Decarbonising Last Mile Logistics

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Abstract. Logistics is at the core of modern society and essential to transport food and goods in the heart of cities, where most Europeans live. However, recent statistics show that only half of truckloads moved at maximised capacity in 2021 [1], and the rapid increase in the last mile deliveries - 78% by 2030 [2] - affects the economics of logistics and its externalities on the urban tissue, including high traffic, noise and air pollution. It is worth noting that last mile logistics represent 30% of the total CO2 emissions of logistics transportation. Amongst the EU Green Deal objectives, several aim to tackle this: 55% reduction of emissions from cars and 50% from vans by 2030 [3]. On a local level, there is also an increasing push for zero-emission zones in inner cities, as 26 of the world's largest cities signed up to the Green and Healthy streets pledge [4]. To foster and accelerate this transition towards economically, environmentally, and socially sustainable city logistics, systemic changes in last mile delivery ecosystems are needed. The analysis of previous collaborative urban logistics experiences shows that future urban logistics consolidation frameworks must be built on six fundamental pillars to guarantee the success and sustainability of their generalisation: collaboration, sustainable business models and added-value services, urban integration and space management optimisation, regulation, digital infrastructure, and innovation transferability enablers.

Keywords: Last-mile logistics · decarbonisation · collaboration · digitalisation · intelligent transport systems · Physical Internet · Logistics-as-a-Service · Digital Twins · Blockchain · Micro-consolidation

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1 Introduction

The rapid growth of e-commerce poses sustainability challenges, with a 25 million-tonne CO2 increase and 21% rise in traffic congestion in the last mile. This contradicts European Green Deal, Paris Agreement, and Green City Accord goals for zero-emission urban logistics by 2030. Urban logistics faces challenges like a lack of focus, coordination, and data. European Union (EU)-funded projects aim to address these by testing solutions, emphasizing the need for strategic urban logistics focus, better coordination among stakeholders, and improved data and information for operational efficiency and long-term planning, aligning with overarching sustainability objectives.

2 State of Play- Key Areas

2.1 Collaboration

The existing literature reviews highlight various forms of collaboration, each presenting distinct potentials and barriers. Vertical collaboration involves coordination across modes and service operators throughout the value chain, while horizontal collaboration focuses on multiple providers working within the same transport chain section, sharing orders and infrastructure [5]. The motivation behind such collaborations includes demonstrated effectiveness in reducing last-mile logistics costs and environmental impact, and improvements in service quality by minimizing lead times [6]. Despite these benefits, financial sustainability remains uncertain, contingent on the type of goods being delivered. Trust issues, along with competitive dynamics in the logistics sector, pose challenges, particularly in terms of data sharing. Access to data is vital to enhance knowledge, develop digital tools, and tailor hypotheses and optimization scenarios to showcase the economic advantages of collaboration. Public authorities play a crucial role in fostering a conducive environment for collaboration and solution implementation, with powerful legal frameworks to promote sustainable practices and innovative models within their local strategies. This synergy ensures a transformative ecosystem, making projects like those discussed in this paper highly promising.

2.2 Sustainable Business Models and Added-Value Services

Regarding collaboration and asset sharing, the evolving challenges in city logistics also demand innovative business models. Overcoming traditional asset management boundaries, these models create added value services. A notable example is the joint establishment and management of Urban Consolidation Centers (UCCs), where logistics players (potential competitors) implement horizontal collaboration to enhance performance and resource utilization. Recognizing each entity's contribution and role within the urban freight ecosystem and assessing each entity's contribution to value creation, paralleled by an estimation of the distribution of related benefits and costs is of utmost importance. Exploring sharing, specialization, and allocation strategies can lead to sustainable Collaborative Business Models (CBMs) in city logistics, fostering economic viability and cooperation among providers. Integrating value-added delivery models (such as urban

logistics hubs, micro-consolidation centers, etc.), together with autonomous vehicles, innovative cargo-bikes, and zero-emission transport modes optimizes urban logistics for sustainability and efficient resource allocation.

2.3 Regulation

On another note, the acceptability of low emissions zones (LEZs) may face economic and social challenges, but their demonstrated positive environmental impact, including a notable reduction in NO2 concentrations [7], provides a compelling rationale. LEZs can serve as an incentive for carriers to invest in sustainable vehicles, such as cargo bikes, prompting a fleet upgrade to continue operations in restricted-access areas [8]. Concurrently, restricting conventional delivery trucks through policies like time limits, congestion charges, noise pollution restrictions, and pedestrian zones can bolster support for alternative transport modes like cargo bikes. In addition to adapting local regulations, endorsing cycle logistics as a viable and competitive alternative in last-mile transport is crucial. Complementary support from public frameworks includes strategies such as facilitating real estate access in dense areas, incorporating urban logistics into broader planning schemes, utilizing cycle logistics in public procurement, offering financial incentives, and creating platforms for knowledge exchange among cycle logistics stakeholders. Numerous ongoing projects exemplify best practices and success factors in regulations and public policy frameworks, aiming to provide accessible, replicable, and operational guidelines for a sustainable transition across economic, environmental, and social dimensions.

2.4 Urban Integration and Space Management Optimization

Modular approaches in urban logistics involve dissecting the intricate logistics ecosystem into smaller, interoperable modules adaptable to urban needs. These modules, including electric vehicles, micro-containers, micro-fulfilment centers, and smart traffic management systems, offer flexibility for customized integration in city planning. The three primary solution categories are 1) delivery fleet modal shifts, 2) consolidation and emerging urban storage infrastructure, and 3) innovative delivery frameworks, encompassing the entire last-mile process. European Union-funded projects like URBANE (39 partners with 12 Living Labs and 6 pilots - 6 feasibility studies), DECARBOMILE (31 partners, with 4 Living Labs and 4 Satellite Cities, implementing 11 use cases), and GREEN-LOG (30 partners with 5 LLs, 10 cities implementing various use cases - at least one per city) bring together diverse partners to tackle urban logistics challenges. Through living labs and pilot studies, these initiatives aim to address congestion, emissions, and delivery costs in real-life scenarios, contributing to the evolution of sustainable urban logistics (Table 1).

2.5 Digital Infrastructure

Digital transformation has revolutionized logistics and last-mile delivery, playing a pivotal role in the transition path towards safe, efficient, and sustainable last mile transport. In

Table 1. Intervention mapping (At the time the paper is written, these are the planned interventions. As we are in preparation phase of the pilots, changes may occur.)

INTERVENTIONS	URBANE	DECABOMILE	GREEN-LOG
Alternative delivery fleet mode			
Electric Delivery Vehicles	Valladolid, Helsinki, Bologna, Karlruhe	Hamburg, Istanbul, Logrono, Nantes	Athens, Gent, Leuven, Mechelen, Oxfordshire
Drones, droids			Ispra
Autonomous vehicles, connected Autonomous vehicles, cargo-bikes and robots	Helsinki, Karlsruhe	Sarajevo	Ispra, Athens, Gent, Leuven, Mechelen, Oxfordshire
Public Transport modes for delivery fleet re-balancing (e.g. trams, trains)	Karlsruhe		Barcelona
Consolidation & emerging urban storage infrastructure			
Innovative standard micro-container for aggregation and multimodal use		Nantes, Logrono, Hamburg	
Urban consolidation centers (UCC), micro consolidation centers, mobile depot, micro logistics hub	Helsinki, Bologna, Thessaloniki, Barcelona	Nantes, Hamburg, Logrono, Istanbul, Getafe, Ghent, Tallinn	Athens, Barcelona, Oxfordshire
Connected parcel lockers for both pickup and delivery	Helsinki, Bologna, Thessaloniki	Hamburg, Logrono, Istanbul, Nantes, Getafe	Athens, Barcelona
Innovative Delivery Framework			
Delivery parking zones	Valladolid	Nantes	Athens, Barcelona, Oxfordshire
Real time assets monitoring and tracking		Istanbul, Logrono, Hamburg, Nantes	Ispra, Barcelona
Vehicle routing and crowd shipping deliveries	Bologna, Thessaloniki, Helsinki	Istanbul, Logrono, Hamburg	Oxfordshire, Ispra

(*continued*)

Table 1. (*continued*)

Innovative Delivery Framework			
New urban access regulation to LEZ & respecting loading/ unloading zones	Valladolid	Tallinn, Sarajevo	
Dynamic re-routing	Bologna, Valladolid	Hamburg, Logrono, Istanbul	Oxfordshire, Ispra
Fleet and route optimisation	Valladolid, Karlsruhe, Thessaloniki, Barcelona	Logrono Nantes, Istanbul	Oxfordshire, Ispra

this crucial phase of the supply chain, digital tools, technologies, and concepts that realize Physical Internet vision [9] through interconnected dataspaces, optimization tools, Logistics-as-a-Service (LaaS) platforms [10], the inclusion of green autonomous vehicles, Digital Twins (DT) and blockchain are the key elements to reduce traffic congestion, emissions, and energy consumption achieving efficiency and sustainability. Indicative tools for optimizing logistics include: i) LaaS marketplaces with dynamic pricing for flexible logistics services; ii) Artificial Intelligence-enabled augmented intelligence platforms for demand modeling and location planning; iii) Dynamic routing with real-time tracking and monitoring, supported by machine learning and demand prediction, to optimize deliveries and reduce congestion; iv) DT leveraging real-time data through interactive user interfaces, incorporating modern digital mapping and geographic information systems. These tools collectively enhance efficiency, reduce empty loads, and address congestion challenges in the logistics ecosystem. All these digital tools accompanied by their underlying supporting technologies and scientific knowledge can augment the planning of modern supply chains at all levels: strategic, tactical, and operational levels.

3 Innovation Transferability Enablers

EU Member States (MS) are actively working towards promoting the seamless adoption of innovative last-mile solutions across multiple European cities through the use of "Innovation Transferability Enablers" (ITE). These tools aim to facilitate the implementation of successful interventions in optimizing last-mile networks. The previous sections outlined a diverse range of interventions, spanning both physical and digital infrastructure, regulatory measures, and policy implementations. These interventions span a broad spectrum, ranging from the application of crowd shipping services [11] to fleet smart management systems [12], as well as other types of Intelligent Transport Systems enabled by enhanced connectivity [3]. Even scientific tools like mathematical programming scheduling models [13] for optimal transshipment or unloading of vessels [14] and trucks [15] constitute interventions that can offer decision support towards effective transportation and logistics networks planning. The key emphasis is on ensuring that these interventions go beyond ad-hoc solutions, requiring creators to prioritize scalability, adaptability, and robustness to meet the varied requirements of EU cities

and MS. Open-access digital platforms, known as transferability enablers, allow for the exploitation and replication of successful last-mile logistics innovations in European cities. These platforms support upscaling, re-deployment, and the identification of sustainable solutions, allowing follower cities to implement cost-effective, green logistics networks with defined Key Performance Indicators (KPIs) and efficient sustainable solutions.

4 Conclusions

Digital tools are crucial for enhancing collaboration between Public and Private sectors in European last-mile logistics. The ITEs support stakeholders, local authorities, and logistics providers in exploring collaborative schemes to benefit the city and boost private sector competitiveness. Public authorities can encourage collaboration, promote shared logistics infrastructure, and impose legislative frameworks or KPIs for improved urban community outcomes. Thus, the integration of digital tools is crucial for realizing emission-free innovative and collaborative logistics initiatives.

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