Urban Logistics Challenges

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1. Executive summary

This report, Deliverable 1.1 (D1.1) of the NEXTLOGIC project, provides a comprehensive analysis of urban logistics challenges across the eight EU Mission Cities that form the project's pilot network (Aarhus, Bergamo, Differdange, Dublin, Frankfurt, Heidelberg, The Hague, and Wroclaw). The work supports "Work Package 1: Setting the stage" (led by LAET, France) and establishes the foundational evidence base for all subsequent project activities, including the development of Digital Twins, co-design of solutions, pilot implementation, and impact assessment.

The report combines a literature and policy review, a benchmarking of five solution areas (mobile microhubs, smart loading zones, 15-minute multimodal hubs, incentive mechanisms, and electrification), and primary data collection through semi-structured interviews or written questionnaires with city representatives. The benchmarking draws on real-world implementations from Europe and beyond, extracting key success factors, failure modes, observed performance ranges (where quantitative data exist), design choices, and suggested indicators for monitoring. Where quantitative data are scarce (15-minute multimodal hubs, incentive mechanisms, electrification strategies), a qualitative assessment is provided.

Despite their diversity in size, geography, and policy maturity, all eight cities face common challenges: a persistent lack of granular, real-time logistics demand data; weak enforcement of delivery time windows; financial unsustainability of pilot projects after subsidies end; severe competition for scarce curbside space; and limited political priority for freight compared to passenger mobility. Each city also has unique constraints (e.g., heritage preservation in Aarhus, medieval topography in Bergamo, cross-border flows in Differdange, a pro-business culture resistant to regulation in Dublin, grid congestion in Frankfurt, limited municipal funding for logistics innovation in Heidelberg, a legal framework that permits loading anywhere in The Hague, and strong reliance on university-led research and facilitation in Wroclaw). These findings confirm that one-size-fits-all solutions will not work; NEXTLOGIC's pilots need to be tailored to local contexts.

Digital readiness varies from high (The Hague, Aarhus, Frankfurt) to low (Bergamo, Differdange, Heidelberg). Even the most advanced cities lack a freight-dedicated Digital Twin and real-time delivery stop data. The most urgent shared need is for standardised, anonymised real-time data on delivery vehicle stops, dwell times, and loading zone occupancy.

Stakeholder dynamics and knowledge are critical to success. Cities with formal Freight Quality Partnerships (Wroclaw, The Hague) or strong university collaboration (Aarhus, Bergamo, Wroclaw) progress faster. Where such structures are absent, progress depends on individual champions or ad-hoc consultations, which are fragile and less effective.

Implications for NEXTLOGIC: The report identifies considerations for each work package:

- **WP2 (Digital tools):** Low-cost, user-friendly, and interoperable dashboards may be more practical than complex Digital Twins. Extended reality can add value in specific applications (e.g., stakeholder visualisation in Wroclaw, citizen co-design in Aarhus).
- **WP3 (Solutions):** Business models need to be co-designed alongside technical features, with a focus on financial sustainability across all solution areas, particularly Microhubs and Smart Loading Zones.
- **WP4 (Pilots):** City-specific political and cultural constraints (e.g., limited regulation in Dublin, costly sensors in Heidelberg) need to be respected. Working through existing stakeholder platforms is recommended.

- **WP5 (Impact assessment):** The indicators identified in this report (e.g., compliance rates, illegal parking reduction, cost per delivery) can inform the impact assessment. Developing a replicable Freight Quality Partnership governance template is a potential area for further work.

Next steps: D1.1 directly informs the upcoming deliverables D1.2 Methodological approach and D1.3 Data framework specifications. The benchmarking findings and city assessments will also serve as inputs to D3.1 Toolkit for sustainable urban logistics solutions and D4.1 Operational guidelines for pilot implementation and monitoring, where the applicability of observed performance ranges to NEXTLOGIC pilots will be assessed. D1.1 also serves as a baseline reference for the project's technical and piloting phases, documenting baseline conditions against which future impacts will be measured. The cross-city synthesis confirms that no single solution works everywhere; NEXTLOGIC's greatest contribution will be to document which solutions work under which conditions, providing a replicable blueprint for other Mission Cities.

Keywords: Urban logistics, benchmarking, last-mile delivery, climate neutrality, zero-emission logistics, digital enablers, key success factors, challenges and barriers, Mission Cities

2. Objectives

This section describes the specific objectives of Deliverable 1.1 (D1.1) in the context of the NEXTLOGIC project and Work Package 1 (WP1). It explains how the work performed aligns with these objectives and confirms their achievement.

2.1 Overall NEXTLOGIC objectives and link to D1.1

NEXTLOGIC aims to develop a digitally empowered co-design platform to help eight EU Mission Cities transform urban logistics and mobility towards climate neutrality by 2030. The project's specific objectives are set out in the Grant Agreement and include: developing integrated transport and urban planning tools (O1), creating digitally-empowered tools for dynamic curbside management (O2), redefining multimodal hubs (O3), proposing solutions for infrastructure reallocation (O4), involving stakeholders in co-design (O5), and conceiving new business and financial models (O6).

D1.1 directly supports all six of these objectives by providing the foundational evidence base, characterising current urban logistics challenges, benchmarking best practices, and assessing city-specific contexts. Without D1.1, the subsequent technical development (WP2), solution co-design (WP3), piloting (WP4), and impact assessment (WP5) would lack the necessary empirical grounding.

2.2 WP1 objectives and D1.1 contribution

WP1, "Setting the stage", has four tasks, each with specific objectives. D1.1 contributes to all four:

Table 1. Contribution of D1.1 to WP1 tasks and objectives

WP1 Task	Objective	How D1.1 fulfils it
Task 1.1	Analyse trends, drivers and links between urban logistics, urban space and climate neutrality	Section 4 establishes the conceptual nexus; Section 5 reviews the state of the art
Task 1.2	Develop a data acquisition and management framework	Sections 7 and 8 map existing data sources and gaps across the eight cities, informing D1.3
Task 1.3	Establish an impact evaluation framework	Section 6 provides benchmark indicators, observed performance ranges, and suggested indicators for monitoring for each solution
Task 1.4	Implement co-creation methods	Section 7 identifies stakeholder dynamics and existing co-creation platforms (e.g., Wroclaw FQP, The Hague parcel covenant)

Contribution to subsequent deliverables: The benchmarking analysis and city assessments provided in this deliverable directly inform two subsequent project deliverables:

- **D3.1 Toolkit for sustainable urban logistics solutions, due in M24:** will use the benchmarking findings and design choices to develop benchmark analysis, design principles, and guidelines for implementing Smart Loading Zones (SLZs), Microhubs, Incentive and Reward mechanisms, and Electrification of urban logistics.
- **D4.1 (Operational guidelines for pilot implementation and monitoring, due in M12:** will draw on the city profiles and the identified local barriers, enablers, and required adaptations to define operational guidelines for pilot-specific implementation, replication and monitoring.

Thus, D1.1 serves as the evidence base for WP3 and WP4. The discussion of which benchmark targets are achievable under NEXTLOGIC conditions belongs to D3.1 and D4.1, where city-specific constraints and resources will be considered.

2.3 Specific objectives of this deliverable

D1.1 was designed to achieve the following specific objectives:

- **Objective 1**: characterise the relationship between urban logistics, urban space allocation, and climate neutrality through literature and policy review.
- **Objective 2**: benchmark real-world implementations of five solution families (Microhubs, SLZs, 15-minute hubs, Incentives and Rewards, Electrification), extracting success factors, failure modes, design choices, and where quantitative data exist, observed performance ranges and suggested indicators for monitoring.
- **Objective 3**: assess the eight NEXTLOGIC pilot cities through interviews or questionnaires, focusing on their assigned solution and identifying local barriers and enablers.
- **Objective 4**: Synthesise cross-cutting findings to derive actionable implications for WP2, WP3, WP4, and WP5.

2.4 Achievement of objectives

All four specific objectives have been fully achieved:

- **Objective 1** is addressed in Sections 4 and 5, drawing on academic literature and EU policy documents.
- **Objective 2** is addressed in Section 6, which benchmarks the five solution families. Where quantitative data exist (Microhubs and SLZs), the framework includes observed performance ranges and suggested indicators; for the remaining three solutions, a qualitative assessment is provided.
- **Objective 3** is addressed in Section 7, with detailed profiles of all eight cities (Aarhus, Bergamo, Differdange, Dublin, Frankfurt, Heidelberg, The Hague, Wroclaw) based on interviews or written questionnaires.
- **Objective 4** is addressed in Section 8, which identifies common challenges, unique constraints, governance patterns, data readiness tiers, and implications for each WP.

No major deviations from the work plan occurred. Some cities (Frankfurt, Heidelberg) could not schedule interviews and provided written answers instead; this did not affect the quality or completeness of the city assessments.

3. Background and Methodology

3.1 Background

Transport remains one of the most challenging sectors for reducing greenhouse gas emissions in the European Union. Despite progress in vehicle efficiency and alternative fuels, transport emissions have not declined sufficiently to meet the EU's 2050 climate neutrality target. Urban mobility alone accounts for about 25% of total EU transport emissions, and city logistics contributes approximately one-fourth of that share [1], [2]. Freight vehicles, often diesel-powered, also generate significant local air and noise pollution while competing with pedestrians, cyclists, and private cars for increasingly scarce public space [3].

The European Commission has responded with ambitious policy frameworks: the European Green Deal, the Sustainable and Smart Mobility Strategy, and the EU Mission "Climate-Neutral and Smart Cities". The Mission aims to deliver 100 climate-neutral cities by 2030. In April 2022, 112 cities, 100 from the EU and 12 from Horizon Europe associated countries, were selected to participate, serving as experimentation and innovation hubs for all European cities [4], [5]. Central to this ambition is the need to rethink urban spaces, to reallocate road space, redesign infrastructure, and integrate passenger and freight mobility in ways that reduce emissions while maintaining accessibility and liveability.

However, many cities still lack dedicated urban logistics plans (Sustainable Urban Logistics Plans; SULPs), and where they exist, they are often poorly integrated with Sustainable Urban Mobility Plans (SUMPs) [6]. Data on freight flows, loading zone usage, and delivery patterns remain scarce, especially in smaller or less digitally mature cities. Stakeholder engagement is often ad-hoc, and business models for innovative solutions (e.g. Microhubs, electric cargo bikes) remain untested outside subsidised pilots [7], [8]. The NEXTLOGIC project was designed to address these gaps by providing a digitally empowered co-design platform and testing concrete solutions in eight Mission Cities.

3.2 Purpose and scope of this deliverable

The present deliverable, D1.1 Urban logistics challenges, forms part of WP1 Setting the stage, led by LAET (France).

The scope of D1.1 is limited to qualitative and quantitative desk research, complemented by primary data collected via semi-structured interviews with city representatives. It does not include primary data collection from logistics operators or citizens, as these will be conducted in subsequent WPs. The deliverable is intended for project partners, the European Commission, and other cities interested in replicating NEXTLOGIC approaches.

3.3 Methodology overview

The work carried out for D1.1 followed a mixed methods approach, organised into four phases:

- **Phase 1, Conceptual framework and state of the art (sections 4 and 5):** This phase consisted of a review of the academic literature on urban logistics, urban space allocation, and transport emissions, alongside EU policy documents. It establishes the conceptual nexus linking urban logistics, urban space, and climate neutrality (Section 4). Furthermore, it then presents a literature review of peer-reviewed articles and project reports from relevant Horizon

2020/Europe initiatives, identifying key concepts, technologies, and policy approaches for each of the NEXTLOGIC solution families (Section 5).

- **Phase 2, Benchmarking (Section 6):** Five solution families corresponding to NEXTLOGIC's planned interventions were identified. For each solution family, real-world implementation examples were collected from project evaluation reports and literature. From these examples, the following elements were extracted:
  - Key success factors and common failure modes.
  - Key design choices for pilot cities.
  - Where quantitative data exist (Microhubs and SLZs), observed performance ranges and suggested indicators for monitoring are provided.
  - For the remaining three solutions (15-minute multimodal hubs, Incentives and Rewards mechanisms, and Electrification strategies), a qualitative assessment is presented due to the scarcity of published operational results.
- **Phase 3, City assessment (Section 7):** Semi-structured interviews were conducted with representatives from each of the eight NEXTLOGIC pilot cities. For cities unable to schedule an interview (Frankfurt, Heidelberg), a detailed written questionnaire was administered. Each city profile presented in this report focuses exclusively on the solution assigned to the respective city in the project's Description of Action, using the benchmarking framework from Section 6 as a reference.
- **Phase 4, Cross-cutting synthesis (Section 8):** The eight city profiles were compared to identify common challenges, unique constraints, governance patterns, and data readiness levels. Implications and recommendations for each NEXTLOGIC work package (WP2-WP5) were then derived from the cross-cutting analysis.

3.4 Structure of the report

The remainder of this deliverable is organised as follows:

- **Section 4** presents the conceptual nexus of urban logistics, urban space, and climate neutrality, including definitions and policy drivers.
- **Section 5** reviews the state of the art across the five solution areas, focusing on concepts and key references.
- **Section 6** provides a benchmarking framework for the five solution families, including real-world examples, success factors, failure modes, design choices, observed performance ranges, and suggested indicators for monitoring.
- **Section 7** contains the individual assessments of the eight NEXTLOGIC Mission Cities, presented as concise profiles focused on each city's assigned solution.
- **Section 8** synthesises cross-cutting findings, discussing common challenges, unique constraints, governance dynamics, data readiness, and implications for NEXTLOGIC work packages.
- **Section 9** concludes the report with a summary of key findings, the contribution to WP1 objectives, and next steps for D1.2, D1.3, and the overall project.
- **References** list all cited literature, project documents, and policy sources.
- **Annex** includes the interview guide.

4. The Nexus of Urban Logistics, Urban Space, and Climate Neutrality

4.1 Defining the three analytical dimensions

Urban logistics, urban space, and climate neutrality represent three interdependent dimensions that collectively shape the functioning and sustainability of contemporary cities. Their interactions define both the opportunities and the constraints associated with the transition towards more efficient and environmentally sustainable urban systems.

Urban logistics refers to the planning, management, and coordination of the flow of goods and related information within urban areas, encompassing activities such as transportation, warehousing, distribution, and last-mile delivery. It involves multiple stakeholders, including logistics service providers, retailers, public authorities, and end consumers, and plays a fundamental role in supporting economic activity and urban life. At the same time, urban logistics generates significant externalities, including congestion, emissions, noise, and pressure on urban infrastructure [9], [10].

Urban space refers to the physical and functional structure of cities, including road networks, public spaces, land use configurations, and infrastructure systems. It is a limited and highly contested resource that must accommodate a wide range of functions, including mobility, economic activity, social interaction, environmental services, and logistics-related activities. Within this context, urban logistics constitutes a major but often under-recognised user of urban space [11]. Freight activities require space not only for movement but also for loading and unloading, temporary storage, and consolidation operations, supported by a variety of urban logistics facilities and dedicated logistics spaces [12]. The curbside, in particular, is a critical interface where delivery vehicles compete with other uses such as parking, public transport, cycling, and pedestrian activities. Inefficient or unregulated use of curbside space leads to congestion, operational inefficiencies, illegal parking, and increased environmental impacts, posing challenges for both urban mobility and sustainability [9], [13].

Climate neutrality refers to the objective of achieving net-zero greenhouse gas emissions, which is central to European and global sustainability strategies. Urban freight transport contributes substantially to emissions, air pollution, and energy consumption. Achieving climate neutrality in urban logistics requires a combination of technological, operational, and organisational changes, including low- and zero-emission vehicles, alternative fuels, optimisation of logistics operations, and integration of freight considerations into urban planning [14].

The interactions between these three dimensions create a complex system characterised by interdependencies and trade-offs. Urban logistics depends on urban space for its operations, while simultaneously shaping how that space is used. At the same time, efforts to reduce environmental impacts require changes in both logistics systems and spatial planning approaches. These interdependencies highlight the need for integrated and systemic approaches, precisely the gap that NEXTLOGIC addresses by combining digital tools (Digital Twins (DT), eXtended Reality (XR), data analytics) with co-designed urban logistics solutions.

4.2 How logistics occupies urban space

Urban logistics requires physical space for a range of activities: moving vehicles, loading and unloading goods, temporarily storing parcels, parking delivery fleets, and operating consolidation facilities. The most visible and pressured spaces are the curbside and the street network. In dense urban areas, loading/unloading zones are scarce. When such spaces are occupied by unauthorised vehicles or are non-existent near the destination, delivery drivers resort to double-parking, blocking traffic lanes, or parking on sidewalks, causing congestion, safety risks, and delays [15].

Beyond the curb, logistics occupies space in the form of Microhubs, delivery depots, and increasingly cargo bike parking stations. The growth of e-commerce has intensified this spatial footprint: more delivery trips, smaller parcels, and pressure to locate consolidation facilities closer to customers [16]. In many historic city centres, narrow streets and protected buildings further constrain the space available for freight operations, forcing logistics providers to use smaller vehicles or make deliveries outside normal hours.

Consequently, the amount and quality of space dedicated to logistics directly affects delivery efficiency, congestion levels, and the ability to shift to cleaner modes (e.g. cargo bikes require secure parking and loading areas). Understanding how logistics occupies space is therefore the first step toward designing interventions that use space more efficiently, a central goal of the NEXTLOGIC solutions.

4.3 Environmental footprint of urban logistics

Urban freight transport is a significant contributor to environmental degradation. Within the European Union, urban freight accounts for approximately 25 % of CO_2 emissions from urban transport and 30-50 % of transport-related pollutants such as particulate matter (PM) and nitrogen oxides (NOx) [17], [18]. The environmental footprint is intensified by frequent stop-and-go operations, increasing delivery demand, and the rapid growth of e-commerce-driven last-mile deliveries [19].

Electrification of delivery vans and cargo bikes reduces tailpipe emissions to zero, but the overall benefit depends on the carbon intensity of the electricity grid and the life cycle of batteries. Moreover, zero emission vehicles still occupy space and contribute to congestion. Therefore, space efficiency and emissions reduction are closely interconnected, providing the rationale for NEXTLOGIC’s integrated approach.

Achieving climate neutrality in urban logistics cannot rely solely on vehicle technology. It also depends on logistics organisation (consolidation, route optimisation), spatial planning (location of Microhubs, loading/unloading zones), stakeholder behaviour (delivery times, mode choice), and digital tools that enable real-time monitoring and simulation, helping to optimise logistics processes. NEXTLOGIC directly addresses these factors by providing a DT platform, XR tools for co-design, and a set of practical solutions (Microhubs, SLZs, etc.).

4.4 Policy drivers (EU Green Deal, Cities Mission)

The European Green Deal set the target of reducing transport-related greenhouse gas (GHG) emissions by 90 % by 2050 compared to 1990 levels [20]. The Sustainable and Smart Mobility Strategy explicitly calls for “zero-emission” urban logistics by 2030 in major cities [21]. To accelerate progress, the EU Cities Mission (formally “Climate-Neutral and Smart Cities Mission”) selected 112 European cities (100 from the EU and 12 from Horizon Europe associated countries) that have signed a Climate City Contract, a binding roadmap to achieve climate neutrality by 2030 [4], [22]. All eight NEXTLOGIC pilot cities are Mission Cities.

These policy frameworks create both pressure and opportunity: cities that fail to decarbonise logistics risk losing funding and falling behind on legal obligations. At the same time, Mission Cities receive dedicated support from the EU, including platforms for knowledge exchange, technical assistance, and access to innovation funding (such as Horizon Europe). NEXTLOGIC directly contributes to the Cities Mission by providing tools (DTs, XR, data analytics) and co-created solutions (Microhubs, SLZs, 15-minute hubs, Incentives and Rewards, Electrification) that help cities turn their Climate City Contract targets into concrete actions.

Despite the growing policy attention, the integration of logistics into urban planning remains limited in many cities. Historically, urban planning has focused on passenger mobility, while freight has been treated as a secondary issue [23]. The complexity of urban freight systems, involving municipalities, logistics operators, retailers, residents, and technology companies, makes coordination difficult. Limited data availability, fragmented institutional responsibilities, and lack of expertise further hinder progress. NEXTLOGIC is designed to help bridge these gaps by providing evidence-based benchmarking (this deliverable), digital tools (WP2), co-designed solutions (WP3), real-world pilots (WP4), and the development of business models and impact assessment frameworks (WP5).

5. State of the Art: Urban Logistics Solutions in Practice

Numerous solutions and innovations have been proposed to improve the efficiency and sustainability of urban freight transport. These range from infrastructure and regulatory measures to technological and organisational approaches. Examples include urban consolidation centres, low-emission zones, parcel lockers, crowdshipping, delivery time regulations, autonomous vehicles, and demand-management measures [24], [25], [26], [27], [28]. Therefore, the solutions reviewed in this section do not represent an exhaustive overview of all available urban logistics interventions.

Instead, this section focuses on the five solution areas and digital enablers addressed by NEXTLOGIC, namely integrated Mobile Microhubs and cargo bikes, Smart Loading and Unloading Zones, 15-minute multimodal hubs, Incentives and Rewards mechanisms and Gamification, and the Electrification of urban logistics, together with enabling digital technologies such as DTs, XR, and data analytics. These solutions were selected because they constitute main domains investigated within the project and represent complementary technological, spatial, operational, and behavioural approaches to supporting climate-neutral urban logistics. Therefore, the purpose of this section is not to review the entire spectrum of urban logistics solutions, but rather to establish the state of the art and provide a knowledge base for the solutions and digital tools developed within NEXTLOGIC.

5.1 Integrated Mobile icrohubs & cargo bikes

Urban logistics systems are increasingly challenged by rising delivery demand, limited urban space, traffic congestion, and the environmental impacts of last-mile freight distribution. In response to these pressures, integrated Mobile Microhubs and cargo-bike delivery systems have emerged as promising approaches for improving the sustainability and efficiency of urban freight operations. These systems aim to reorganise last-mile logistics by combining localised consolidation facilities with low-emission delivery modes, particularly cargo bikes and other light electric vehicles [29].

Microhubs are small-scale urban logistics facilities located close to dense delivery-demand areas, where goods are transferred from larger freight vehicles to smaller and more sustainable delivery modes for final distribution. Unlike traditional urban consolidation centres typically located at the urban periphery, Microhubs are integrated directly within urban neighbourhoods and commercial districts, enabling shorter delivery distances and improved operational flexibility. Recent studies highlight that the combination of Microhubs with cargo-bike delivery can significantly reduce freight-related congestion, emissions, and space consumption in dense urban environments [30].

Several classifications of Microhubs exist in the literature. Katsela et al. [8] identify three Microhub typologies based on an analysis of 17 European and North American cases: (i) last-mile collaboration (receiver-led or third-party logistics initiatives); (ii) shared infrastructure (government-supported projects); and (iii) private systems (single-carrier, privately-owned facilities). A complementary classification distinguishes between stationary Microhubs, which are situated within existing infrastructure (e.g. basements, parking garages, or shopping centres), and Mobile Microhubs, which can be relocated to different sites (e.g., container-based or trailer-mounted units).

Cargo bikes have gained particular attention due to their ability to operate efficiently within congested urban areas while requiring substantially less road and parking space than conventional delivery vans. Studies show that cargo bikes can replace a considerable share of urban parcel-delivery trips, particularly in dense city centres characterised by short delivery distances and high stop density. The ITF report highlights that cargo bikes could replace up to 51% of urban motorised freight trips in European cities under appropriate operational conditions [3]. Similarly, a study conducted for the

European Commission highlights substantial potential reductions in GHG emissions, congestion, and delivery-related space occupation through large-scale cargo-bike deployment [31].

The operational effectiveness of integrated Microhub systems depends strongly on urban density, delivery concentration, and infrastructure availability. High delivery density and mixed-use urban environments generally improve the economic viability of cargo-bike operations by enabling route consolidation and reducing travel distances. At the same time, the availability of cycling infrastructure, safe curb access, loading spaces, and temporary trans-shipment areas significantly influences operational performance and delivery efficiency [32]. Several studies also emphasise the importance of locating Microhubs within approximately 3 km of delivery areas to maintain operational efficiency and minimise additional handling costs and delays [33], [34].

Despite their potential benefits, integrated Microhub systems face several implementation challenges. One major barrier concerns the availability and affordability of urban space for establishing Microhub facilities within dense city centres. Urban land scarcity, competing land uses, and high rental costs often limit opportunities for long-term deployment. Financial viability also remains uncertain in many pilot projects, particularly when operations rely heavily on public subsidies or temporary policy support. Research further highlights challenges related to fragmented logistics operations, limited cooperation between municipalities and logistics operators, regulatory uncertainty, and the need for operational adaptation among freight carriers [34], [35].

Training and operational adaptation among logistics operators and couriers are also essential, particularly when transitioning from van-based delivery models toward cargo-bike logistics systems. Several recent pilot projects demonstrate that successful implementation depends not only on physical infrastructure but also on governance arrangements, public-private cooperation, and the integration of logistics planning into broader urban mobility and climate-neutrality strategies [32].

5.2 Smart Loading Zones & dynamic curbside management

Growing competition for urban curb space has become one of the central challenges of contemporary urban logistics systems. The rapid growth of e-commerce, on-demand deliveries, ride-hailing services, cycling infrastructure, outdoor commercial activities, and public-transport prioritisation has substantially intensified pressure on limited curbside space within dense urban environments. Recent studies increasingly describe the curb as one of the most dynamic and contested components of urban public space, requiring more flexible and adaptive management approaches [36]. In many cities, however, curb regulations and loading infrastructure have not evolved at the same pace as changing urban freight patterns, resulting in insufficient loading capacity, illegal parking, double parking, congestion, and operational inefficiencies.

Freight vehicles depend heavily on access to curbside infrastructure for loading and unloading operations. Several studies demonstrate that insufficient or poorly managed loading zones substantially increase parking-search behaviour and unregulated stopping practices among delivery vehicles. Using GPS data from parcel-delivery operations in Seattle, a recent study estimated that commercial vehicles spent an average of 2.3 minutes per trip cruising for parking, accounting for approximately 28% of total trip time [37]. Their findings further show that cruising behaviour decreases when additional commercial vehicle loading zones and off-street parking facilities are available. Similarly, recent work on designing urban distribution networks with loading and unloading zones highlights that inadequate spatial coverage of loading zones in high-demand commercial districts significantly increases unregulated parking behaviour by freight vehicles [38].

In response to these challenges, cities are increasingly adopting Smart Loading Zones (SLZs) and dynamic curbside management approaches. Unlike traditional static curb regulations, these approaches recognize that curb demand varies across locations, user groups, and times of day. Therefore, dynamic curbside management seeks to allocate curb space more flexibly through time-dependent regulations, digital reservation systems, demand-responsive pricing, real-time monitoring technologies, and multifunctional curb-use strategies. Recent municipal curb-management policies increasingly integrate freight operations, ride-hailing services, public transport, cycling infrastructure, and micromobility within coordinated curbside-management frameworks [36].

Digital technologies play a particularly important role in enabling dynamic curbside management. Sensors, cameras, occupancy-monitoring systems, digital curb inventories, and app-based reservation platforms allow cities to monitor curb use and adapt regulations in near real time [39]. Studies emphasise that integrating temporal and operational dimensions into loading-zone management can significantly improve curb efficiency without necessarily increasing physical curb capacity [38].

Despite their potential benefits, SLZs and dynamic curbside systems face several implementation barriers. Enforcement remains one of the most frequently identified challenges, particularly where curb regulations change dynamically throughout the day. Institutional fragmentation between transport departments, parking authorities, public works agencies, and enforcement bodies also complicates implementation processes [40]. In addition, many cities face significant limitations related to data availability, technological costs, legal constraints, and inconsistent cooperation between municipalities and private logistics operators. Recent research further highlights that many curbside pilot projects struggle to transition toward long-term institutionalised practices due to regulatory uncertainty, business-model limitations, and governance challenges [41].

5.3 15-Minute multimodal hubs

The concept of 15-minute multimodal hubs has emerged from broader discussions surrounding the 15-minute city, sustainable accessibility, and integrated urban planning approaches. The 15-minute city framework promotes the organisation of urban systems in a way that enables residents to access essential daily services, employment, retail, leisure activities, and mobility options within short distances through sustainable transport modes such as walking, cycling, and public transport [42]. Within this context, multimodal hubs can be conceptualised not only as passenger-transport interchanges, but also as multifunctional urban nodes integrating mobility services, logistics activities, public space, and neighbourhood-scale urban functions.

Recent research highlights that urban logistics should become an integral component of 15-minute city planning rather than remaining disconnected from broader accessibility and land-use strategies [43]. Planning logistics in the 15-minute city highlights that freight distribution systems strongly influence the functionality, accessibility, and liveability of proximity-based urban models, particularly due to the rapid growth of e-commerce and on-demand deliveries [44]. As a result, station areas, mobility hubs, and neighbourhood centres should be viewed as strategic locations for integrating sustainable last-mile logistics operations within dense urban environments.

Traditionally, transport hubs were designed primarily to facilitate passenger transfers between transport modes. However, contemporary multimodal hubs can combine public transport, cycling infrastructure, pedestrian accessibility, shared mobility services, parcel lockers, cargo-bike facilities, shared loading zones, and localised freight-consolidation functions within integrated urban environments. Such approaches could ultimately aim to improve the efficiency of both passenger and freight movements while optimising the use of limited urban space. Integrating logistics functions within multimodal hubs may also reduce delivery distances, support low-emission last-mile distribution systems, and limit freight-related congestion in dense urban districts.

The growing interest in integration of logistics into multimodal urban planning would be a reflect of wider recognition that freight transport is fundamentally linked to urban accessibility and public-space management. Integrating logistics into urban planning emphasises that urban freight activities are often insufficiently considered within sustainable urban-development frameworks despite their major influence on congestion, emissions, curbside competition, and urban liveability [45]. Consequently, integrating logistics infrastructure into multimodal hubs and station areas is increasingly considered an important strategy for supporting climate-neutral urban mobility transitions.

Multimodal hubs may provide several operational and environmental benefits. Their integration with public transport and active mobility systems can reduce private-car dependency while improving accessibility to urban services and employment. From a logistics perspective, localised consolidation activities and cargo-bike operations integrated into multimodal hubs may improve delivery efficiency and reduce emissions associated with conventional van-based distribution systems. Several recent European policy discussions also emphasise the role of multimodal accessibility and integrated urban hubs in supporting climate-neutral and resilient cities [46].

Despite these potential benefits, the implementation of 15-minute multimodal hubs involves important governance, spatial, and operational challenges. Effective integration requires coordination between transport and land-use planning, infrastructure management, logistics operators, and local authorities [47]. In many cities, freight activities remain institutionally separated from passenger mobility planning, limiting opportunities for integrated implementation. Limited urban space, competing land uses, unequal accessibility between neighbourhoods, and financial constraints further complicate implementation processes. In addition, integrating logistics operations within highly accessible and pedestrian-oriented urban environments requires careful balancing between freight efficiency, public-space quality, and urban liveability objectives.

5.4 Incentive and Reward mechanisms & gamification

In recent years, incentive and reward mechanisms and gamification approaches have gained attention as complementary strategies for supporting sustainable urban mobility and logistics transitions. Unlike traditional regulatory measures that rely primarily on restrictions and enforcement, these approaches seek to influence user behaviour through rewards, behavioural nudges, competition, social engagement, and digital interaction mechanisms [48]. However, compared with more established urban logistics solutions (e.g., Microhubs, SLZs or low-emission zones), incentive and reward mechanisms and gamification remain relatively underexplored and experimentally oriented, especially in the freight and urban logistics field [49], [50].

Gamification is commonly defined as the use of game-design elements, such as points, badges, challenges, and rewards in non-game contexts to encourage behavioural change and user engagement [48], [51]. Within urban logistics, these approaches are getting integrated into digital platforms and smart-city applications to promote sustainable delivery choices, improve operational coordination, and strengthen collaboration between stakeholders. Recent research highlights that gamification can support behavioural adaptation among logistics actors by increasing awareness of urban freight impacts and encouraging participation in sustainability-oriented practices [48].

From a mechanisms perspective, gamification systems typically operate through motivational affordances that address both extrinsic and intrinsic user needs. Common mechanisms include virtual rewards (points, badges), social recognition (leaderboards, rankings), competence building (personalised challenges, feedback loops), autonomy (goal setting, progress tracking), and relatedness (team competitions, social interaction) [52], [53]. In urban logistics, these mechanisms are often embedded in mobile applications, delivery platforms, or real-time monitoring systems to influence choices such as off-peak deliveries, use of low-emission vehicles, consolidation practices, shared logistics services, and participation in data-sharing initiatives. Digital technologies significantly expand the potential of such systems by enabling dynamic reward mechanisms, personalised behavioural interventions, and real-time feedback [50].

However, despite their potential to encourage cooperation and support behavioural change, gamification approaches also face important limitations and implementation challenges. Empirical evidence consistently shows that behavioural changes achieved through gamification are often difficult to sustain over long periods, especially when systems rely heavily on external rewards (e.g. points or vouchers) rather than fostering intrinsic motivation [50]. The diversity of stakeholders in urban logistics, including logistics operators, couriers, retailers, municipalities, and citizens, further complicates implementation, as different user types may respond differently to the same incentive structures [48]. Additional concerns include user participation fatigue, unequal access to digital technologies, data privacy risks, and the difficulty of measuring long-term behavioural impacts within complex urban systems. Successful implementation therefore requires carefully designed governance structures, user-centred design approaches, continuous stakeholder involvement, and integration with broader urban logistics and climate-neutrality strategies [48].

5.5 Electrification of urban logistics

The electrification of urban logistics has emerged as a central strategy for reducing GHG emissions, air pollution, and noise generated by urban freight transport. Increasing e-commerce activity, fragmented last-mile deliveries, and growing policy pressure for climate neutrality have accelerated interest in replacing conventional diesel freight vehicles with low- and zero-emission alternatives such as electric vans, electric trucks, and electric cargo bikes. Within European cities, electrification is increasingly linked to broader sustainability agendas, including low-emission zones, zero-emission logistics strategies, and climate-neutral urban mobility policies [54]. Consequently, electrification is increasingly viewed not only as a technological transition, but also as an operational, infrastructural, and governance challenge requiring coordination between municipalities, logistics operators, infrastructure providers, and energy systems [55].

Recent studies highlight that electric freight vehicles can substantially reduce environmental externalities associated with urban logistics operations. Bandeira et al. [56] demonstrate that electric delivery vehicles and electric cargo bikes can significantly lower CO_2 emissions and urban noise levels compared with conventional diesel-based systems, particularly in dense urban environments characterised by short delivery distances and frequent stop-and-go operations. Similarly, Llorca and Moeckel [57] show, through agent-based simulation of urban freight flows, that combining electric vans with cargo-bike systems can considerably reduce motorised traffic volumes and emissions in last-mile parcel distribution, although they note that total operating time may increase slightly and that at least half of van tours remain necessary for larger parcels.

Despite these advantages, large-scale implementation of electric urban freight systems remains constrained by several operational and infrastructural barriers. Existing studies identify high vehicle-acquisition costs, limited charging infrastructure, battery-range limitations, charging time requirements, and operational uncertainties as major challenges for logistics operators [58]. Electrification may also require substantial adjustments in routing practices, depot organisation, delivery scheduling, and fleet management systems. For example, charging availability and vehicle range directly affect delivery reliability and operational flexibility, particularly for operators conducting intensive urban distribution activities [55]. The integration of electric vehicles into urban logistics systems therefore requires not only vehicle replacement, but also broader adaptation of logistics networks and urban infrastructure.

Urban freight electrification is also closely connected to evolving policy and governance frameworks. Cities increasingly use regulatory mechanisms such as low-emission zones, zero-emission zones, preferential access policies, and financial incentives to accelerate the transition towards cleaner freight fleets [58]. The POLIS and ALICE [54] guide on zero-emission urban logistics emphasises that successful implementation depends on strong collaboration between public authorities and private logistics stakeholders, as well as clear long-term regulatory frameworks capable of supporting investment certainty.

At the same time, recent experiences demonstrate that electrification alone does not automatically guarantee efficient or sustainable urban logistics systems. The effectiveness of electric freight operations depends heavily on urban density, delivery patterns, availability of charging infrastructure, and the integration of vehicles within broader logistics and land-use systems. The ITF report [59] on urban logistics emphasises that electrification should be combined with operational optimisation measures, cargo-bike deployment, consolidation strategies, and digital coordination systems to maximise environmental and spatial benefits. Therefore, electrification increasingly forms part of integrated urban logistics-transition strategies rather than functioning as an isolated technological solution.

5.6 Digital enablers (DT, XR, data analytics)

Digital technologies are increasingly recognized as critical enablers for improving the efficiency, sustainability, and governance of urban logistics systems. The growing complexity of urban freight operations, combined with increasing demands for climate neutrality and real-time decision-making, has accelerated the adoption of digital tools capable of supporting data integration, simulation, monitoring, stakeholder coordination, and operational optimisation. Within contemporary urban logistics systems, technologies such as DTs, XR, advanced data analytics, and visualisation platforms are increasingly used to support evidence-based planning and more adaptive freight-management strategies.

5.6.1 Digital twins for urban logistics

DTs are virtual representations of physical urban systems that integrate real-time and historical data to simulate, monitor, and optimise urban processes. In urban logistics, DTs have recently emerged as a novel concept to model freight flows, evaluate logistics scenarios, assess infrastructure interventions, and support decision-making under changing urban conditions. Early studies suggest that DTs could potentially support optimisation of delivery operations, curbside management, vehicle routing, and infrastructure allocation by integrating spatial, operational, and environmental data into dynamic simulation environments [60]. They also offer the possibility for cities and logistics stakeholders to test alternative urban freight strategies before physical implementation, thereby reducing uncertainty and improving policy evaluation. However, existing research remains largely exploratory, and practical large-scale applications are still rare. The effectiveness of DTs depends critically on data quality, interoperability, governance structures, and stakeholder collaboration, which are particularly challenging in complex urban freight systems [61].

5.6.2 Extended reality (XR) for stakeholder engagement

XR encompassing Virtual Reality (VR) and Augmented Reality (AR), has emerged as a novel tool to enhance stakeholder engagement, including in the field of urban logistics planning. XR enables stakeholders such as city authorities, logistics operators, residents, and businesses to immerse themselves in and interact with proposed interventions before physical implementation, thereby improving transparency, collaborative decision-making, and accessibility of complex spatial information [62]. Studies show that XR can support sustainability in smart cities by enabling novel forms of e-participation, and that immersive technologies help bridge the analogue-digital divide in stakeholder dialogue by visualising proposals in the real environment [63]. Mixed reality applications have demonstrated potential to assist municipal governments in better engaging partners and improving understanding of the urban environment [64]. At the same time, the literature remains fragmented, and XR use in participation faces practical adoption hurdles including high implementation costs, technical expertise requirements, and the risk of digital exclusion [62]. Consequently, most applications remain at pilot or exploratory stage, and successful implementation depends on careful integration with traditional engagement methods, robust governance, and user-centred design [65]. Within the NEXTLOGIC project, XR will be explored as a component of the digital co-design platform, with dedicated activities to develop and test XR prototypes in pilot cities, thereby assessing their practical value for collaborative planning and communication in zero-emission urban logistics.

5.6.3 Data-driven approaches, analytics and visualization

The growing availability of urban mobility and logistics data has opened new opportunities for data-driven approaches in urban freight planning and management. Advanced analytics, machine learning, geographic information systems, sensor technologies, and visualisation platforms are being explored to monitor freight activity, identify operational inefficiencies, forecast demand, and support dynamic logistics management. Recent literature emphasises that data visualisation and analytics tools can improve the interpretation of complex freight patterns and facilitate evidence-based policymaking by transforming large datasets into accessible and actionable information [66]. However, several studies underline persistent challenges related to data accessibility, interoperability, privacy, standardisation, and institutional coordination across public and private actors involved in urban logistics systems. Notably, a comprehensive review of big data in road freight transport identifies organisational, privacy, technical expertise, and legal challenges that continue to hinder access to and utilisation of big data for freight applications, noting that the data-sharing environment remains at an early stage [67]. These barriers must be addressed before data-driven approaches can be deployed at scale in real-world urban logistics operations.

6. Benchmarking Framework

6.1 Purpose and methodological approach

This benchmarking framework provides an evidence-based reference for the five NEXTLOGIC solutions: Mobile Microhubs, Smart Loading Zones, 15-minute multimodal hubs, Incentive and Reward mechanisms, and Electrification.

For each solution, the methodology follows four consistent steps: (1) surveying real-world implementations from European and international projects and initiatives; (2) extracting success factors and common failure modes; (3) where quantitative data exist, deriving observed performance ranges from the literature; and (4) compiling design choice checklists and suggested indicators for monitoring. All sources are cited. The framework is intended as a living reference to be updated as NEXTLOGIC pilots generate new evidence.

6.2 Benchmarking of integrated Mobile Microhubs

6.2.1 Real-world implementations

Table 2 summarises key examples of Microhub systems combined with e-cargo bike delivery systems, including both stationary and Mobile Microhubs. While NEXTLOGIC focuses on Mobile Microhubs, stationary examples are also included as they provide valuable performance benchmarks and operational insights that are transferable to mobile configurations.

Table 2. Real world Microhub implementations and key results

Location / Project (Period)	System features	Key results
Paris (France) / Parcel service company microhub (2022) [68], [69]	Analysis based on 600,000 real operations in Paris over two months. Compares total cost of ownership of electric light commercial vehicle (LCV) versus cargo-bike solution using optimised Microhub locations.	3 optimally located Microhubs can handle 67% of daily operations at cost similar to e-LCV fleet; Beyond 3 hubs, costs increase; 10 hubs cover >90% of eligible shipments but cost 30% more; Rent price of Microhubs is a critical barrier; Optimal Microhub catchment radius: ≈2 km.
Paris (France) / Fludis (2019-ongoing) [70]	Electrically powered 38 m boat-warehouse operating as a floating hub on the Seine. Goods are delivered overnight by truck from a peripheral logistics platform (Gennevilliers), then transferred onboard to cargo bikes for last-mile delivery. The vessel acts as a mobile hub, stopping at multiple river ports in Paris where deliveries are redistributed directly, with onboard preparation of delivery rounds and no intermediate storage. Reverse logistics flows are also integrated.	3,000 parcels/day handled; ~30 cargo bikes operating in coordinated shifts; 4 daily stopovers along the Seine. One vessel enables ~300,000 km/year of van traffic avoidance and ~110 tons of CO_2 reduction. Demonstrates high delivery density per rider (500-600 kg/day) comparable to van performance, with reduced congestion, improved efficiency, and scalable river-based logistics potential. Key constraint remains infrastructure scalability (ports and fleet expansion).
Lyon (France) / La Ruche Ephémère **(2023-2024)**	Field experiment based on 27 real-world urban logistics operations in Lyon between May 2023 and January	27 ephemeral hub operations handled 3 tons of goods (~110 kg per Ruche) and 317 parcels delivered to 45 customers (~12

Location / Project (Period)	System features	Key results
[71]	2024. Tests a mobile and ephemeral consolidation hub enabling synchronous transshipment between vans/LCVs and cargo bikes without intermediate storage, supported by procedural coordination and semi-manual digital planning via Cyke (no fully integrated real-time system).	parcels per Ruche) with an average 22 minutes of on-site handling per Ruche. The system shows environmental benefits (18.93 kg CO_2 avoided; 74.68 km of conventionally powered vehicle travel avoided; 208 km UVP reduced urban road occupancy) but a negative global economic balance of -655.28 €. This deficit is mainly driven by high subcontracting costs and significant coordination and operational time burdens for shippers, including shipment preparation, parcel eligibility checks, vehicle access and approach to the site, waiting times due to desynchronisation, and on-site transshipment handling.
Paris (France) / Vert Chez Vous - FLUDIS (2013-ongoing) [72]	Modal shift from road to river was implemented, leveraging a conventional barge for freight transport into the city via waterways. The last-mile delivery was transitioned to electric cargo bikes, replacing conventional trucks. The system relied on consolidated flows from multiple suppliers, optimised for the Vert-chez-vous (VcV) service area, and required a new IT system for tracking, order preparation, and last-mile optimisation. A floating logistics hub served as a mixed-use space for personnel, vehicles, and goods, combining storage, order fulfilment, and preparation. FLUDIS replaced VcV with a similar system, only using an eco-friendlier hybrid barge.	Vert Chez Vous Allowed avoiding 15 heavy-duty vehicles and 207.9 kg of CO2 per day (51,975 kg per year). The kilometres travelled by LCVs decreased from 682 in traditional delivery to 194 for the solution (which is 3.5 times less). The freight transfer amounted to 3-4 tons per day, corresponding to 500 parcels and 390 delivered positions. Although no assessment was made for FLUDIS, larger volumes and improvements are expected with the system and the business model proves to be sustainable.
Helsinki (Finland) / DISCO (2023-2026) [73], [74]	Shared Microhub inside Ruoholahti shopping centre; operated as a shared logistics hub where larger shipments arrive by vans/lorries and are redistributed via low-emission modes. Featured a service point for customer parcel pick-up/drop-off.	>1,500 parcels delivered during the trial (May-July 2024) using three cargo bike vehicles and two autonomous delivery robots. Achieved significant CO_2 and noise reductions by shifting deliveries from vans/lorries to lighter modes. Lighter vehicles occupy less space, improving urban safety and comfort. Residents' acceptance level: 86.66% (residential survey).
Seattle (USA) / Urban Freight Lab pilot (2021) [75]	Single e-cargo tricycle serving Uptown neighbourhood; Microhub hosted in a parking lot using a shipping container for charging and storage. Replenished by cargo van from suburban depot. Participatory design involving multi-sector stakeholders.	74% reduction in conventional van vehicle miles travelled per package when stem share was 25% (i.e., stem trip shared across 4 e-cargo routes). 682 g CO_2 saved per package (73% reduction compared to van's 933 g). Over 33 days, 17 packages/day average, totalling 365 cargo van miles

Location / Project (Period)	System features	Key results
		saved. E-cargo tricycle travelled 700m per package.
Toronto (Canada) / On-street micro-hub pilot (2020) [76]	40-foot shipping container occupying five metered on-street parking spaces on university campus. Purolator operates three electric cargo bikes. Functions as micro-distribution centre, overnight storage/charging facility, and retail service window for customer pick-up/drop-off.	E-cargo bikes averaged 25 delivery stops/day (vs 19 for trucks) with dwell time <4 minutes per stop (vs >10 minutes for trucks). Replacing one delivery van with one cargo bike eliminated 3.1-5.5 metric tons of CO_2 emissions annually. Single cargo bike replaced operations of a delivery van without compromising efficiency.
New York City (USA) / NYC DOT Microhubs Pilot (2025-2028) [77]	On-street (24-30 m curb lane zones) and off-street (city-owned properties) micro-hub zones; transfer from large trucks to e-cargo bikes, handcarts, and smaller electric sprinter vans. Mandated by Local Law 166 of 2021.	Launched April 2025; Phase 1: up to 20 pilot sites (2025-2026). Phase 2: feasibility evaluation (Fall 2026). Planned expansion to 36 pilot sites citywide. Quantitative results not yet available. Benchmark for legislative microhub models.
Sydney (Australia) / Goulburn Street Courier Hub (2015-present) [78]	Stationary Microhub in an underground car park (approx. 125 m²). Open-access shared space for multiple couriers to transfer goods from delivery vehicles to active modes (primarily courier bikes).	Operates since 2015 as a proof-of-concept trial, extended multiple times. Enables last-mile deliveries to switch from vehicles to bikes. Benefits outweigh costs considerably (cost-benefit analysis). Reduces vehicle operating costs, CO_2 emissions, pressure on Central Business District (CBD) loading zones, infrastructure maintenance requirements, and improves health outcomes and CBD amenity.
London (UK) / Pimlico Micro-Logistics Hub (Apr 2023 - Dec 2023) [79]	Microhub located in the Q-Park Pimlico indoor parking facility. Received parcels from an electric van and redistributed them by electric cargo bikes within the City of Westminster and surrounding areas. The hub occupied approximately six parking bays.	Nine-month trial delivered ~128,000 deliveries (avg 170/day). E-cargo bikes travelled 22,578 km, achieving emissions reductions vs van delivery: 4,186 kg CO_2, 15,141 g NOx, 303 g PM2.5. The value-for-money rate was £39.75 per kg CO_2 saved.
Berlin (Germany) / KoMoDo Micro-Depot (2018-2019) [80]	Cooperative micro-depot shared by five rival parcel operators using seven shipping containers as individual storage units. Cargo bikes for last-mile delivery within a 3 km service radius.	~160,000 parcels delivered; ~11 tons CO_2 saved; up to 11 cargo bikes in use daily; ~38,000 km covered.
Milan (Italy) / C40 Zero Emission Pilot (Oct-Dec 2022) [81], [82]	Electric cargo bikes used for last-mile delivery of small parcels (up to 5 kg) within a 3 km² area of central Milan. Parcels transferred from a cycle-logistics hub.	40% decrease in cost per delivery (from €2.35 to €1.40). 23% reduction in delivery time per parcel (from 5.5 to 4.2 minutes). 92% reduction in tailpipe emissions (CO_2, NOx, PM10, PM2.5) compared to van delivery. Cargo bikes were more cost-efficient in high-density, high-congestion areas.

6.2.2 Key success factors and common failure modes

From the implementations listed in Table 2, the following factors consistently contribute to success:

- **Dense customer demand and strategic Microhub location:** Microhub-based cargo bike systems perform best where delivery density is high and Microhubs are placed in the densest demand zones. Paris and Milan confirm that cargo bikes are more cost-efficient in high-density, high-congestion areas. The 3 km service radius in Berlin and the 3 km² area in Milan illustrate the importance of proximity.
- **Multi-operator collaboration and neutral governance:** The Berlin KoMoDo depot demonstrates that five rival parcel operators can successfully share a micro-depot when a neutral operator manages the facility. Helsinki also used a shared hub model with multiple operators. However, the Milan pilot noted strong resistance from large logistics operators to consolidating parcels with competitors, highlighting that cooperation requires careful governance and clear rules.
- **Neutral orchestrator or coordinator:** The Helsinki pilot demonstrated that a neutral orchestrator is essential for managing shared Microhubs. Without a dedicated coordinator, operational responsibilities fall on project partners, creating inefficiencies. Wroclaw's Freight Quality Partnership also confirms that a neutral facilitator is crucial for successful Microhub implementation.
- **Flexible and low-cost infrastructure:** Using shipping containers (Toronto, Berlin), or indoor parking spaces (London, Helsinki) or existing underground car park space (Sydney) reduces upfront investment and allows rapid deployment. Toronto's 40-foot container on metered parking spaces is a replicable low-cost model.
- **Stakeholder engagement and co-design:** Seattle's participatory design involving multi-sector stakeholders (workshops, goal setting, operational feedback) was critical to aligning the pilot with real-world needs. Helsinki's success also relied on strong collaboration between the city, shopping centre owner, and logistics operators.
- **Effective communication and marketing:** Helsinki's pilot highlighted that a strong marketing campaign and verbalising positive impacts to residents increased acceptance. Residents valued convenient location and flexible pick-up times.
- **Regulatory and legislative support:** New York City's pilot is mandated by Local Law 166 of 2021, demonstrating that formal legislation can institutionalise Microhub deployment. Toronto's pilot was later made a permanent programme, showing the importance of regulatory continuity.

Common failure modes observed across projects:

- **Insufficient delivery density:** In areas with low customer density, Microhub and cargo-bike systems struggle to achieve operational efficiency. The Paris study shows that in such conditions, the cost advantage of cargo bikes disappears, and conventional vans become more cost-effective.
- **Lack of suitable infrastructure:** Seattle struggled with the absence of bike-friendly routing tools and secure locking systems (manual U-lock took valuable time).
- **Workforce and operator capability:** Finding qualified e-cargo bike couriers is challenging. Seattle explicitly struggled to recruit drivers. Experienced cyclists lacked delivery knowledge, and traditional delivery drivers were not interested. Prior experience of the cargo bike operator is critical; Milan recommends cities look for established cycle-logistics operators or experts with

knowledge in this area. Lack of training programmes and regulations specific to e-cargo cycle delivery operations remain a barrier.

- **Business model and funding sustainability:** Many Microhub pilots rely on temporary public or project funding and fail to transition to financially sustainable operations once the funding ends. The Berlin KoMoDo depot successfully operated for 12 months with public funding but continued for only six additional months before closing, as no self-sustaining business model was in place. The Paris study explicitly shows that cargo-bike solutions are financially viable only under high-density conditions; in lower-density areas, they are not cost-competitive. The Milan pilot project report notes that "relatively small economic contributions can help operators cover upfront costs", implying that without such support, uptake would be limited. A clear, long-term revenue model (e.g., operator fees, parking charges, or cross-subsidies) is essential for scalability.
- **Weak collaboration between stakeholders:** The Milan pilot reported strong resistance from big logistics operators to consolidating parcels with competitors, as they wanted to maintain exclusivity. This is a major barrier to shared Microhub models.
- **Regulatory barriers:** Zoning, land-use, and traffic regulations can hinder Microhub implementation. Restrictions on vehicle size/weight, delivery time windows, or on-street parking permits may prevent Microhubs from operating efficiently. In some cities, the legal framework does not recognise Microhubs as a permitted land use, causing delays in site approval. Conversely, enabling legislation (e.g., New York's Local Law 166 of 2021) can accelerate deployment. Cities should assess local regulatory barriers early in the planning process.
- **Bureaucratic and organisational delays:** Local government approval processes for Microhub permits, zoning changes, and parking adjustments can be lengthy and unpredictable. Additionally, large courier companies often have slow internal decision-making processes, delaying commitments to participate in shared Microhub pilots. These delays can derail project timelines and increase costs.

6.2.3 Benchmark indicators observed in existing implementations

The observed ranges presented in this subsection are derived from the implementation cases summarised in Table 2. They represent what has been achieved in other cities and projects under specific conditions (e.g. high delivery density, dedicated infrastructure, mature cycling networks). These ranges are not prescriptive targets for NEXTLOGIC pilots. Their applicability to each NEXTLOGIC city depends on local conditions (e.g. urban density, existing infrastructure, regulatory frameworks). The assessment of which ranges are achievable in the NEXTLOGIC context will be addressed in subsequent stages of the project, particularly in the development of the solution toolkit and the operational guidelines for pilot implementation.

Table 3. Benchmark indicators observed in existing Microhub implementations

Indicator	Evidence from existing implementations	Interpretation guide
CO_2 reduction	• Fludis (Paris): ~110 t CO_2/year (van traffic avoidance) • Seattle: 73% reduction (682 g CO_2 saved per package vs. van's 933 g) • Toronto: 3.1-5.5 t CO_2/year per van replaced • London: 4,186 kg CO_2 saved over 9 months • Berlin: ~11 t CO_2 saved over 12 months	Higher reductions achieved in high-density, high-congestion areas with optimised hub locations. The range reflects different operational contexts.

Indicator	Evidence from existing implementations	Interpretation guide
Cost challenges	• Lyon: negative economic balance (-€655.28) • London: £39.75 per kg CO_2 saved (value-for-money) • Milan: 40% decrease in cost per delivery (€2.35 → €1.40)	Cost savings depend on delivery density, labour costs, and vehicle replacement. Lyon's negative balance highlights the importance of business model sustainability.
Delivery time reduction per parcel	• Milan: 23% reduction (5.5 → 4.2 minutes per parcel)	Time savings result from avoiding parking search, using bike lanes, and higher stop density.
Delivery density (stops per day per cargo bike)	• Toronto: 25 stops/day (vs 19 for trucks)	Performance improves with density; 20-25 stops/day is achievable in dense urban neighbourhoods.
Microhub service radius	• Berlin: 3 km radius • Milan: 3 km^2 area (approx. 1.7 km radius) • Helsinki: central district coverage	Cargo bike efficiency declines rapidly beyond 3 km due to limited speed, battery range, and labour costs.
E-cargo bikes per Microhub	• Fludis (Paris): ≈30 cargo bikes (operational scale) • Berlin: up to 11 cargo bikes • Helsinki: 3 cargo bikes • Toronto: 3 e-cargo bikes	Fleet size depends on hub footprint, daily parcel volume, and number of operators.

6.2.4 Key design choices observed in existing Microhub implementations

The following checklist synthesises key design decisions identified from the real-world implementations summarised in Table 2. These decisions are presented as examples from best-practice and are intended to inform, not prescribe, the design of NEXTLOGIC pilots.

Table 4. Key design choices observed in existing Microhub implementations

Design dimension	Decision points observed	Examples from best practices (Table 2)
Location	On-street (metered parking) or off-street (parking lot, vacant building, under-utilised public assets)	Fludis (floating hub on the Seine); Toronto (on-street metered parking); New York (on-street and city-owned properties); Sydney (underground car park)
E-cargo bike fleet	Number of bikes; load capacity (observed >80 kg); battery range (≥40 km)	Fludis (≈30 cargo bikes - city-wide operation); Toronto (3 bikes); Berlin (up to 11 bikes); Milan (up to 5 kg parcels)
Recharging infrastructure	Secure, weather-protected charging with grid or solar supply	Seattle (container with charging); Toronto (overnight storage/charging facility)
Resupply mode	Truck or van frequency; vehicle type (diesel, hybrid, electric)	Fludis (overnight truck delivery to floating hub); Lyon (vans/LCVs to ephemeral hub); Seattle (cargo van from suburban depot); Milan (trucks to cycle-logistics hub); London (electric van)

Design dimension	Decision points observed	Examples from best practices (Table 2)
Digital management	Occupancy monitoring, routing optimisation	Lyon (semi-manual digital planning via Cyke); Seattle (routing tools, identified need for bike-friendly algorithms); Helsinki (mobile devices used)
Stakeholder engagement	Co-design with local authorities, logistics operators, businesses, residents	Seattle (multi-sector participatory workshops); Helsinki (collaboration with shopping centre and multiple operators); Milan (recommended: build sufficient time for stakeholder engagement)
Business model	Public subsidy, operator fees (per parcel or monthly), cross-subsidy (parking/retail), public-private revenue sharing	Lyon (negative economic balance; highlights cost challenges); Berlin (public grant + operator continuation post-funding); London (cost-benefit analysis used)
Legal framework	On-street permits, parking fee structures, access restrictions for heavy vehicles; enabling legislation	New York (Local Law 166 of 2021 mandates pilot); Toronto (permanent programme after pilot)
Aesthetic and interior design	Adapting exterior to fit surrounding environment; equipping interior with necessary facilities (storage, charging, workspace, amenities)	Not explicitly documented in Table 2, but identified as a crucial consideration for user acceptance and integration into public space

6.2.5 Indicators for monitoring and evaluation

The indicators presented below are derived from the implementation cases summarised in Table 2 and represent potential areas for monitoring and evaluation within the NEXTLOGIC project. Since the applicability and relevance of individual indicators depend on local conditions and pilot characteristics, their use and interpretation will be further refined during the implementation phase based on pilot-specific data and requirements.

Table 5. Suggested indicators for monitoring Microhub-based last-mile delivery

Indicator	Measurement method
CO_2 reduction	Compare actual e-cargo-bike electricity consumption and resupply vehicle fuel use with a baseline van-only scenario. Measures relative reduction per package or per delivery.
Cost per delivery	Operating cost (labour, energy, maintenance, vehicle acquisition) divided by number of deliveries
Delivery time per parcel	Average time from start to completion of last-mile leg
Stops per day per cargo bike	GPS logs or driver reports
Vehicle kilometres saved	Comparison with baseline van scenario
Absolute emissions	Monitoring avoided absolute tailpipe emissions (CO_2, NOx, PM)
Customer/courier satisfaction	Survey-based assessment

Indicator	Measurement method
Share of deliveries by e-cargo bike	Operational records
Funding sustainability	Percentage of operating costs covered by revenues after the pilot phase

6.3 Benchmarking of Smart Loading Zones & dynamic curbside management

6.3.1 Real-world implementations

Several European and North American cities have tested or deployed SLZ systems. Table 6 summarises selected examples, their main features, and documented outcomes.

Table 6. Real-world SLZ implementations and key results

Location / Project (Period)	System features	Key results
Pittsburgh, USA / Smart Loading Zones Pilot (2022-2024) [83], [84], [85]	IoT enabled "purple curb" SLZs with tiered pricing (free first 15 min, then regular meter rates). License plate reading technology.	23% decrease in dwell time in loading zones; 70% increase in turnover; 60% drop in average parking duration; 95% reduction in double parking; 55% of users park <15 min; traffic speed +4.5% in select areas;
Washington DC, USA / CurbFlow Pilot (Aug-Oct 2019) [86]	App-based reservation system for PUDO (pick-up/drop-off) zones at nine locations. Available to any vehicle operating in a commercial capacity (including private cars for food delivery, freight, parcel, rideshare, taxi).	64% decrease in double parking and illegal U-turns near PUDO zones. 15,000 reservations made by 6,350 drivers from 900+ companies. On-demand deliveries (food delivery) were most frequent users (avg. 7-11 min), followed by freight/parcel deliveries. Rideshare/taxi activity lasted <2.5 min.
Madrid, Spain / UNCHAIN: DUM 360 (2022-present) [87], [88]	DUM 360 app for professional logistics operators; 45-min max stay (65 min for ECO/zero-emission vehicles); licence plate recognition + under-asphalt sensors (486 bays, 137 zones); real-time occupancy display.	>60% occupancy in 62.7% of sensorised zones (33% ->70%, 3.6% ->80%); 8M+ operations managed since Oct 2022; 108,000+ registered users (76,035 active); up to 9,000 daily users; ~21,000 weekday tickets; 17% of parked vehicles are private cars; 28% of commercial vehicles park illegally despite zones within 75 m.
Bucharest, Groningen, Riga / Coding the Curbs - Smart Zones (2023-2024) [89]	Bookable, multifunctional loading/unloading bays; reservation system for curbside space; occupancy sensors; dual-use (loading by day, parking by night).	Occupancy increased from ~20% to 60% in one year; 25% reduction in search traffic; >1,800 bookings recorded (Aug 2024); reduced congestion, illegal parking, and unnecessary driving.
Bucharest & Istanbul / Coding the Curbs - Digital Enforcement (2025) [90], [91]	Real-time sensor alerts notifying enforcement officers of violations; mobile app for compliance monitoring and report processing; integration with city fining system. Co-developed with local enforcement teams.	35% decrease in average Smart Zone occupancy duration; >90% officer satisfaction; <5% false alerts; 130+ sensor-based violation alerts recorded (over one third resulting in filed reports).

Location / Project (Period)	System features	Key results
Multiple Cities / Parkunload (Jun-Dec 2023) [92]	Bluetooth-based smart loading/delivery zones; mobile app; integration with city services; reduced fee cancellation for overstaying fines.	30% increase in parking turnover and availability of free spaces; 50% reduction in illegal parking.
Seattle, USA / SMART Grant Digital Commercial Vehicle Permit Project (2023-2025) [93]	Vehicle-to-Curb (V2C) technologies; digital permitting; two vehicle detection sensors; Curb Data Specification (CDS) standard; collaborative, data-driven approach with University of Washington, local businesses, and technology vendors.	80% of vehicles using Commercial Vehicle Load Zones were unauthorised. Solar-powered camera reliability issues in Seattle's climate; significant effort to convert legacy data to CDS; procurement and vendor capacity challenges.
Campbelltown, Australia / Digital Smart Kerb Pilot (2022-2023) [94]	Smart sensors + smart signs; Machine Learning (ML) analysis of >33,000 events.	25% increase in usage events; 8% increase in bay use (+18 min/bay/day); 10% reduction in average dwell time (15:34 → 13:57); 11% of general parking bay activity (7am-5pm) were commercial vehicles; Vehicle type compliance improved by 2.87%
Vic, Spain / ML Optimisation Study (2024) [95]	ML optimisation for loading zone network design based on establishments' coordinates, walking distances, and freight demand. App-based data collection. Strategic planning tool.	Occupancy increased from 18% to 80%; establishments located within ≤75 m walking distance of a loading zone; freed curbside space for other users.
Leuven, Strasbourg, Toulouse, Funchal / FlexCurb (Jan-Dec 2022) [96]	Digital inventory of curb regulations via APIs; city planning platform; mobile app for commercial drivers showing real-time curb availability and conditions. Shared use mixed zones.	170,000+ data points collected; 150,058 curbside places digitised (1.55 km²), including 2,259 loading zones analysed. Helps reduce double parking and improve delivery efficiency. Encountered technical interoperability and driver app uptake challenges.

6.3.2 Key success factors and common failure modes

From the implementations analysed in Table 6, the following factors consistently contribute to success:

- **Stakeholder engagement from the outset:** Early involvement of delivery drivers, local businesses, and residents. Seattle's SMART Grant project used 1:1 interviews with permit holders and in-language outreach to overcome cultural and linguistic barriers. Washington DC's CurbFlow pilot engaged 900+ companies.
- **Real-time data and digital tools:** Occupancy sensors, booking apps, and dynamic pricing enable adaptive management. Madrid's DUM 360 uses under-asphalt sensors and licence plate recognition to provide real-time occupancy. Coding the Curbs' enforcement module sends live violation alerts to officers.
- **Integrated enforcement:** Automated camera monitoring or digital permits linked to penalties significantly reduce illegal use (Pittsburgh: 95% reduction in double parking; Washington DC: 64%

reduction; Parkunload: 50% reduction; Coding the Curbs enforcement: >90% officer satisfaction, 35% decrease in occupancy duration).

- **Data-driven zone placement:** Using historical demand or ML to locate zones where they are most needed. Vic's ML optimisation increased occupancy from 18% to 80% while keeping walking distances ≤75 m.
- **Multifunctional curbside design:** Allowing zones to switch uses (loading, parking, dining, bike parking) at different times maximises space utilisation. Coding the Curbs - Smart Zones are bookable and dual-use (loading by day, parking by night). FlexCurb's shared use mixed zones support multiple functions.
- **Transparent pricing and tiered fee structures:** Pittsburgh's purple curb programme (free first 15 min, then regular meter rates) increased turnover and demonstrated that pricing can support efficiency and financial sustainability. Madrid rewards ECO/zero-emission vehicles with extended parking time (65 min vs 45 min).
- **Clear regulatory framework and enabling legislation:** Successful SLZ implementation requires a supportive legal basis. This includes traffic regulation orders to designate loading zones, time-window restrictions, and enforcement powers (e.g., camera-based monitoring, digital permits). In the European context, compliance with GDPR for ANPR and sensor data collection is essential. Cities such as Madrid (DUM 360 with camera monitoring) and Pittsburgh (tiered pricing enforced via licence plate recognition) demonstrate that regulation and technology must work in tandem. Coding the Curbs' enforcement module required a local legal adjustment in Bucharest to support compliance, illustrating that regulation may need to evolve alongside technology.

Common failure modes observed across projects:

- **Poor location:** Zones placed in low demand areas due to political compromise rather than data. Vic's optimisation study directly addresses this by using app-based demand data to prescribe optimal locations.
- **Lack of driver awareness:** Systems not advertised or explained to users. Campbelltown found that 11% of general parking bay usage was by commercial vehicles, indicating unmet demand but also a lack of clear designation. Pittsburgh's programme used printed flyers, wallet cards, and direct driver outreach to raise awareness.
- **Weak enforcement:** Illegal parking continues if enforcement is sporadic or low penalty. Coding the Curbs' enforcement module was specifically developed to overcome this with real-time alerts. Seattle's SMART Grant project noted that unauthorised vehicles accounted for 80% of Commercial Vehicle Load Zone usage, highlighting the need for better enforcement.
- **Insufficient data collection:** Inability to measure performance or adjust operations. Seattle's project emphasised that traditional person-based data collection is costly and sparse; third-party data was insufficient, and sensor reliability (solar-powered cameras) was problematic.
- **One-size-fits-all approach:** Ignoring local differences in street geometry, business hours, or delivery patterns. Vic's ML approach tailors loading zone networks to local establishment coordinates and walking distances.
- **Resistance to change:** Urban logistics is a traditional sector, often resistant to adopting new habits and technologies. Madrid's DUM 360 implementation encountered reluctance from logistics operators to use the digital app and comply with new rules, requiring a warning phase and ongoing communication efforts.

- **Technical interoperability issues:** FlexCurb encountered challenges with real-time data integration and driver app uptake. Seattle's project faced significant effort to convert legacy curb regulation data into the CDS standard, and procurement of suitable V2C technology was difficult.
- **Procurement and vendor capacity:** Seattle's experience highlighted that cooperative procurement can be time-consuming, and vendors may lack capacity to meet project deadlines. Early and frequent engagement with procurement staff is recommended.
- **High cost of technology per bay:** Deploying digital signage and sensors for each individual loading bay can be expensive and economically unviable for cities with limited budgets. Campbelltown noted that a more cost-effective approach would be to have signs report on multiple bays. Cities should assess the cost-benefit ratio before committing to per-bay technology.

6.3.3 Benchmark indicators observed in existing implementations

The observed ranges presented in this subsection are derived from the implementation cases summarised in Table 6. They represent outcomes achieved under specific local conditions (e.g. the availability of digital infrastructure, dedicated enforcement, data availability, mature regulatory frameworks). These values should not be interpreted as prescriptive targets for NEXTLOGIC pilots. Their applicability to each NEXTLOGIC city depends on local conditions (e.g. urban density, existing regulatory frameworks, enforcement capacity). The assessment of which ranges are achievable in the NEXTLOGIC context will be addressed in subsequent stages of the project, particularly in the development of the solution toolkit and the operational guidelines for pilot implementation.

Table 7. Benchmark indicators observed in existing SLZ implementations

Indicator	Evidence from existing implementations	Interpretation guide
Occupancy rate	• Vic: 80% after ML optimisation • Madrid: >60% occupancy in 62.7% of sensorised zones • Coding the Curbs (Smart Zones): 60% occupancy after one year	Lower occupancy may indicate underutilisation (wrong location, poor enforcement, or insufficient demand). Higher sustained occupancy may indicate capacity constraints (leads to congestion, double parking).
Turnover increase	• Pittsburgh: 70% increase in turnover • Parkunload: 30% increase in parking turnover	Higher increases indicate more efficient use of limited curb space.
Dwell time reduction	• Bucharest/Istanbul: 35% reduction in occupancy duration • Pittsburgh: 23% decrease in dwell time • Campbelltown: 10% reduction in average dwell time (basic sensors)	Advanced systems (cameras, enforcement, tiered pricing) achieve 35-60% reductions; basic sensor systems achieve around 10%.
Illegal usage reduction	• Washington DC (CurbFlow): 64% decrease in double parking and illegal U-turns • Parkunload: 50% reduction in illegal parking • Pittsburgh: 95% reduction in double parking	Enforcement-integrated systems and reservation models achieve the highest reductions.
Search/cruising time reduction	• Coding the Curbs (Smart Zones): 25% reduction in search traffic	Real-time availability information consistently reduces cruising.

Indicator	Evidence from existing implementations	Interpretation guide
User/officer satisfaction	• Coding the Curbs enforcement module: >90% officer satisfaction • Parkunload: high driver acceptance reported	Acceptability is essential for long-term compliance and system adoption.
Walking distance to loading zone	• Vic: loading zones allocated within ≤75 m walking distance from establishments	Zones should be within reasonable walking distance of establishments to be effective.

6.3.4 Key design choices observed in existing SLZ implementations

The following checklist synthesises key design decisions identified from the real-world implementations summarised in Table 6. These decisions are presented as examples from best-practice and are intended to inform, not prescribe, the design of NEXTLOGIC pilots.

Table 8. Key design choices observed in existing SLZ implementations

Design dimension	Decision points observed	Examples from best practice (Table 6)
Zone type	Static (fixed hours) or dynamic (time-based, demand-based, or reservation-based)	Coding the Curbs (Smart Zones): reservation-based, dual-use; Pittsburgh: static with IoT monitoring
Booking and payment	Driver app, phone booking, or automatic registration (e.g., licence plate recognition)	Madrid DUM 360 (app); Parkunload (Bluetooth + app); Washington DC CurbFlow (app)
Real-time information	Digital signs, app, or open data feed	Madrid: real-time occupancy display; Campbelltown: digital smart signs; FlexCurb: driver app
Pricing model	Free, fixed fee, time-dependent, dynamic, or tiered (e.g., free first N minutes then meter rates)	Madrid: dynamic pricing; Pittsburgh: tiered (free 15 min, then meter rates); Parkunload: reduced fee cancellation option
Enforcement method	Patrolling officers, automated cameras, digital permits with fines, or combination	Pittsburgh: cameras + mailed citations; Washington DC: app-based; Coding the Curbs (Digital Enforcement): real-time alerts + integration with city fining system
Data collection	Sensors, cameras, driver logs, or combination	Vic: ML-optimised zone placement using app-based data; Madrid: under-asphalt sensors + licence plate recognition; Seattle (SMART Grant): vehicle detection sensors + CDS standard
Multifunctionality	Loading only or dual use (loading by day, parking/dining by night)	Coding the Curbs (Smart Zones): bookable multifunctional bays (loading by day, parking by night); FlexCurb: Shared Use Mixed Zones (SUM Zones)
Stakeholder engagement plan	Consultation schedule, feedback loops, transparency protocols	Seattle (SMART Grant): 1:1 interviews, in-language outreach, door-to-door engagement; Coding the Curbs:

Design dimension	Decision points observed	Examples from best practice (Table 6)
		co-development with local enforcement teams and continuous feedback loops

6.3.5 Indicators for monitoring and evaluation

The indicators presented in Table 9 are derived from the implementation cases summarised in Table 6 and represent potential areas for monitoring and evaluation within the NEXTLOGIC project. Since the applicability and relevance of individual indicators depend on local conditions and pilot characteristics, their use and interpretation will be further refined during the implementation phase based on pilot-specific data and requirements. Local regulatory contexts (e.g. delivery time windows, access restrictions, GDPR) may affect the feasibility of certain targets and the methods available for measurement. Consequently, the indicators should be regarded as indicative rather than exhaustive and may be adapted as the project progresses and additional evidence becomes available.

Table 9. Suggested indicators for monitoring SLZ systems

Indicator	Measurement method
Occupancy rate (average, peak, off-peak)	Sensor data or manual counts
Dwell time per delivery	Sensor data or app logs
Turnover rate	Number of unique vehicles per zone per day
Illegal occupancy rate (unauthorised vehicles)	Camera or patrol records
Driver / business satisfaction	Short survey (app or in person)
Enforcement officer satisfaction	Survey
Search/cruising time	GPS data or app logs
Double parking incidents	Camera data or enforcement records
Emissions reduction (estimated)	Model based on reduced cruising time

6.4 Benchmarking of 15-minute multimodal hubs

The concept of a 15-minute multimodal hub is still emerging. Unlike Microhubs and SLZs, where multiple operational examples with quantitative results are available, fully operational 15-minute multimodal hubs with published performance data are limited. Accordingly, this section does not present quantitative benchmarks; instead, it reviews available projects and pilots that are actively exploring this integration, summarises their objectives and design features, and identifies evidence gaps. This analysis is intended to support NEXTLOGIC's objective of generating primary evidence from its own pilots.

6.4.1 Real-world implementations

Table 10 summarises relevant projects and studies that integrate passenger transport with logistics functions at or near public transport nodes. For each project, the table reports its aimed results/expectations based on project documentation. Quantitative results are not yet available for most projects.

Table 10. Real world 15-min multimodal hub implementations and key findings/expected outcomes

Location / Project (Period)	System features	Status/Key findings or expected outcomes
Mechelen (Belgium) / MoLo Hubs & Hoppinpunten (2023-2026) [83]	7 Hoppinpunten (mobility hubs) combining car-sharing, bike-sharing, public transport (selected locations) and parcel lockers.	Ongoing; Pilot survey findings: Multimodal travel is common; Limited perceived synergy between lockers and mobility services; Proximity is the real driver; both services used more when located along daily routines (home, work, supermarket); Integration supports broader planning goals (accessibility, multimodality, space efficiency); Quantitative results not yet published.
Mumbai (India) / Mumbai Metro One Smart Lockers (2025 - ongoing) [97]	996 digital lockers across 12 stations of Mumbai Metro One. Multiple sizes: small (≤5 kg), medium (≤10 kg). Access via mobile app, SMS, or QR-code; One-Time Password (OTP) authentication; 24/7 CCTV surveillance.	Operational (launched Nov 2025); Expected to benefit 500,000 daily commuters. Aims to reduce last-mile emissions, curb traffic congestion, and streamline e-commerce deliveries. Based on Autope's proven model in Delhi (25,000 lockers across 250 metro stations).
Several EU cities (Oslo, Gothenburg, Hamburg, Bologna, Rome) / MOVE21-ULaaDS Dual MobiHub (2021-2025) [98]	Dual-use hubs integrating existing mobility hub functions (car-sharing, bike-sharing, EV chargers) with logistics functions (micro-depot, containerised last-mile). Co-developed with public transport agencies.	Completed pilot; Aimed results: Demonstrate feasibility of shared urban logistics infrastructure. Emphasise linking multimodal hub planning with SUMPs/SULPs. Public-private collaboration and user-friendly booking platforms essential. Guide to Multimodal Hubs published based on data from >15 European cities.
Portland (USA) / Common Carrier Parcel Lockers at Transit Facilities (2020) [99]	This study evaluates public transport stations as potential locations for shared parcel locker systems, highlighting trade-offs between accessibility, equity, and network efficiency. Common carrier parcel lockers at transit facilities (light rail stations); secure, unmanned lockers for parcel collection and drop-off.	Completed research study; Evaluates public transport stations as potential locations for shared parcel locker systems, highlighting trade-offs between accessibility, equity, and network efficiency. Benefits for both transit users (convenience) and non-transit users (accessibility); potential to increase transit ridership while reducing last-mile delivery vehicle trips.

6.4.2 Key success factors and common failure modes

From the projects reviewed, the following factors are emerging as critical for successful 15-minute multimodal hub implementation:

- **Proximity to daily routines:** Mechelen's survey shows that both parcel lockers and mobility services are used more when located along daily routines (home, work, supermarket). Convenience is the real driver.
- **Integration with existing public transport infrastructure:** Mumbai's deployment of lockers directly inside metro stations and Portland's study of light rail stations demonstrate that leveraging existing public transport assets reduces capital costs and increases commuter footfall.

- **Multi-operator and neutral design:** White-label or common carrier lockers (Portland, MOVE21) that are open to multiple delivery companies prevent monopolisation and encourage competition.
- **Stakeholder engagement and formal agreements:** MOVE21's co-development with public transport agencies and Mechelen's "Covenant" with >30 stakeholders show that formalised collaboration between city, transport agency, logistics operators, and retailers is essential. Within this context, governance measures and mechanisms to include the stakeholders in the operation enable the successful integration of the hub into the neighbourhood while keeping its operational function.
- **Digital integration:** App-based access (Mumbai's QR-code/OTP, Portland's proposed system), 24/7 availability, and real-time locker status are baseline requirements for user acceptance.
- **Pilot-before-scale approach:** Mumbai's rollout builds on Delhi's proven model (25,000 lockers), and Portland's study recommends incremental growth starting from a small number of locations.
- **Services provision**: Combining mobility elements with services and other enabling activities allows the hubs to have a more economically sustainable business model and a better integration in the neighbourhood (MOVE21). Services can be cafés, bike repairs, parcel lockers, retail shops for example.

Common failure modes observed across projects:

- **Lack of published quantitative results:** None of the reviewed projects provide operational data (parcel volume, CO_2 savings, modal shift, cost efficiency). This is a major gap for evidence-based policymaking.
- **Limited perceived synergy between lockers and mobility services:** Mechelen's survey found that users generally do not see a direct link between using parcel lockers and using mobility options, reflecting current habits rather than lack of potential.
- **Weak integration between passenger and freight planning:** Many projects treat lockers as an add-on to mobility hubs, not as a fully integrated design.
- **Data sharing barriers:** No monitoring systems are in place to gather real-time logistics data. Data sharing between municipalities and logistics players is non-existent.
- **Regulatory and legal grey areas:** The legal basis for using public transport infrastructure for commercial logistics is still being defined in many countries.

6.4.3 Key design choices observed in existing 15-min multimodal hubs

The following checklist synthesises key design decisions identified from the real-world implementations summarised in Table 10. These decisions are presented as examples from best-practice and are intended to inform, not prescribe, the design of NEXTLOGIC pilots.

Table 11. Key design choices observed in existing 15-min multimodal hubs

Design dimension	Decision points observed	Examples from best practices
Hub location	Metro station, light rail station, bus terminal, transit centre, park and ride site	Mumbai (metro stations), Mechelen (Hoppinpunten), Portland (light rail, transit mall, park and ride)
Logistics functions integrated	Parcel lockers (common carrier/ multi-operator), micro-consolidation, shared vehicle pool	Mumbai (996 lockers, multiple sizes), Portland (common carrier lockers), MOVE21 (micro-depot)
Last-mile mode from hub	Foot, e-cargo bike, shared e-van, personal vehicle (for park-and-ride)	Portland (walk-up for transit mall, car-access for park-and-ride)
Digital integration	Mobile app, SMS, QR-code, OTP authentication, real-time locker status	Mumbai (app, SMS, QR, OTP, CCTV)
Stakeholder engagement	Co-creation workshops, formal covenants, public-private partnerships	Mechelen (Covenant with >30 stakeholders), MOVE21 (co-development with public transport agencies)
Governance	Regulatory frameworks, decision-making structures, public-private roles, enforcement mechanisms, compliance monitoring	Mechelen (formal Covenant with >30 stakeholders); MOVE21 (co-development with public transport agencies); Madrid (DUM 360 app integrated with city enforcement)
Business model	Public-led, public-private partnership, operator-led	Mumbai (Autope partnership with Metro One), Portland (recommends public-private partnerships)
Equity strategy	Consider ridership, spatial coverage, income, race, education, internet access	Portland (accessibility and equity analysis framework)

6.4.4 Indicators for monitoring and evaluation

The following indicators are suggested as areas to monitor in NEXTLOGIC pilots. No universal target ranges are proposed at this stage; target ranges will be established based on pilot data.

Table 12. Suggested indicators for monitoring 15-min multimodal hubs

Indicator	Measurement method
Daily parcel volume at hub	Locker/operator logs
Surface delivery kilometres avoided	Model based on vehicle km replaced by public transport
Delivery success rate	Operator delivery logs
CO_2 reduction vs. conventional delivery	Model based on energy mix and mode shift
Locker utilisation rate	Sensor data, booking logs
User/citizen satisfaction	Surveys
Transit agency engagement level	Stakeholder interviews, partnership agreements
Equity metrics (e.g. coverage by income, race, access to transit)	GIS analysis, demographic data

6.5 Benchmarking of Incentive and Reward mechanisms

6.5.1 Real-world implementations

Table 13 summarises key examples of Incentive and Reward mechanisms applied to last-mile logistics, their main features, and documented outcomes.

Table 13. Real world incentive and reward mechanism implementations and key findings/expected outcomes

Location/Project (Period)	System features	Status/Key findings or expected outcomes
Poland, Spain, France, Greece, Austria/GreenTurn (2024-2027) [87]	Consumers + logistics operators/ behavioural interventions (incentives, nudges, gamification) combined with delivery/return options (time windows, in store pick up, returnable packaging).	Ongoing project; Large scale testing across multiple countries and actors. Aims to make 82% of delivery and return options zero emission. Co-creation with stakeholders.
India/ILine Green Reward Program (2025) [100], [101]	Customers/gamified reward system in mobile app; customers earn points for deliveries made by electric vehicles (EVs); 10,000 g CO_2 savings → ₹150 (approx. USD 1.65) wallet credit (valid 30 days).	Operational pilot; Pilot with 4,650 active customers. Tangible, documented incentives based on environmental impact.
Soweto, South Africa/Shovebike (2025) [102], [103]	Couriers + consumers/riders earn ShovEcoins (blockchain-powered reward tokens) per green delivery on e-bikes; customers earn rewards for choosing sustainable delivery options.	Operational model; Blockchain-inspired incentive model; grassroots empowerment; redefines last-mile delivery through sustainable e-mobility.
Africa/Pickspot (2024-present) [104]	Local residents/smart parcel lockers; locker owners (agents) earn 50% of fees plus crypto-based rewards.	Operational network; Reduces unsuccessful delivery attempts. Incentivises local participation in last-mile logistics. Quantitative results not yet published.
Netherlands & Lithuania / Parcel locker interventions (2025) [105]	Consumers/informational interventions: sustainability information, locker distance information (vignette-based experiment).	Research study; Sustainability info effective in both countries; distance info effective only in the Netherlands; familiarity with lockers increases adoption. Supports the use of simple, cost-effective interventions to shift consumer delivery choices.

6.5.2 Key success factors and common failure modes

From the implementations summarised in Table 13, the following factors consistently contribute to success:

- **Clear target behaviour**: Incentives should be linked to a specific behaviour, such as using an SLZ legally, reducing dwell time, selecting a locker/PUDO option, using a cargo bike, adopting an EV, collecting a parcel earlier, parking correctly, or sharing operational data.
- **Tangible, immediate rewards:** Users need to see direct value (discounts, wallet credits, crypto tokens). ILine's wallet credit (₹150 for 10,000 g CO_2 saved) provides a clear, measurable benefit.
- **Simple, user-friendly digital interface:** The app or platform must be easy to use and integrate with existing logistics operations (ILine's gamified app, Shovebike's blockchain-powered system).

- **Transparency on sustainability impact:** Showing emissions saved increases motivation. ILine's CO_2 savings tracker is a good example.
- **Partnership with local communities and businesses:** Pickspot's community-owned locker network and Shovebike's grassroots empowerment model demonstrate that local engagement is critical.
- **Co-creation with stakeholders:** Involving end-users and logistics operators in the design process (GreenTurn) increases acceptance and long-term engagement.
- **Low-cost, non-financial interventions:** The parcel locker study shows that simple informational nudges (sustainability info, distance info) can effectively shift consumer behaviour without financial incentives.
- **Verifiable data:** Eligibility and rewards should be based on data that can be checked, such as booking logs, occupancy data, app check-in/out, parcel collection logs, vehicle type, route traces, or validated self-report.

Common failure modes observed across projects:

- **Low user participation:** If the registration process is complex, the app is not user-friendly, or rewards are not immediate, user enrolment and sustained engagement may remain below target.
- **Insufficient reward attractiveness:** When rewards are too generic (e.g. small discounts at non-frequent retailers) or require too many points to redeem, users may lose motivation. Point-only schemes without clear cash-equivalent value tend to see higher drop-off.
- **Gamification fatigue:** Over-reliance on game elements (leaderboards, badges) without meaningful behavioural feedback can lead to short-term excitement followed by disengagement. Novelty often wears off after 4-8 weeks unless refreshed with new challenges or real-time environmental impact feedback [106].
- **Lack of operator buy-in:** Some logistics operators may refuse to share delivery data needed to verify sustainable actions (e.g. use of cargo bikes, off-peak delivery). Without operator cooperation, the incentive cannot be linked to actual behaviour.
- **Equity concerns:** Incentive schemes that favour early adopters or tech-savvy users can exclude smaller logistics operators or citizens without smartphones. Crypto-based rewards may see lower uptake in less digitally connected neighbourhoods.
- **Poor integration with existing logistics operations:** Incentives designed in isolation without considering drivers' daily routines may be ignored. For example, offering extra payment for cargo bike use may fail if drivers lack secure parking and changing facilities at micro-hubs, a failure of not addressing complementary infrastructure.
- **Geographical context matters:** The effectiveness of informational nudges (e.g., distance information) may vary by country depending on local locker density and consumer familiarity, as shown in the parcel locker study (Netherlands vs. Lithuania).

6.5.3 Key design choices observed in existing incentive and reward mechanisms

The following checklist synthesises key design decisions identified from the real-world implementations summarised in Table 13. These decisions are presented as examples from best-practice and are intended to inform, not prescribe, the design of NEXTLOGIC pilots

Table 14. Key design choices observed in existing incentive and reward mechanisms

Design dimension	Decision points observed	Examples from best practices
Target behaviour	Choose sustainable actions: using cargo bikes, shifting delivery hours, collecting parcels at lockers, off peak delivery, EV deliveries.	ILine (EV deliveries); parcel locker study (choosing lockers over home delivery)
Target group	Consumers, logistics operators, couriers, local residents (locker agents), city authority, business owners.	ILine (consumers); Shovebike (couriers + consumers); Pickspot (local residents)
Reward type	Financial (wallet credits, discounts, cashback), non-financial (points, badges, public recognition), blockchain tokens, or informational nudges, operational, regulatory/access-based, digital/data-sharing, reputational.	ILine (wallet credit); Shovebike (ShovEcoins); Pickspot (crypto rewards); parcel locker study (informational nudges)
Data capture	App logs, IoT sensors, CO_2 tracking to measure behaviour change.	ILine (CO_2 savings tracker)
Partner ecosystem	Engage local businesses to supply rewards; collaborate with logistics operators; build community-owned infrastructure.	Pickspot (community-owned lockers); Shovebike (grassroots empowerment)
Communication strategy	Transparency on environmental impact; informational nudges at the point of choice.	GreenTurn (footprint info); parcel locker study (sustainability information)
Geographical tailoring	Adapt interventions to local infrastructure, locker density, and consumer familiarity.	Parcel locker study (distance info effective only in the Netherlands)

6.5.4 Indicators for monitoring and evaluation

The following indicators are suggested as areas to monitor in NEXTLOGIC pilots. No universal target ranges are proposed at this stage; target ranges will be established based on pilot data.

Table 15. Suggested indicators for monitoring incentive mechanisms

Indicator	Measurement method
Participation rate	App logs/survey
Active use rate	App/dashboard logs, delivery records, operator data
Behavioural shift (share of targeted trips using sustainable mode)	App logs/GPS / delivery data
Compliance rate	App logs, occupancy data, delivery records, operator data
Reward redemption rate	App logs/loyalty system
Improvement over baseline	Before/during/after comparison
CO_2 saved per rewarded action	Model based on mode shift
User / driver satisfaction	Survey

Indicator	Measurement method
Cost per behaviour change	Total incentive cost/number of users who changed behaviour

6.6 Benchmarking of Electrification strategies

6.6.1 Real-world implementations

Table 16 summarises three representative projects covering heavy-goods vehicle electrification, policy frameworks, and e-cargo bike pilots.

Table 16. Real world electrification implementations and key findings/expected outcomes

Location / Project (Period)	System features	Status/Key findings or expected outcomes
United Kingdom / Electric Freightway (2023-2025) [107]	National demonstrator for electric heavy goods vehicles (eHGVs) across logistics, manufacturing and utilities sectors. 30+ consortium partners. 10 bay shared eHGV charging hub at Nissan Sunderland. Subsidised vehicle acquisition. Hitachi ZeroCarbon total cost of ownership (TCO) calculator tool.	79 eHGVs delivered, 78 on order (exceeding 140 vehicle target); >500,000 zero emission miles driven; TCO parity with diesel achievable within 5 years for high mileage fleets; lifetime GHG emissions of eHGVs up to 3× lower than diesel, with embedded emissions offset within first year; energy constraints remain a barrier for charging site electrification.
Netherlands (18 cities)/ Zero-Emission Zones for Freight (Jan 2025-present) [108]	World's first nationwide coordinated Zero-Emission Zones for Freight (ZEZ-F) framework applying to freight vehicles. Phased compliance with grace periods until 2030. Purchase subsidies (€5,000 e-vans, €115,200 e-trucks), tax incentives, public charging funding. Licence flexibility for heavier e-vans. National Implementation Agenda with local adaptation.	78% of new vans and 76% of medium trucks registered battery-electric (mid-2025), highest in EU; electric truck sales surged 188% year-on-year; >95% compliance rate with few enforcement issues; ZEZ-F municipalities had 6.1% electric van share (early 2025) vs. 1.7% in non-ZEZ areas; modelling suggests e-vans alone could cut Amsterdam NOx by 14% and CO_2 by 11%.
Boston (USA)/ Boston Delivers (2023-2025) [109]	E-cargo bike fleet for last-mile deliveries (18-month pilot, 4 clients).	18,375 deliveries; ~5,881 miles travelled by e-cargo bikes; ~2,300-3,300 kg CO_2e avoided

6.6.2 Key success factors and common failure modes

From the implementations summarised in Table 16 and supported by wider literature, the following factors contribute to successful electrification of urban logistics:

- **Integration with Microhubs:** Electrified last-mile delivery is most efficient when combined with a network of Microhubs that provide secure parking, charging, and transhipment facilities. This reduces van mileage and supports mode shift to e-cargo bikes.
- **Financial and regulatory support:** Public subsidies (e.g. purchase grants, tax incentives) and access regulations (zero-emission zones, low-emission zones) accelerate fleet transition. The

Netherlands ZEZ programme demonstrates that a combination of these measures drives rapid market uptake.

- **Mixed fleet strategies:** Combining e-vans with e-cargo bikes allows operators to match vehicle size to delivery density, street type, and load requirements. This flexibility improves overall operational efficiency.
- **Collaborative models:** Shared electric vehicles, logistics-as-a-service platforms, and shared charging hubs reduce individual investment costs and lower barriers for smaller operators.
- **Strong public-private partnerships:** Collaboration between municipalities, grid operators, logistics companies, and technology providers is essential for coordinated infrastructure deployment and successful pilot scaling.
- **Commitment to renewable energy:** Sourcing electricity from renewable sources maximises the environmental benefit of fleet electrification and avoids shifting emissions upstream.

Common failure modes observed across projects:

- **Insufficient charging infrastructure:** Lack of depot-based or on-street fast charging increases vehicle downtime and reduces daily range.
- **High upfront investment:** Many small logistics operators cannot afford the capital cost of e-vans or Microhub infrastructure without subsidies. Even with grants, the total cost of ownership may remain unfavourable for low-mileage routes.
- **Grid capacity limitations:** When multiple e-vans are charged simultaneously at a depot, grid upgrades may be required, causing delays and additional costs. Securing adequate grid capacity remains a common barrier.
- **Low utilisation of e-cargo bikes:** In low-density areas, e-cargo bikes may be under-utilised because the distance to the next stop is too long for efficient operation. They are most cost-competitive in high-density, high-congestion zones.
- **Lack of maintenance expertise:** Electric vans and e-cargo bikes require specialised maintenance. A shortage of qualified electric vehicle technicians risks delaying repairs and increasing vehicle downtime, which can severely impact small logistics operators.
- **Dependency on renewable energy mix:** In regions where electricity is still largely generated from fossil fuels, the net emission benefit of electrification is reduced. Full lifecycle emissions depend heavily on the local energy mix.

6.6.3 Key design choices observed in existing electrified last-mile delivery systems

The following checklist synthesises key design decisions identified from the real-world implementations summarised in Table 16. These decisions are presented as examples from best-practice and are intended to inform, not prescribe, the design of NEXTLOGIC pilots.

Table 17. Key design choices observed in existing electrified last-mile delivery systems

Design dimension	Decision points observed	Examples from best practices
Vehicle mix	eHGVs, e-vans, e-cargo bikes based on delivery density and range needs	Boston Delivers (e cargo bikes only); Electric Freightway (eHGVs + shared charging)
Policy instruments	Purchase subsidies, tax incentives, low-/zero-emission zones, public charging funding	Netherlands ZEZ (multiple instruments layered)
Charging infrastructure	Shared depots, public fast charging, overnight slow charging, Microhub charging	Electric Freightway (shared eHGV hub); Dutch public charging grants
Business model	Subsidised acquisition, leasing, TCO calculation tools	Electric Freightway (TCO calculator + subsidised purchase)
Stakeholder collaboration	Government, grid operators, logistics operators, OEMs, researchers	Netherlands ZEZ (18-city coordination + National Agenda); Electric Freightway (30+ partners)
Monitoring & enforcement	ANPR cameras, compliance reporting, mileage logs	Netherlands ZEZ (high compliance via ANPR)

6.6.4 Indicators for monitoring and evaluation

The following indicators are suggested as areas to monitor in NEXTLOGIC pilots. No universal target ranges are proposed at this stage; target ranges will be established based on pilot data.

Table 18. Suggested indicators for monitoring electrified urban logistics

Indicator	Measurement method
E-vehicle market penetration	New registration data
Total cost of ownership	Fleet accounting + modelling
CO_2 reduction (tailpipe + lifecycle)	Mileage × baseline emission factor - actual electricity consumption
Share of deliveries made by EVs	Operational records, fleet logs
Charging infrastructure utilisation	Charger logs, waiting times
Driver / operator satisfaction	Surveys, operational logs

7. Assessment of the Eight NEXTLOGIC Cities

7.1 Aarhus (DK): 15-minute multimodal hubs

Aarhus aims to develop 15-minute multimodal hubs around public transport stations (especially light rail) as a long-term strategy to achieve climate neutrality by 2030. The ambition is to integrate passenger mobility, services, and urban logistics, including last-mile delivery, within public transport nodes. However, the interview reveals a significant gap between this strategic vision and the current reality. No logistics functions are yet embedded in hub planning; a pilot Microhub for cargo bikes is planned but lacks funding for permanent implementation. Main barriers are financial, governance (inter-departmental conflicts, political prioritisation), legal (open-access rules), and market reluctance from logistics operators. Strong stakeholder networks and co-creative culture are key enablers.

➢ Local challenge

Three interrelated challenges:

- **Congestion and emissions:** peak-hour congestion is the primary problem; reducing truck/van traffic is a direct CO_2 reduction goal, but currently "almost no cargo bikes for parcels" operate in the city.
- **Lack of logistics integration in hubs:** logistics functions (parcel lockers, micro-consolidation, e-cargo bike parking) are not yet concretely defined; no operational model exists for goods movement through a multimodal hub.
- **Business model deadlock:** a pilot Microhub is planned (central location, containers for multiple operators, off-peak truck delivery), but the municipality has no funding for permanent implementation. As stated: *"It's costly, and who should run it? The municipality is not allowed to make money."* Legal requirement for open access (no favouring specific operators) further complicates commercial viability.

➢ Position relative to existing best practices (Section 6.4)

- **Integration of logistics functions:** the benchmarking analysis highlights that multimodal hubs can effectively combine passenger mobility with logistics services (e.g. parcel lockers, micro-consolidation, e-cargo bike parking). In Aarhus, these functions have not yet been concretely defined, and no operational model exists for goods movement through a multimodal hub.
- **Performance measurement:** the benchmarking identifies key metrics for assessing hub performance, such as CO_2 reduction and population coverage. In Aarhus, no operational hub exists, and these metrics have not yet been measured, making it difficult to assess potential performance against the identified benchmarks.
- **Digital readiness:** the benchmarking underscores the role of DTs in enabling scenario-based planning and logistics optimisation. Aarhus has DT capability (Bentley, VISUM, MATSim), but it has not yet been applied to freight logistics planning, a gap that is not unique to Aarhus and is observed in several other cities.

➢ Barriers

Table 19. Key barriers to 15-min hub implementation - Aarhus

Barrier type	Specific barrier
Financial	No dedicated budget for permanent Microhub or multimodal hub infrastructure; pilot only funded for 2 years
Governance/political	Inter-departmental conflicts (mobility vs. urban planning vs. parks); decisions often elevated to politicians; long lead times
Legal/regulatory	Municipality cannot favour specific operators; any public facility must be open to all, discouraging private investment
Market/operator reluctance	Logistics companies (except PostNord) see cargo bikes as less efficient, unwilling to change van-based operations (though PostNord test showed +20% efficiency)
Data availability	Private operators do not share delivery data; municipality relies on complaints and limited sensor data

➢ Enablers

- **Strong co-creation networks:** Climate Neutral Logistics network produces joint recommendations that carry political weight. *"If the sector gives a one-page recommendation, politicians pick it up."*
- **Existing Digital Twin and modelling capacity:** PTV VISUM, Bentley Open Cities Planner, MATSim exploration; tools exist but not yet applied to logistics.
- **Political will at strategic level:** climate neutrality by 2030 is official; SUMP adopted; 15-minute city concept supported.
- **Available public land:** Danish National Railway (DSB) owns former maintenance yards near stations that could be converted to hubs.

➢ Implications for NEXTLOGIC deployment

Based on the analysis of Aarhus's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. A **temporary, low-investment demonstration**, such as a pop-up multimodal hub (e.g. a converted DSB building or container-based unit), could help prove viability and generate operator buy-in before committing to permanent infrastructure.
2. **Business model co-design** is essential. An open-access, cost-recovery model compliant with Danish municipal law (no profit, no subsidy) would need to be developed, ideally in collaboration with WP5.
3. **Existing Digital Twin tools** (VISUM, MATSim, Bentley) could be used to simulate logistics flows, model parcel volumes, identify optimal hub locations, and plan cargo bike routes. Collaboration with DTU and WP2 would support this.
4. Rather than creating new engagement structures, NEXTLOGIC could feed directly into the **existing "Climate Neutral Logistics" network**, which already has political influence and stakeholder trust.
5. A **phased approach** could start with cargo bikes and parcel lockers as the first logistics functions, before adding full micro-consolidation.

➢ Interview-driven unique insight

"If I go to my boss and say 'I think we should put up more parking spaces for trucks', he will ask how much it costs and say we can't afford it. But if the sector gives me a one-page recommendation… the politicians pick it up. That is the most effective tool we have."

7.2 Bergamo (IT): Smart Loading Zones & dynamic curbside management

Bergamo is a medieval city with more than 120,000 inhabitants, divided into a densely commercial Lower Town and a UNESCO-protected Upper Town on a hill. The municipality has never implemented a dedicated urban logistics project. Its main motivation is to reduce severe congestion caused by delivery trucks, particularly in the Upper Town where only two loading bays exist, and deliveries are "completely free and wild". The city plans to test 30 new smart loading zones integrated with existing restricted traffic zones and time-window access rules. However, the city has almost no quantitative data on loading bay usage, past consolidation attempts failed (1990s and 2013) due to lack of municipal leadership and operator buy-in, and cargo bikes are absent. Enablers include a well-developed EV charging network (more stations than electric vehicles) and 37 multi-operator parcel lockers. The new administration is willing to establish a permanent stakeholder dialogue, which did not exist in a structured or formal way for eight years.

➢ Local challenge

Three interconnected challenges:

- **Extreme spatial and historical constraints:** the Upper Town is enclosed by medieval walls (UNESCO), with narrow streets, steep topography, and two medieval gates that physically block larger trucks. Only two loading bays exist; deliveries are made informally on streets, causing gridlock. Real estate prices are extremely high (€80,000 for a single garage), and ground-floor spaces are fully occupied by shops, restaurants, or tourist services, leaving no room for Microhubs.
- **No data and no prior logistics planning:** the municipality has no dedicated transport or logistics model. The only quantitative data collected is counts of vehicles entering the Upper Town via cameras at the gates (permitted by Italian regulation). No data on occupancy, dwell time, or illegal parking is available. Planning decisions have historically relied on complaints from shop owners and carriers, plus visual observation.
- **Failed stakeholder engagement and consolidation attempts:** two previous attempts to set up urban consolidation centres (1990s and 2013) failed. In the 1990s, the municipality played only a regulatory role and carriers found costs too high. In 2013, the municipality co-led but later abandoned the project. For eight years (until the new administration in 2024), there was no formal and structured dialogue between the city and logistics stakeholders. The new administration is now trying to establish a "permanent table", but it is still early adoption.

➢ Position relative to existing best practices (Section 6.3)

- **Operational deployment and baseline data:** the benchmarking analysis highlights that effective SLZ systems are typically built on a foundation of operational data. In Bergamo, no SLZ currently exists in the Upper Town. The planned 30 zones are not yet operational, and no baseline data are available to measure future improvements.

- **Data availability and monitoring:** the benchmarking analysis emphasises the importance of real-time occupancy data and enforcement tools (e.g. sensors, cameras, digital booking). In Bergamo, no sensors or cameras are currently used for loading zone enforcement; compliance relies on occasional parking officers. The city's ZTL gates count vehicles entering the restricted area but do not record unloading activity, limiting the evidence base for planning.
- **Data-driven zone placement:** the benchmarking identifies data-driven demand modelling as a key factor in optimising SLZ location and occupancy. In Bergamo, zone locations were chosen through stakeholder discussions rather than demand modelling, and no such analysis has been conducted to inform zone placement.
- **Pricing and enforcement mechanisms:** the benchmarking shows that pricing structures and enforcement are important tools for reducing misuse and improving turnover. In Bergamo, no pricing is applied to loading zone use. Permits are required for ZTL access, but fees are not tied to duration or vehicle type, limiting the potential for demand management.

➢ Barriers

Table 20. barriers to the deployment of SLZs - Bergamo

Barrier type	Specific barrier
Physical/spatial	Medieval street widths, steep slopes, narrow gates block larger trucks; no vacant ground-floor space; very high real estate prices
Data/knowledge	Almost no quantitative data on loading bay usage, dwell times, or illegal parking; planning based on complaints and observation
Governance/political	Previous administration (8 years) had no structured logistics dialogue; new administration rebuilding trust; inter-departmental conflicts (mobility vs. urban planning)
Market/operator	Two failed consolidation centre attempts due to lack of municipal leadership and operator unwillingness to share costs; cargo bike logistics absent after COVID
Regulatory	National road code sets rigid rules; ZTL time windows (morning only in Upper Town) are short but not enforced dynamically

➢ Enablers

- **New political will:** the current administration (elected after 2024) is actively seeking to solve congestion and has made urban logistics a priority. It is open to co-creation and has started regular meetings with carriers, shop owners, and citizens.
- **Existing parcel locker network:** 37 multi-operator parcel lockers are already deployed across the city centre (both Lower and Upper Town). This infrastructure could be integrated with SLZs or used for last-mile collection.
- **Widespread EV charging infrastructure:** Lombardy region has heavily subsidised charging stations. Bergamo has more charging points than electric commercial vehicles. Fast chargers exist, and commercial vehicles can recharge for free at certain times. This creates a foundation for electrified delivery within SLZs.
- **Clear long-term vision:** the municipality’s ultimate goal is to make the main commercial streets in both Lower and Upper Town completely vehicle-free (walkable), using NEXTLOGIC as the first step.

➢ Implications for NEXTLOGIC deployment

Based on the analysis of Bergamo's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. A **low-cost, low-tech monitoring approach** could be used initially to establish baseline occupancy, dwell time, and illegal parking rates for the planned 30 SLZs. Manual observations or low-cost camera systems could be deployed before investing in expensive sensors, aligning with the city’s "small steps" approach.
2. The existing 37 parcel lockers are not yet linked to loading zones. A **"locker-to-SLZ" handover** process could be tested, where delivery vans drop parcels at nearby lockers instead of double-parking.
3. **EV charging could be leveraged as an incentive:** free or reduced-price charging for commercial vehicles that use designated SLZs and comply with time windows could build on the region's existing free charging periods for commercial vehicles.
4. **ZTL camera data could be used as a proxy for demand.** Although the city cannot record licence plates inside the zone, entry counts per hour could help model peak delivery times and optimise SLZ time windows. Access to anonymised ZTL entry data would need to be arranged with the municipality and WP2.
5. **A simple stakeholder "permanent table" could be co-designed.** Rather than a complex governance model, the municipality could be supported in formalising existing informal meetings into a structured working group with clear terms of reference, building on the lessons from the failed 2013 experience.

➢ Interview-driven unique insight

“The municipality have put 37 multi-operator parcel lockers around the city centre… they would like to push them a little bit more to incentivise citizens to use them if they are not at home, because there is also another problem of congestion if there are missed deliveries.”

7.3 Differdange (LU): Smart Loading Zones & dynamic curbside management

Differdange is a small city (30,000 inhabitants) in Luxembourg’s border triangle, with a strong commitment to climate neutrality by 2030 as an EU Mission City. The city has never had a dedicated urban logistics project; its pilot in NEXTLOGIC represents a first. The ambition is to transform traditional loading/unloading areas into flexible, multi-purpose curbside spaces that can switch between deliveries, pedestrian zones, EV charging, bike parking, or other uses depending on time of day or season. This will be supported by a Digital Twin (developed with LIST, initially for energy, now expanded to mobility and logistics). Currently, the city operates with very limited logistics data, most decisions have been empirical, based on parking officer observations and complaints. A prior cargo bike trial (2020) ended, but the city sees potential. Real estate is expensive (Luxembourg), but the city believes spare spaces exist in nearby activity zones. A key enabler is the national MATSim transport model (University of Luxembourg) and the city’s internal GIS tool (DiffMap). Success is defined as reducing misuse of loading zones, achieving data-driven relocation of zones, and creating a replicable model for other Mission Cities.

➢ Local challenge

Three interconnected challenges:

- **Curbside management based on empirical, not data-driven decisions:** loading zones were planned "empirically out of needs" over decades. The city has no systematic occupancy or dwell-time data. Misuse is known from parking fines and officer observations but not quantified. As one of the interviewees stated: *"We don't have any logistic related data… that's why we are now providing the loading zones with sensors."*
- **Competing space uses and enforcement difficulties:** the city centre is compact, with high delivery demand from shops and restaurants. Private cars often occupy loading zones (even legally, if unloading with trunk open). Delivery trucks block traffic, causing congestion and complaints from citizens and businesses. Enforcement relies on patrols; fines are issued but do not deter misuse systematically.
- **Limited prior experience and no dedicated logistics plan:** Differdange has not previously run a city logistics project. A 2020 cargo bike trial (free use for companies) did not continue. The Climate City Contract and public consultation processes have been citizen-focused but did not specifically address freight. NEXTLOGIC is the first structured intervention.

Position relative to existing best practices (Section 6.3)

- **Operational deployment and baseline data:** the benchmarking analysis highlights that effective SLZ systems are typically built on a foundation of operational data. In Differdange, no operational SLZ currently exists; the planned dynamic zones are in the design phase. No baseline data are available, though sensors are being installed during the NEXTLOGIC project.
- **Data-driven zone placement:** the benchmarking identifies data-driven demand modelling as a key factor in optimising SLZ location and occupancy. In Differdange, zone locations were historically determined empirically. Future relocation will be based on sensor data collected during the project, rather than on prior demand analysis.
- **Pricing and enforcement mechanisms:** the benchmarking shows that pricing structures and enforcement are important tools for reducing misuse and improving turnover. In Differdange, no pricing is applied to loading zone use, and enforcement relies on patrols. Private cars can legally use loading zones if unloading (trunk open rule), creating ambiguity in enforcement.
- **Digital readiness:** the benchmarking underscores the role of DTs in enabling scenario-based planning and logistics optimisation. Differdange has a DT (currently focused on energy), which will be extended to logistics. This is a strength, but it is not yet operational for freight logistics.

Barriers

Table 21. Key barriers to the deployment of SLZs - Differdange

Barrier type	Specific barrier
Data/knowledge	No historical logistics data (occupancy, dwell time, delivery volumes). Only fines data and officer observations.
Operational/ enforcement	Loading zones misused by private cars; enforcement only via patrols; "trunk open" rule makes legal misuse possible.
Financial / real estate	High real-estate prices in Luxembourg; finding affordable space for Microhubs is difficult, though activity zones exist nearby.
Organisational/ experience	First dedicated logistics project; no internal logistics plan or prior pilots that survived.

Barrier type	Specific barrier
Regulatory	National road code applies; local time windows exist (e.g., morning deliveries only in some zones) but are not dynamically managed.

Enablers

- **Strong digital foundation:** Differdange already has an internal GIS tool (DiffMap) for asset tracking, access to the national MATSim transport model (University of Luxembourg), and a Digital Twin (with LIST) that is being extended to mobility and logistics. The city is also exploring collaboration with Transcality for automated DT pipelines.
- **Political will and EU Mission commitment:** climate neutrality by 2030 is a formal city goal. The new administration is personally engaged.
- **Planned sensor deployment:** the city is installing sensors on loading zones as part of NEXTLOGIC, which will generate the first granular occupancy and usage data. This is viewed as a game-changer for evidence-based planning.
- **Open data and data space readiness:** Differdange is familiar with the European Mobility Data Space (EMDS) and relevant EU legislation (Data Governance Act, Data Act). It plans to publish some data on Luxembourg's open data portal and make real-time occupancy data publicly available via DiffMap.

Implications for NEXTLOGIC deployment

Based on the analysis of Differdange's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. **A baseline should be established before installing dynamic rules.** Collecting 3-6 months of sensor data on existing loading zones (occupancy, dwell time, vehicle types, misuse patterns) would help inform the design of dynamic time-dependent allocation. This aligns with the interviewee's view: "*We need to know who is parking where… over day, not only two hours.*"
2. **The Digital Twin could be integrated with low-cost sensor data.** Differdange already has an energy DT and access to MATSim. A lightweight logistics module that ingests sensor data and visualises occupancy heatmaps, peak hours, and recommended zone relocations could be developed. Outputs should be planner-friendly (GIS, Excel, dashboards), as requested by the city.
3. **A single "living lab" street could be tested.** The city identified the T-shaped intersection between Rue Michel Rodange and Grand Rue as the most critical area (70% of shop deliveries, dense residential zone). Focusing pilot deployment there rather than city-wide would help prove the concept and minimise risk.
4. **Microhub considerations could be linked to nearby activity zones.** Differdange alone may be too small for a Microhub, but a cross-communal hub (shared with neighbouring communes) in an activity zone 2-3 km away could be viable. This multi-municipality business model could be further assessed.

Interview-driven unique insight

"My daughter is a chocolatier in the city centre… I asked her what's the problem. She said 'logistics'. If I could have some logistics outside, where I could put all my packages and just go there with my cargo bike, I could sell a part of my stockage area, which would make my costs go down."

7.4 Dublin (IE): Smart Bike Parking Digital Twin & e-cargo bike logistics

Dublin's pilot in NEXTLOGIC is the Smart Bike Parking Digital Twin (SBPDT), designed to optimise bike parking management (including for e-cargo bikes) through real-time occupancy monitoring, dynamic space allocation, and compliance mechanisms combining rewards and penalties. The city has no dedicated urban logistics plan; the word "logistics" appears only once in the national Climate Action Plan. A past e-cargo bike trial (Bleeper Bikes, with Dublin City Council) provided cargo bikes to local businesses, achieved documented carbon savings, but most businesses did not continue after subsidies ended. The city has a strong digital foundation (RealSim.ie, Bentley, open data portal) but very limited freight-related data. Curbside management for deliveries is minimal; loading zones exist mainly for congestion, not decarbonisation. The main barriers are a pro-business culture that resists regulation, unwillingness of private operators to share data or consolidate deliveries, and physical constraints (narrow bike lanes, tight park gates). Success is measured by carbon savings and congestion reduction (Dublin is one of the most congested cities in Europe).

➢ Local challenge

Three interconnected challenges:

- **Very limited urban logistics policy and data:** Ireland does not have a formal SUMP; logistics is covered by multiple bylaws but no central strategy. The Climate Action Plan mentions "logistics" only once. No Microhubs, no dynamic loading zones, no low-emission zones with enforcement. The only quantitative logistics data comes from a few traffic counters and the past cargo bike trial. As one of the interviewees stated: *"We don't have SUMPs… the word logistic is mentioned only once in the Climate Action Plan."*
- **E-cargo bike viability depends on subsidies, not business case:** a successful trial (Bleeper Bikes) provided free cargo bikes to businesses, saving carbon emissions. However, when businesses had to pay, most stopped. Reasons cited: city centre is dense enough, but the wider municipality is not; bike lanes are narrow and park gates too tight for cargo bikes; no dedicated parking for cargo bikes. The city's role was as enabler, but without ongoing subsidy, the market did not sustain itself.
- **Business-friendly culture resists regulation and consolidation:** delivery companies are unwilling to share back-office functions or consolidate deliveries due to commercial sensitivities. A previous attempt to unite Amazon and DPD failed. The local authority sees itself as an enabler only if there is sufficient business demand; it does not impose drastic changes. An interviewee: *"Ireland is very pro-business… local authorities are not eager to impose drastic changes."*

➢ Position relative to existing best practices (Sections 6.2 and 6.5)

- **Operational viability and business models:** the benchmarking analysis highlights that successful cargo-bike operations often depend on a viable business model that can sustain operations beyond pilot funding. In Dublin, the Bleeper Bikes trial demonstrated carbon savings, but no operator continued using cargo bikes without subsidy. No Microhubs exist, and cargo bike operations remain marginal, as efficiency gains were not sufficient to overcome operational costs.
- **Incentive mechanisms:** the benchmarking identifies effective incentive schemes as those combining tangible rewards with performance-based mechanisms and stakeholder engagement. In Dublin, no active incentive scheme for logistics is currently in place. The past trial provided

free bikes (a subsidy rather than a performance-based incentive). One interviewee suggested that "disincentives are required more than incentives" (e.g. allowing only electric deliveries during daytime), but such regulation is politically unlikely given the city's pro-business culture.

- **Digital readiness:** the benchmarking underscores the importance of integrating logistics data into digital platforms to support evidence-based decision-making. Dublin has strong digital tools (RealSim.ie, Bentley, open data portal) and DT components (energy, buildings), but logistics is not yet integrated into these platforms. Traffic data exist but are not currently feeding into logistics decision-making.

➢ Barriers

Table 22. Key barriers to smart bike parking and e-cargo bike logistics - Dublin

Barrier type	Specific barrier
Policy/strategic	No formal SUMP/SULP; logistics not a priority in Climate Action Plan; no low-emission zones or dynamic loading zones
Cultural/political	Strong pro-business culture; local authority reluctant to impose rules that might upset businesses
Operator cooperation	Delivery companies unwilling to share data or consolidate deliveries due to commercial sensitivities; past consolidation attempt failed
Physical infrastructure	Narrow bike lanes, park gates too tight for cargo bikes; no dedicated cargo bike parking; limited charging infrastructure for e-vans
Data/evidence	Very little freight-related data; only traffic counters and one trial dataset; no real-time logistics monitoring
Business model	E-cargo bike operations not financially viable without subsidy; businesses did not continue after free trial ended

➢ Enablers

- **Strong digital and open data foundation:** Dublin has RealSim.ie (traffic simulation), Bentley platforms, an open data portal with cycling infrastructure data, and DT components (energy, buildings). The city is exploring integration of traffic data into digital twins.
- **Proven carbon savings from cargo bikes:** the Bleeper Bikes trial produced published papers quantifying carbon savings. This evidence can be used to build a business case.
- **Existing shared mobility and bike data**: Dublin collects cycling data from docked and dockless operators (Bolt, Bleeper). The city has experience with sensor-based traffic counters (e.g. Docklands project counting trucks).
- **Interest in disincentives** (even if not yet implemented): An interviewee's personal view that "disincentives are required more than incentives" (e.g. time-based access restrictions for non-electric vehicles) shows awareness of regulatory levers, even if political will is absent.
- **National mobility hubs project:** although the 140 national mobility hubs (trialed in Dublin) do not include logistics functions, the infrastructure and stakeholder engagement mechanisms could be adapted.

➢ Implications for NEXTLOGIC deployment

Based on the analysis of Dublin's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. A **financially sustainable business model** for e-cargo bike logistics could be developed, building on Dublin's existing DT capability. A cost-benefit analysis for cargo bike operations without subsidy, using data from the Bleeper Bikes trial, could inform the design of incentive mechanisms that are built into the business model rather than provided as free hardware.
2. **The SBPDT could be used as a testbed** for monitoring e-cargo bike parking occupancy and dwell time. The resulting data could help demonstrate demand for dedicated cargo bike spaces and inform dynamic allocation (e.g. reserving certain bays for cargo bikes during morning delivery hours).
3. A **performance-based incentive scheme** could be tested instead of providing free bikes. Possible mechanisms include reduced parking fees, priority access to bike bays, or gamified points redeemable for EV charging. This would align with the incentive mechanisms reviewed in the benchmarking analysis.
4. Dublin's congestion ranking (among the worst in Europe) could serve as a **political motivator**. Modelling the potential impact of a shift from vans to e-cargo bikes in the city centre and publishing the results could help build support for policy changes.
5. Given operator unwillingness to share back-office data, a **lightweight, anonymised load-matching system** (e.g. unused van capacity notification) could be tested. This could offer a low-cost alternative to full consolidation centres, without requiring operators to disclose commercial secrets.

➢ Interview-driven unique insight

“I think it’s disincentives that are required more than incentives. Maybe they should decide that only deliveries via electric vehicles can take place between 8am and 4pm… But that’s a personal opinion; I don’t know how realistic it is.”

“Ireland is very pro-business… local authorities are not eager to impose drastic changes.”

7.5 Frankfurt (DE): Mobile and Modular Microhubs

Frankfurt is a major transport and financial hub, facing intense delivery traffic, limited urban space, and ambitious climate goals. Its Logistics Concept 2021 and Mobility Masterplan 2030 explicitly target Microhubs, delivery zones, and parcel stations to reduce emissions and improve efficiency. In NEXTLOGIC, the city plans a phased deployment of two mobile, modular Microhubs; the first on Deutsche Bahn property, the second informed by learning from Wroclaw and the first pilot. However, past Microhub pilots failed (one due to construction, another single use with UPS/DHL). Currently, only Amazon operates a Microhub like facility in a private parking garage. The city has no continuous freight data (only occasional traffic counts), no incentive schemes, and faces severe land scarcity and grid capacity constraints. Enablers include a logistics roundtable (since January 2025), an Urban Data Platform (mainziel.de), and transport models (VISUM/VISSIM). Success for NEXTLOGIC is defined as a scalable, financially sustainable business model for Microhubs, not merely a demonstration.

➢ Local challenge

Three interconnected challenges:

- **Scarcity and high cost of suitable locations:** finding space for Microhubs is extremely difficult. Land is expensive, and underutilised locations (e.g. parking garages) are being considered as alternatives. Past pilots failed partly because sites became unavailable (construction project) or were not economically viable for operators.
- **Data gaps and lack of continuous monitoring:** Frankfurt conducts traffic counts only on a case-by-case basis (2019-2023). No city-wide, continuous freight data exists. Data on truck movements is limited to occasional counts differentiated by vehicle weight (>3.5t, articulated). The city has no real-time logistics data, no occupancy data for loading zones, and no operator delivery data.
- **Regulatory and operational constraints:** delivery windows in pedestrian zones are narrow (5:00-11:00), concentrating delivery vehicles into the same time slot, worsening congestion. Enforcement of loading zone misuse is possible but cannot be intensified due to resource constraints. Grid capacity is already strained, and new data centres are making it worse, limiting electrification.

➢ Position relative to existing best practices (Sections 6.2)

- **Operational models and collaboration:** the benchmarking analysis highlights that successful Microhub models often involve multi-operator collaboration and shared, agnostic infrastructure. In Frankfurt, past Microhub pilots were single-operator initiatives (UPS, DHL) and were not sustained. The only current operation is Amazon's private facility in a parking garage, which does not represent a shared, public Microhub model.
- **Location and infrastructure:** the benchmarking identifies location as a critical factor for Microhub viability, with examples ranging from on-street metered parking to public-private partnerships. In Frankfurt, the first NEXTLOGIC Microhub is planned on Deutsche Bahn property (railway land), an innovative but untested approach. Location scarcity remains a dominant barrier.
- **Digital readiness:** the benchmarking underscores the role of DTs in supporting scenario testing and operational optimisation. Frankfurt has VISUM/VISSIM models and an Urban Data Platform, but no unified DT. The current focus is on location optimisation rather than real-time operational management.

➢ Barriers

Table 23. Key barriers to the deployment of Mobile Microhubs - Frankfurt

Barrier type	Specific barrier
Spatial/real estate	Extreme scarcity and high cost of land for Microhubs; reliance on underutilised spaces (parking garages, railway land)
Data/monitoring	No continuous freight data; only occasional traffic counts; no loading zone occupancy data; no real-time logistics data
Regulatory	Narrow delivery windows (5:00-11:00) concentrating traffic; enforcement limited by resources; no specific Microhub regulations
Grid/energy	Grid capacity already strained; new data centres worsening the problem; charging infrastructure expansion limited

Barrier type	Specific barrier
Business model	Past pilots failed commercially; need for scalable, financially sustainable model (not just subsidised demonstration)
Political/acceptance	Residents perceive logistics as “loud and dirty”; resistance when benefits are not visible

Enablers

- **Strong strategic framework:** the Logistics Concept 2021 and Mobility Masterplan 2030 provide a clear policy foundation. Microhubs are explicitly included.
- **Stakeholder roundtable (Logistics Dialogue):** launched January 2025, bringing together city administration, logistics operators (DB, HOLM), businesses, and researchers. This is a structured co-creation platform that NEXTLOGIC can directly use.
- **Existing data and modelling infrastructure:** Urban Data Platform (mainziel.de) and VISUM/VISSIM models exist. Traffic count results are publicly available via the Geoportal. The city is open to sharing data with NEXTLOGIC.
- **Deutsche Bahn partnership:** the first Microhub on DB property is a unique asset, offering a large, centrally located site that might otherwise be unavailable.
- **Phased, learning by doing approach:** the city explicitly plans to learn from Wroclaw (leading city) and from its own first Microhub before deploying the second. This adaptive approach reduces risk.

Implications for NEXTLOGIC deployment

Based on the analysis of Frankfurt's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. A **financially sustainable business model** could be developed before deployment. Past pilots failed because they were not commercially viable. A multi-operator, cost-recovery model that accounts for Frankfurt's high land costs could be explored, with potential revenue from space leasing, service fees, or cross-subsidisation from adjacent uses (e.g., EV charging, parcel lockers).
1. **Existing tools such as the Urban Data Platform and VISUM/VISSIM could be used for location optimisation**. Rather than building a new DT, integrating traffic count data, delivery demand proxies (e.g., from commercial vehicle counts), and accessibility analysis could help rank potential microhub locations (e.g., parking garages, DB land, underused lots).
2. **A shared, agnostic Microhub model could be tested**. Unlike past single-operator pilots, the NEXTLOGIC Microhub could be open to multiple logistics providers (DHL, UPS, Amazon, others) to increase utilisation and share costs. The city's experience with failed single-operator models supports this approach.
3. **Grid capacity assessment could be integrated into Microhub siting**. Given Frankfurt's severe grid constraints, evaluating available electrical capacity (for e-cargo bike charging and e-van resupply) at potential Microhub locations could help inform site selection.
4. The **existing logistics roundtable could serve as the primary co-creation mechanism**. Rather than creating new stakeholder structures, NEXTLOGIC could feed directly into the existing Logistics Dialogue, providing evidence (simulations, business models) to support decision-making.

➢ Interview-driven unique insight

"Key lessons learned from past Microhub pilots include the importance of suitable delivery access and adequate infrastructure. The selected area must be economically viable for logistics operators."

"Currently, there is only one Microhub-like operation by Amazon, located in a privately-owned parking facility rather than on municipal space."

7.6 Heidelberg (DE): Smart Loading Zones & Mobile Microhubs

Heidelberg has a compact, dense urban structure with narrow and medieval streets, a 2-km long pedestrian zone, and high competition for limited curb space. The city aims to deploy Smart Loading Zones with digital status detection and mobile Microhubs with electric cargo bikes to reduce illegal parking, improve safety, and cut emissions. However, implementation faces severe barriers: no logistics demand data, no existing SLZ or Microhubs, no data collection on loading zone occupancy, discontinued funding schemes (cargo bikes, corporate mobility), and insufficient enforcement staff. The only regulation is a delivery time window (Monday-Saturday 6 - 11am) in the pedestrian zone, with some exemptions. Past experiments (craftsmen on street parking, cargo bike funding) were discontinued. The city has VISUM, an open data portal, and vehicle cameras, but no dedicated freight model. Success is defined as "enough loading zones with no illegal parking" and shifting last mile to e-cargo bikes.

➢ Local challenge

Three interconnected challenges:

- **Extreme spatial constraints and illegal parking:** the pedestrian zone (2 km) and narrow streets cause delivery vehicles to stop illegally on sidewalks, bike lanes, and crossroads, creating safety hazards. Loading zones are insufficient, and those that exist are often occupied by wrongly parked vehicles. Enforcement is weak due to "not enough staff for checks." Residents and craftsmen compete for the same limited space.
- **Complete lack of logistics demand data:** the city has no data on where delivery stops are needed, vehicle types, stop frequency, duration, or time of day. Static parking supply data exists, as do bike loop sensors and vehicle cameras (distinguishing types), but no freight-specific data. This makes evidence-based planning for SLZ locations and Microhub siting impossible.
- **Discontinued funding and no operational models:** past initiatives (cargo bike funding, corporate mobility management, craftsmen hub) were discontinued due to tight budgets. No Microhub concept or experience exists outside NEXTLOGIC. The city has no regulatory requirements for electrification, and charging availability for trucks is limited.

➢ Position relative to existing best practices (Sections 6.2 and 6.3)

- **Operational deployment and baseline data:** the benchmarking analysis highlights that effective SLZ systems are typically built on a foundation of operational data and enforcement mechanisms. In Heidelberg, no SLZ currently exists; no data collection or sensors are in place. Illegal parking is the norm, and enforcement is too weak to deter misuse.
- **Microhub operational models:** the benchmarking identifies multi-operator collaboration and shared infrastructure as key features of successful Microhub systems. In Heidelberg, no Microhubs exist, and there is no prior experience or stakeholder commitment yet. The city sees

Microhubs primarily as a way to substitute last-mile trips in the pedestrian zone for craftsmen, retail, and parcel services.

- **Digital readiness:** the benchmarking underscores the role of DTs in supporting scenario testing and operational optimisation. Heidelberg has VISUM and an open data portal, but no unified DT for logistics. Vehicle cameras provide some traffic data, but these are not integrated into logistics planning.

Barriers

Table 24. Key barriers to SLZs and mobile Microhubs - Heidelberg

Barrier type	Specific barrier
Spatial/infrastructure	Narrow medieval streets, 2-km-long pedestrian zone; insufficient loading zones; no dedicated areas for cargo bikes
Data / evidence	No logistics demand data (stop locations, frequency, duration, vehicle types); only static parking data and vehicle cameras
Enforcement/staffing	“Not enough staff for checks”; illegal parking in loading zones unaddressed
Financial/budgetary	All past funding schemes discontinued (cargo bikes, corporate mobility, craftsmen hub); no municipal budget for incentives
Operational/business model	No Microhub concept; no stakeholder commitment; operational model “not resolved”
Regulatory	Only delivery time window (6-11am) in pedestrian zone; no low-emission zone; no requirements for electrification

Enablers

- **Existing modelling and open data infrastructure:** VISUM traffic model, open data portal (Offene Daten Heidelberg), geoportal showing loading zones, and Climate Compass for emissions tracking. Vehicle cameras along major routes distinguish vehicle types (including trucks).
- **Clear demand from stakeholders:** logistics operators and shop owners actively seek solutions (e.g. after receiving parking tickets, they ask for loading zones). The Department for Economic Development and Mobility can sometimes find solutions.
- **Political awareness of safety issues:** wrong stopping delivery vehicles cause safety issues (blocking views, occupying bike lanes). This creates pressure for action.
- **Willingness to use Smart Rewards, if self-financing:** the city explicitly states that incentives “would have to be financially self-sustained through the companies that make use of this service.” This opens the door for B2B models.
- **Potential for cargo bikes in the pedestrian zone:** the city sees substitution of last mile trips for craftsmen, retail, and parcel services as a key opportunity.

Implications for NEXTLOGIC deployment

Based on the analysis of Heidelberg's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. **A low-cost data collection campaign** could be conducted before investing in expensive SLZ sensors. Manual surveys or existing vehicle camera data could be used to estimate demand for

delivery stops (location, frequency, duration, time of day). This would align with the city's limited budget for logistics innovation.

2. **A simple, low-tech SLZ pilot** could be developed in one high-conflict street, such as Neuenheim Brückenstraße, Weststadt Rohrbacher Straße, or Bergheim Bergheimer Straße. Painted zones, clear signage, and a self-financing Smart Reward (e.g. coffee vouchers from local shops for drivers who use the zone correctly) could be tested, avoiding the need for costly sensors and enforcement staff.
3. **A Microhub** could be tested **as a "pop-up" in underused space**. Given space constraints, a temporary Mobile Microhub in a parking garage or underused lot could serve multiple operators (agnostic) and use e-cargo bikes for last-mile delivery in the pedestrian zone, focusing on craftsmen and parcel services rather than retail only.
4. The **existing VISUM model** could be used **for scenario testing**. Simulating the impact of removing delivery vans from the pedestrian zone and shifting to e-cargo bikes from a Microhub could help build a business case for private investment.
5. **Incentives that cost the city nothing** could be designed. Smart Rewards could be funded by logistics operators (e.g. reduced fines for using designated zones, or priority access). The interview's suggestion of "coffee, snacks" could be provided by local businesses in exchange for reduced delivery conflicts.

➢ Interview-driven unique insight

“Coffee and snacks would be effective types of incentives.”

“It would have to be financially self-sustained through the companies that make use of this service; there is no amount in the municipal budget.”

7.7 The Hague (NL): Smart Loading Zones & dynamic curbside management

The Hague is one of the most advanced cities in the NEXTLOGIC consortium for urban logistics policy. It has implemented zero-emission (ZE) zones for city logistics (city centre since 2025, coastal zone since 2026), part of a national Dutch programme (18 cities). The ZE zone phases out diesel delivery vehicles by 2030. The city is deploying Smart Loading Zones with real-time sensors (about 11 zones with 26 sensors) and plans to integrate ANPR data. However, the city faces significant barriers: weak legal framework for loading zones (in the Netherlands, loading/unloading is allowed anywhere unless signed otherwise), enforcement challenges (bike parking chaos, illegal use of loading zones), grid congestion for EV charging, and lack of dedicated logistics demand data. The municipality has only a few full-time equivalents (FTEs) on logistics compared to 80-100 on personal mobility. Success is measured by curbside efficiency, reduced illegal parking, and smoother logistics flows, but monitoring remains qualitative.

➢ Local challenge

Four interconnected challenges:

- **Weak legal basis for loading zones:** in the Netherlands, loading/unloading is permitted anywhere in public space unless a no stopping sign applies. This makes enforcement and digital reservation systems legally complex. The city is testing two systems (Parkunload, Coding the Curbs) but legal approval for traffic decisions takes six weeks, and design costs are high.

- **Enforcement difficulties:** the city has scan cars for parking permits, but bike parking is unregulated (Dutch “disease”; bikes parked everywhere). Illegal use of loading zones by private cars and bikes is common. Enforcement staff are limited. The city wants digital enforcement (e.g. ANPR, sensors) but privacy regulations and technical issues (sensors misclassifying bikes as vans) hinder progress.
- **Grid congestion and charging for Small and Medium-sized Enterprises (SME):** large logistics operators (PostNL, DHL) already have positive TCO for electric vans/trucks and will transition. The main barrier is SME tradespeople (plumbers, painters) who cannot afford €50,000 vans and face grid congestion for home charging. The city also lacks data on where SMEs park their vans overnight (privacy restrictions).
- **Lack of logistics demand data:** no real time freight model; regional transport model does not distinguish personal from freight. ANPR data is “in the pipeline” but not yet operational. The city relies on sensor data from a few streets, not city wide.

➢ Position relative to existing best practices (Sections 6.3)

- **Operational deployment and legal framework:** the benchmarking analysis highlights that effective SLZ systems typically combine real-time monitoring with a supportive legal framework for enforcement and reservation. The Hague has pilot SLZs (11 zones, 26 sensors), but the legal framework does not yet support reservation or digital enforcement. Illegal parking persists, and no pricing mechanism is in place.
- **Data-driven zone placement:** the benchmarking identifies data-driven demand modelling as a key factor in optimising SLZ location and occupancy. In The Hague, zones have been selected based on local road managers' personal judgement rather than systematic analysis. The city acknowledges that there is no formal assessment framework and that decisions are made at an individual level.
- **Digital readiness:** the benchmarking underscores the role of DTs in enabling scenario-based planning and logistics optimisation. The Hague has a "Mirror City" DT concept and the MRDH regional model, but these are not yet operational for logistics. The city is currently working on building a logistics modelling capability with Antea.

➢ Barriers

Table 25. Key barriers to SLZs and dynamic curbside management - The Hague

Barrier type	Specific barrier
Legal/regulatory	In NL, loading/unloading allowed anywhere unless signed otherwise; making SLZ exclusive requires complex traffic decisions (6 weeks lead time)
Enforcement	Scan cars effective for parking, but bikes have no registration; illegal parking in SLZ by private cars and bikes; limited enforcement staff
Data/monitoring	No city-wide freight data; ANPR in pipeline not yet operational; sensors misclassify bikes as vans; privacy restrictions limit data sharing (CBS anonymization needed)
Grid/energy	Charging points congestion; more selective rules in July 2026; SME/home charging points deployment uncertain

Barrier type	Specific barrier
Business model/SME	SMEs cannot afford electric vans; cargo bikes not cost-effective compared to vans (lower productivity)
Organisational	Logistics has only a few FTEs vs. 80-100 for personal mobility; challenging coordination across departments

➢ Enablers

- **Strong national and local policy framework:** zero emission zone legally established, with clear phase out schedule (2025-2030). The city is part of the DMI (Dutch Metropolitan Innovations) collaboration with other G4 cities (Amsterdam, Utrecht, Rotterdam), sharing procurement and learning.
- **Existing sensor infrastructure:** 11 SLZs with 26 sensors (Parkunload and Coding the Curbs) already deployed. ANPR cameras coming Q2. The city is willing to test both systems and share learnings.
- **Stakeholder co creation:** the city has a parcel covenant with major delivery companies (including Amazon) to shift to parcel lockers and PUDO points. This is a public private agreement signed February 2026, demonstrating collaborative governance.
- **DT and modelling work in progress:** the city is developing a building logistics model with Antea and has a “Mirror City” DT. It participates in DMI projects on spatial logistics demand.
- **Clear political will:** the head of the mobility department acknowledges logistics importance. The city’s environmental law now requires logistics considerations in spatial planning.

➢ Implications for NEXTLOGIC deployment

Based on the analysis of The Hague's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. **Microhubs or cargo bikes may not be the primary focus.** The Hague's experts explicitly doubt their viability for the city's context. Greater emphasis could instead be placed on SLZs, better use of existing private hubs, and electrification of vans and trucks.
2. A **legal framework for digital enforcement** could be developed. Working with the city's legal team to test a reservation-based SLZ model (e.g. Parkunload's on-spot reservation) within existing Dutch traffic law could help document legal hurdles and potential workarounds for replication in other cities.
3. **Sensor data** could be used **to create a simple KPI dashboard**. Rather than complex models, the city needs "steering information". A real-time dashboard showing occupancy, dwell time, and misuse rates for the 11 SLZs, with before-after comparisons, could be more useful than a full DT.
4. **The parcel locker covenant** could be supported. The Hague has already signed a public-private agreement to shift parcels to lockers. Integrating locker occupancy data into the SLZ system and modelling the traffic reduction from shifted deliveries could contribute to this effort.
5. **SME transition** could be prioritised. The city's biggest challenge is not large operators but small tradespeople. A leasing guarantee or "EV bank" concept for SME could be explored, leveraging the city's data on parking and charging locations.

➢ Interview-driven unique insight

"I'm a strong non-believer of Microhubs… The only thing, the definition of a Microhub, for parcel lockers, I would consider that a Microhub, and then yes, we could provide locations. But we're not going to play a logistical role."

"Cargo bikes… Do not underestimate the extra cost. The van is a lot more productive. From a logistic perspective, most parties will not use the cargo bike."

7.8 Wroclaw (PL): Mobile Microhubs with cargo bikes

Wroclaw is a Polish city that has become a national pioneer in urban logistics, driven not by political mandate but by motivated municipal staff and university partners. The city has no systematic network of designated loading zones; loading zones are created only on demand from receivers. A 2021 study found that 60% of deliveries in the city centre occur outside the permitted time window (6-10am), with 39% outside designated locations. In response, the city established a Freight Quality Partnership (FQP) in 2024, now involving 24 organisations. A first Microhub was launched in June 2025 in an underground car park (owned by the municipality, managed by Interparking), serving five courier companies and one food distributor. The space is free; operators pay only for electricity and waste. The city has also established dedicated parking spaces for cargo bikes in the city centre, though operators reported that they find them unnecessary and underused. The NEXTLOGIC pilot will deploy a mobile, modular Microhub on a city-owned parking lot (two containers), designed to be visually harmonious and flexible. The city has no SULP yet, and logistics is not a top political priority, but the FQP and university collaboration have enabled co-creation. Key barriers remain weak enforcement of time windows, and unsustainable business models for Microhubs beyond project funding.

➢ Local challenge

Three interconnected challenges:

- **Poor compliance with delivery time windows:** the city centre has a delivery window from 6-10am, but a 2021 survey showed 60% of deliveries occur outside this window, and 39% of drivers park illegally (blocking pavements, bike lanes). Enforcement is insufficient, and there is a social tolerance for rule-breaking. A similar survey was conducted in May 2026 to measure changes.
- **Lack of loading zones and curbside management:** Wroclaw has no systematic network of designated loading/unloading zones; spaces are created only on request from receivers. Two cargo bike parking spaces were created as an incentive, but operators reported that they do not use them because cargo bikes are flexible enough to park anywhere. This highlights the challenge of designing effective infrastructure.
- **Financial sustainability of Microhubs:** The existing Microhub is free for operators, funded by the municipality (space) and Interparking (fit-out). The NEXTLOGIC Microhub will also be free during the project. However, after the project ends, a commercial model will be needed to ensure long-term viability.

➢ Position relative to existing best practices (Sections 6.2)

- **Operational models and business sustainability:** The benchmarking analysis highlights that successful Microhub models often involve multi-operator collaboration and commercially viable business models. Wroclaw's existing Microhub is shared among five operators, but it is provided free of charge and is not commercially viable. The NEXTLOGIC Microhub aims to be mobile and modular, though performance metrics such as CO_2 reduction and stop data have not yet been measured.

- **Digital tools and optimisation:** The benchmarking identifies real-time monitoring and optimisation tools as common features of advanced Microhub systems. Wroclaw's existing hub uses QR-code access and cameras. The NEXTLOGIC pilot plans to integrate DT and XR tools to support design, simulation, and stakeholder engagement.
- **Location and infrastructure:** The benchmarking notes that Microhubs are often located in high-demand zones with dedicated parking or access to existing infrastructure. Wroclaw's existing hub is located in an underground car park (height 2.5m, accessible for 8-tonne trucks). The NEXTLOGIC hub will be on a city-owned parking lot, which offers greater visibility but is subject to space constraints.

Barriers

Table 26. Key barriers to the deployment of mobile Microhubs - Wroclaw

Barrier type	Specific barrier
Enforcement/ compliance	Delivery time windows widely ignored (60% outside window); insufficient enforcement staff; social tolerance of illegal parking
Financial/business model	Microhub free during projects; no sustainable post-project commercial model; operators unwilling to pay for space
Infrastructure/space	No systematic network of designated loading zones; scarce space in city centre for additional Microhubs; cargo bike parking spaces unused
Data/evidence	Limited freight data (one-day survey in 2021, repeated in May 2026); no freight model; no real-time monitoring
Regulatory	Polish law requires cargo bike width ≤90cm to access city centre, limiting palletized loads; FQP is working to change this
Political priority	Logistics not a top political priority; no SULP; SUMP is voluntary in Poland, not compulsory

Enablers

- **Strong Freight Quality Partnership:** established in 2024 with 24 organisations (couriers, cargo bike manufacturers, retailers, university, city departments). The FQP meets 4-5 times per year and has been the engine of co-creation. The university (WUEB) acts as facilitator and coordinator, building trust.
- **Existing operational Microhub:** The underground Microhub (since June 2025) is a proven proof-of-concept. It demonstrates that multi-operator sharing works, even if not yet financially sustainable. Lessons learned inform the NEXTLOGIC pilot.
- **Comprehensive travel survey 2024:** a freight module using SIM card and M2M data was conducted for one working day (18 April 2024), providing origin-destination, vehicle type, and trip purpose data. This is publicly available and can be used for modelling.
- **University expertise and continuity:** a university research group has been closely involved since 2021, providing research, facilitation, and connection to European projects. The city acknowledges that without this academic engagement, city logistics would not be on the agenda.

- **Interest in advanced digital tools:** Wroclaw plans to use AHP/PROMETHEE for Microhub location selection, DT for scenario testing, and XR for stakeholder visualisation and co-design. These are ambitious and could set a benchmark for other Polish cities.

➢ Implications for NEXTLOGIC deployment

Based on the analysis of Wroclaw's local context, barriers, and enablers, the following considerations emerge for the design and implementation of the NEXTLOGIC pilot:

1. A **post-project business model** could be developed during the pilot phase. The biggest risk is that the Mobile Microhub, like the previous one, becomes unsustainable after EU funding ends. A fee structure (e.g. per parcel, monthly rental, or a cooperative model) could be co-designed with the FQP to ensure operator acceptance, as the current "free" model is not replicable.
2. **Repeated surveys (2021 and May 2026)** could be used **as the baseline** for impact assessment. The city is already conducting a second 10-street observational survey. Aligning NEXTLOGIC's before-after evaluation with this survey (same methodology, same streets) would ensure comparability and reduce duplication.
3. **Secure overnight parking and charging for cargo bikes inside the Microhub** could be ensured. The existing dedicated cargo bike parking spaces in the city centre serve a different purpose and are not part of the Microhub. For the NEXTLOGIC pilot, the Microhub will be designed with internal storage and charging facilities for cargo bikes, as this is essential for operational efficiency and security.
4. **XR could be used to address the "wide cargo bike" regulation.** Polish law limits cargo bike width to 90cm, preventing palletised loads. The FQP is advocating for change. Meanwhile, XR simulations could train couriers on how to navigate narrow spaces with wider bikes (if the law changes) or optimise loads within the 90cm limit.
5. **The FQP could be leveraged as the primary co-creation forum.** Rather than creating new stakeholder structures, NEXTLOGIC could feed data, simulations, and business models directly into the existing FQP meetings, which already have trust and regular attendance.

➢ Interview-driven unique insight

"The Microhub space is provided free of charge, they only pay for electricity and waste. When the project will finish, then probably we will discuss with the courier companies about changing the business model to work more commercial."

8. Cross-Cutting Findings and Discussion

This section synthesises the key findings from the eight NEXTLOGIC mission cities. It does not repeat the individual city profiles (Section 7), but rather identifies common patterns, unique differences, and actionable implications for the NEXTLOGIC Work Packages.

8.1 Common challenges across cities

Despite their diversity in size, geography, and policy maturity, all eight cities face a set of shared challenges:

- **Lack of logistics demand data:** no city has continuous, city-wide data on delivery stop locations, vehicle types, dwell times, or load factors. Most rely on occasional manual surveys (Wroclaw, The Hague), complaint-based evidence (Dublin, Differdange), or no data at all (Bergamo, Heidelberg). Even advanced cities like The Hague lack real-time freight models.
- **Weak enforcement of existing regulations:** delivery time windows are widely ignored (Wroclaw: 60% of deliveries outside window; Dublin, Heidelberg, Bergamo similarly). Enforcement is under-resourced, and in some countries (Dublin) there is cultural resistance to imposing fines on businesses.
- **Financial unsustainability of pilots:** almost all Microhub or cargo-bike pilots to date have been free to operators (Wroclaw, Dublin, Frankfurt). Once EU or municipal subsidies end, operators do not continue. Business models that work without ongoing subsidy are largely absent.
- **Competition for scarce curb space:** loading zones are often misused by private cars (Aarhus, Heidelberg, The Hague), bikes (The Hague), or delivery vehicles that stop illegally because designated spaces are insufficient. No city has a fully dynamic, demand-based curbside management system.
- **Limited political priority for logistics:** in most cities, logistics receives far fewer staff resources than passenger mobility (The Hague: 2-3 FTEs vs 80-100 for mobility). Logistics is rarely a standalone political portfolio, and SULPs are not yet mandatory or widespread.
- **Operator reluctance to share data or consolidate:** delivery companies cite commercial sensitivities and refuse to share back-office data (Dublin, Aarhus). Past consolidation attempts failed for this reason.

8.2 City-specific unique challenges

While common challenges exist, each city has a distinctive constraint that shapes its NEXTLOGIC pilot:

Table 27. Unique challenges by city

City	Unique challenge
Aarhus (DK)	Heritage constraints; 15-minute hubs must not disrupt iconic architecture; slow political decisions
Bergamo (IT)	Medieval topography; steep slopes, narrow gates, UNESCO walls; real estate extremely expensive
Differdange (LU)	Cross-border logistics flows (LU/BE/FR); multi-jurisdiction data sharing required
Dublin (IE)	Pro-business culture; local authority refuses to impose regulations; "disincentives" politically impossible

City	Unique challenge
Frankfurt (DE)	Severe grid congestion; new data centres worsen EV charging capacity; land extremely scarce
Heidelberg (DE)	Limited municipal funding for logistics innovation; incentives must be self-financing
The Hague (NL)	Legal framework; in NL, loading/unloading allowed anywhere unless signed otherwise, making SLZ enforcement complex
Wroclaw (PL)	Strong reliance on university-led research; limited municipal in-house capacity for logistics planning

8.3 Governance and stakeholder dynamics

Four patterns emerge across cities:

1. **Freight Quality Partnerships accelerate progress**: cities with formal multi-stakeholder platforms (Wroclaw, The Hague) have moved faster. Wroclaw's FQP (24 organisations, university-facilitated) co-created the existing Microhub. The Hague's parcel covenant (including Amazon) shifted behaviour voluntarily. Where no such partnership exists (Bergamo, Heidelberg), progress relies on individual relationships or occasional consultations.
2. **University-municipality collaboration is a critical enabler:** Wroclaw's progress is closely linked to university-led research and facilitation. Aarhus benefits from DTU, Bergamo from UniBG, and Differdange from LIST and UniLU. Cities without strong university links (Dublin, Heidelberg) have weaker analytical capacity.
3. **Co-creation works best when it delivers tangible benefits to operators:** free Microhub space, reduced fines, or preferential access are effective. Generic workshops without clear incentives (Bergamo's past attempts) are less successful.
4. **Political will is fragile:** in Aarhus, inter-departmental conflicts escalate decisions to politicians, causing delays. In Dublin, the pro-business culture blocks regulation. In Heidelberg, budget cuts ended all logistics funding. In Wroclaw, logistics is not a political priority, but motivated municipal staff drive change from below.

8.4 Data availability and digital readiness

Cities fall into three levels:

Table 28. Digital readiness levels

Level	Cities	Characteristics
High	The Hague, Aarhus, Frankfurt	Real-time sensors (SLZ, traffic), transport models (VISUM/VISSIM/MATSim), open data portals, ANPR in development; however, freight-dedicated data remains limited.
Medium	Dublin, Wroclaw	Some DTs (energy, buildings), traffic models, open data, but no freight-specific real-time data. Relies on manual surveys and occasional counts.

Level	Cities	Characteristics
Low	Bergamo, Differdange, Heidelberg	No freight data; only ZTL entry counts, fines records, or visual observation. DTs exist but for energy, not logistics.

Common data gaps across all levels:

- No real-time delivery stop data (location, dwell time, vehicle type).
- No operator delivery data (reluctance to share).
- No freight demand models.
- No city-wide loading zone occupancy monitoring.

What cities need most (from interviews):

- Granular stop data (e.g. Bergamo, Heidelberg, Wroclaw).
- APIs for real-time curbside availability (e.g. The Hague, Frankfurt).
- Standardised, anonymised data sharing platforms (all cities).

8.5 Implications for NEXTLOGIC (WP2, WP3, WP4, WP5)

WP2 (DT, XR, data analytics)

- **Complex DTs are not always necessary:** simple dashboards showing occupancy, dwell time, and misuse rates may be more practical for cities like The Hague and Heidelberg. Low-tech sensors or manual surveys can provide useful starting points.
- **Interoperability is a priority:** cities have expressed a clear need for open APIs, OGC standards, GeoJSON, and compatibility with existing tools (VISUM, MATSim, Bentley). Proprietary systems should be avoided.
- **XR adds value in specific applications:** XR can be useful where it addresses a clear need, such as stakeholder visualisation and co-design in Wroclaw, or citizen engagement in Aarhus. Its use should be driven by practical requirements rather than novelty.

WP3 (Solutions)

- **Microhub business models require post-project planning:** pilots that are free to operators often fail when funding ends. A fee structure (per parcel, rental, or cooperative model) could be co-designed with operators during the project. Wroclaw's FQP offers a suitable platform for such discussions.
- **SLZs depend on enforcement capacity:** without digital enforcement (cameras, ANPR, scan cars), SLZs are vulnerable to misuse. The legal barriers encountered in The Hague could be documented to inform replication efforts in other cities.
- **Cargo bikes are not universally applicable:** their viability depends on local conditions such as geography, density, and cost structure. In cities like The Hague, they are considered less cost-effective; in Dublin, previous trials did not continue without subsidy.

- **Incentives may need to be self-financing:** in cities with limited budgets (e.g. Heidelberg) or regulatory constraints (e.g. Dublin), reward mechanisms could be funded by operators (e.g. reduced fines, priority access) or local businesses.
- **Electrification efforts should consider SME:** while large operators are transitioning to electric fleets, smaller tradespeople (e.g. plumbers, painters) face greater barriers. Grid capacity and home charging infrastructure are particular concerns in cities like The Hague and Aarhus.

➢ WP4 (Pilots)

- **Solutions should be adapted to local contexts:** political and cultural constraints vary across cities. For example, regulatory approaches may not be feasible in Dublin, costly sensors may not be suitable for Heidelberg, and heritage constraints must be respected in Aarhus.
- **Replication requires adaptation:** lessons from leading cities (e.g. The Hague, Wroclaw) should be interpreted in light of local conditions. For instance, Wroclaw's Microhub model benefits from an unusually high underground car park (2.6m), which may not be replicable elsewhere.
- **Existing stakeholder platforms should be leveraged:** rather than creating new consultation structures, NEXTLOGIC could work through established platforms such as Wroclaw's FQP, The Hague's parcel covenant, or Aarhus's Climate Neutral Logistics network.

➢ WP5 (Impact assessment, governance, business models)

- **Suggested indicators for monitoring** include:
    - Compliance with delivery time windows (before/after comparison).
    - Reduction in illegal parking in loading zones.
    - Cost per delivery (Microhub vs baseline).
    - Operator satisfaction (survey-based).
    - Modelled emissions reduction (given current data gaps).
- **Governance models could formalise FQP-like structures:** a template for FQPs could be developed, including terms of reference, stakeholder mapping, and decision-making protocols, to support replication in other Mission Cities.
- **Business models should be commercially viable without subsidy:** a financially sustainable Microhub business model, tested in at least two cities (e.g. Wroclaw, Frankfurt), could be a key output. Without such a model, there is a risk of repeating past failures where pilots did not continue after project funding ended.

9. Conclusion

9.1 Summary of key findings

Deliverable 1.1 has provided a comprehensive analysis of urban logistics challenges across the eight NEXTLOGIC mission cities (Aarhus, Bergamo, Differdange, Dublin, Frankfurt, Heidelberg, The Hague, and Wroclaw). The work combined a state-of-the-art literature review, a benchmarking of five core solutions (Microhubs, Smart Loading Zones, 15-minute multimodal hubs, Incentive and Reward mechanisms, and Electrification), and in-depth interviews or written questionnaires with city representatives.

The key findings are:

- **Common challenges:** all eight cities face a persistent lack of granular, real-time logistics demand data; weak enforcement of delivery time windows; financial unsustainability of pilot projects once subsidies end; severe competition for scarce curbside space; and limited political priority for freight compared to passenger mobility. These are not technical problems but systemic governance and data gaps.
- **City-specific constraints:** each city has a unique barrier that shapes its pilot: heritage preservation (Aarhus), medieval topography (Bergamo), cross-border logistics (Differdange), pro-business culture resistant to regulation (Dublin), grid congestion (Frankfurt), limited municipal funding for logistics innovation (Heidelberg), a legal framework that permits loading anywhere (The Hague), and strong reliance on university-led research (Wroclaw). One-size-fits-all solutions will fail.
- **Digital readiness varies widely:** The Hague, Aarhus, and Frankfurt have transport models and sensor infrastructure, but none have a dedicated freight-ready DT. Bergamo, Differdange, and Heidelberg lack basic freight data. The most urgent shared need is for standardised, anonymised real-time delivery stop data.
- **Stakeholder dynamics are critical:** cities with formal FQPs (Wroclaw, The Hague) or strong university collaboration (Aarhus, Bergamo, Wroclaw) progress faster. Where such structures are absent, progress depends on individual champions or ad-hoc consultations, which are fragile and less effective.
- **Business models remain the weakest link:** almost all existing Microhub and cargo-bike pilots are free to operators, funded by EU or municipal subsidies. They do not continue after funding ends. Without a commercially viable, multi-operator business model, NEXTLOGIC's pilots will replicate past failures.

9.2 Contribution to WP1 objectives

Deliverable 1.1 directly fulfils the objectives of WP1 - Setting the stage as defined in the NEXTLOGIC Description of the Action:

- **Task 1.1 Trends, drivers and links between urban logistics, urban space and climate neutrality:** this deliverable provides a detailed literature review and benchmarking of best practices, linking urban logistics to the EU Green Deal, Cities Mission, and climate neutrality targets. It identifies key trends (e-commerce growth, last-mile decentralisation) and adoption barriers (data gaps, financial unsustainability, regulatory fragmentation).

- **Task 1.2 Data acquisition framework and management:** while the full data framework is the subject of D1.3, this deliverable has mapped existing data sources and gaps across all eight cities. It has documented what data is collected (e.g. The Hague's sensors, Wroclaw's travel survey), what is missing (real-time delivery stops, operator data), and what legal or cultural barriers prevent sharing (privacy, commercial sensitivities, lack of interoperability standards).
- **Task 1.3 Impact evaluation framework:** the benchmarking in Section 6 provides observed performance ranges and suggested indicators for each solution, drawn from existing projects. These will inform WP5's impact assessment, with applicability to NEXTLOGIC pilots to be assessed in subsequent deliverables (D3.1, D4.1).
- **Task 1.4 Co-creation methods:** the analysis of stakeholder dynamics in each city (Section 6 and Section 7) provides the baseline for WP1.4's co-creation guidelines. The deliverable identifies which cities already have effective co-creation platforms (Wroclaw's FQP, The Hague's parcel covenant, Aarhus's Climate Neutral Logistics network) and which need to establish them.

Thus, D1.1 serves as the foundational evidence base for all subsequent work packages, particularly WP2 Digital Tools), WP3 Solution Design, WP4 Pilots, and WP5 Impact and Business Models.

9.3 Next steps (D1.2, D1.3, and the project)

➢ **Deliverable 1.2 - Methodological approach** (due M08, led by LAET): D1.2 will build directly on the findings of D1.1. It will specify:

- The co-creation methods to be used in each city, adapted to the stakeholder dynamics identified in Section 8.3.
- The impact evaluation framework, using the benchmark indicators and suggested indicators from Section 6, with tailored baselines for each city (from Section 7).
- A standardised protocol for fulfilling monitoring indicators data across the eight cities, addressing the common data gaps identified in Section 8.4.

➢ **Deliverable 1.3 - Data framework specifications** (due M12, led by SAU): D1.3 will translate the findings of D1.1 into a technical data acquisition and management framework. It will:

- Identify and document city datasets provided by participating cities, including their formats, APIs, and applicable interoperability standards (e.g. OGC API, DATEX II, GTFS, SensorThings API). For each dataset, relevant GDPR and privacy constraints, as well as existing anonymisation or pseudonymisation measures, will be documented.
- Define a common metadata framework and attribute dictionary for dataset description, enabling the consistent documentation of urban logistics and mobility datasets across participating cities through a shared terminology and metadata structure.
- Establish a governed data-sharing architecture that supports secure and interoperable data exchange among project partners, while providing a migration path towards compatibility with the European Mobility Data Space (EMDS/MDS).

➢ **Next steps for the NEXTLOGIC project (beyond WP1)**

- **WP2 Digital Tools:** priorities include interoperability and low-cost solutions. Modular dashboards that ingest existing sensor and traffic data are recommended over a monolithic Digital Twin.

Specific focus areas include The Hague's SLZ sensors, Wroclaw's stakeholder visualisation, and Aarhus's scenario visualisations.

- **WP3 Solutions:** business models need to be co-designed alongside technical features, with a focus on financial sustainability across all solution areas, particularly Microhubs and smart loading zones.
- **WP4 Pilots:** city-specific political and cultural constraints need to be respected (e.g. regulation in Dublin, costly sensors in Heidelberg, heritage preservation in Aarhus). Working through existing stakeholder platforms is recommended rather than creating new ones.
- **WP5 Impact assessment:** the indicators and baseline data from Sections 6 and 7 can inform the impact assessment. Metrics such as compliance rates, illegal parking reduction, and cost per delivery are suggested alongside emissions. Developing a replicable FQP governance template is a potential area for further work.

The applicability of observed performance ranges to NEXTLOGIC pilots will be assessed in D3.1 Toolkit for sustainable urban logistics solutions and D4.1 Operational guidelines for pilot implementation and monitoring. As cities collect new data during the pilots (e.g. Wroclaw’s repeat survey, The Hague’s ANPR data), the benchmarking and city assessments can be updated. The cross-city synthesis (Section 8) already reveals that no single solution works everywhere; the project’s greatest contribution will be to document which solutions work under which conditions, rather than to promote a universal model.

10.Abbreviations

Table 29. Abbreviations

Term	Definition
AR	Augmented Reality
CBD	Central Business District
CDS	Curb Data Specification
D1.1	Deliverable 1.1
DT	Digital Twin
eHGV	Electric Heavy Goods vehicle
EU	European Union
EV	Electric Vehicle
FQP	Freight Quality Partnership
FTE	Full-time Equivalents
GHG	Greenhouse Gas
KPI	Key Performance Indicator
LCV	Light Commercial Vehicle
ML	Machine Learning
OTP	One-Time Password
PUDO	Pick-Up/Drop-Off
SBPDT	Smart Bike Parking Digital Twin
SLZ	Smart Loading Zone
SME	Small and Medium-sized Enterprises
SULP	Sustainable Urban Logistics Plan
SUMP	Sustainable Urban Mobility Plan
V2C	Vehicle-to-Curb
VR	Virtual Reality
WP	Work Package
XR	eXtended Reality
ZE	Zero-Emission

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A. Annex

WP1/D1.1 Interview Guide: Urban Logistics Challenges

Purpose: This interview aims to collect comparable information from the pilot cities to support "Deliverable 1.1" on *Urban Logistics Challenges*. The discussion focuses on the current state of urban logistics, the use of urban space, and climate neutrality objectives. Particular attention will be given to identify key challenges, existing solutions, and data availability to enable cross-city benchmarking and analysis.

A. City Context (5-10 minutes)

A1. What are the main economic drivers that influence urban logistics demand in your city? (e.g., retail, e-commerce, industry, tourism, port activities)

A2. Based on your existing planning documents (e.g., SUMP, or similar strategies), what are the most advanced or pioneering actions related to urban logistics in your city? Are there any recent developments not yet reflected in published documents?

A3. Based on your Climate City Contract, what are the key logistics-related priorities and challenges for achieving climate neutrality in your city?

A4. What freight-related regulations are currently in place in your city? (e.g., low-emission zones, access restrictions, time windows, vehicle limitations, permit systems)

A5. How are urban logistics issues coordinated across different city departments? (e.g., transport, urban planning, environment, data, economic development)

B. Core Logistics Infrastructure (15-20 minutes)

B1. Loading/Unloading Zones & Curbside Management

B1.1. How are deliveries typically accommodated in public space in your city (e.g., designated loading zones, shared curb use, informal practices)? How are these arrangements managed?

B1.2. Do you collect any data on the occupancy or use of loading/unloading zones or other delivery-related curb space? If yes, what kind of data is collected and how is it used?

B1.3. What are the main challenges related to loading/unloading zones? (e.g., misuse, insufficient capacity, enforcement, competing curb uses)

B1.4. Beyond deliveries, how is curb space used for other purposes (bike parking, outdoor dining, car sharing)? Are there conflicts and how are they addressed?

B1.5. If you could redesign one street or area to improve deliveries, which would it be and why?

B2. Microhubs & Consolidation Centers

B2.1. Where microhubs or urban consolidation centers exist (or are being considered), could you briefly describe their key characteristics (e.g., agnostic/branded, one operator or multiple, space owned by municipality or private operator, business model such as subsidies, public funding, or already financially viable) and share any key lessons learned?

B2.2. What are the main barriers your city faces in implementing or scaling microhubs or consolidation centers?

B3. Cargo Bikes & Active Logistics

B3.1. Based on your city's experience, how are cargo bikes currently used for urban deliveries (if applicable), and by which types of operators? Are there any dedicated parking or loading areas for cargo bikes?

B3.2. What conditions would make cargo bike logistics more viable in your city? (e.g., infrastructure, dedicated parking, incentives, regulatory support)

B4. Electrification of Urban Logistics

B4.1. Based on your city's current initiatives, how is electrification of urban logistics being implemented locally (e.g., adoption of electric vans, trucks, etc.)?

B4.2. What infrastructure or operational measures support electrification (e.g., charging infrastructure, dedicated zones, incentives)?

B4.3. What are the main barriers to further electrification of urban logistics in your city? (e.g., costs, charging availability, grid capacity, operational constraints)

B5. Incentive & Reward Mechanisms

B5.1. Does your city use any incentives or reward mechanisms to encourage more sustainable urban logistics behavior? (e.g., off-hour delivery incentives, benefits for cargo bikes, reduced fees for low-emission vehicles)

B5.2. From your perspective, what types of incentives would be most effective to influence the behavior of logistics operators or delivery drivers?

B6. 15-Minute Multimodal Hubs

B6.1. In the context of proximity-based planning approaches (e.g., 15-minute city), how is urban logistics considered in your city?

B6.2. Are there any plans or discussions about creating multimodal hubs that combine passenger transport with last-mile logistics functions? What barriers do you foresee in implementing such hubs?

C. Challenges & Pain Points (10-15 minutes)

C1. Could you please identify the 2-3 most important main urban logistics challenges your city is currently facing? (e.g., policy constraints, operational issues, stakeholder conflicts, data gaps)

C2. For each challenge, could you briefly elaborate on:

- What are the main causes?
- Who is most affected and how? (e.g., residents, businesses, logistics operators, city administration)
- Have any solutions been tested? If yes, what were the outcomes?

C3. Are there aspects where publicly available planning documents (e.g., SUMP or similar strategies) do not fully reflect the current reality of urban logistics in your city?

D. Stakeholder Dynamics (5-10 minutes)

D1. Who are the main stakeholders influencing urban logistics decisions in your city? (e.g., businesses, logistics operators, residents, associations, public authorities)

D2. Which of these are most supportive of new logistics initiatives? Which pushes back the most?

D3. Is there any example of a recent conflict related to logistics (e.g., residents vs. delivery vans, shop owners vs. city)? How was it resolved?

D4. How are decisions about urban logistics typically made in your city? (e.g., top-down, multi-stakeholder working groups, political processes)

D5. What effects do you expect from closer co-creation with stakeholders affected by logistics decisions?

E. Data & Digital Readiness (5-10 minutes)

E1. Do you use any digital tools for logistics planning or analysis? (e.g., Digital Twins, simulation models, decision-support tools, transport models)

E2. What freight-related data does your city currently collect? (e.g., traffic counts, delivery volumes, surveys, GPS data, sensor data, operator data)

E3. For how long has this data been collected, and could it potentially be shared within the NEXTLOGIC project?

E4. What additional data would you ideally need to better manage urban logistics?

E5. Within your tools or datasets, how is urban logistics represented (e.g., integrated within general transport models, separate freight model, or not explicitly modelled)? Are relevant inputs and outputs potentially available for sharing?

E6. Do you have a platform and/or are you sharing the city data on open platforms / with private stakeholders? E.g. regulatory constraints, U/L zones locations, etc.

E7. Are you familiar with the concept of Data Space? Yes/No/I've heard of it, but it's unclear.

F. Expectations & Success Criteria (5 minutes)

F1. How does your city typically measure the success of urban logistics initiatives? (e.g., emissions reduction, improved delivery efficiency, reduced congestion, stakeholder satisfaction)

F2. From your perspective, what would success look like for your city at the end of the NEXTLOGIC project? What key outcomes are you hoping to achieve?