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Case Report

Defining Urban Freight Microhubs: A Case Study Analysis

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Abstract: Urban freight distribution has confronted several challenges, including negative environmental, social, and economic impacts. Many city logistics initiatives that use the concept of Urban Consolidation Centers (UCCs) have failed. The failure of many UCCs does not mean that the idea of additional terminals or microhubs should be rejected. There is limited knowledge about the advantages and disadvantages of using microhubs, requiring further exploration of this concept. To expand this knowledge, this research combines 17 empirical cases from Europe and North America to develop a framework for classifying different microhubs typologies. This research presents an integrated view of the cases and develops a common language for understanding microhub typologies and definitions. The research proposes microhubs as an important opportunity to improve urban freight sustainability and efficiency and one possible step to manage the challenge of multi-sector collaboration.

Keywords: microhubs; urban freight; city logistics; freight consolidation; last-mile logistics

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1. Introduction

The meteoric rise of urban deliveries in the lingering aftermath of COVID-19 elevates the importance of sustainable urban freight solutions. Despite the benefits that online shopping brings, increasing urban freight traffic has dramatic consequences for city, country, and company sustainability goals, including climate impact, air quality, road safety, livability, and congestion. Among several proposed last-mile delivery solutions are microhubs, which appear to reduce delivery emissions and congestion [1–3].

Microhubs, sometimes called 'micro-distribution' facilities or 'micro-depots,' are last-mile consolidation and distribution nodes located in or next to urban neighborhoods. Microhubs depart from the well-defined concept of Urban Consolidation Centers (UCC), which emerged as a popular logistics strategy for decreasing emissions and minimizing congestion in densely populated pedestrian, commercial, or historical zones [4], and improving the quality of life in urban areas and city centers [5]. UCCs, according to [4], are logistics facilities that are located within relatively close proximity to the geographic area that it serves, whether it is a city center, an entire town, or a specific location (e.g., shopping center), from which consolidated deliveries are made within the vicinity. A range of other value-added logistics and retail services can also be provided at the UCC. However, several research findings show many UCCs are not successful due to unsustainable long-term operational models [6], low profitability, high reliance on government subsidies [7], strict policy measures regarding UCCs [8], and dissatisfaction with service levels [8,9]. In response, some suggest microhubs are a transition away from classic UCCs. Learning from previous experiences, Janjevic and Ndiaye (2014) [10] define microhubs as "facilities that are located closer to the delivery area and have a more limited spatial range for delivery than classic UCCs".

According to [10], microhubs are transport provider-owned and led initiatives, located near the end receivers. By optimizing load distribution within a delivery zone, microhubs aim to reduce total vehicle trips in urban areas (ibid). The activities of microhubs include logistical setups and parcel handling in the city center (ibid). A microhub facilitates delivery through a variety of environmentally friendly modes, such as light-duty electric vehicles, electric cargo bicycles with pedal assistance or without, and/or by foot or handcarts (ibid).

Transport providers utilize microhubs for storage, transshipment, and last-mile distribution of goods for both business-to-business and home delivery [5,11–14]. Locating hubs closer to end-users enables the utilization of environmentally friendly transportation modes such as light electric freight vehicles (LEFVs) (e.g., electric cargo bicycles and small-sized electric vehicles) and pedestrian transportation, which have shorter travel ranges than conventional diesel and petrol delivery vehicles [14–17]. Microhubs may additionally alleviate traffic congestion by providing a facility for transport providers to optimize load distributions prior to entering denser market regions [18]. To this degree, the authors of [19] shows that consolidating freight both in the UCC or transport providers' respective terminals and the microhubs can reduce both predicted distance traveled and negative environmental impacts. Further, efficient terminal handling is the key to cost-effective city logistics and urban freight [20].

Research in the field is multidisciplinary and diverse. In addition to the challenges of business models, microhubs locations, and policy formulation, there is, of course, a need to consider modeling approaches as they might be relevant. However, there is still a need to synthesize broader microhubs definitions, enabling conditions, and impacts. This research suggests that one way to do so is through qualitative and empirical data. The chosen 17 microhub cases provide a more holistic overview of microhub typology and use the argument by [21] that, despite ample microhub examples around the world, a synthesis is lacking concerning broader microhub definitions, enabling conditions, and impacts.

To extend this knowledge, this paper aims to establish a framework and typology for implementing and scaling microhubs in the field of urban freight. Microhub typologies, their characteristics, and the project objectives that shape their implementation are discussed in terms of a shared language. We address two research questions to make this purpose more tangible. The ***first research question*** is: "*To what extent can we see a common or shared definition of microhubs?*". The ***second research question*** is: "*What are the different microhub typologies and their sustainability objectives that came out of the cases' review?*".

The paper's organization is as follows. First, the paper presents the materials and the methods for case selection and data analysis. The following section introduces the suggested framework. Then, the paper presents the sustainability objectives as observed during the analysis of the projects, which are related to the suggested framework. This is followed by a discussion of the findings. The final section contains the conclusion, implications, and recommendations for future research.

2. Materials and Methods

This study was designed to answer the research questions and to provide rich data from multiple sources, something that is lacking in the current literature. These multiple data sources helped capture the complexity of microhubs, the phenomenon under study, which is beneficial for sustainable urban freight activities. Hence, a case study was most suitable to answer the research questions. In particular, the method selected for this paper follows the guidelines by [22] on how to perform case studies.

This section describes the research process from the beginning of the study, where the phenomenon under study was defined, up to the consolidation of this paper. As Figure 1 shows, it starts with the research problem, purpose, and objectives and defines the methodological approach. Then comes the research design, data collection, and analysis. Finally, is the answer to the questions, framework, and sustainability objectives.

The research process (Figure 1) shows what sustains the logical part of this research; it is the visible structure that frames the search for knowledge from the research questions to the development of the research and choice of the method [22]. Overall, by defining the research process, the researchers consciously decide what will be observed and how so that the research purpose is fulfilled and research questions are answered [22]. The scientific area that is studied, together with the type of research questions, determines the research strategy and the appropriate methods. Considering the research's purpose and questions, it is natural to follow a descriptive path, prioritizing qualitative research methods. As [23] emphasizes, "Qualitative research tries to develop a complex picture of the problem or issue under study. This involves reporting multiple perspectives, identifying the many factors involved in a situation, and generally sketching the large picture that emerges".

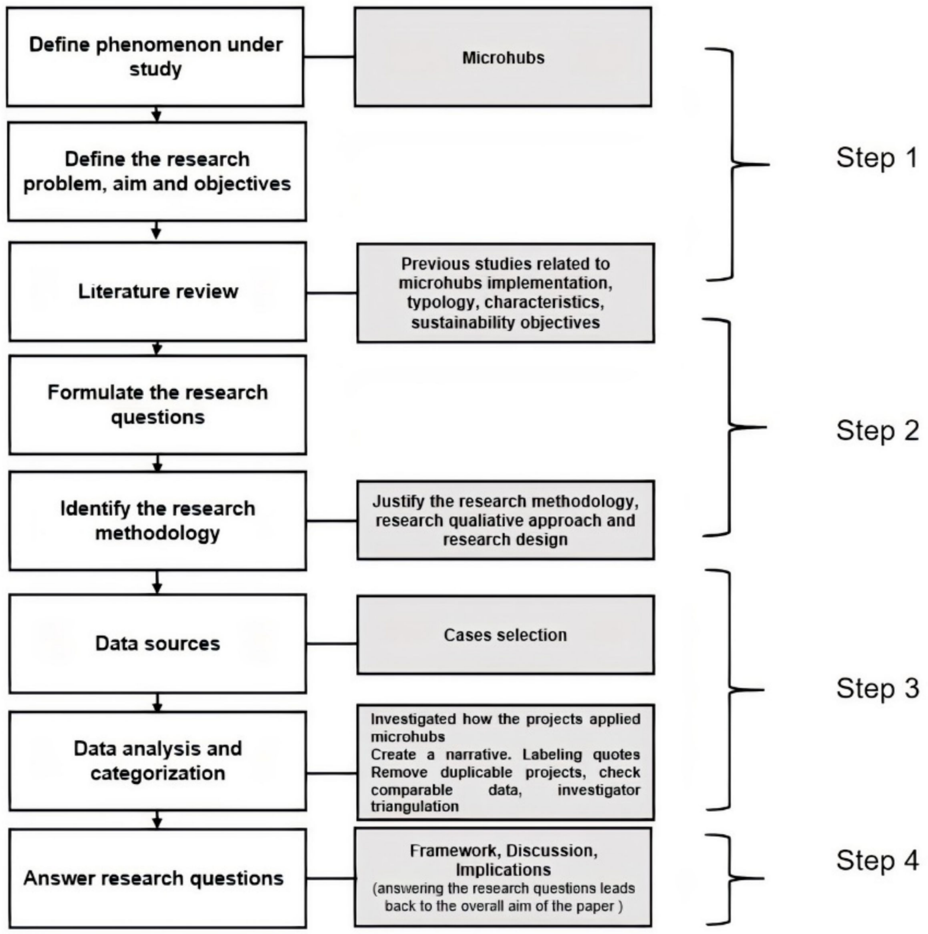

Figure 1. Research process.

2.1. Research Design

This research followed a case study research approach. The field of urban freight is well known for designing studies based on empirical cases. This provides rich data and information that better reflects reality and helps to capture the complexity of urban freight as a system. Case studies are context-dependent and relevant when the researcher aims to answer how and why questions lead to understanding a phenomenon under study [22]. Specifically, the research presented is context-dependent because it considers the natural contexts in which microhubs function to collect the data and provide an in-depth understanding of the phenomenon under study. Further, the research breaks down the research questions and focuses on two overarching objectives, the range of typologies and the sustainability objectives.

A case study approach uses theoretical sampling to do cross-case comparisons using a range of empirical evidence, resulting in trustworthy and reproducible results [23]. Cases are chosen with caution since they can foretell similar or opposing outcomes [22] and provide more extensive descriptions and explanations of the phenomenon under study [23].

On the other hand, a single-case study focuses on the uniqueness or representativeness of a specific example to speculate about the phenomenon.

2.2. Data Sources

The selection process targeted cases that implemented microhubs and provided a range of information. As this paper aims for a broader geographical and spatial coverage, the research includes cases from Scandinavia, Central Europe, and North America. The sample of relevant cases that was retrieved consisted of 17 projects. The cases are presented in Table 1. The cases explored microhubs in a similar way and pursued a similar research goal. In particular, the 17 projects were selected for the following reasons: (a) they were significant cases in urban freight at their respective geographical location in terms of their effort, scale, and rich data they provide; (b) they provided a better understanding of common practices and the dominant processes that guide city logistics initiatives; (c) they developed at least one solution to alleviate urban freight challenges; (d) they provided insights for similar projects that were attempting consolidation through different set-ups; and (e) they demonstrated diversity in scope, role, and approaches in microhub implementation and how they approached urban freight systems. According to [24], the sample is sufficient to elicit perceptions and draw general outcomes about the typology of microhubs.

Table 1. The selected projects.

Project Name	Location
Northwestern Europe	
TNT Express	Brussels, Belgium
Vert Chez Vous	Paris, France
Gnewt Cargo	London, UK
Beaugrenelle Logistic Hotel	Beaugrenelle, France
Chapelle Logistic Hotel	Chapelle, France
Proximity Logistics Spaces	Paris, Bordeaux, Rouen, France
Last Mile Logistics Hub	London, UK
Scandinavia	
Oslo City Hub	Oslo, Norway
Lindholmsleveransen	Gothenburg, Sweden
Nordstan Cargo Bike Hub	Gothenburg, Sweden
USA	
Seattle Neighborhood Delivery Hub Pilot	Seattle, Washington
Commercial Cargo Bike Program	New York City, New York
Ecofriendly Cargo Bike Delivery Project	Miami, Florida
UPS Urban Solutions E-bike	Portland, Oregon
B-Line (private business model)	Portland, Oregon
Canada	
Project Colibri	Montreal, Quebec
The Drop (private business model)	Toronto, Ontario

The data were collected in a natural setting (and not in a laboratory setting as in several experimental studies), and the authors were active in collecting and observing data collection, as [23] describes. Along the research process, rich data from multiple sources were gathered and analyzed to capture the complexity of microhubs implementations. These multiple data sources included workshops, reports, (online) events, conferences and journal papers, media observations, and articles in the business press. When further information was needed, the researchers contacted key personnel from several of the projects.

The research documents these multiple sources of data in Microsoft Excel spreadsheets, using the coding and classification guidelines established by [25], which provides assistance and guidance for the data collection and analysis. Different spreadsheets were created for a better categorization of the cases according to their geographical position, i.e., European and North American. The information in Microsoft Excel consists of 5 spreadsheets and 18 categories. In particular, the spreadsheets include:

1. Project name;
2. Location;
3. Implementation type;
4. A detailed list of the involved stakeholders, including the organization and number of participants from each organization involved in the projects;
5. Operational, transport provider configuration and project type;
6. Public support;
7. Business and/or ownership model;
8. Last-mile fleet composition;
9. Value-added services;
10. Catchment area, location, and distance from market served;
11. Size and infrastructure;
12. Integrated mobility and access;
13. Environmental impacts;
14. Socio-economic impacts;
15. Financial and efficiency impacts;
16. Other forms of documentation, such as pictures and illustrations;
17. References to bibliographical information and relevant documents, such as journal publications, conference publications, reports, best practices reports (e.g., BESTUFS and OECD) on the projects;
18. Links to webpages.

A separate spreadsheet covering the glossary and definitions of all the terminology mentioned in the literature was also created.

2.3. Data Analysis and Categorization

The paper analyzed the data in two steps. In the first step, the researchers investigated how the projects were designed, implemented, and perceived. To do so, the researchers thoroughly examined the literature and the multiple sources (see Section 2.1) connected with the projects. Each source that mentioned microhubs was marked and summarized. This process captured the overarching views of microhubs in the projects. In the second step, the researchers first created a coherent narrative with important quotes from the projects. The researchers further analyzed this narrative to determine the different types of microhubs and microhub characteristics; hence, specific labeling was created. The researchers added the labeling and quotes to the spreadsheets. The outcomes were then compared with each other in order to evaluate how each of the projects defined and implemented the microhubs. Due to confidentiality issues, internal documents, images of the microhubs, as well as notes cannot be displayed publicly here.

Finally, the researchers removed duplicate projects and grouped comparable data. In this study, investigator triangulation was used to ensure that the authors' personal beliefs did not influence the interpretation and evaluation of the data, which is consistent with [26] findings. Investigator triangulation was also a method of cross-checking data among the researchers involved in order to determine what was relevant and important and develop conclusions. In addition, when clarification was needed, feedback from the key project personnel was requested to ensure that the authors accurately depicted their points of view.

3. Framework

We propose a framework to define microhub typologies and their sustainability objectives found in the selected projects. This study contends that a systems approach to the content analysis of the cases allows one to address key project components and their interrelations and allows one to capture microhub diversity and complexity. The core of the framework consists of the five distinct and sequenced components; (1) microhub definition, (2) operational typologies, (3) the key and value-added activities, (4) infrastructure and location, (5) partnerships, (6) public support, and (7) last-mile fleet composition, as seen in Figure 2. Finally, the selected projects provide a holistic overview of the system and its environment. The framework further outlines both back-end and front-end perspectives. The front-end includes microhub definition, typologies, and characteristics. The back-end includes the sustainability objectives, which are often case-contextual and can shape microhub characteristics and implementation processes. In the following subsections, we describe the framework components with examples from the selected projects.

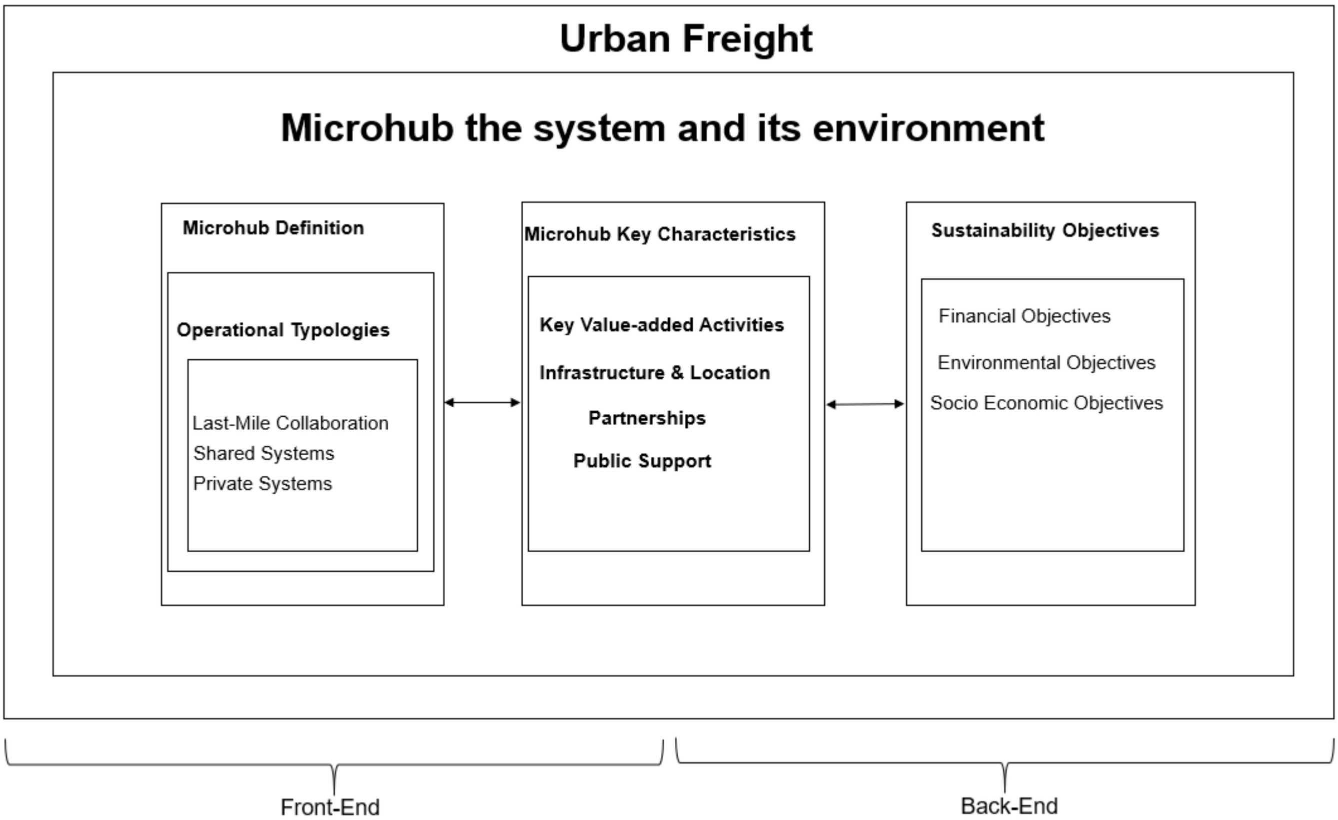

Figure 2. Overall framework.

3.1. Microhub Definition

Based on the analysis, the paper defines microhubs as logistics facilities where commercial transport providers (or 'carriers') consolidate goods near the final delivery point and serve a limited spatial delivery area in a dense urban setting. Microhubs also allow for a mode shift to sustainable electric and non-motorized transportation modes such as electric cargo bikes or handcarts. As stated in the introduction, this paper distinguishes microhubs from UCCs as having shorter distances to the end-customer and a smaller facility footprint appropriate to the spatial constraints in dense urban environments. For package deliveries, the last mile starts from the microhub, with transport providers completing the delivery. This paper, therefore, distinguishes microhubs from collection and delivery points (CDPs), such as parcel lockers, where 'receivers' (e.g., retailers and consumers) complete the last leg of delivery themselves. However, microhubs can provide the option for receiver pickup either by installing an automated parcel locker on-site or employing attendants for in-person pickup. Figure 3 describes the spectrum of consolidation practices in urban deliveries.

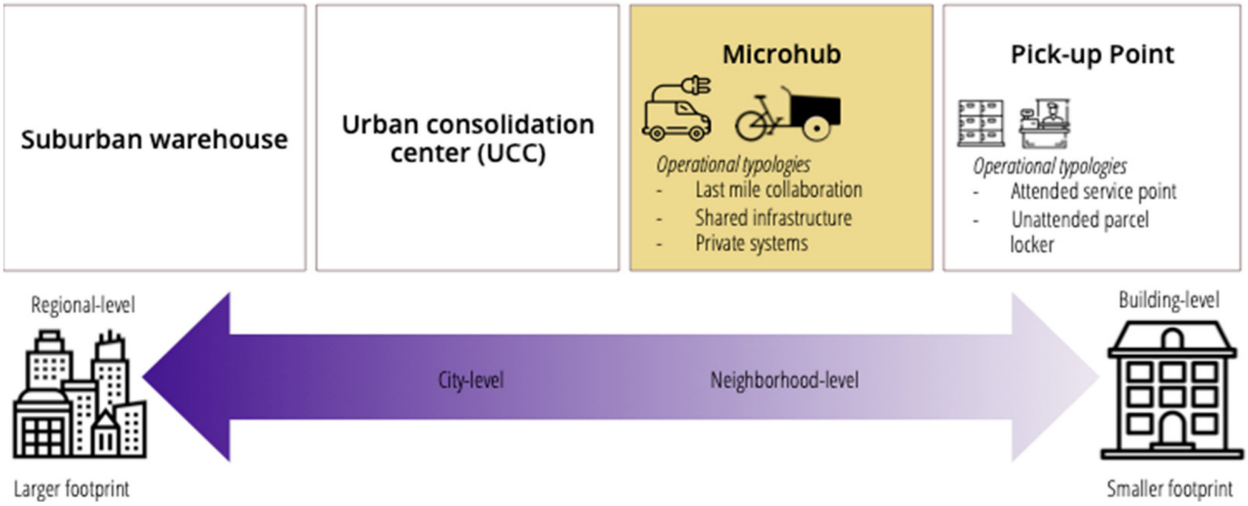

Figure 3. Consolidation practices in urban deliveries.

3.2. Operational Typologies

Most efforts to classify operational typologies pertain to UCCs. Egger and Ruesch (2002) [27] distinguishes freight consolidation at various geographic scales and identifies three operational types at the urban level: (1) single-company UCCs, (2) multi-company UCCs, and (3) freight villages, a model popularized by Germany and Italy where larger intermodal facilities in the urban periphery serve smaller logistics companies. The authors of [4,28] elaborate further and propose a scheme based on intended usage, service type, and geographical services. These include: (1) special project UCCs (i.e., temporary consolidation facilities typically serving a large construction site); (2) UCCs on single-sites with one landlord (i.e., off-street facilities that serve a large, contained retail center like an airport or a shopping mall); (3) UCCs that serve a town or city. These classifications do not distinguish between facility size and spatial proximity to receivers, which are features of microhubs.

Most research that explores microhub operational typologies is case-specific. Janjevic and Ndiaye (2014) [10] identify three microhub operational configurations widely implemented in Europe: (1) micro-consolidation centers, which are similar to the UCC concept but smaller in size, closer to the terminal market area, and have limited spatial range; (2) stationary transshipment points that serve as staging areas for transloading goods from trucks to smaller vehicles, like cargo bicycles; and (3) mobile depots. Mobile depots are often trucks with custom loading features to serve LEVS on existing loading and curbside infrastructure [29–32]. However, we find these operational conceptions narrow in understanding the complexities of relationships between private and public stakeholders, infrastructure and location, scale, and ownership structure. Therefore, the analysis derives three microhub typologies: (1) last-mile collaboration (receiver-led initiatives, third-party logistics companies); (2) shared infrastructure (government-supported initiatives); and (3) private systems (private-led initiatives, single carrier logistics facility). Figure 4 shows the three distinct typologies from the select cases.

3.2.1. Last-Mile Collaboration

Large-scale freight companies, online retailers that offer home deliveries, or a group of customers (i.e., receivers, mostly shop owners) can contract third-party logistics (3PL) companies and delegate them to complete home deliveries. The 3PL companies act as 'transport providers' and are usually regional last-mile delivery companies focusing on green transportation modes, possibly with electrified fleets.

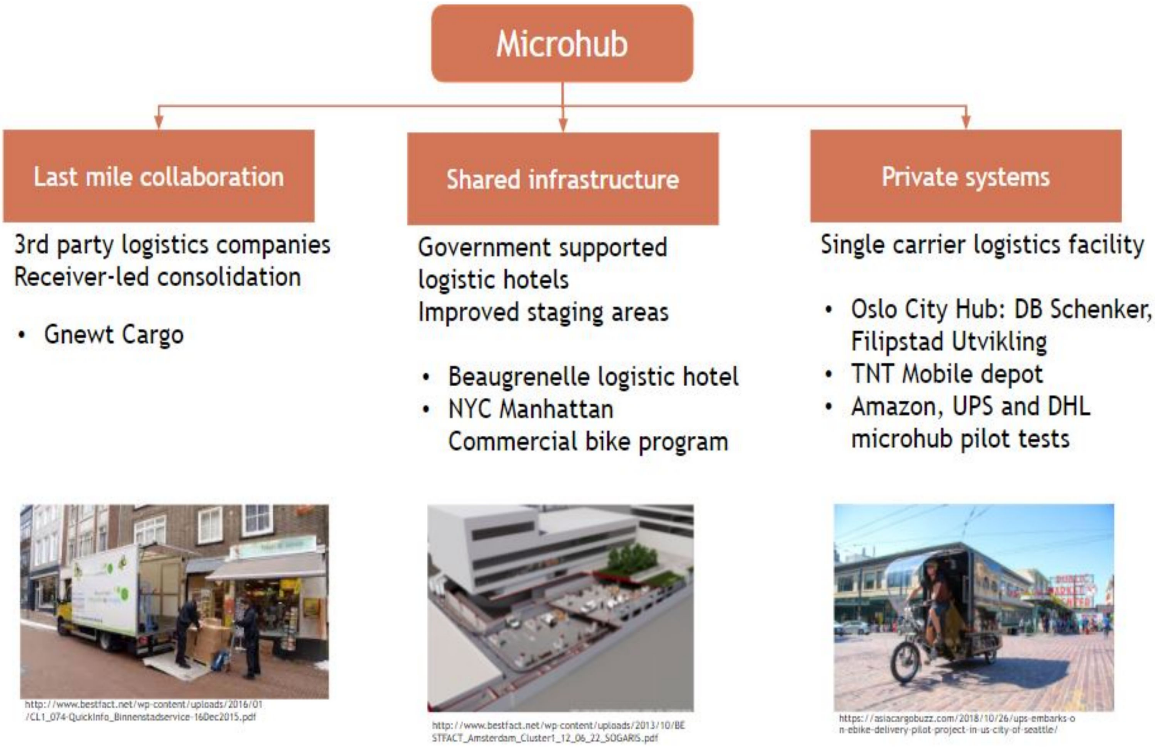

Figure 4. Microhub operational typologies and examples.

3PL providers also offer green urban delivery systems, which is a benefit given increasing air pollution and climate regulations in cities around the world. Gnewt Cargo in London uses a network of microhubs to complete deliveries to its clients such as Hermes, TNT, and other retailers nearby. During off-hours, the client company's transport packages for to their customers in the city are delivered to their depot (if central enough) or Gnewt Cargo's microhubs, some of which are shared by multiple clients [33]. This practice resulted in an 88% reduction in CO2 emissions per parcel, as well as a 52% reduction in vehicle-miles-traveled (VMT) per parcel in London [34].

3.2.2. Shared Infrastructure

Despite the high level of competition in their industries, transport providers may benefit from opportunities to consolidate shipments through shared resources and facilities. Since logistics depots are scarce in central urban areas, municipalities can create shared, multi-purpose facilities in collaboration with industrial partners. Paris, for example, incorporates "logistic hotels" to reduce commercial VMT in the city center, especially for the last mile, and to reduce emissions by encouraging the use of soft transportation modes such as biking [35–37]. A logistic hotel is a multistory building that mixes different uses vertically, such as office space, retail shops, and small businesses [38]. Public feedback on government-funded projects is better when multiple transportation modes are available at the site, such as railroads or waterways. Single or multiple transport providers can manage the delivery operations. For the last mile, logistics hotels can consolidate upstream, share resources, and consolidate downstream [38]. A former parking lot, the Beaugrenelle logistics hotel is a multi-use, multi-story urban warehouse in a very dense and commercial urban area of Paris [37].

The consolidation processes require a designated area where transport providers can sort and de-consolidate their shipments to smaller delivery vehicles. Implementing staging areas on-site and off-street near buildings that routinely receive freight improves freight loading/unloading efficiency. Urban areas with limited curb space may require the use of common staging areas due to a lack of parking and/or loading facilities. These ad hoc microhubs, where loading/unloading and transshipments take place, can occur at the curb, in public or private parking lots, or in repurposed vacant lots or buildings. Improvements to staging areas are generally referred to in the literature either as 'shared drop zones' [36], 'proximity logistics spaces' [39], or 'nearby delivery areas' [40–42].

Carriers use nearby delivery areas as transshipment platforms, possibly with a dedicated staff to assist with dispatching shipments and completing the last mile. The shared drop zone can be used by delivery vehicles delivering goods to nearby warehouses, shops, and residences to load/unload, organize packages, and, potentially, switch to soft modes of transportation for the last mile. The most common challenges to implementing these facilities are finding the necessary space and avoiding conflicts with nearby residents [43]. In Bordeaux, the proximity logistics space is a collaboration between freight companies, the Bordeaux Chamber of Commerce, and the Bordeaux metropolitan authority [10].

3.2.3. Private Systems

Transport companies can integrate microhubs into logistics operations using a private model [14]. Single-carrier microhubs are typically private-led initiatives. Transport companies can use these microhubs as additional transshipment platforms within their existing and exclusive delivery networks and build them to be either stationary or mobile.

A mobile microhub can be a bus, truck (trailer), barge, or tram that circles or is stationed during the day in the city and connects to low emission last-mile delivery options. For three months in 2013, TNT Express pilot-tested its innovative mobile depot concept in Brussels, an area with a high density of small shipment deliveries [14,44]. The mobile depot consisted of a trailer equipped with a loading dock, a small warehouse, and an office. During off-hours, the TNT Mobile Depot transported consolidated inner-city deliveries and was towed to a central location, where packages were distributed using either human or electrically assisted vehicles in a cycle. According to [32], this pilot test resulted in a significant drop in the emission of pollutants and diesel kilometers, although it was not cost-effective at low levels of economies of scale. Similar examples of mobile depots include a private green delivery service provider in Paris, Vert Chez Vous, that used a barge on the River Seine [10,45].

Typical examples of single transport provider microhubs are electrically assisted cargo bicycle delivery pilot tests conducted by private carrier companies. Single-transport providers and municipalities are testing private microhubs that facilitate electric cargo bicycle deliveries in cities such as Gothenburg, Seattle, and Miami. In collaboration with the shipping company DHL Express and the logistics hub Reef Technology, the City of Miami is piloting four low-powered electric-assisted cargo bicycles that will make deliveries in the downtown area [46]. DHL trucks deliver containers for cargo bicycles at the microhub; the containers are loaded on the bicycles and complete last-mile deliveries during the day. DHL expects microhub operations and the use of electric cargo bicycles in Miami to reduce CO2 emissions by 101,000 kg every year, which aligns with DHL's sustainability goals [46].

3.3. Location and Infrastructure

Locating a microhub is an important tactical decision in the microhub planning process. The outcome of a microhub facility location choice should minimize operational costs and difficulties for stakeholders while also satisfying city regulatory requirements and community concerns. Locational parameters typically include variables for demand (e.g., residential, commercial, and/or employment density), infrastructure considerations (e.g., pedestrian/bicycle infrastructure provision, road classifications, pedestrian zones, and traffic-calming measures), and land-use restrictions [14,47–49]. These variables weigh against logistical conditions, including delivery VMT, speeds, costs, and fleet composition. Several studies evaluate optimal locations for microhub implementation. Arrieta-Prieto et al. (2021) [50] presents a heuristic algorithmic model for the number of stationary microhubs in Manhattan and finds diminishing returns in terms of VMT reductions, pollution-related social costs, and marginal benefit after the first microhub implementation. This finding places an upper bound for public investment for first-time microhub implementation and subsequent scaling. Although model results from the Seattle microhub pilot suggest a series of networked microhubs in high-density market areas could multiply emission savings for truck-based resupply trips [21]. Assmann et al. (2021) [51] applies a deterministic model to evaluate a cycle logistic microhub's impact on traffic, GHG, and local pollutant emissions and finds the commercial modes that resupply microhubs, e.g., diesel or electric trucks versus vans, substantially influence overall results. In other words, microhubs act as consolidators not just for goods but also trucks [52], which can have negative localized impacts if planners and transport providers fail to consider the resupply mode. As a result, the authors recommend that relevant stakeholders locate microhubs on the peripheries of neighborhood market areas.

Optimal solutions often come with practical restraints. These could be the cost to lease an off-street facility, as well as important logistical criteria such as ease of microhub access for transport providers and adequate space for loading and unloading. Project members might also value sites with utilities, internet connection, and protections against environmental exposure. As mentioned before, road access and design considerations relating to commercial truck or van operations are important [12]. However, stakeholders must also consider design proposals that accommodate cargo bicycles with safe, integrated passenger-freight infrastructure, including appropriate bicycle lane-width and loading zone provision near the microhub location. Public perceptions and urban integration are also important. Assmann et al., (2020) [12] notes that street users generally perceive stationary off-street microhubs (e.g., in parking lots) utilizing small resupply vans in place of trucks as safer and preferred.

Furthermore, Assmann et al. (2020) [12] proposes an iterative decision-making process between city planners, logistics providers, and relevant public participants (e.g., people living within the vicinity of a proposed microhub) where project leaders collaboratively define suitable sites based on stakeholder inquiries, GIS, and real estate data analysis, and site visits. Janjevic and Ndiaye (2014) [10] proposes another useful decision-making framework relating to the transferability of locating new target environments for a microhub project. They propose three parameters:

- Relevance relates to the market need for a microhub project and is primarily concerned with demand factors such as delivery volume, commercial and/or residential density.
- Suitability relates to logistical and transport network criteria that define the ease of access and utilization of the microhub for logistics providers.
- Feasibility suggests the level of buy-in from relevant stakeholders as well as the availability of public resources and support.

While practical restraints occasionally trump optimal solutions, these concessions are not harmful to the overall project objectives. For instance, Niels at el. (2018) [53] utilizes real-world data from a microhub project in Munich and demonstrates that, despite occasionally large discrepancies between optimal and practical microhub locations, they still find substantial VMT and emissions reductions while completing on-time deliveries.

Although difficult to determine in every case example, we observe that project leaders generally locate microhubs through practical decision-making. Seattle's microhub pilot members collaboratively defined desirable location criteria and selected the final location based on the negotiated agreement of the landlord. Whereas in NYC, NYCDOT appears to have located cargo bicycle corrals based on transport provider feedback regarding operations. Both pilots located microhubs within the market area they were servicing, rather than on the periphery and away from potential conflict with residences. In contrast, the Miami microhub pilot is located in a commercial-only district just outside of downtown.

In other cases, stakeholders occupy empty urban spaces (e.g., parking lots) to contribute to transforming the urban environments with relatively low cost. Examples include the case of Nordstan Cargobike Hub Cargobike Hub in Gothenburg, which occupies the empty spaces of the Nordstan Cargobike Hub Mall, and Project Colibri in Montreal, where the city established a microhub in an abandoned transit center near downtown.

Other microhubs are located at campus facilities where distribution is provided by an electric mini-truck that delivers goods around the area and brings waste back to the microhub. Further, there is the Oslo City Hub, located at the city's port and serving the city center, which utilizes a shipping container that enables operators to easily disassemble, move, or modify equipment as needed and at a low level of financial and temporal investment. The contract term for the land lease is relatively short. In contrast, some microhubs located in close proximity to the city center have the characteristics of a bigger distribution and consolidation terminal. These microhubs serve businesses with specific delivery requirements resulting from their own decisions or constraints.

3.4. Last-Mile Fleet Composition

It is common for urban consolidation initiatives to use clean, last-mile vehicle fleets [32,54,55]. Microhubs shorten last-mile delivery chains to accommodate smaller electric vehicles, which have shorter travel ranges than traditional diesel and petrol trucks [15,17,19]. Some transport providers take advantage of microhubs to store and charge small electric vehicles, as in the case of Nordstan Cargobike Hub, Oslo City Hub, TNT Express, Vert Chez Vous, Gnewt Cargo, Last Mile Logistics, and Puralator in Montreal's Project Colibri. North American and European microhubs prioritize zero-emission deliveries primarily through cargo bicycle delivery and secondarily through LEFVs. With carrying capacities from 45 to 90 kilos [56], pedal-assisted cargo bicycles are ideal for urban parcel delivery, as package weights are generally small (usually under 6 kilos) and end-to-end travel distances short (average trip distances in downtown areas typically do not exceed 4 miles) [44,54,57]. In fact, one European study estimates that cargo bicycles can feasibly deliver nearly half of all urban freight goods [58].

Some disadvantages for bicycle-based deliveries were observed during the analysis. The smaller carrying capacity of a cargo bicycle may multiply last-mile delivery VMT. One case study in London showed that replacing diesel vans with electric tricycles increased last-mile commercial VMT by nearly 350% [59]. Even though the result reflects the replacement of truck miles with bicycle miles, which is beneficial, the added VMT may increase the number of drivers and/or labor hours needed to complete the last-mile delivery. According to [60], these additional labor costs in B-Line's business model exceed the savings in cargo bicycle purchase and maintenance, as well as fuel. On the other hand, the Seattle microhub found its cargo bicycle VMT per parcel to be 50% lower than business-as-usual truck deliveries [21]. Moreover, several of the projects estimate delivery speed differences between cargo bicycles and conventional vans as inconsequential given pragmatic delivery distances and densities [57,61]. In other words, evidence that suggests cargo bicycle logistics is more time-expensive and costly than conventional deliveries is highly contextual, with some examples showing the reverse.

The majority of cargo bicycle projects use electric pedal-assisted cargo tricycles. Seattle's pilot used a 120 cm wide rear-wheeled tricycle with a carrying capacity of 90 kilos, a maximum battery operating range of 24 miles, and the maximum speed for pedal assistance capped at 32 km/h. There are no dimensional, speed, or payload restrictions for cargo bicycles in urban areas, so this model appears to be the most common since it maximizes payload capacity and delivery speed. However, vehicle widths and speeds may preclude cargo bicycles from preexisting, narrow bike lanes. According to the results, tricycles often rode on sidewalks because of operator discomfort and a lack of space for unloading or parking in the bicycle lane. Cargo bicycle transport providers in NYC, where bicycle width and speed are capped at 90 cm and 19 km/h due to aforementioned policies, had a wider diversity of bicycle configurations, including narrower, front-wheeled tricycles, 2-wheeled cargo bicycles, and bicycles with trailers.

Despite the preponderance of cargo bicycle pilots, we also observed other zero-emission last-mile modes (see Figure 5). In Montreal and Toronto, Canada-based transport provider, Puralator, introduced electric low-speed vehicles (ELSVs), including one implemented in Montreal's Project Colibri. ELSVs have smaller vehicle geometries and speeds than conventional vans. Lindholmsleveransen and Oslo City Hub use ELVSVs for their deliveries in the city center. Though interesting cases, scientific research specific to the operational efficacy and environmental impacts of ELSVs appear unavailable [62].

Figure 5. Vehicle fleet examples from the selected cases.

3.5. Stakeholder Partnerships

Microhub projects include various stakeholders from the public, private sector, and civil society (see Table 2). These categories are a synthesis of the stakeholders in the literature on city logistics, which are: retailers, transport providers, society, residents, and end-receivers (e.g., [63–65]). These key partners share the same physical space and therefore interact, even though they do not have direct business relations [66]. Each key partner has a distinct role in the projects and has several benefits to gain. Microhubs help retailers gain access to an environmentally sustainable, cost-effective, same-day delivery network that enables them to compete with their competitors and large e-commerce players without the massive upfront investment and recurring expense of operating a same-day delivery service.

Microhubs seem ideal for national or local chain stores, local retailers and restaurants, and small online retailers that have no other choice but to offer rapid and flexible delivery options to compete with major e-commerce retailers. The majority of retailers cannot offer profitable same-day or next-day delivery options to their customers. Therefore, the receivers can use their biggest asset, proximity to micro-hubs, to offer same-day delivery without having to focus on the challenges of logistics. Transport providers have the potential to make multiple deliveries on each run, which could increase earnings [66–68]. End receivers could expect improved accuracy, consistency, and flexibility in delivery times [69,70]. Society could benefit from a reduction in emissions, pollution, and congestion, which are the primary quality of life benefits. In addition, improvements in safety for pedestrians and residents could ultimately make cities more sustainable and livable.

Table 2. Multi-stakeholder roles and interests in urban delivery.

Sector	Stakeholder	Role	Interest
PPP	Project owner	Point of contact Generates public advocacy, support, resources	Short- and long-term sustainability Collaboration
	Project coordinator	Facilitates partnership and engagement meetings	
	Data, monitoring, and evaluation manager	Data sharing agreements and impact reporting	Transparency Cost-benefit
Private	Shippers	Pays for carrier services Demands quality and time-sensitive shipping	Receive the same service level at the same price
	Transport providers (e.g., integrators, owner-operators, and on-demand, gig-based drivers)	Delivery handling and transportation Captive to shipper and receiver demands	Provide competitive service while minimizing costs Provide competitive service while maximizing profits May have sustainability goals (e.g., emission reduction targets)
	3PL and supply chain partners (e.g., startups and social entrepreneurs)	Physical and IT support for routing, operations, inventory, fulfillment, pre-retail and packaging, and delivery management	
	Vehicle and downstream OEMs (e.g., LEV, batteries, refrigerated containers, pallets, etc.)	Enters procurement agreements with carriers	
	Real estate developers and landlords	Enters leasing agreements Abides by land use and legal criteria	
	Retailers and restaurants	Demands reliable, high-quality, and time-sensitive delivery	Receive affordable, on-time deliveries May be agnostic or prefer sustainable deliveries
	Energy and utility providers	Enters service agreements Meets energy and other utility demand	
Public	Transport planners, engineers, and authorities	Plan and build infrastructure Investment planning Mobility strategy	Improve city livability in terms of emission reduction, air quality and road safety improvement, economic development, and equitable access to goods and services
	Municipal services (e.g., waste, public works, safety)	Maintenance and construction Enforcement and safety	
	City council and administrators State- and country-level policymakers	Enact policies and ordinances Allocate funds and grants	Public service Re-election
Civil society	Universities	Academics and research Intermediary between public and private stakeholders	Scientia potentia est
	Nonprofit organizations	Volunteer, advocacy, and research	Social and environmental good
	Home receivers	Demands reliable, high-quality, and time-sensitive delivery	Receive affordable, on-time deliveries May be agnostic or prefer sustainable deliveries
	Humans	Live, travel, bear the existential weight of being	Live free from burden and injustice

Given the diversity of stakeholder sectors, roles, and interests, collaboration is a critical factor for project success and sustainability [66,70,71]. Early collaboration is especially important between public stakeholders and transport providers, the latter of whom stand to experience the greatest levels of disruption and might not financially benefit from additional and costly transshipment operations in the urban core. As a result, multi-sector collaborations present a considerable challenge [71,72]. The authors of [5] identify three primary collaborative partnership structures in European UCC schemes: (1) private-joint ventures where companies cooperatively manage a shared consolidation site, potentially starting a joint logistics company; (2) public-private partnerships (PPP); and (3) publicly-owned facilities where public authorities contract private transport providers via tender.

Public involvement is high in European cities. Government administrators and agencies are responsible for developing appropriate operator licensure and training, bidding agreements with transport providers, policy advocacy, and granting or purchasing off- or on-street space for transloading activities. As part of Nordstan Cargobike Hub Cargo Bike Hub, Velove, a startup falling under the 3PL category, was integrated to offer cost, efficient, and city-friendly logistics solutions. This creates a more livable city center and efficient deliveries. Oslo City Hub is driven forward as a private initiative, with DB Schenker handling the deliveries. This project aims to evaluate the establishment of a microhub for the transshipment of goods for last-mile distribution in Oslo. Nevertheless, the Oslo microhub required the involvement of the public sector.

In North America, the most commonly observed collaborative partnership models are public-private partnerships (PPPs). In New York City, Miami, and Montreal, cities with higher levels of public involvement, government agencies were primarily responsible for initiating appropriate operator licensure and training (NYC only, unobserved in Montreal), tendering agreements with transport providers, policy advocacy, and permitting or purchasing off- or on-street space for transloading activities. In Seattle and Portland, universities played a leadership role in coordinating partners and collecting and reporting data. Other participating 3PL partners sometimes included bicycle manufacturers, pallet and container equipment providers, strategy consultants, digital supply chain startups, and value-added services (e.g., dark kitchens, food trucks, parcel lockers, and car and bike-sharing). This study did not observe any private-joint ventures or last-mile collaborative typologies in North America. Moreover, we find no comprehensive research regarding the role of the nonprofit sector and civil society in supporting last-mile delivery projects.

3.6. Public Support

Since cities stand to benefit from sustainable urban freight practices, they can take an active role in their implementation. In fact, the analysis of the European projects points to the critical role of public involvement in financial sustainability and the overall success of a project [4,28]. Public involvement and support also attract collaborative, multi-sector UCCs [73]. Most commonly, support comes in the form of subsidies. Mainly, UCCs receive public financial support for operations at the startup phase, with the intention of phasing out subsidies as the center generates enough market volume to create self-sustaining operations. Researchers observe, however, that many UCCs struggle to generate profits or break even once subsidies are reduced or lifted [67,74,75]. In fact, most successful UCCs required government financial support for longer than partners anticipated at the project's outset [76]. In their work [77], observe additional financial support mechanisms, including longer-term structural support (including support through favorable loans or infrastructure provision) and indirect support such as financing fleet electrification and/or digital innovation.

The authors of [77] also identify regulatory incentives such as favorable licensing, priority infrastructure access, and delivery time windows, as well as indirect regulations involving time-, weight-, size-, age-, and emission-based restrictions and congestion charging. Moreover, while companies would certainly prefer gentle incentive (or 'pull') strategies rather than restrictive directives ('push' strategies), regulatory mandates are practical for driving sustainable freight practices [18], which could include fee and restriction exemptions for sustainable practices. Other case studies have found varying degrees of UCC sustainability when examining the impact of specific regulations, including increasing access fees or limiting access to traffic zones for commercial vehicles not using a UCC [72,78,79], granting transit-lane access to UCC vehicles ([28] and integrating UCCs with off-hour delivery initiatives (i.e., permitting deliveries during time windows when traffic is at its lowest) [72,80]. However, some of these studies also point to a lack of government awareness of urban freight issues and early engagement with transport providers as a major barrier for generating public and private support for urban consolidation projects [72,78,81]. Therefore, cities should approach urban consolidation efforts with clarity around desired sustainability outcomes and a collaborative model of engagement with logistics providers. Table 3 outlines examples of direct and indirect policies influencing sustainable urban freight, although most of these policies have yet to see widespread implementation.

Table 3. Examples of direct and indirect policies influencing sustainable urban freight.

	Push	Pull
Regulations	Off-hour delivery mandates Low/Zero Emission Delivery Zones Commercial operator licensing restrictions Commercial EV/cargo bike procurement, manufacturing mandates	Extended delivery time windows Waiving zone-based access restrictions Flexible and pragmatic vehicle size requirements for low-speed EVs Flexible and pragmatic vehicle size requirements for e-cargo bicycles
Infrastructure	Road access restriction based on commercial vehicle size, weight, and/or age Complete street, parking reduction Traffic calming measures that make unsustainable delivery unattractive	Non-motorized infrastructure provision accommodating cycle logistics Off- or on-street staging provision Priority lane access (e.g., bus lanes) Priority and dynamic loading zone and curb access Revised building code Cargo bay requirements to accommodate clean deliveries
Finance	Congestion charge/urban tolling Parking penalties Licensing fees	Using fee revenues to subsidize fleet electrification Using fee revenues to subsidize sustainable urban freight programs Tax credits and rebates Direct startup and long-term subsidy Favorable loan/grant offerings Facility subsidy Emission-related fee waiving
Governance		Organizational support and partner coordination Data sharing and reporting agreements Stakeholder engagement Institutional training around urban freight issues Dedicated planning divisions and authorities for urban freight management

The most commonly observed public support mechanism for microhubs are on- or off-street staging infrastructure provision and/or permissions. In Montreal, city authorities purchased a former bus depot to stage transport providers, with additional funds earmarked for administering the tendering, stakeholder coordination, and reporting of the project. NYCDOT created a Letter of Understanding with companies and provided companies free on-street parking, use of commercial parking space, and loading and staging space. They also updated their existing Commercial Licensing and Safety program to include e-cargo bike requirements, created a public unit tasked with managing commercial cargo licensing, regulations, and enforcement. NYCDOT identified updated operator permitting fees, cargo bike-only loading zones, parking meter exemption for cargo bikes, and flexible regulations for e-cargo bike models (e.g., trailer width, throttle versus pedal assist, scooter and trailer combinations) as critical elements for propelling the pilot program permanently. NYCDOT promoted a legislative change to a 2020 state policy that restricted e-cargo bicycles wider than 80 cm. This policy created inflexibilities for commercial bicycle manufacturers and operators who mainly deploy 120 cm-wide bicycles that match the standard width of a pallet. Both NYC and Montreal programs also implemented data-sharing agreements between operators, enabling public reporting and communications of impact.

In Scandinavia, city authorities, together with the traffic administration authorities, focus on street infrastructure to prevent crashes with bicycles and cargo bicycles and alleviate the consequences of an accident if one should occur. They prioritize action areas for increased safety for cyclists while offering an operation and maintenance of the bicycles. In Oslo, authorities allowed the use of shipping containers that could be easily disassembled, moved, or modified as and when needed. This provides a more flexible containerized solution, and particular certificates for the containers were created. In contrast to when containers are used for shipping, the certificate for the containers is just as valid after the containers have been used for a building. Therefore, there is not much depreciation in the value of the containers over the course of the lease period. These certificates make the construction well suited for temporary projects like Oslo City Hub, where the contract term for the land lease is relatively short, in contrast to when containers are used for shipping.

3.7. Key and Value-Added Activities

A major financial hurdle for any urban consolidation scheme is to make costs comparable to conventional last-mile distribution [82]. To break even, several authors point to prerequisite parcel volumes or delivery densities necessary to generate cost-effectiveness and economies of scale [20,83]. The question of financial viability is important when considering the long-term sustainability of an urban consolidation project, especially when public subsidies disappear, as many public officials are inclined to do. Despite the emphasis on financial sustainability, it is not clear to what extent partners plan for long-term implementation and scaling at the outset of an urban consolidation project. One study found that only 4% of UCC initiatives conduct any sort of cost-benefit analysis, a component of strategic financial planning [78]. Major transport company costs include strategic planning, upfront investments, and operational costs, which include labor (arguably the largest expense for any business), fixed vehicle costs, and overhead costs [20]. While microhubs' smaller real estate may mitigate some overhead costs, it is still critical to consider key and value-added activities for long-term financial sustainability.

The review identifies nine key activities and several potential value-added activities that maximize financially sustainable operation. These key activities include:

- Planning common urban freight strategies between relevant agencies and stakeholders. The collaboration between different agencies and stakeholders is crucial for the scalability of the projects. The projects also focus on establishing the concept, mapping, and evaluating the options and deliveries.
- Developing cost-efficient and sustainable solutions for eliminating the negative environmental impact of urban freight traffic and enhancing the financial continuity of the microhubs. Projects test solutions with the intention of evaluating business opportunities and creating a direct link between the tested solutions and last-mile delivery.
- Consolidating and distributing freight. This activity relates to combining multiple parcels into fewer shipping containers, which allows transport companies to use fewer and joint loads to transport freight efficiently.
- Storage, which involves making proper arrangements for retaining goods at the microhub in a perfect state without losing properties and qualities until distributed to the end receiver.
- Quality control, in which both the project manager and their stakeholders' employees strive to implement certain solutions and the scaling up of the initiatives.
- Implementing tactical and operational planning for traffic, infrastructure, and logistics management that ensures safe, efficient operation and adequate use of the resources that meet the needs of the city and project scope. Operational planning includes the terminal, vehicle routing plan, and scheduling with their respective drivers and personnel.

- Advertising initiatives employ different types of advertising, such as campaigns, speeches, workshops, and online advertising. Visual advertising on LEVs (e.g., on the outside of the vehicle or container) can also generate auxiliary revenue and improve the project's attractiveness for stakeholders and consumers.
- Mitigate project barriers and address complex issues and challenges, such as the negative outcomes of freight transport and scalability. Scaling services mean a larger number of shops and home receivers could receive products facilitated by a microhub. Furthermore, this implies that if the services continue, they can be opened to all businesses and residences in the inner-city area, where there is a strong focus on making services commercially sustainable.
- Logistics and value-added services, such as off-site stockholding, consignment, unpacking, preparation of products for display and price labeling, and waste handling, maintenance, and repairs. Revenues from logistics services can help reduce delivery prices, thus making the projects more financially attractive for users. We discuss value-added services in further detail below.

Innovative, value-added offerings are the critical factor for the success of many urban consolidation schemes [63,64,75]. In addition to providing added sources of revenue and/or mitigating expenses, value-added services can boost the perceived attraction of a microhub and help enlist more users. Value-added services generate additional value through auxiliary services and demand generation or capture value through reverse logistics and EV charging management (see Table 4). For off-street building facilities, the most commonly observed revenue-generating service is selling storage space, warehousing, and order fulfillment capacity to local or online retail. We observe these practices as especially common within the private systems typology, where transport providers or retailers offer fulfillment-as-a-service, as is the case of Nordstan Cargobike Hub, Oslo City Hub. Portland-based B-Line—a private cargo bicycle courier service—also offers 'flexible' and managed warehousing and fulfillment services (including refrigerated storage) to third-party retailers, in addition to offering advertising space on their tricycles. B-Line's impact-oriented business model is also a major draw for retailer clients, who identify environmental outcomes as a justification for B-Line's higher delivery premiums. In contrast, the Lindholmsleveransen use the same electric mini-truck for their deliveries in the area and to collect waste when returning to the microhub. In this way, Lindholmsleveransen has cut heavy goods and waste transportation by more than 80% since the system was implemented 10 years ago.

Cargo bicycle delivery pilots also offered some value-added services. Transport providers participating in Montreal's Project Colibri utilized excess off-street space to store and charge last-mile vehicles, in addition to providing a rest area for drivers. The city located car share and bicycle share facilities near the microhub, providing a mobility hub for nearby residents. Furthermore, Nordstan Cargobike Hub's city center location facilitates safe areas for parking, changing rooms, traffic management, transshipment, and maintenance and repair. The project partners aim to improve accessibility within the city. By using more efficient transportation, traffic congestion and the environmental impact are reduced. In addition, this operation model reduces logistics costs and secures delivery to the city center. The Seattle microhub pilot introduced a food truck/dark kitchen where people placed orders online for pickup or delivery. The Seattle pilot also implemented an outdoor, common-carrier parcel locker and provided a secure container for cargo bicycle storage and charging.

Table 4. Example of value-added services for value generation or value capture.

Value Generation	Value Capture
Auxiliary services Dark kitchen/retail space Fulfillment-as-a-service Dry and refrigerated storage Green advertisement Pre-retail services (e.g., unpacking, labeling, kitting, preparation for display, security tagging) Digital inventory management/tracking Urban agriculture and Community Supported Agriculture Job training services Logistics management consulting	**Reverse logistics** Return drop-offs Packaging recycling and reuse Advanced recycling and disposal (e.g., batteries, motor oil) Waste coordination Donation drop-off containers Food rescue
Demand driving Passenger-freight integration (e.g., bike share, car share, and transit stop co-location) Common-carrier parcel lockers Online ordering assistance Employee rest area, bathroom, and washroom Urban integration (e.g., public art, planter separators, green space, public rest area) Mobile food pantries Library of things (e.g., power tool rental)	**EV charging and storage** Battery swapping Vehicle-to-grid charging Off-grid solar charging Public charging infrastructure

4. Sustainability Objectives

This section presents the sustainability objectives derived from the analysis of the projects. It consists of three subsections: (a) financial objectives, (b) environmental objectives, and (c) socio-economic objectives with examples from the selected projects.

4.1. Financial Objectives

A major indicator of efficiency in microhubs is their ability to replace conventional trucks. This is, however, a contextual estimate. Microhub implementations rarely conduct cost-benefit analyses, so it is hard to determine the true value of cargo bicycles versus conventional delivery in terms of overall competitiveness and sustainability. However, the analysis notes that differences in delivery speeds between commercial bikes and vans are negligible given adequate delivery densities, suggesting relatively equal cost-efficiency. The analysis of B-Line's business model suggests that operating costs are, in fact, higher than those of conventional van-based distribution networks. However, some retailers (including major chains) are willing to pay a higher delivery premium for green distribution.

Many European cases attempted to combine private and municipal parcels in the microhubs to increase the volume of the total goods. Furthermore, adding logistics services to the projects in the future may reduce delivery prices, thus making them more attractive to customers financially. This is in line with the findings of [61], who demonstrated that logistics services are often viewed as a means of generating revenue and reducing the negative outcomes of shipping. The benefits and costs of the value-added services are transparent to stakeholders [67]. As a result, such value-added services are often viewed as a way to generate a flow of income through payments from those who benefit from them [73].

The ability of the projects to adapt to new business and organizational conditions is critical. Through this adaptation, new and/or innovative services can be provided, thus resulting in economies of scale. Browne et al. (2011) [59] demonstrated that financial sustainability in city logistics projects requires managing both the strategic and operational aspects. This can also be achieved by adjusting to the characteristics or policies (including rules and regulations) of the specific cities in which the initiatives are implemented.

A challenge in using a microhub is to absorb increased costs from terminals, vehicles, and administration. One way to cover these increased costs is to compare the costs of externalities in the overall financial evaluation of a project and urban freight transportation.

4.2. Environmental Objectives

The transportation sector is one of the largest contributors to greenhouse gas emissions (GHG) across sources [54,58,60–62]. In addition, tailpipe emissions are the source of significant health-adverse air pollutants such as particulate matter (PM), nitrogen oxides (NOx), volatile organic compounds (VOCs), and short-lived climate pollutants (e.g., black carbon) [84]. Mitigating resupply truck emissions is crucial to improving local air quality around the microhub. These, together with efficiency and the climate emergency, are the motivators of implementing most microhubs projects (e.g., Nordstan Cargobike Hub, Lindholmsleveransen, Oslo City Hub, TNT Express, Vert Chez Vous, Gnewt Cargo, Last Mile Logistics, and Puralator in Montreal's Project Colibri, Miami's Ecofriendly Cargo Bike Delivery Project). The analysis showed that due to consolidation and the key activities taking place in microhubs, fewer polluting trucks enter the city center, and VMT is reduced. This is in line with the findings by [65] that showed that replacing diesel vans with electric tricycles increased last-mile commercial VMT by nearly 350%. According to the analysis, there is also a reduction in total transport energy use in tons of oil equivalent as well as a reduction in empty and less-than-full vehicles. The observed cases from North America find GHG emission savings between 30 and 45% per parcel and up to 80% in the observed cases from Europe when compared to conventional delivery vehicles. Delivering by LEFVs rather than by conventional heavy vehicles, the microhubs can prevent almost 1.94 tons of CO_2 from being emitted into the atmosphere, as suggested in the findings by [19,33,34,54,61,62].

Most participating transport provider companies cite cargo bicycles and EVs as a critical component of their companies' climate emission reduction targets. Private business models that solely provide cargo bicycle-based delivery services (e.g., B-line) center climate outcomes as a core component of their operations and marketing [60]. However, only the Seattle pilot offers strategies to mitigate these emissions, namely by chaining trips between multiple microhub locations. Few programs (e.g., Oslo city hub, Nordstan Cargobike Hub, TNT Express, Vert Chez Vous, Gnewt Cargo, Last Mile Logistics, and Lindholmsleveransen) offer electrification or policy-based solutions for mitigating GHG and local criteria pollutants for this middle phase of the urban supply chain and last leg of the last mile.

4.3. Socioeconomic Objectives

Reducing last-mile VMT is one of the most complex steps in a logistic process. Doing so helps with improving the quality of life for urban residents. Faced with the social challenges of urban freight, several microhub projects focused on improving urban livability in city centers and residential neighborhoods, emphasizing living wages and improving road safety as well as reducing noise and air pollution, traffic, and congestion. For example, NYCDOT frames its cargo bicycle project within the larger framework of Vision Zero strategic initiatives and their 'Green Wave' comprehensive bicycle plan. The pilot finds that cargo bicycles make 80% of their deliveries on residential side streets with limited commercial loading provision, pointing to possible reductions in commercial VMT, double-parking, and improved safety in these neighborhoods. The pilot also instituted safety programs such as commercial bicycle operator training in addition to coordinating with New York Police Department to enforce moving violations.

Socio-economic objectives differ across geographic extents, however. Some target an individual location, neighborhood, or street like in Seattle, while others can be implemented city-wide or can span multiple municipalities in dense metropolitan areas, like the Greater London area or Gothenburg, where planning can happen on a regional level. Other cases, such as Vert chez Vous in Paris, invented a new distribution model that is more efficient, cleaner, and quieter, focusing on electric mobility and the complementarity of more economical modes of transport in the heart of the city.

5. Discussion

The study proposes microhubs as an important opportunity to improve urban freight sustainability and efficiency. Several cities worldwide, therefore, stimulate the use of microhubs for freight transported within their city boundaries. Networks with microhubs benefit from economies of scale in the transportation between hubs and receivers. However, those efficiencies have to balance fixed and operational costs involved with operating the hubs [5,21]. Thus, this study examines the broad spectrum of microhubs that exist based on their operational typologies, location and infrastructure, private partnerships, public support, key and value-added activities, and sustainability objectives.

5.1. Typologies of Microhubs

On the one hand, this variety of typologies is useful because stakeholders can adapt microhub solutions for the different challenges faced by a city and urban area, including negative environmental (e.g., CO_2 emissions), social (e.g., noise, poor quality of life, public health), and economic (e.g., waste of resources and congestion resulting in decreasing deliveries and journey reliability) impacts. These challenges affect not only the efficiency of freight distribution in the cities and the quality of life of residents but also the eco-efficiency (reducing ecological damage while at the same time maximizing cost efficiency) and sustainability of cities and countries [84,85].

On the other hand, the typology of different microhub implementations is complicated. Different stakeholders involved in a particular microhub project may have another type of hub or terminal in mind when discussing the project and may end up choosing a solution that does not fit the challenge at hand. This is because microhub operations are a new concept and lack an established definition and typology. Further, the stakeholders and, in particular, the transport providers need to collaborate with their competitors and regulators, which present unique contentions.

5.2. Multiple Sector Collaboration and Sustainability Objectives

Implementing a microhub is one possible step to manage the challenge of multi-sector collaboration, as it may be easier to collaborate in only the last leg of transportation. This is in line with the findings by [19,86]. However, it might be more sustainable to implement the microhub together with a UCC, which increases the effects of consolidation. A microhub combined with the transport providers' own consolidation terminal also reduces environmental impact. Therefore, the microhub implementation shows a reduction in both the environmental impact and the costs of externalities. It also contributes to the challenge of reducing the number of vehicles in the cities by approximately 80% as the deliveries are done by LEFVs and cargo bikes [59,87,88]. This alleviates the social problem of emissions and noise in the cities and urban areas.

Better coordination of freight flows in urban areas and densely populated city centers can also improve initiative viability. The analysis shows that governmental support is often present and needed (also as a mediator) in several microhub projects where logistic companies share space with other users and their competitors. Generally, governmental support is highly favored and common in microhubs projects in Europe, both in forms of funding and planning [38]. In North America, meanwhile, the level of long-term government support and subsidy is uncertain. There are many reasons why public support for microhubs is stronger in European versus North American contexts. For instance, studies show that European cities have higher levels of urban density and access [89] as well as government control on taxation, land use, and subsidy that directly and indirectly influence sustainable travel mode choice [43,90]. Moreover, while private-sector is the predominant player in both regions, North America encouraged a greater degree of liberalization that led to stronger private ownership of regional distribution infrastructure [91]. Private systems do not directly require governmental cooperation, but they need public support to approve their initiatives. Delivery operations take place in public areas and are in frequent interaction with society.

Also, in cases involving multiple stakeholders, it is crucial to have a strong communication and engagement network. This falls in line with [92], as it aims to bring better interaction, collaboration, and trust among stakeholders [71,92]. To produce even more efficient results, stakeholders need to share a mindset of balancing the city's economic vitality and environment, build trust, and compromise by having a neutral transport provider to operate joint delivery systems. Therefore, cooperation between the private and public sectors is key to ensuring delivery activities are beneficial for both private companies and society as a whole. The analysis also highlights that the microhubs have been tested and implemented in different forms, but not with a sharing economy and business model in mind.

5.3. Policies of Microhubs

There is also a series of policies that should be implemented together with microhubs. For instance, restricting access for polluting freight vehicles from urban centers (e.g., Low/Zero Emission Delivery Zones), certain favorable licenses, or during off-peak hours to minimize congestion and maximize the use of existing infrastructure. Meanwhile, policies can incentivize microhub utilization by waiving certain restrictions, offering favorable loan and franchise agreements, or offering subsidies that derive from unsustainable freight-related fees (e.g., congestion charge, carbon pricing, licensing, and parking penalties). In a collaborative model, however, private sector partners will likely vocalize more support for incentive strategies as opposed to regulatory directives (including regulatory exemptions), even though these might be needed to push sustainable practices.

5.4. Infrastructure of Microhubs

In some cases, unsafe and insufficient infrastructure stands as a barrier to bringing microhubs into fruition, especially if the last-mile mode is a cargo bicycle. In some cities, bicycle lanes and sidewalks might not be adequate to accommodate both LEV and non-motorized freight movement, commercial loading/unloading, pedestrians, and bicyclists. While no case reported collisions and injuries of commercial operators or general road users, a cargo bicycle operator for the Seattle microhub claimed discomfort with existing infrastructure and often used the sidewalk for mid-block loading operations. Unsafe and inadequate infrastructure also puts vulnerable road users at risk, including cargo bicycle operators who are more exposed to traffic conditions. Mitigating negative urban freight externalities (e.g., collisions, noise, pollution, and infrastructure damage) requires cities to implement intentional design and planning principles that prioritize pedestrians and bicyclists and shared-system transport, such as those identified in a Complete Streets and Safe Systems approach [93]. More research is also needed to determine the impacts and perceptions of localized truck traffic near microhubs. Centralized commercial facilities in dense urban environments may present collision dangers and undesirable perceptions for both commercial operators and road users if stakeholders fail to consider public space designs and regulations that integrate commercial and passenger activities. Moreover, if stakeholders fail to lower the emissions of the resupply mode (i.e., the truck that delivers goods to the microhub), microhubs may localize health-adverse air pollution within the vicinity of the microhub.

6. Conclusions

This research presents an integrated view of projects and attempts to develop a common language and understanding of a typological definition of microhubs. It thus proposes a framework. The framework contributes to a more coherent understanding of what a microhub is and how it is implemented. This contribution is important because it helps scholars distinguish between the different types of consolidation. The research establishes microhubs as an important opportunity to improve urban freight sustainability and efficiency and is one possible step to manage the challenge of multi-sector collaboration. This research sheds light on innovative micro consolidation practices taking place in diverse cities all around the world.

6.1. Implications for Research

The research presented in this paper extends the current body of knowledge on microhubs by analyzing 17 projects in Europe and North America. In particular, the research investigates how microhub implementations differ geographically in terms of objectives, operations, and challenges faced. The core contribution is the proposed framework that provides a foundation and shared language for identifying microhubs. An important implication of this research is that it establishes a definition for microhubs. This definition can be used in micro consolidation practices. This contribution is important because it helps scholars distinguish the different types of consolidation. This research also makes an important contribution to the typology of the microhubs as it reviews microhub implementations in different cities around the world and categorizes them by creating a typology to clarify the differences between implementation styles. Further, this research highlights the sustainability aspects and objectives of the framework. Finally, the findings of this research shed light on micro consolidation practices taking place in diverse cities all around the world.

6.2. Implications for Practitioners

Practitioners, policymakers, and policy planners can find evidence to strengthen and stimulate the development of new and improved guidelines that are helpful for the implementation of microhubs. Key findings of the research provide insight into the effect of consolidation on the environmental impact of urban freight using microhubs. This contributes to the challenge of reducing vehicle movements and externalities and their costs in urban areas and supports the findings by [19,94]. Consolidating freight, for instance, in the microhubs and distributing the same amount of freight can also reduce the calculated distance traveled by the vehicles. This supports the findings by [94]. Policymakers can use this information to develop policy measures that correspond to the costs of externalities. For instance, restricting access for polluting freight vehicles from urban centers (e.g., Low/Zero Emission Delivery Zones), certain favorable licenses, or during off-peak hours to minimize congestion and maximize the use of existing infrastructure. In the meantime, policymakers can implement policies that encourage microhub usage by waiving certain restrictions, fostering favorable loan and franchise agreements, and offering subsidies derived from unsustainable freight-related fees (e.g., congestion charges, carbon pricing, licensing, and parking penalties).

6.3. Limitations and Avenues for Future Research

This study is subject to some limitations. The first limitation is the potential omission of relevant projects from the analysis, which undoubtedly results in the loss of some literature and projects related to the microhubs. Second, the shortlisted samples were all in English, while other proceedings, books, reports, and manuscripts in other languages were excluded. This framework suggests the typology of microhubs and defines relevant attributes; however, the choice of precise indicators is to a greater extent conditioned by the availability of data regarding the features and characteristics of each microhub and the target environment. These limitations may affect the statistical results of the study but have little impact on the research outcomes.

Various opportunities remain for scholars to make a meaningful contribution to the growing body of knowledge in the broad domain of urban freight microhubs. These limitations show the way to future research. In particular, learning from these experiences and replicating them remains one of the major challenges for both private and institutional actors, making transferability a key issue in urban freight research. Future research could use this framework as a starting point for identifying transferability and scalability considerations linked to the implementation of microhubs initiatives in a new urban area. In future research, it may also be possible to assess the impact and perception of localized truck traffic near microhubs.

However, various opportunities remain to implement microhubs both in research and in practice. Although researchers and policy-makers recognize the importance of freight data, a number of issues still exist which hinder the proper collection, use, and sharing of freight data. The quantity and quality of data is considered a critical factor that directly affects the potential output of microhub implementation. A reliable and sufficient amount of data allows for detailed analysis for future planning, both for the infrastructure and operation of microhubs and the transport network that connects them. Data collection and data sharing are complicated and time-consuming processes due to the presence of many stakeholders and authorities, as well as the use of other non-traditional or proprietary data sources. As a result, sources of data for microhubs implementation and operation, as well as schemes for sharing these data between public and private sectors, should be reviewed, and new ones should be suggested. The interaction and collaboration of stakeholders under a clearly defined partnership can result in mutual benefits for both sectors for data sharing. For future projects, a structured procedure in the form of an agreement could facilitate efficient data collection, sharing, and reporting among relevant actors. The research also does not deeply explore the role of information technology and data. Several projects, such as the Seattle microhub case, are demonstrating innovative use cases for data technology, such as dynamic routing, loading zone allocation, and advanced data analytics. Urban freight research is only just grasping the role that emerging data technologies play in transforming sustainable urban freight practices, which requires a formal investigation.

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