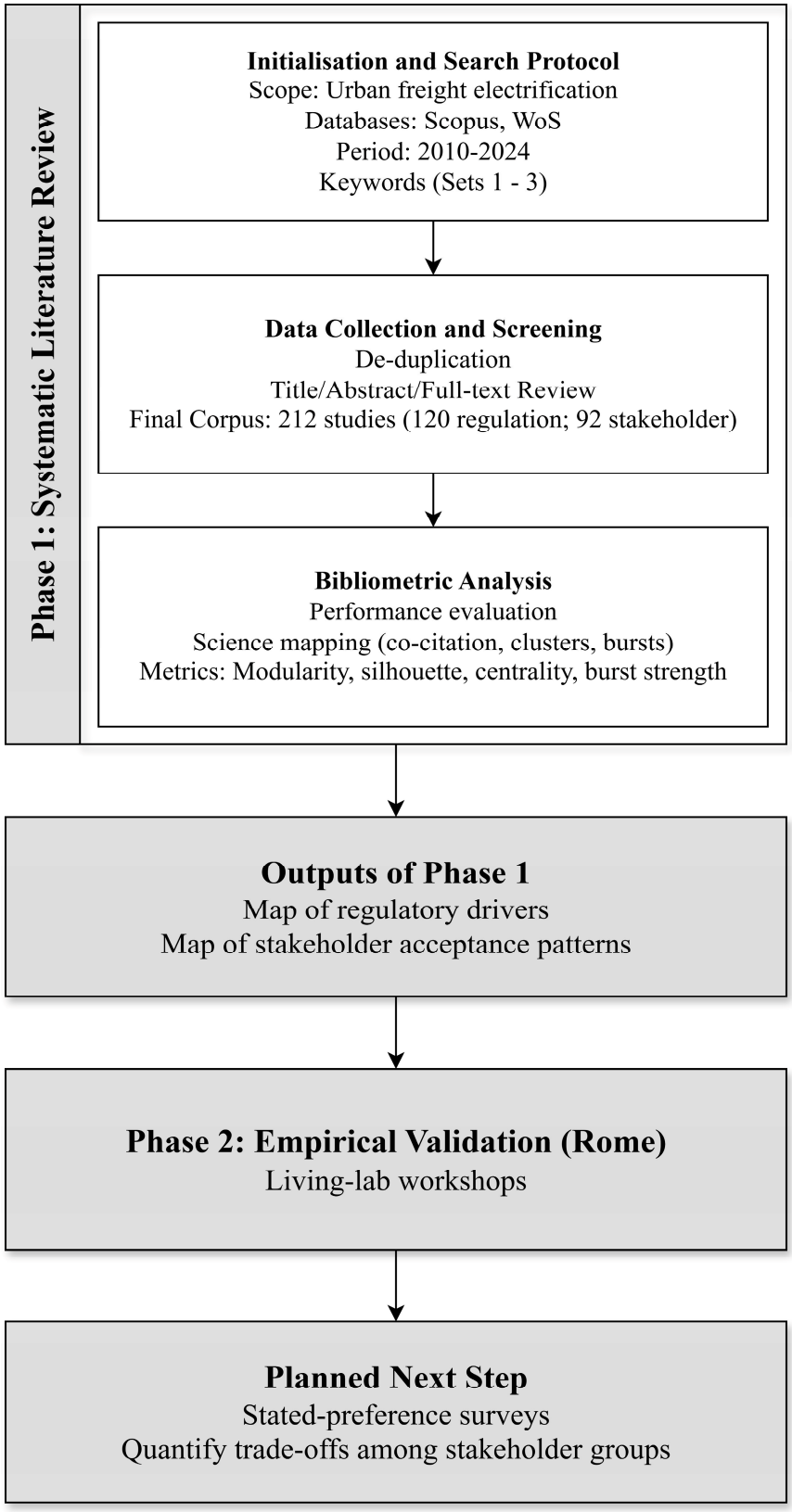


Figure 2. Methodological Approach.

2.1. Systematic Literature Review

The systematic literature review was conducted according to PRISMA standards [19]. The PRISMA checklist detailing all the actions performed can be downloaded at Supplementary Materials.The procedure includes the following three interconnected stages.

(1) Initialisation and Search Protocol: During the initialisation stage, the scope of the review was defined as urban freight electrification, and the search protocol was established. Peer-reviewed journal articles, conference papers, and book chapters published in English between 2010 and 2024 were retrieved from the Scopus and Web of Science databases. The search strategy combined three sets of keyword strings. The first set delineated the domain of application (urban freight and logistics), while the second set targeted eco-friendly vehicles. The third set was divided into two dimensions: one addressing regulation and the other focusing on stakeholders' acceptance.

The search strategy was based on three sets of keyword strings:

Set 1 (Application domain): terms capturing the field of urban freight and city logistics (e.g., "urban freight," "city logistics," "urban goods," "last-mile deliver*," "freight distribution").

Set 2 (Eco-friendly vehicles): expressions identifying clean technologies, such as "eco vehicle," "electric vehicle*," "hydrogen vehicle*," "eco-friendly vehicle*," "green logistics," "pollutant emission*," and "sustainable mobility."

Set 3.1 (Analytical dimensions): "regulation" OR "regulatory" OR "ordinance" OR "decree" OR "ban" OR "incentive*" OR "subsid*" OR "tax*" OR "zero emission*" OR "LEZ" OR "ZEZ" OR "enforcement" OR "sanction*" OR "compliance" OR "measures" OR "policy*".

Set 3.2 (Stakeholder acceptance): further divided into regulation- and stakeholder-related keywords. The regulation string included words such as "regulation," "ordinance," "incentive," "subsidy," "tax," "zero emission," "low-emission zone," and "policy." The stakeholder string comprised "stakeholder," "actor," "carrier," "receiver," "policymaker," "end-consumer," and "acceptability."

The regulatory search string included terms such as "regulation," "ordinance," "incentive," "subsidy," "tax," "zero emissions," "low emission zone," and "policy." As shown in Table 1, this search retrieved 283 records across the two databases, of which 120 were retained for analysis after the exclusion of duplicates and out-of-scope items. The stakeholder-acceptance search string included terms such as "stakeholder," "actor," "carrier," "receiver," "policymaker," "end consumer," and "acceptability." As reported in Table 2, this search produced 166 records, of which 92 were included in the final dataset following screening.

Table 1. Specific keywords and documents reviewed—regulation.

Search Phrase (Set 3.1)	Documents					
	WoS	**Scopus**	**Excluded**	**Total**	**Duplicates**	**Reviewed**
"regulation" OR "regulatory" OR "ordinance" OR "decree" OR "ban" OR "incentive*" OR "subsid*" OR "tax*" OR "zero emissions" OR "LEZ" OR "ZEZ" OR "enforcement" OR "sanction*" OR "complian*" OR "measures" OR "polic*"	163	146	26	**283**	163	**120**

Table 2. Specific keywords and documents reviewed—stakeholders' acceptance.

Search Phrase (Set 3.2)	Documents					
	WoS	**Scopus**	**Excluded**	**Total**	**Duplicates**	**Reviewed**
"stakeholder*" OR "player*" OR "actor" OR "agent" OR "industry" OR "suppliers" OR "shippers" OR "carrier" OR "receiver" OR "policymaker" OR "end-consumer" OR "end consumer" OR "acceptability"	74	108	16	**166**	74	**92**

(2) Data Collection and Screening: The second stage of the review involved applying PRISMA's identification, eligibility, and inclusion filters. Records were de-duplicated, and titles, abstracts, and, where necessary, full texts were assessed for relevance, resulting in a final corpus of 212 studies (120 regulation-focused and 92 stakeholder-focused). Figure 3 is a PRISMA 2020 flow diagram summarising record identification, screening, and inclusion for regulation- and stakeholder-focused studies. The flow illustrates how 449 records were retrieved from Scopus and Web of Science, 237 duplicates removed, 212 screened, and 212 studies included (120 regulation-focused, 92 stakeholder-focused).

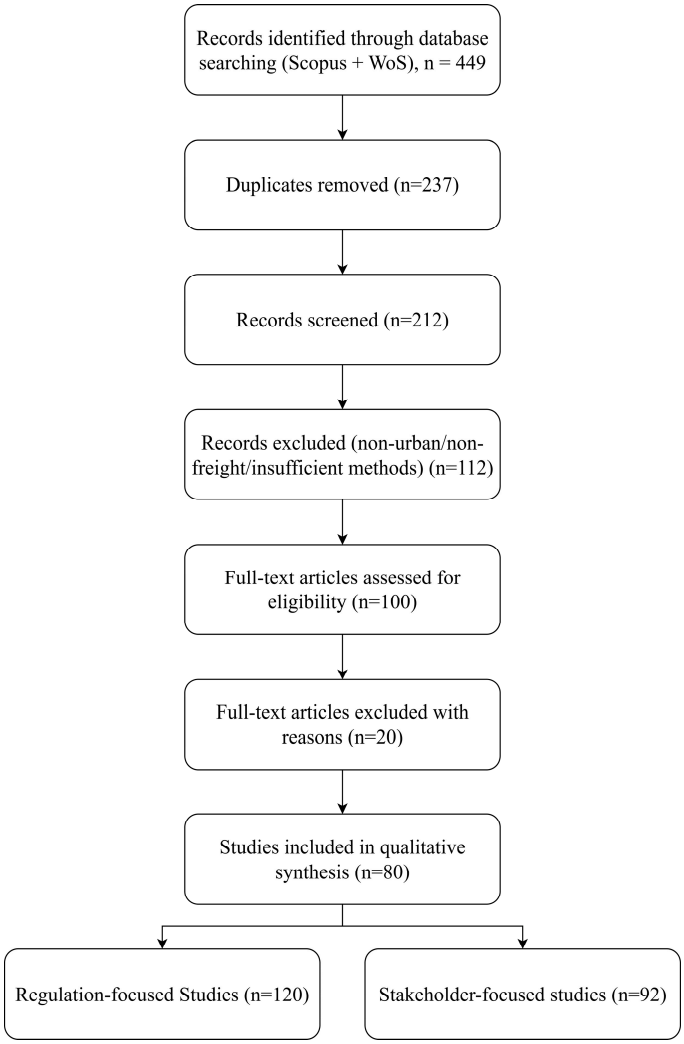


Figure 3. PRISMA 2020 Flow Diagram.

(3) Bibliometric Analysis: Using CiteSpace© [20], the final corpus was examined through both performance analysis (authors, journals, institutions, countries ranked by productivity and citations) and science mapping (co-citation networks, cluster detection, temporal bursts). Key metrics included modularity and silhouette (network cohesion), centrality (brokerage), and burst strength (topic surges) [21,22]. Clusters with high silhouette values were reviewed first, focusing on both central and highly cited works to capture thematic cores and bridging contributions. This process ensured a transparent, replicable mapping of how EFV regulation and stakeholder perspectives have evolved over the past 15 years.

2.2. Empirical Validation: Living-Lab Workshops

The second phase validated and contextualised the review findings through participatory engagement with practitioners in Rome. We adopted a purposive, criterion-based sampling strategy aimed at involving those actors most directly positioned to co-design and stress-test a pre-feasibility assessment of the project's two solutions. Concretely, we targeted organisations that (i) operate or enable urban freight services in Rome, (ii) hold decision authority over assets/processes relevant to S1 (shared charging/refuelling hub for electric and hydrogen freight vehicles) or S2 (cargo-bike scheme with service-trip decoupling and reverse logistics), and (iii) had expressed willingness to participate in an iterative Living-Lab process. This approach prioritises information-rich key stakeholders over representativeness, consistent with the study's pre-feasibility objective and the Living-Lab format. We acknowledge that this yields a small, non-representative sample, and we explicitly limit our inference accordingly (see the limitations described in the conclusion section). The workshops complement, rather than substitute, the systematic review conducted under PRISMA guidance, providing grounded input to further analysis.

Five Living-Lab workshops were organised with diverse actors in Rome's freight ecosystem: DACHSER-FERCAM (multinational freight operator), Doctor Bike (largest city cargo-bike operator), Switch (digital freight coordination/IoT), MOTUS-E (national e-mobility alliance), and A2A (multi-utility for energy transition and smart-city services). Organisations were invited through the project's practitioner network and city contacts, based on the criteria above and their operational interest in S1 and/or S2. Each organisation nominated senior staff with operational or strategic responsibility to ensure decisions and constraints could be discussed at the right level.

This empirical component not only validated insights from the literature but also surfaced new considerations such as land-use restrictions, grid-connection bottlenecks, subsidy uptake, financing mechanisms, and workforce training needs. The combination of systematic review, bibliometric mapping, and Living Lab engagement provides a comprehensive basis for analysing how regulation and stakeholder dynamics condition EFV adoption in Rome.

3. Literature Review

The systematic review identified 120 regulation-focused and 92 stakeholder-focused contributions, together forming a corpus of 212 studies. These works confirm that the adoption of eco-friendly vehicles (EFVs) is not driven solely by technological readiness but by the interplay of regulatory design, market incentives, and behavioural responses. Bibliometric mapping showed that regulation-related studies cluster around six policy areas, while stakeholder-related studies consolidate around four principal actor groups.

3.1. Regulation-Focused Literature

Studies consistently emphasise that access and regulations (e.g., low- and zero-emission zones (LEZ/ZEZs) or delivery time-window restrictions) strongly encourage the adoption of eco-friendly vehicles (EFVs) [5,7,9,15]. However, some experts caution that these rules often create negative impacts on small and medium-sized enterprises (SMEs), particularly when compensatory measures (e.g., preferential access for clean fleets or targeted subsidies) are absent [23,24]. This tension between rapid compliance and equity is directly relevant for Rome, where fragmented operator structures and resource constraints increase the vulnerability of SMEs. Fiscal and economic levers, such as direct subsidies, accelerated depreciation, and differentiated tolls, are widely shown to minimise the total cost of ownership (TCO) gap between EFVs and conventional fleets [6,24,25]. Yet, several studies report that acceptance of subsidies remains limited without parallel governance mechanisms that reduce transaction costs—an issue echoed by Roman stakeholders who noted underutilisation of national funds [17,26,27]. Operational interventions such as consolidation centres and curb-use regulations are praised for improving efficiency, but empirical research underscores significant transaction costs in shared-facility governance, which many municipalities fail to absorb [7,28]. Smart-city and technological instruments, including data-interoperability decrees and digital curb management, offer potential efficiency gains but are often designed for passenger mobility rather than freight, creating mismatches in implementation [5,9,29]. Overall, the regulatory literature converges on a key insight: single instruments rarely deliver systemic change. Instead, carefully sequenced policy packages that integrate fiscal, access, operational, and governance measures are needed [8,23,30].

3.2. Stakeholder-Focused Literature

Evidence suggests that the effectiveness of regulatory design depends on the degree to which stakeholder incentives align across four key groups: policymakers, logistics operators, vehicle manufacturers, and consumers [14,16–18,31]. Policymakers prioritise enforceability and fiscal neutrality, but misaligned rules often generate compliance costs without delivering expected outcomes [32,33]. Logistics operators, particularly SMEs, highlight the risk of sunk costs given uncertain vehicle lifecycles, grid capacity, and service reliability [26,34]. Several studies using agent-based and microsimulation models confirm that carriers' fleet-renewal choices are highly sensitive to operational constraints [3,26,34]. Vehicle manufacturers are shown to rely on stable demand signals to justify long-term platform investment; however, the literature notes a persistent disconnect between urban pilot schemes and manufacturers' global product strategies [17,27,35]. Consumers, meanwhile, express willingness to support "green delivery" primarily when cost and reliability remain unaffected. Choice experiments underline that eco-labelling and flexible delivery windows increase acceptance, but willingness-to-pay premiums are modest and vary across socio-economic groups [16,32,33]. Critically, these perspectives are not independent: transaction costs emerge precisely when actors pursue divergent priorities. The Living Lab workshops confirmed this dynamic in Rome, revealing how policy incentives can be undermined by grid bottlenecks, siting barriers, and the absence of neutral governance bodies.

3.3. Cross-Cutting Gaps

Three broader limitations emerge from the literature. First, there is an overrepresentation of European case studies, while empirical insights from Global South cities remain sparse [23,24]. Second, few studies integrate both regulatory design and behavioural responses in a unified framework; most analyse either policy instruments or stakeholder choices in isolation [5,17,26]. Third, bibliometric mapping shows that although collab-

orative governance is frequently cited as critical, systematic evaluations of governance models (e.g., consortia, PPPs, municipal alliances) are scarce [8,27]. Addressing these gaps is essential, since Rome exemplifies the institutional fragmentation that complicates governance design. By linking regulatory debates to stakeholder realities, this study moves beyond descriptive catalogues of measures to examine how specific instruments map onto heterogeneous actor incentives.

This review reveals that while prior studies identify a broad catalogue of instruments, very few examine how these interact with actor-specific incentives during implementation. The present study advances this discussion by explicitly linking regulatory design with stakeholder acceptance mechanisms, combining systematic evidence with Living-Lab validation. In doing so, it addresses three under-explored gaps: (i) the lack of empirical grounding for governance models; (ii) the limited integration of behavioural responses in regulatory design; and (iii) the scarcity of operational metrics for evaluating feasibility in practice.

4. Stakeholders' Priorities

The Living Lab workshops provided detailed insights into the conditions that logistics operators, energy providers, technology firms, and associations consider essential for the adoption of eco-friendly vehicles (EFVs) in Rome. These findings confirm what the literature highlights—namely, that the success of regulatory measures depends less on technology and more on how incentives and governance are designed [7,14,16,17,26,27,32,33]. In Rome, stakeholders stressed three sets of priorities: the charging and refuelling hub, the cargo-bike decoupling scheme, and the governance arrangements required to sustain them.

4.1. Shared Charging/Refuelling Hub (S1)

Stakeholders agreed that the feasibility of a common hub depends on three technical and organisational elements. First, the charging capacity must match the actual operating schedules of freight fleets. Evidence from operators shows that average daily distances in Rome range from 120 to 200 km, which requires overnight charging windows between 17:00 and 06:00, as well as fast-charge options of 30–45 min for second-round deliveries. A smart power-management system is needed to avoid peak loads while ensuring that all vehicles are ready for service. Second, siting is decisive. Only locations within existing logistics clusters or public loading bays can provide both grid capacity and neutral access. In Rome, fragmented land ownership, uncertain zoning rules, and limited mid- to low-voltage substations create serious siting barriers. Stakeholders discussed possible integration with photovoltaic panels or grid-side storage, though technical and financial feasibility remain uncertain. Third, financing arrangements are essential. Small and medium-sized enterprises (SMEs) cannot sustain large upfront costs. Stakeholders therefore proposed proportional user fees, tiered electricity pricing that distinguishes depot-exclusive from open-access chargers, and the creation of a neutral public–private consortium. This consortium would manage the hub, ensure non-discriminatory access, and unlock national subsidies, which remain underused. The literature also supports this view, emphasising that without collaborative governance and neutral financing, shared infrastructure risks underutilisation [17,26,27,35].

4.2. Cargo-Bike Decoupling and Reverse Logistics (S2)

For the cargo-bike scheme, operational reliability was the dominant concern. Splitting delivery from installation can reduce curbside dwell times and increase vehicle turnover, but only if a digital dispatcher keeps the handover between van and rider within 15–20 min. Any delay undermines both efficiency and customer satisfaction. Doctor Bike, already

running a 26-bike fleet in central Rome, confirmed that riders must be distributed across several shippers to ensure stable employment. This calls for a payment model based on tasks completed, adjusted for service type—basic delivery, delivery plus installation, or installation with packaging removal. The workshops also highlighted the importance of certified training, since riders frequently handle complex items such as fitness equipment and household appliances. Safety, reliability, and service quality all depend on such training. The scheme also requires dedicated overnight parking and charging spaces in the city centre, with micro-hub configurations negotiated with the municipality. These findings are consistent with studies that emphasise the importance of real-time coordination, fair remuneration, and training in ensuring acceptance and efficiency of cargo-bike schemes [16,32,33].

4.3. Governance and Cross-Cutting Issues

Both solutions require a governance model that aligns incentives and allocates risk transparently. For the hub, stakeholders converged on creating a neutral, third-party consortium to ensure competitive fairness, act as a single interface with the distribution system operator (DSO), and streamline negotiations with municipal authorities. Such an entity would maintain a level playing field, match grid capacity to carriers' demand, and convene actors for permitting and operational coordination. For the cargo-bike scheme, city involvement is necessary to repurpose underutilised spaces (e.g., containers or loading bays) into micro-hubs. More broadly, both cases illustrate the need for integrated regulatory packages: tiered tariffs matter only when linked to observed charging profiles, and cargo-bike transfers work only when digital dispatch systems guarantee reliability. These Rome-specific insights reinforce the literature's argument that EFV adoption depends on carefully sequenced, multi-actor strategies rather than isolated interventions [5,9,23,24,28–30].

In summary, the workshops confirmed that in Rome, the barriers to EFV adoption are less about the vehicles themselves and more about the supporting infrastructure, financing, and governance. The hub requires grid-matched sizing, neutral management, and tailored tariffs, while the cargo-bike scheme depends on strict time coordination, performance-based remuneration, and certified rider training. Both solutions also need strong municipal involvement to secure space, subsidies, and regulatory clarity. Table 3 summarises the workshops. Table 4 summarises the key indicative operational parameters for the solutions.

Table 3. Summary of the stakeholders' workshops.

Stakeholder	Organisation Type	Participants (n)	Focus Solution	Key Consensus	Key Dissent
DACHSER-FERCAM	Logistics Operator	2 (Senior Ops)	S1	Need for night charging	Cost recovery model
Doctor Bike	Cargo-bike operator	2 (Managers)	S2	Rider training essential	Tariff structure
MOTUS-E	e-mobility alliance	2	S1 & S2	Neutral governance critical	Subsidy design
Switch	Tech/IoT provider	1	S2	Dispatcher platform feasibility	Integration with the city API
A2A	Utility/energy provider	2	S1	Grid coordination vital	Land-use permitting

Table 4. Key indicative operational parameters for the solutions (S1 and S2).

Indicator	Solution 1—Shared Charging/Refuelling Hub (S1)	Solution 2—Cargo-Bike Decoupling & Reverse Logistics (S2)	Source/Basis
Typical daily operating range	120–200 km per vehicle	25–30 delivery tasks per rider per day	Operator feedback (DACHSER-FERCAM; Doctor Bike)
Charging/handover duration	Overnight (17:00–06:00) + fast charge 30–45 min	Handover between van and rider within 15–20 min	Living Lab data + literature
Peak power demand	≈400 kW (10 fast chargers × 40 kW each)	n/a—battery swap and slow charge at micro-hubs (1–2 kW per unit)	A2A technical inputs
Utilisation rate	70–85% (expected, shared access)	80–90% fleet availability (target)	Stakeholder estimates
Indicative CAPEX/OPEX	CAPEX ≈ €0.8–1.2 million OPEX ≈ €60–80 k/year	CAPEX ≈ €3–5 k per bike OPEX ≈ €1 k/year (battery + maintenance)	Literature + project data
Emission reduction potential	≈70% vs. diesel fleet (based on energy mix)	≈65% vs. diesel van for inner-city deliveries	Estimated from the literature
Key bottleneck/risk	Grid capacity and land-use permitting	Rider training and dispatch reliability	Workshop discussion

5. Discussion

The results of this study confirm that eco-friendly vehicle (EFV) adoption in Rome is conditioned less by technological availability and more by the institutional and behavioural environment in which freight systems operate. This echoes the findings of previous research, which stresses that effective transition pathways rely on coherent policy packages that integrate regulatory instruments, financial incentives, and governance mechanisms [5,6,24,32,35]. The Living Lab workshops enrich this evidence by showing how these insights translate into the specific operational thresholds that logistics operators, energy providers, manufacturers, and consumers regard as decisive. Figure 4 illustrates how results from the literature review are validated through the workshops to yield the results this paper describes.

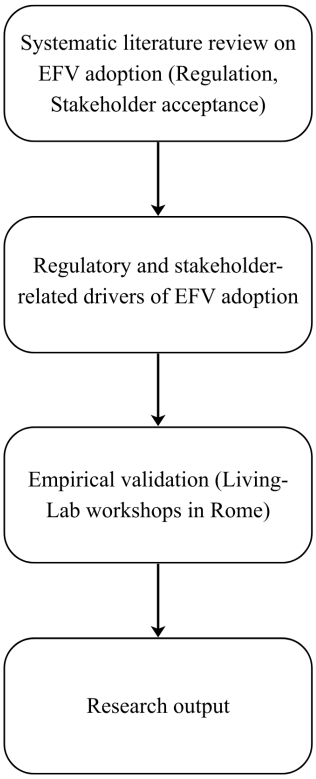


Figure 4. Research results' flow.

5.1. Discussion of Shared Charging and Refuelling Hub (S1)

The workshops highlighted three priorities that align closely with the literature on infrastructure provision and governance. First, capacity alignment is crucial. Studies show that under-sized hubs create bottlenecks and over-sized hubs waste resources. Rome's operators confirmed this by pointing to daily distances of 120–200 km and the need for overnight charging windows, complemented by 30–45-min fast charges. These findings stress the importance of smart grid management to flatten peaks, reduce transaction costs, and maximise fleet availability. Second, siting and accessibility emerged as critical. Literature consistently links siting to both grid availability and operational efficiency. In Rome, fragmented land ownership, complex zoning rules, and limited substations make this even more challenging. Without locations embedded in existing logistics clusters or public loading bays, hubs risk exclusionary effects and limited utilisation. Third, financing and governance determine whether SMEs can participate. The workshops reinforced what research has long emphasised: that SMEs face capital constraints and require proportional fees, tiered tariffs, and access to subsidies. The proposed neutral consortium is a neutral, third-party institution that manages the shared charging/refuelling hub and guarantees non-discriminatory access and competitive fairness. It serves as a single interface with the distribution system operator (DSO), streamlines negotiations with municipal authorities, and convenes actors for permitting and operational coordination. It maintains a level playing field, matches grid capacity to carriers' demand, and helps unlock underused national subsidies, thereby supporting workable financing and transparent risk allocation.

5.2. Discussion of Cargo-Bike Decoupling and Reverse Logistics (S2)

The second solution shows how operational design and labour conditions shape adoption. Literature demonstrates that consumers are willing to support green delivery only if reliability and service quality are maintained. In Rome, this translated into a strict requirement that van-to-rider transfers occur within 15–20 min (Stakeholder-reported time window from the co-design workshops). Anything longer undermines efficiency and satisfaction. The workshops also revealed that digital dispatch platforms are indispensable to achieve this precision, confirming earlier evidence that digitalisation enhances efficiency when paired with clear governance rules. Another key lesson is the importance of remuneration models. Paying riders per task, with adjustments for service type, ensures fairness and encourages efficiency. Without this, the system risks labour precarity, which has been flagged in broader gig economy studies. Finally, certified training was stressed as necessary for safe and reliable service delivery, especially for bulky or complex items. This echoes prior work on the role of human capital in supporting sustainable logistics transitions. Municipal provision of micro-hubs and overnight charging facilities adds a further layer of support, ensuring that cargo-bike schemes can expand beyond pilot stages.

5.3. Discussion of Governance and Cross-Cutting Insights

Both solutions highlight a broader principle: regulatory instruments and stakeholder acceptance evolve together. Financial incentives are effective only when linked to actual usage profiles; zoning measures encourage clean fleets only when paired with neutral hubs; and digital dispatch systems generate trust only when they guarantee predictable transfers and fair compensation. This confirms the argument advanced in the literature that multi-actor coordination is a precondition for successful EFV adoption. Rome illustrates this interdependence clearly: operators demand predictable costs and access, manufacturers require stable demand signals, consumers expect service reliability, and policymakers must reconcile environmental ambition with enforceability. Misalignment across these

perspectives raises transaction costs and delays adoption, while coordinated approaches lower risks and accelerate uptake.

To illustrate sensitivity in implementation pathways, the discussion also considers simple "what-if" scenarios. For instance, if hub tariffs are reduced, there would be more usage, especially from SMEs. On the other hand, if an oversized hub is built, then it would be expensive and under-utilised. Similarly, if performance-linked subsidies or staggered access fees were introduced, the timing of adoption and coordination among stakeholders could change. These scenario-based reflections provide qualitative insight into how different regulatory and financial settings might influence uptake, without requiring speculative quantitative modelling.

The findings also underline the role of public–private collaboration. Without a neutral consortium, the hub risks underuse. Without municipal support, cargo-bike schemes lack space for micro-hubs. These lessons echo evidence that fragmented governance remains one of the most significant barriers to sustainable freight transitions. Rome's case suggests that capacity-building in local institutions is as important as technological innovation, since only effective governance can bridge the gap between regulatory intent and operational practice.

In summary, the discussion shows that Rome's pathway to sustainable freight requires not only vehicles and infrastructure but also finely tuned regulatory and financial packages, transparent governance, and strong stakeholder engagement. The two case solutions—hub and cargo-bike—demonstrate how the general categories identified in the literature become concrete operational thresholds in practice. When these thresholds are jointly satisfied, eco-friendly logistics initiatives can move from pilot projects to everyday operations, delivering the emission reductions that cities seek.

5.4. Replicability and Transferability

While findings are grounded in Rome's institutional and infrastructural context, several elements are generalisable: (i) the need for grid-matched capacity planning; (ii) transparent, neutral governance for shared assets; and (iii) incentive alignment across operators. Locally specific variables include zoning regulations, land-use permits, and grid ownership. Other European cities with comparable governance complexity (e.g., Madrid, Milan) could replicate the process using the same minimum dataset—fleet profiles, grid maps, and policy instruments.

6. Conclusions

This study offers a pre-feasibility assessment of regulatory and acceptance conditions for EFV uptake. The findings are indicative rather than exhaustive, serving as a bridge between conceptual frameworks and operational trials. Future research will expand both the empirical base and quantitative modelling.

This study examined how regulation and stakeholder acceptance shape the adoption of eco-friendly vehicles (EFVs) in urban freight, using Rome as a testbed. By combining a systematic review of 212 studies with empirical evidence from five Living Lab workshops, it demonstrated that technological readiness is necessary but not sufficient. What determines uptake is the alignment of regulatory frameworks, financial instruments, and stakeholder incentives. This aligns with the broader literature, which stresses that effective EFV policies emerge from integrated packages across six domains—access, fiscal, operational, smart-city, environmental, and collaborative governance—and four actor groups: policymakers, operators, manufacturers, and consumers.

The analysis of Rome produced two main findings. First, the viability of the shared charging and refuelling hub rests on three foundations: demand-calibrated capacity supported by smart power management; siting within existing logistics clusters or publicly

controlled bays with adequate grid connections; and financial models that distribute costs fairly across operators, especially SMEs. A neutral consortium is essential to manage governance, ensure equitable access, and unlock underused subsidies. Second, the cargo-bike decoupling scheme depends on strict operational reliability and labour standards. Transfers between vans and riders must remain within a 15–20-min window, coordinated by digital dispatch platforms. Riders must be paid on a task basis, with tariffs reflecting service complexity, and trained to handle diverse product categories safely. Municipal action is also necessary to provide overnight parking and charging facilities. These findings illustrate that EFV adoption in Rome is less about the vehicles themselves and more about the infrastructure, financing, and institutional design that surround them.

The implications extend beyond Rome. For policymakers, the results suggest that regulatory instruments cannot be designed in silos. Access restrictions such as low-emission zones are credible only if paired with fiscal levers that reduce cost disparities and governance mechanisms that ensure fairness. For logistics operators, the findings underline the importance of participating in governance structures such as consortia, which can reduce risk exposure and improve bargaining power with authorities. For manufacturers, the lessons concern the need for coordination between product roadmaps and urban charging infrastructure, since fleet adoption is shaped by the availability of neutral, grid-matched hubs. For consumers, the evidence confirms that willingness to support green delivery hinges on reliability and affordability. In other words, environmental benefits must be embedded in service quality rather than offered as a trade-off.

Limitations remain. The Living Lab workshops involved a bounded set of actors, which, while diverse, do not capture the full spectrum of stakeholders in Rome's complex logistics ecosystem. In this sense, future research should explicitly involve receivers, SME carriers, and municipal authorities to obtain a more comprehensive picture of stakeholder priorities and preferences regarding the two solutions. It should also compare findings across other cities to assess the degree of transferability of the results.

Future research should address these limitations along three paths. First, quantitative methods are needed to complement the qualitative evidence. A stated-preference survey will be used to measure trade-offs around hub capacity, tariff structures, and incentive levels, allowing researchers to test how different actors weigh costs, benefits, and risks. Second, comparative studies across cities are required. Rome is a useful case because of its fragmented governance and infrastructure constraints, but other cities may present different institutional, cultural, or economic conditions. Cross-city research would test the transferability of the findings and identify context-specific versus generalisable levers. Third, further experimentation should explore the operational and governance innovations suggested by stakeholders. These include dynamic electricity and curb-access pricing integrated with peak-control systems at hubs, alternative governance models for the neutral consortium, and refinements to dispatcher algorithms and rider training protocols. Such research would help close the gap between regulatory design and on-the-ground practice.

In conclusion, Rome's experience underscores a broader principle: EFV adoption is a socio-technical process that requires continuous alignment between regulatory design and stakeholder behaviour. The six policy domains identified in the literature do not remain abstract categories; in practice, they become operational thresholds—grid capacity, tariff design, governance fairness, dispatch reliability, and service quality—that stakeholders must negotiate. The city's case shows that only when these thresholds are jointly satisfied do eco-friendly logistics solutions move from pilot projects to daily practice. For Rome, and for other European cities pursuing decarbonisation, this means that sustained investment in governance capacity, infrastructure integration, and stakeholder alignment will be as critical as advances in vehicle technology itself.

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Abbreviations

The following abbreviations are used in this manuscript:

DSO	Distribution System Operators
EFV	Eco-Friendly Vehicle
EV	Electric Vehicle
SME	Small and Medium-sized Enterprise
TCO	Total Cost of Ownership
LEZ	Low Emission Zone
ZEZ	Zero Emission Zone
PPP	Public–Private Partnership
DCM	Discrete Choice Model
ABM	Agent-Based Model
MCDA	Multi-Criteria Decision Analysis
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PULSe	Pre-feasibility analysis for Urban Logistics Solutions based on Eco-friendly vehicles
ICT	Information and Communication Technology
IoT	Internet of Things
NGO	Non-Governmental Organization
EU	European Union
ITS	Intelligent Transport Systems
CO_2	Carbon Dioxide
SP	Stated Peference
WoS	Web of Science

References

1. ALICE. Urban Freight Research & Innovation Roadmap. 2022. Available online: https://www.etp-logistics.eu/wp-content/uploads/2022/08/Urban-Freight-Roadmap.pdf (accessed on 26 October 2024).
2. EEA. Transport and Mobility. 2024. Available online: https://www.eea.europa.eu/en/topics/in-depth/transport-and-mobility (accessed on 24 October 2024).
3. Train, K.E. *Discrete Choice Methods with Simulation*, 2nd ed.; Cambridge University Press: Cambridge, UK; University of California: Berkeley, CA, USA, 2009; ISBN 978-0-511-80527-1.

4. Gatta, V.; Marcucci, E. Urban freight transport and policy changes: Improving decision makers' awareness via an agent-specific approach. *Transp. Policy* **2014**, *36*, 248–252. [CrossRef]
5. Ehrler, V.C.; Schöder, D.; Seidel, S. Challenges and perspectives for the use of electric vehicles for last mile logistics of grocery e-commerce—Findings from case studies in Germany. *Res. Transp. Econ.* **2021**, *87*, 100757. [CrossRef]
6. Cagliano, A.C.; Carlin, A.; Mangano, G.; Rafele, C. Analyzing the diffusion of eco-friendly vans for urban freight distribution. *IJLM* **2017**, *28*, 1218–1242. [CrossRef]
7. Muñuzuri, J.; Larrañeta, J.; Onieva, L.; Cortés, P. Solutions applicable by local administrations for urban logistics improvement. *Cities* **2005**, *22*, 15–28. [CrossRef]
8. Bruzzone, F.; Cavallaro, F.; Nocera, S. The integration of passenger and freight transport for first-last mile operations. *Transp. Policy* **2021**, *100*, 31–48. [CrossRef] [PubMed]
9. Fatnassi, E.; Chaouachi, J.; Klibi, W. Planning and operating a shared goods and passengers on-demand rapid transit system for sustainable city-logistics. *Transp. Res. Part B Methodol.* **2015**, *81*, 440–460. [CrossRef]
10. Ravi, S.S.; Osipov, S.; Turner, J.W.G. Impact of Modern Vehicular Technologies and Emission Regulations on Improving Global Air Quality. *Atmosphere* **2023**, *14*, 1164. [CrossRef]
11. Marcucci, E.; Gatta, V.; Lozzi, G. Innovative Business Models, Governance and Public-Private Partnerships; Deliverable 1.3, LEAD Project. 2021. Available online: https://www.leadproject.eu/wp-content/uploads/2021/12/LEAD-D1.3.pdf (accessed on 27 August 2025).
12. Kim, H.J.; Jo, S.; Kwon, S.; Lee, J.-T.; Park, S. NO_X emission analysis according to after-treatment devices (SCR, LNT + SCR, SDPF), and control strategies in Euro-6 light-duty diesel vehicles. *Fuel* **2022**, *310*, 122297. [CrossRef]
13. Mulholland, E.; Miller, J.; Bernard, Y.; Lee, K.; Rodríguez, F. The role of NOx emission reductions in Euro 7/VII vehicle emission standards to reduce adverse health impacts in the EU27 through 2050. *Transp. Eng.* **2022**, *9*, 100133. [CrossRef]
14. Ben-Akiva, M.; Bierlaire, M. Discrete choice methods and their applications to short term travel decisions. In *Handbook of Transportation Science*; Springer: Boston, MA, USA, 1999.
15. Browne, M.; Allen, J.; Nemoto, T.; Patier, D.; Visser, J. Reducing Social and Environmental Impacts of Urban Freight Transport: A Review of Some Major Cities. *Procedia-Soc. Behav. Sci.* **2012**, *39*, 19–33. [CrossRef]
16. Gatta, V.; Marcucci, E.; Pira, M.L.; Inturri, G.; Ignaccolo, M.; Pluchino, A. E-groceries and urban freight: Investigating purchasing habits, peer influence and behaviour change via a discrete choice/agent-based modelling approach. *Transp. Res. Procedia* **2020**, *46*, 133–140. [CrossRef]
17. Cao, J.; Chen, X.; Qiu, R.; Hou, S. Electric vehicle industry sustainable development with a stakeholder engagement system. *Technol. Soc.* **2021**, *67*, 101771. [CrossRef]
18. Yang, W.; Ma, J.; Fan, A.; Zhang, J.; Pan, Y. Effectiveness of policies for electric commercial vehicle adoption and emission reduction in the logistics industry. *Energy Policy* **2024**, *188*, 114116. [CrossRef]
19. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [CrossRef] [PubMed]
20. Chen, C. Science Mapping: A Systematic Review of the Literature. *J. Data Inf. Sci.* **2017**, *2*, 1–40. [CrossRef]
21. Kleinberg, J. Bursty and Hierarchical Structure in Streams. *Data Min. Knowl. Discov.* **2003**, *7*, 373–397. [CrossRef]
22. Vignery, K.; Laurier, W. A methodology and theoretical taxonomy for centrality measures: What are the best centrality indicators for student networks? *PLoS ONE* **2020**, *15*, e0244377. [CrossRef]
23. Quak, H.; Nesterova, N.; Van Rooijen, T.; Dong, Y. Zero Emission City Logistics: Current Practices in Freight Electromobility and Feasibility in the Near Future. *Transp. Res. Procedia* **2016**, *14*, 1506–1515. [CrossRef]
24. Basma, H.; Rodríguez, F. *Electrifying Last-Mile Delivery: A Total Cost of Ownership Comparison of Battery-Electric and Diesel Trucks in Europe*; International Council on Clean Transportation (ICCT): Washington, DC, USA, 2022.
25. González-Varona, J.M.; Villafáñez, F.; Acebes, F.; Redondo, A.; Poza, D. Reusing Newspaper Kiosks for Last-Mile Delivery in Urban Areas. *Sustainability* **2020**, *12*, 9770. [CrossRef]
26. Nuzzolo, A.; Persia, L.; Polimeni, A. Agent-Based Simulation of urban goods distribution: A literature review. *Transp. Res. Procedia* **2018**, *30*, 33–42. [CrossRef]
27. Jafarzadeh Ghoushchi, S.; Shaffiee Haghshenas, S.; Vahabzadeh, S.; Guido, G.; Geem, Z.W. An integrated MCDM approach for enhancing efficiency in connected autonomous vehicles through augmented intelligence and IoT integration. *Results Eng.* **2024**, *23*, 102626. [CrossRef]
28. Ghilas, V.; Demir, E.; Van Woensel, T. The pickup and delivery problem with time windows and scheduled lines. *INFOR Inf. Syst. Oper. Res.* **2016**, *54*, 147–167. [CrossRef]
29. Correia, D.; Teixeira, L.; Marques, J.L. Last-mile-as-a-service (LMaaS): An innovative concept for the disruption of the supply chain. *Sustain. Cities Soc.* **2021**, *75*, 103310. [CrossRef] [PubMed]

30. Melo, S.; Baptista, P. Evaluating the impacts of using cargo cycles on urban logistics: Integrating traffic, environmental and operational boundaries. *Eur. Transp. Res. Rev.* **2017**, *9*, 30. [CrossRef]
31. Balla, B.S.; Sahu, P.K. Assessing regional transferability and updating of freight generation models to reduce sample size requirements in national freight data collection program. *Transp. Res. Part A Policy Pract.* **2023**, *175*, 103780. [CrossRef]
32. Russo, F.; Comi, A. Investigating the Effects of City Logistics Measures on the Economy of the City. *Sustainability* **2020**, *12*, 1439. [CrossRef]
33. Sureeyatanapas, P.; Poophiukhok, P.; Pathumnakul, S. Green initiatives for logistics service providers: An investigation of antecedent factors and the contributions to corporate goals. *J. Clean. Prod.* **2018**, *191*, 1–14. [CrossRef]
34. Alp, O.; Tan, T.; Udenio, M. Transitioning to sustainable freight transportation by integrating fleet replacement and charging infrastructure decisions. *Omega* **2022**, *109*, 102595. [CrossRef]
35. Yanar, T. Understanding the choice for sustainable modes of transport in commuting trips with a comparative case study. *Case Stud. Transp. Policy* **2023**, *11*, 100964. [CrossRef]