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Optimizing Micro-Hub Site Selection: A Data-Based Framework for Sustainable Urban Freight

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Abstract

The rapid growth of e-commerce has intensified pressure on cities to manage last-mile deliveries efficiently while minimizing congestion and environmental impacts. Micro-hubs—small, decentralized logistics facilities located within urban areas—are increasingly recognized as a key solution to improve delivery efficiency, reduce vehicle kilometers, and support more sustainable freight transport. However, selecting suitable locations for micro-hubs remains a major challenge for cities, as it requires balancing logistical performance with urban planning objectives. This paper presents a data-driven framework to support cities in identifying potential micro-hub locations. The framework is based on key performance indicators (KPIs), including proximity to motorways and main roads, short distances to residential and commercial areas, and accessibility for freight operators. To operationalize these criteria, we leverage floating vehicle data as a proxy for traffic flows and accessibility, enabling the identification of candidate sites with high logistical potential. The proposed approach bridges the gap between urban data and practical decision-making, offering city authorities and logistics stakeholders a replicable method to guide micro-hub planning. Case study results in Braga, Portugal, demonstrate how floating vehicle data can reveal location patterns that align with both delivery demand and urban sustainability goals.

Keywords: Micro-hub: urban logistics: floating vehicle data: location

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1. The role of micro-hub in urban logistics

Urban logistics is essential for city life. Urban logistics contributes between 10% and 20% of vehicle kilometres travelled (VKT) and two of five percent of the employed urban workforce according to Eurostat (2020). Urban freight volumes have continued to increase, driven by ongoing urbanisation and, more recently, the rapid growth of e-commerce. Since the COVID-19 pandemic, consumer expectations for on-demand and fast deliveries have further accelerated this trend, reshaping the dynamics of urban freight distribution. According to Eurostat (2023), in 2022 the most common online purchases in the European Union were clothing, footwear, and accessories, ordered by 42% of internet users. The rapid expansion of e-commerce has transformed the landscape of urban freight, leading to an unprecedented increase in last-mile deliveries.

Traditional delivery models, relying on large distribution centers located on city outskirts, often result in increased congestion, higher emissions, and inefficiencies in densely populated areas. The rising demand for home delivery of online purchases, combined with the employment opportunities created by collaborative economy platforms, has also led to a marked increase in the use of cargo bikes for last-mile logistics. While this transition contributes to sustainable transport objectives, it also presents significant challenges for cities. In particular, the successful deployment of cargo bikes and smaller delivery vehicles depends on the availability of logistics depots located close to city centres, enabling efficient transshipment and last-mile operations. However, the integration of such facilities into dense urban environments remains a major difficulty, given the scarcity of space and competing demands for land use. At the same time, concerns related to road safety and the protection of workers' rights are becoming increasingly prominent. These issues underline the need for holistic planning approaches that not only facilitate the operational efficiency of cargo-bike logistics but also ensure its social sustainability.

In response to these challenges, micro-hubs have emerged as a promising solution. Micro-hubs serve as small-scale, flexible logistics facilities within urban areas, bridging the gap between large distribution centers on city outskirts and the final delivery to customers. Acting as intermediate consolidation points, micro-hubs allow goods to be transferred from larger trucks to smaller vehicles or cargo bikes, supporting shorter delivery routes, the use of low-emission transport modes, and improved service quality for end consumers. By bridging the gap between urban freight demand and operational constraints, micro-hubs provide a practical and scalable approach to managing the growing complexity of last-mile logistics in cities.

Micro-hubs may have various functions such as:

- Deport for Delivery Vehicles; Micro-hubs act as decentralized depots where goods are temporarily stored before being dispatched to their final destinations. This allows logistics operators to maintain shorter delivery routes and reduce congestion in urban centers.
- Transshipment from Trucks to Light Vehicles; Large trucks or vans often cannot efficiently access dense urban areas due to traffic restrictions or limited parking. Micro-hubs enable the transfer of goods from these larger vehicles to smaller delivery modes, such as light commercial vehicles (vans) or electric vehicles, optimizing last-mile operations.
- Cargo-Bike Operations; For highly congested or pedestrianized areas, micro-hubs can serve as bases for cargo-bike deliveries. Cargo bikes are more environmentally friendly, allow access to restricted zones, and reduce emissions while maintaining delivery speed.
- Pick-Up and Collection Points; Some micro-hubs also function as pick-up points for consumers or businesses, enabling e-commerce customers to collect parcels directly. This reduces the number of failed deliveries and further decreases vehicle kilometers traveled in city centers.

By integrating these functions, micro-hubs contribute to more sustainable, efficient, and flexible urban logistics, supporting both operators and city authorities in managing growing e-commerce demand.

Despite their potential, the effectiveness of micro-hubs depends critically on their location. Poorly placed hubs can exacerbate traffic issues and reduce operational efficiency. Placing logistics hubs in residential areas can also create conflicts due to noise, traffic, or safety concerns. In addition, urban land is scarce and expensive, particularly in central areas, and micro-hubs require sufficient space for vehicle parking, loading and unloading, and storage. This makes it challenging to secure suitable sites close to end consumers. Effective micro-hub locations must also maintain good connectivity to main roads, motorways, and other transport infrastructure, yet traditional zoning does not always prioritize such accessibility for commercial zones that host logistics hubs.

These challenges underscore the need for systematic, data-driven approaches to identify locations that balance accessibility, operational efficiency, and urban planning constraints. This has created a growing need for systematic, data-driven approaches that help cities identify optimal micro-hub locations, balancing accessibility, proximity to demand, and integration with the urban road network.

2. State-of-the-art: examples of micro-hubs in major European Cities

2.1. Examples of micro-hubs in major European Cities

The integration of micro-hubs into urban logistics systems has gained momentum across Europe, reflecting a strategic response to the challenges posed by urbanization, e-commerce growth, and the need for sustainable transportation solutions.

In the framework of the LEAD project (from European Union's Horizon 2020 research and innovation programme under grant agreement No 861598), Madrid's Municipal Transport Company (EMT), in collaboration with CITYlogin, a local logistics service provider, has established a logistics micro-hub beneath Plaza Mayor, a central location in the Spanish capital. This initiative is part of the city's broader 360 Environmental Sustainability Strategy, aiming to reduce emissions and optimize urban freight operations. The micro-hub serves as a consolidation point where goods are transferred from larger vehicles to smaller, electric-powered delivery modes, facilitating efficient last-mile distribution (Ribeiro, 2021). The facility operates a fleet of 100% electric motorcycles, specifically adapted for urban distribution, which are charged within the parking facility itself. This setup allows for the sustainable delivery of goods to various destinations, including homes, supermarkets, and neighborhood stores. Since its inception, the micro-hub has demonstrated significant improvements in delivery efficiency. There has been a 33% reduction in the distance travelled for deliveries, contributing to lower emissions and less congestion in the city centre. Additionally, the initiative has led to job creation, with 12 new positions filled to manage the operations of the micro-hub (Ribeiro, 2022). This project exemplifies the potential of integrating urban logistics solutions within existing infrastructure to promote sustainable and efficient last-mile delivery systems.

Oslo has implemented a network of micro-hubs as part of the MOVE21 project (funding from the European union's Horizon 2020 research and innovation programme under grant agreement N 953939), aimed at transforming urban logistics into a more sustainable, low-emission system. These micro-hubs are strategically located within the city to facilitate efficient last-mile deliveries while reducing reliance on private vehicles and minimizing traffic congestion. Key sites include the Filipstad and Ski station areas, which were selected to integrate seamlessly with existing transport infrastructure, providing easy access for cargo bikes, electric vans, and other sustainable delivery modes (MOVE21, 2021). The Oslo micro-hubs operate as consolidation points where goods from larger freight vehicles are transferred to smaller, zero-emission vehicles for distribution within the city centre. This approach allows logistics providers to optimize routes, reduce vehicle kilometers, and limit emissions in densely populated areas. A distinctive feature of Oslo's strategy is the emphasis on co-delivery models and data sharing among stakeholders, which improves operational efficiency and enhances service quality for consumers while promoting environmentally friendly practices. Moreover, these micro-hubs are designed to integrate with the city's broader mobility framework, including public transport and micro-mobility solutions, creating a multimodal logistics ecosystem. The Oslo pilot demonstrates the potential of micro-hubs to provide flexible, adaptive solutions that balance operational efficiency, environmental sustainability, and social acceptability.

In Paris, Amazon has partnered with RATP (Régie Autonome des Transports Parisiens) to utilize bus depots as micro-logistics hubs, effectively transforming these facilities into cycle logistics centres during off-peak hours. This collaboration leverages the underutilized space in bus depots during the day to facilitate the transfer of goods from larger vehicles to smaller, zero-emission delivery modes such as cargo bikes, thereby promoting sustainable urban logistics solutions (Amazon, 2021). The integration of these micro-hubs aligns with Amazon's broader strategy to decarbonize its delivery operations. As of November 2021, two-thirds of Amazon deliveries in Paris were achieved using zero-emission last-mile transportation, including e-vans, bikes, and foot deliveries from micro-hubs in the city EU About Amazon. The strategic use of bus depots as micro-hubs not only optimizes the existing infrastructure but also contributes to the development of a more sustainable and efficient urban logistics network in Paris (Sustainability

Magazine, 2021). Compared to Madrid's Plaza Mayor micro-hub, which focuses on electric motorcycles within a single central facility, and Oslo's networked micro-hubs emphasizing integration with public transport and co-delivery models, the Paris approach highlights how existing urban infrastructure can be creatively repurposed to enable zero-emission urban logistics without requiring new constructions. Use of bus depots can also provide additional financial support to public transport operators that often require government subsidies.

The following table summarises the 3 cities' micro-hub approaches which create excellent examples to other European cities and logistics service providers:

Table 1. Comparison of Micro-hubs in Madrid, Oslo and Paris

	Madrid	Oslo	Paris
Location	Beneath Plaza Mayor, central urban area	Near Filipstad and Ski station, close to main roads and public transpor 1	Bus depots across the city, repurposed during off-peak hours
Functionality	Logistics deport, charging for logistics vehicles, workers 'resting areas and office	Logistics deport, Charging stations for all types of vehicles, parcel lockers	Logistics deport only
Logistics service	B2B and B2C using eelectric motorcycles	B2C using cargo-bikes	B2C using cargo-bikes and foot-delivery
Key innovation feature	Using underused parking slots	Integrated with public transport and shared mobility services	Efficient use existing urban transport infrastructure
Main social benefits	Meeting demand for freight transport in low emission zones	Serving as a community centre and mobility hubs for local residents	Repurposing existing transport infrastructure
Project funding	Initiated by public authorities with EU funded project, LEAD	Initiated by public authorities with EU funded project, MOVE21	Initiated by private company in cooperation with public transport operator

2.2. Lessons learnt from the current practices

These case studies collectively indicate that the successful implementation of urban micro-hubs in other cities may rely on several interrelated strategies. First, the adaptive reuse of existing infrastructure, including underutilized parking facilities, public buildings, or transport depots, can minimize investment costs while limiting disruptions within residential areas. Second, the incorporation of multifunctional designs, which integrate complementary urban services alongside logistics operations, can enhance social acceptance, improve operational efficiency, and optimize urban land use. Third, temporal flexibility—through time-sharing of infrastructure with other urban functions—enables more efficient utilization of scarce urban space without generating conflicts between competing uses. Furthermore, the integration of micro-hubs with sustainable mobility networks, prioritizing accessibility via walking, cycling, and low-emission vehicles, supports reductions in private car dependence and advances broader urban sustainability objectives. Finally, the adoption of flexible, evidence-based policy and regulatory frameworks allows cities to evaluate micro-hub performance and make iterative adjustments. By combining these approaches, cities can design context-specific micro-hub strategies that promote sustainable urban logistics, mitigate environmental impacts, and enhance overall urban quality of life. Future research should aim to assess the scalability of these models and systematically evaluate their economic, environmental, and social outcomes across diverse urban contexts.

2.3. Policy recommendations

Several European initiatives have recently provided recommendations on the establishment and operation of micro-hubs for urban logistics. Within the MOVE21 project, emphasis is placed on the need for co-creation with local stakeholders, including municipal authorities, logistics operators, SMEs, knowledge institutes, and citizens, in order to ensure that hub design reflects local needs and spatial conditions. A structured governance framework, such as Innovation Co-creation Partnerships and Task Force groups, is recommended to support planning continuity and stakeholder engagement. Furthermore, MOVE21 highlights the importance of distinguishing between hub typologies depending on their location in dense urban centres or less connected suburban areas, since spatial context determines both the functional scope and the degree of multimodality required. Micro-hubs are advised to be modular and multifunctional, combining last-mile logistics functions with shared mobility services and, where appropriate, additional socio-community activities. Their success also relies on careful location choice, particularly proximity to public transport nodes, residential and commercial areas, and main transport arteries (MOVE21, 2021).

The LEAD project complements this perspective by stressing the role of digitalisation, especially the use of Digital Twin models to simulate and predict the performance of micro-hubs in terms of vehicle use, routing efficiency, and emissions. Such tools are considered crucial for evidence-based decision-making. LEAD also underlines the importance of interdisciplinary collaboration and structured data sharing among stakeholders, as well as the need for capacity building within local administrations to manage the technical and operational complexities involved in micro-hub deployment (LEAD, 2022).

Current urban planning frameworks typically classify logistics activities as industrial, restricting the establishment of micro-hubs in residential areas. While micro-hubs may generate negative externalities, such as increased noise and traffic, evidence from cities in the Netherlands and France indicates that outright bans on urban “dark stores” can hinder sustainable last-mile delivery solutions. The growth of e-commerce, remote working, and reduced car ownership has created opportunities to repurpose underutilized urban spaces, such as multistorey or underground car parks, as micro-hubs. Strategic deployment of micro-hubs near residential areas and city centers can support cargo-bike operations, enhancing urban logistics efficiency while mitigating environmental and traffic impacts.

To facilitate this, four main actions are proposed by the Expert Group on Urban Mobility (EGUM 2025). First, local authorities should adopt Key Performance Indicators (KPIs) to evaluate micro-hub suitability, including noise, air pollution, traffic impact, and employment generation, with periodic assessments guiding permission renewal. Second, national ministries should review land-use legislation to remove barriers for micro-hub implementation and collaborate with supranational bodies, such as the European Commission, to standardize KPIs, evaluation frameworks, and capacity-building initiatives. Third, public and private stakeholders should develop digital tools to inventory and assess urban assets suitable for micro-hubs, enabling rapid identification and optimization of available infrastructure. Fourth, micro-hubs and parcel lockers should be located within a 15-minute walking distance for residents and integrated into safe, accessible locations, such as grocery stores, to encourage active transportation, reduce reliance on private vehicles, and promote community engagement and public health. The EGUM concludes that enabling micro-hubs in residential areas through KPI-based evaluation, national harmonization, digital asset management, and strategic placement can facilitate sustainable urban logistics, support cargo-bike deployment, and enhance urban quality of life without imposing significant negative externalities.

3. Data-Driven Approach to micro-hub planning

3.1. Data-Driven Approach for Micro-hub planning

This study employs a data-driven framework to optimize the planning and deployment of urban logistics hubs, aiming to enhance operational efficiency, reduce environmental impacts, and improve accessibility for last-mile delivery. The methodology integrates heterogeneous data sources, including spatial information on warehouses, pickup points, and loading zones, combined with real-time urban data such as traffic flows, vehicle telemetry, and mobility patterns. These datasets provide a comprehensive representation of urban logistics dynamics, forming the foundation for evidence-based decision-making.

Geospatial analysis using Geographic Information Systems (GIS) is applied to evaluate the suitability of potential hub locations, incorporating variables such as population density, land-use types, accessibility, and existing transport infrastructure. Multi-criteria decision analysis (MCDA) techniques are employed to balance operational efficiency, environmental sustainability, and social acceptability in selecting optimal hub sites.

Predictive modeling, including machine learning algorithms, is utilized to forecast delivery demand, traffic congestion, and temporal variations in logistics activity, enabling proactive planning of hub capacities and delivery schedules. Optimization algorithms, such as vehicle routing problem (VRP) solvers and network flow models, are applied to determine efficient last-mile delivery routes while minimizing travel distances, emissions, and operational costs. Scenario analysis further allows assessment of alternative deployment strategies under varying conditions, including low-emission zones, population growth, and infrastructure availability.

Finally, the framework incorporates continuous monitoring and feedback mechanisms through real-time data streams, allowing dynamic adjustment of hub operations and delivery planning in response to evolving urban conditions. This data-centric and computationally rigorous methodology provides a scalable and adaptable tool for urban logistics planning, supporting sustainable last-mile delivery and efficient utilization of urban space while aligning with environmental and societal objectives.

3.2. Operational Characteristics of micro-hubs

Based on operational characteristics and service scope, two types of urban micro-hubs are considered:

- Type A Micro-Hubs are dedicated facilities serving logistics service providers exclusively. These hubs primarily receive deliveries via heavy trucks, which are subsequently redistributed using smaller vehicles, predominantly cargo-bikes, for last-mile delivery. These hubs are being accessed by logistics service providers only
- Type B Micro-Hubs accommodate a broader range of delivery modalities, receiving goods via trucks or light commercial vehicles. These hubs not only facilitate last-mile delivery through cargo-bikes but also integrate additional services such as customer pick-up points, parcel lockers, and the management of return flows (reverse logistics). Those hubs are being accessed by logistics service providers and end users (consumers).

The operational characteristics of Type A and Type B micro-hubs imply distinct considerations for location selection. Type A micro-hubs, serving only logistics service providers, prioritize direct accessibility for trucks and efficient transfer to cargo-bike fleets for last-mile delivery. In contrast, Type B micro-hubs, which combine cargo-bike deliveries with customer-facing services such as pick-up points, parcel lockers, and returns management, require locations that balance truck accessibility with proximity to high-demand areas for both delivery and customer interactions. Despite these differences, both hub types must remain within a feasible cargo-bike operational radius to ensure efficiency in last-mile distribution. Consequently, while the optimal siting criteria differ—operational efficiency and network consolidation for Type A versus mixed accessibility and customer reach for Type B—the overarching requirement is truck access coupled with cargo-bike service coverage. This dual requirement underscores the complementary nature of the two hub types within an integrated urban logistics network.

3.3. Location selection KPIs

The strategic placement of urban micro-hubs is a critical factor in the efficiency of last-mile logistics. Optimal locations minimize travel distances for cargo-bike deliveries, ensure seamless accessibility for trucks or light commercial vehicles, and, for customer-facing hubs, maximize convenience for end-users. Effective site selection balances operational efficiency, cost considerations, and service quality, while accounting for urban density, traffic conditions, and spatial constraints. Given the differing operational profiles of micro-hub types, location selection criteria must be tailored to each type's specific objectives and functional requirements. In general, Type B micro-hubs, which integrate customer pick-up, parcel lockers, and returns, are preferably located in denser urban areas to maximize accessibility for end-users, whereas Type A micro-hubs, focused solely on logistics provider operations, may be positioned based primarily on truck accessibility and cargo-bike coverage.The location selection factors for the two types of micro-hubs are shown in the following tables:

Table 1. Comparison of Micro-hubs in Madrid, Oslo and Paris

	Type A	Type B
Vehicle Accessibility	Truck access; proximity to major freight corridors; availability of loading/unloading zones	Truck or Light Vehicle Accessibility
Availability of loading/unloading zones	✓	✓
Cargo-Bike Service Coverage	≤10 km	≤5 km
Distance to warehouses	✓	✓
Customer Accessibility	✗	✓

4. Case Study: Braga, Portugal

4.1. Overview of Braga and main challenges in urban logistics

Braga, located in the northwest region of Portugal (Minho), is one of the country's major urban centers with a population of approximately 200,000 inhabitants. The city is historically significant, often referred to as the "Portuguese Rome" due to its concentration of religious and cultural heritage sites. Economically, Braga exhibits a diversified profile, with notable strengths in commerce, services, and technology sectors. Its urban structure combines a dense historical center with expanding peripheral residential and commercial areas.

Braga's urban logistics system faces significant constraints arising from the city's historical and spatial characteristics. The narrow streets and high pedestrian density in the historic centre severely limit access for conventional delivery vehicles, resulting in operational delays, increased costs, and higher emissions. Compounding this issue, designated loading and unloading areas are scarce, often forcing logistics operators to resort to temporary or unauthorized parking, which further contributes to congestion and disrupts traffic flow. Moreover, the integration of sustainable delivery modes, such as cargo-bikes and electric vehicles, is hindered by insufficient infrastructure and the need to adapt existing operations to accommodate these alternatives, limiting the potential for greener and more efficient last-mile logistics.

In the context of Braga, the deployment of urban micro-hubs must account for both the city's historical urban fabric and contemporary logistical demands. Type A micro-hubs, which serve logistics service providers exclusively, are primarily designed to receive truck deliveries and redistribute goods via cargo-bikes for last-mile delivery. In Braga, such hubs would be best located in areas that provide straightforward truck access while remaining within the operational range of cargo-bike networks, thereby optimizing efficiency without contributing to congestion in the city center. In contrast, Type B micro-hubs, which combine cargo-bike deliveries with customer-facing functions such as parcel lockers, pick-up points, and reverse logistics, require siting in denser urban areas where customer demand is concentrated. The historic centre and surrounding high-density neighborhoods are particularly suitable for Type B hubs, as proximity to end-users enhances the effectiveness of last-mile operations and facilitates convenient access for parcel collection and returns. Consequently, Braga exemplifies the complementary nature of the two micro-hub types: Type A hubs prioritize operational efficiency and truck accessibility, short-distance from to main motorways, while Type B hubs focus on urban density and consumer accessibility, together enabling a more sustainable and effective urban logistics network.

4.2. Overview of Braga traffic in historical city centre and challenges in urban logistics

The following map shows the congestion level in the Braga city centre. 4 main roads in the historical city centre area have been selected to show the congestion level. Congestion index (shown below), Average Speed (AS) of Light Commercial Vehicles, and Trucks have been presented in the following table. The congestion index is calculated as:

$$CI=(V_f - \overline{v})/\ V_f \qquad (1)$$

Variables:

- CI is the Congestion Index (%)
- V_f is the free flow speed
- $\overline{v}$ is the average speed of all types of vehicles

The map is from the Insight Traffic Data map, provided by Urban Radar using commercial floating vehicle data with more than 10% of sample size indicating confidence of using the data for analysis of congestion and average speed (Li, 2004). The data has been covered the period of 1 June 2025 to 31 August 2025.

	CI	AS of LCVs	AS of Trucks
Avenue Central	0.59	16km/h	9km/h
Rua do Raio	0.57	12km/h	12km/h
Avenida da Liberdade	0.58	9km/h	10km/h
Rua 25 de Abri	0.48	14km/h	11km/h

Fig. 1. Congestion map and speed of freight vehicles

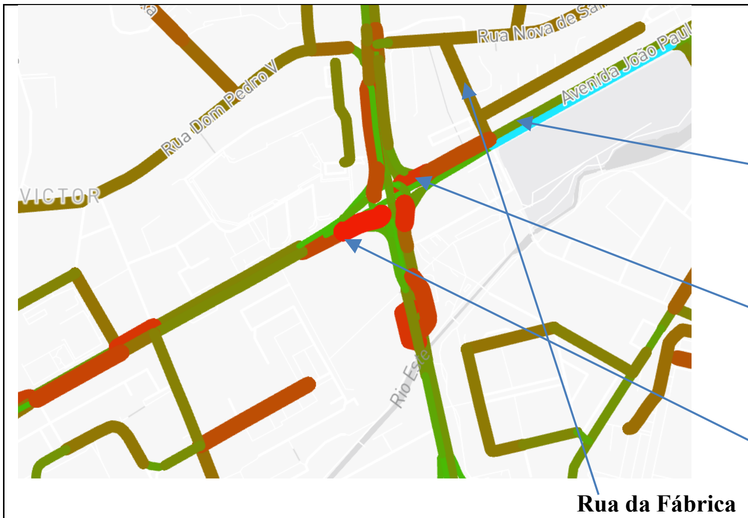
Urban freight operations in Braga are severely affected by widespread congestion, particularly in the historic center and dense residential areas. Traffic conditions limit the average speed of light commercial vehicles to approximately 12 km/h, while trucks are further constrained to an average of 10 km/h. Such low travel speeds significantly increase delivery times and operational costs for freight operators, reducing overall efficiency and raising emissions per delivery. These conditions underscore the challenges of conventional last-mile logistics in Braga and highlight the potential value of alternative delivery solutions, such as micro-hubs combined with cargo-bike distribution, which can circumvent congestion and improve service reliability.

4.3. Understand the traffic flow entering the Braga city centre and identifying locations for Type A micro-hubs

Given the pervasive congestion and low travel speeds for trucks and light commercial vehicles in Braga, there is a strong need for the deployment of urban micro-hubs and the use of smaller, more agile vehicles such as cargo bikes.

Micro-hubs can serve as intermediate consolidation points, enabling bulk deliveries to be transferred from trucks to cargo bikes, which are better suited to navigate narrow streets and high-density areas. This approach not only reduces travel times and operational costs for freight operators but also mitigates traffic congestion and environmental impacts, supporting more sustainable and efficient last-mile logistics in the city.

Freight vehicles traveling to Braga can maintain average speeds of approximately 60 km/h on motorways, reflecting efficient regional access. However, upon entering the urban area, speeds sharply decrease to around 10–12 km/h due to congestion, narrow streets, and high pedestrian density. This dramatic reduction in travel speed not only increases operational costs and delivery times but also underscores the need for strategically located micro-hubs near key city junctions. By transferring goods from trucks to smaller, more maneuverable vehicles such as cargo bikes at these nodes, last-mile deliveries can bypass the most congested areas, improving efficiency and reducing environmental impacts.



	CI	AS of LCVs	AS of Trucks
Avenida João Paulo II (N103)	0.32	58km/h	46km/h
Avenida João Paulo II (N103) close to Brage	0.54	24km/h	20km/h
Avenida João Paulo II inside the ring	0.69	9km/h	7km/h

Fig. 2. Congestion from N103 to Braga

The junction of Avenida João Paulo II (N103) and Rua da Fábrica is located approximately 6 km from Braga's historic city center, which lies well within the operational range of cargo bikes for last-mile deliveries. This proximity makes the area a highly suitable candidate for a micro-hub, enabling the transfer of goods from trucks to cargo bikes before entering the most congested parts of the city. The site is situated in a predominantly commercial and institutional zone, with no nearby dense residential areas, which minimizes concerns related to noise and local emissions from freight operations. Its strategic value is further reinforced by the presence of a university campus and a retail park, providing access to concentrated commercial and institutional delivery demand. Within this area, specific micro-hub locations for Type A can be identified to optimize delivery efficiency, reduce traffic congestion in the historic center, and support sustainable last-mile logistics without impacting residential quality of life.

A similar opportunity for micro-hub deployment exists along the northern approach to Braga from the N14. Freight vehicles can travel at average speeds of approximately 47 km/h on the regional road, but upon entering the urban area, speeds sharply decline to around 16 km/h due to congestion and the constraints of the city's street network. This significant reduction in travel speed highlights the inefficiency and high operational costs of direct truck deliveries into the city center. Establishing a Type A micro-hub near this access point would allow goods to be offloaded from trucks and transferred to cargo bikes for last-mile delivery, bypassing the most congested streets. The surrounding area is predominantly commercial and institutional, with no residential zones, which reduces concerns regarding noise and emissions while maintaining operational efficiency. Such a location would complement other strategically positioned micro-hubs, collectively improving delivery performance and reducing urban congestion in Braga's historic center.

4.4. Understanding traffic flow within the city centre and identifying locations for Type B micro-hubs

While most roads in Braga's city center experience significant congestion, certain areas—particularly those in close proximity to residential buildings, historical sites, shops, and restaurants—tend to be less congested. These lower-congestion zones present potential opportunities for the placement of micro-hubs or localized delivery points, as they allow cargo bikes or smaller delivery vehicles to operate more efficiently while minimizing disruption to urban traffic flow. Mapping these areas can provide valuable insights for optimizing micro-hub location selection and last-mile logistics strategies, ensuring that deliveries are routed through streets with manageable traffic conditions while preserving accessibility to key destinations.

	CI	AS of LCVs	AS of Trucks
Avenue Central	0.59	16km/h	9km/h
Rua Professor Machado Vilela	0.26	25km/h	19km/h
Rua do Fujacal	0.3	24km/h	22km/h

Fig. 3. Traffic congestion map in Braga city centre

Two locations have been identified within Braga's residential areas that offer promising conditions for micro-hub deployment. Light commercial vehicles in these areas maintain an average speed of approximately 25 km/h, and both sites are situated only 1.5 km from the historic city center, well within the operational range of cargo bikes for last-mile deliveries. These characteristics make the locations ideal for Type B micro-hubs, which combine business-to-business (B2B) deliveries with customer-facing services. Cargo bikes can efficiently deliver goods to nearby shops, hotels, and other commercial establishments, while the proximity to residential areas allows the hubs to serve as convenient parcel locker points for local residents. The relatively lower congestion in these streets, compared to the main urban thoroughfares, further enhances delivery efficiency and operational reliability, while ensuring minimal disruption to surrounding traffic. By strategically locating micro-hubs in such residential zones, it is possible to optimize both commercial and residential last-mile logistics, supporting sustainable and flexible urban delivery systems in Braga.

4.5. Next Steps for Micro-Hub Implementation in Braga

Following the identification of potential micro-hub locations in Braga, the next phase of this study will focus on a comprehensive analysis of these sites using not only traffic maps but also urban logistics data. The traffic maps will be employed to evaluate accessibility for trucks and light commercial vehicles, as well as the operational feasibility of cargo-bike deliveries. This spatial analysis will allow for the prioritization of locations that optimize travel efficiency while minimizing disruptions to urban traffic and pedestrian flows. Special attention will be given to streets designated for cargo-bike operations to ensure safe and efficient last-mile deliveries. The analysis will consider existing bike lanes, traffic calming measures, pedestrian flows, and road conditions to identify routes that minimize conflict with motorized traffic while maximizing operational efficiency. Where necessary, recommendations for infrastructure improvements, such as dedicated loading areas, signage, or temporary delivery zones, will be proposed to enhance safety for both cargo-bike operators and other road users. By prioritizing safe cycling routes, the study aims to support the effective integration of cargo-bike deliveries into Braga’s urban logistics network while reducing the risk of accidents and ensuring smooth traffic flow.

In parallel, a structured stakeholder consultation process will be initiated to ensure that the planning and deployment of micro-hubs align with the needs and expectations of all relevant parties. This will include engagement with municipal authorities, local businesses, logistics service providers, and community organizations. Citizen participation will also be sought to capture the perspectives of residents and end-users, particularly regarding parcel locker locations and potential impacts on urban spaces. Workshops, surveys, and participatory mapping exercises will be used to collect input on preferred locations, operational hours, and acceptable levels of noise or emissions, ensuring that the resulting solutions are socially and operationally sustainable.

Another critical component of the next steps involves the identification and mapping of underutilized urban buildings, vacant lots, and other available public or semi-public spaces that could be repurposed as micro-hub sites. By analyzing factors such as accessibility, size, and proximity to both major transport routes and delivery demand centers, the study aims to develop a shortlist of viable sites that can support Type A and Type B micro-hub operations. Considerations will also include the structural suitability of existing buildings for logistics purposes, the potential for modular construction, and the integration of cargo-bike storage and handling areas.

5. Conclusions

The growing demand for urban e-commerce has placed unprecedented pressure on cities to deliver goods efficiently while mitigating congestion, emissions, and other negative impacts of urban freight. Micro-hubs have emerged as a critical solution, enabling the consolidation and redistribution of goods within urban areas, and facilitating the use of smaller, more agile delivery modes such as cargo bikes. Experiences in European cities such as Madrid, Oslo, and Paris demonstrate the effectiveness of micro-hub systems in optimizing delivery operations, reducing reliance on conventional delivery trucks in city centers, and contributing to environmental sustainability. These examples highlight that the success of micro-hub deployment is closely linked to strategic site selection, which must balance accessibility for freight operators with proximity to areas of high delivery demand.

This study presents a data-driven framework for identifying potential micro-hub locations in urban areas, using traffic data and congestion patterns as the primary indicators for site selection. By analyzing areas where vehicle speeds sharply decline, the framework pinpoints strategic nodes where transferring goods from trucks or light commercial vehicles to cargo bikes would maximize delivery efficiency and minimize travel through highly congested streets. The approach provides city planners and logistics stakeholders with a replicable, evidence-based method to balance operational performance with urban sustainability objectives.

Braga, Portugal, serves as a pilot case study to demonstrate the practical application of this framework. The city’s widespread congestion and low travel speeds for trucks and light commercial vehicles, particularly in the historic center, highlight the inefficiency of traditional last-mile delivery methods and the need for localized micro-hubs.

Within this context, potential micro-hub sites have been categorized into two complementary types. Type A micro-hubs primarily serve logistics service providers, acting as consolidation points near major road junctions or city access routes. Trucks deliver bulk shipments to these hubs, from which cargo bikes complete last-mile deliveries into congested urban areas. These hubs are particularly suitable for commercial or institutional zones with minimal residential presence, allowing continuous operations without significant noise or emissions. Type B micro-hubs, in contrast, combine cargo-bike deliveries with customer-facing services, including parcel lockers, pick-up points, and returns. Typically located in dense residential or commercial zones, Type B hubs enable both B2B and B2C deliveries, efficiently serving local shops, hotels, and residents while providing accessible points for parcel collection.

The application of the framework in Braga demonstrates how traffic-based data can guide the strategic placement of both hub types. Locations near major junctions are ideal for Type A hubs, intercepting deliveries before trucks enter the historic center. Residential areas approximately 1.5 km from the city center provide optimal sites for Type B hubs, allowing cargo bikes to serve nearby commercial establishments and local residents efficiently. By combining data-driven analysis, safe cycling routes, and the strategic reuse of underutilized urban spaces, the framework enables Braga to enhance the sustainability, reliability, and efficiency of its urban logistics system. Stakeholder engagement, citizen participation, and detailed mapping of potential sites ensure that micro-hub deployment is both operationally feasible and socially acceptable. Overall, the dual deployment of Type A and Type B hubs in Braga illustrates the framework's effectiveness, offering a practical and replicable approach for other mid-sized cities seeking to optimize last-mile logistics while reducing congestion and environmental impacts.

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