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Initiatives and Technologies for Smart Urban Logistics and Sustainable Cities

Abstract

Rapid urban growth, the rise of online shopping, and increasing demand for fast deliveries are putting significant pressure on city logistics, particularly on the "last mile" of delivery. These pressures contribute to traffic congestion, higher emissions, and inefficient use of urban space. This paper examines how smart urban logistics solutions can make city deliveries more sustainable. Such solutions include the use of micro-hubs (small local distribution centers), consolidation centers, low-emission delivery vehicles, digital technologies, and improved coordination between logistics planning and urban planning. The study is based on a review of relevant literature, as well as examples from European cities. It considers initiatives such as micro-hub networks, clean air zones, car-free city centers, and the 15-minute city concept, supported by selected data from previous studies. The findings demonstrate that effective regulations and appropriate infrastructure can significantly reduce pollution and spatial challenges associated with urban deliveries. When integrated with urban planning, digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Blockchain, and Digital Twins can improve route planning, enhance transparency, and support better decision-making. However, smart urban logistics also faces challenges, including high infrastructure costs, fragmented regulations, technical complexities, and resistance from stakeholders. To address these issues, the paper proposes a phased approach for implementing smart urban logistics solutions. Overall, the research concludes that a successful transformation requires a comprehensive strategy combining urban planning, policy measures, infrastructure development, digital technology adoption, cooperation between public and private actors, and active citizen involvement.

Keywords: smart urban logistics, digital technologies, urban planning, sustainability

1. Introduction

As urban areas continue to grow, the demand for efficient, reliable, and fast delivery of goods has increased, driven by the rapid expansion of e-commerce, on-demand services, and changing customer behavior. At the same time, cities are under increasing pressure to reduce greenhouse gas emissions, improve air quality, and reclaim public space for citizens.

Traditional models of urban logistics are proving inadequate in sustaining the demands of modern cities. In response, cities and logistics operators are experimenting with smart urban logistics solutions that combine physical infrastructure, regulatory measures, and digital technologies. Key findings indicate that micro-hub-based delivery systems, when combined with low-emission zones and electrified cargo fleets, can reduce GHG emissions by 80% [1]. However, success requires coordinated policy frameworks, investment in green infrastructure, data transparency, and stakeholder engagement [2].

Digital technologies serve as enablers of the transition. The Internet of Things (IoT), Artificial Intelligence (AI), Blockchain, and Digital Twins enable cities and logistics operators to monitor, predict, and manage freight flows more efficiently. Without proper spatial planning, investment in physical infrastructure, and inclusive governance, digital solutions may become fragmented or underused.

This paper examines smart urban solutions for sustainable cities. The focus is on the interaction between delivery models, digital technologies, and urban planning, using European case examples. Through analysis of both successful case examples and key challenges, the paper aims to identify conditions under which smart urban logistics can provide sustainable solutions. Accordingly, the paper addresses the following research questions:

RQ1: How can smart urban logistics solutions reduce congestion and emissions in dense urban areas?

RQ2: What are the crucial challenges to integrating smart urban logistics solutions within urban planning and governance frameworks?

RQ3: What activities and governance mechanisms are required for the successful implementation of smart urban logistics solutions?

The methodological approach is conceptual and exploratory, including a review of the interdisciplinary academic literature and examples of European solutions for smart urban logistics.

In addition to the qualitative literature review, the paper presents selected quantitative indicators from empirical case studies. These indicators (e.g., emission reductions, changes in pollutant concentrations, and distance travelled) are used descriptively, without additional statistical modelling.

Through analysis of European examples, this research contributes to a better understanding of how cities can redesign or improve urban logistics to support sustainability.

2. Theoretical background

2.1. Urban logistics in dense cities

Urban logistics in dense cities is a complex process, requiring efficient delivery through cities, often with limited road networks and constrained urban spaces. Online purchasing has become dominant in consumer behavior. The rise in same-day and next-day delivery expectations adds further strain, prompting logistics operators to redesign traditional distribution models. Cities and logistics operators are investing in digital technologies and delivery solutions: micro-distribution hubs and urban consolidation centers strategically located closer to consumers. These facilities shorten travel distances and reduce the environmental impact of delivery services. [2].

Cargo bikes and micro-hubs offer scalable, low-emission alternatives to traditional delivery systems [3]. Cargo bikes, in particular, are effective in dense urban areas with narrow streets and heavy traffic, where larger vehicles face operational constraints. Their agility and low environmental footprint make them ideal for short-distance, high-frequency deliveries, especially when integrated into micro-hub networks [3].

Electric vehicles also contribute to sustainable urban logistics. Although transition requires substantial infrastructure investment, the long-term benefits are lower emissions and improved delivery. Cities that invest in electric vehicle charging networks and incentivize fleet electrification have already demonstrated improvements in air quality [4].

Achieving continuous movement with minimal congestion requires a multimodal approach that combines electric vehicles, cargo bikes, public transit, and pedestrian infrastructure. When these modes are integrated, they increase flexibility, reduce bottlenecks, and accommodate diverse mobility preferences [4].

2.2. Digital technologies as enablers

Digitalization is essential to modern urban logistics [5]. Digital technologies enable predictive planning, secure data exchange, and real-time infrastructure oversight, creating resilient and adaptive logistics and mobility networks. Digital technologies in urban logistics include traditional technologies and systems that have been used for a long time, such as Real-Time Location Systems, RFID, Barcodes, Wi-Fi, Bluetooth, and Fleet Management Systems, as well as disruptive digital technologies such as Digital Twins, IoT, Blockchain, and AI, which are still not widely used in practice [6].

Real-time vehicle and goods tracking, powered by IoT sensors, enhances operational efficiency and supply chain transparency [7]. Advanced route-optimization technologies, powered by real-time data, IoT, and AI, further enhance efficiency by identifying the quickest and least congested routes for delivery vehicles. AI-driven bike-sharing systems integrated with IoT technology contribute to sustainable urban mobility. IoT sensors monitor bike availability and user behavior, while AI algorithms optimize bike redistribution and maintenance planning. These enhancements have improved the usability of bike-sharing programs and reduced dependence on conventional motorized transportation in urban areas [5].

Digital Twins enable planners to simulate and optimize infrastructure decisions by modelling how route changes and traffic regulations affect overall system performance [9]. Simulation capability reduces decision-making risks through continuous scenario evaluation.

Blockchain can support the development by enabling secure sharing of data related to traffic congestion, traffic flow, and other transport-related information that is valuable for future analysis [8]. As cities adopt interconnected technologies, both the volume and sensitivity of shared data grow significantly. Blockchain infrastructure provides a secure and reliable foundation for these multi-technology ecosystems, improving administrative efficiency while ensuring transparency and reducing the risk of data manipulation.

2.3. Integrated planning of urban logistics

Urban logistics should be integrated into broader urban planning and coordinated policy implementation. Unlike traditional planning, which often prioritizes only the needs of cities, integrated planning involves city planners, policymakers, transport authorities, logistics operators, and community stakeholders. This collaborative approach ensures that logistics is treated as a core component of urban planning, infrastructure design, and environmental policy.

Integrated planning aligns logistics infrastructure (loading zones, micro-hubs, and delivery networks) with residential and commercial development patterns, reducing conflicts between freight and passenger mobility [10]. Zoning regulations serve as key tools for managing vehicle flows into and out of urban cores.

In practice, integrated planning includes coordinating land-use decisions, transportation networks, and freight infrastructure to optimize the location of warehouses, distribution centers, and loading zones. Furthermore, it includes designing multimodal freight corridors that enable goods to move via trucks, trains, cargo bikes, or electric vehicles.

Effective urban logistics depends on collaboration among government authorities, logistics operators, and citizens. Governments provide the regulatory framework and invest in infrastructure, while logistics operators contribute with operational expertise and innovation [10]. Citizens play a critical role, as the success of the system depends on maintaining a safe, healthy, and efficient urban environment. To be effective, citizens must perceive the system as beneficial, whether traveling on foot, by public transit, or in personal vehicles [11]. Well-designed urban mobility systems ensure continuous traffic flow and minimize delays in congested areas. Incorporating logistics requirements at the earliest stages of urban planning, alongside strong stakeholder collaboration, can significantly improve urban sustainability.

3. Case examples of smart urban logistics

3.1. European micro-hub initiatives

European transport and logistics operators utilize micro-hubs combined with small electric vehicles for clean last-mile delivery (Nordstan Cargobike Hub, Oslo City Hub, TNT Express, Vert Chez Vous, Gnewt Cargo) [1]. Goods are transferred from large vehicles outside urban cores to smaller zero-emission vehicles, creating a two-tier distribution system. These hubs also function as transshipment centers and charging points for electric fleets [1]. Emission reductions range from 24% to 88%, depending on implementation (Brussels: 24%; Nijmegen: 40%; London: 88%) [12] (Table 1). Higher reductions are typically achieved where micro-hubs are combined with access restrictions and low-emission regulations. Cargo bikes and electric vans reduce congestion, noise, and air pollution in urban areas [12].

Table 1. Emission reductions achieved by micro-hub initiatives in selected European cities.

City	Type of solution	Emission reduction (%)	Key measures
Brussels	Urban micro-hubs combined with low-emission vehicles	24	Access restrictions and low-emission regulations
Nijmegen	Micro-hub network integrated with clean air measures	40	Low-emission zones and delivery time windows
London	Dense micro-hub network and electrified last-mile	88	Strict vehicle access regulations and LEZ policy

These examples show that spatial reorganization of freight flows, supported by regulation, can significantly reduce congestion and emissions. Infrastructure alone is insufficient; coordinated governance is essential for scalability.

3.2. Low-emission and clean air zones

In the UK, London and Birmingham implemented zones in densely populated areas with high traffic volumes. They require the use of newer, lower-emission vehicles and impose financial penalties on non-compliant vehicles [13]. This approach has enabled municipal governments to offer incentive programs allowing citizens to exchange older, high-emission vehicles for cleaner ones at reduced cost.

A study from 2020 has shown significant decreases in emissions within clean air zones (CAZ), surpassing yearly limit values [13]. By 2021, although emissions increased relative to 2020 levels, they remained below pre-pandemic baselines [13]. These trends show that clean air zones effectively constrain high-emission vehicles. Table 2 summarizes the environmental and health impacts of clean air zones in London and Birmingham, showing that pollutant concentrations decreased relative to pre-CAZ baselines and that London's scheme is associated with substantial health-care savings.

Table 2. Environmental and health impacts of clean air zones in selected UK cities

City	**Reference period**	**Change in pollutant levels vs. pre-CAZ baseline**	**Key regulatory features**	**Estimated health-care effects**
London	First years of CAZ implementation	Substantial reductions; pollutant concentrations remain below pre-CAZ levels	Central clean air zone; charges for non-compliant vehicles	Approx. 4.2 billion USD total health-care savings from low-emission policies
Birmingham	Initial CAZ implementation	Measurable reductions in NO_2 concentrations vs. synthetic control scenario	Charges for older vehicles; support schemes for fleet renewal	Contributes to overall reductions in air pollution–related health risks

Furthermore, clean air zones and related regulatory measures contribute significantly to public health improvements [13]. Recent studies recommend expanding these zones across entire metropolitan regions rather than limiting them to inner-city areas [13]. Beyond environmental outcomes, clean air zones also generate substantial economic savings by reducing air pollution-related illnesses, with documented healthcare benefits totaling approximately $4.2 billion [14]. However, these savings depend on citizens' willingness to adopt alternative transport modes such as cycling and walking [14].

3.3. The 15-minute city concept

The concept of the 15-minute city implies human-centered urbanism, where citizens can access their daily destinations within 15 minutes by walking or cycling. This approach encourages the use of alternative modes of transport and reduces reliance on private vehicles [15]. Numerous European cities have adopted the 15-minute city model as a strategic framework for decentralizing services and reducing overall mobility demand.

In the city of Bologna, essential services are provided within neighborhoods, through decentralized services and community involvement [16]. The city aims to transform neighborhoods into interconnected service networks that can be reached on foot. This approach enables local governments to align planning priorities with local needs [16]. When local authorities prioritize citizens' interests by promoting sustainable transport options, deliveries can be organized with fewer conflicts between passenger and freight mobility. Through this integrated approach, Bologna has successfully advanced its 15-minute city model. Similar to Bologna, Lisbon enables citizens to access short-distance points, such as commerce, healthcare, and green spaces [16].

Vienna has shown particular interest in integrating urban logistics solutions within the 15-minute city framework. For example, the WienBox parcel locker system addresses last-mile challenges by providing white-label parcel delivery solutions with 24/7 access for businesses, delivery companies, and private users [16]. These lockers reduce the circulation of delivery vehicles, which often contribute to congestion and delays. As a result, Vienna promotes more sustainable, accessible, and flexible urban logistics.

Successful 15-minute cities ensure that essential services remain within walking or cycling distance, thereby preventing unnecessary vehicle use for short trips [16]. Key factors for effective implementation include urban design, density, diversity, flexibility, proximity, digitalization, and connectivity [17]. The integration of digital technologies into urban planning can further address implementation challenges, enhance quality of life, and improve overall system efficiency [18].

3.4. Vehicle-free city centers and logistics terminals

In Ljubljana, sustainable urban logistics is supported by integrated vehicle-free city center policies and centralized logistics terminal infrastructure. Over the years, the city has systematically addressed air pollution, traffic congestion, and noise by restricting motorized traffic in the central zone [19]. A logistics terminal on the urban periphery consolidates goods and transfers them to low-emission delivery vehicles for final distribution, creating cleaner, quieter, and more accessible urban areas [20].

In Copenhagen, similar terminals function as consolidation hubs where freight from regional and national networks is processed before entering the dense urban core [20]. Despite restrictions on motorized vehicles, commercial functionality is preserved through systematically rerouting goods to the peripheral terminal. Within the terminal, goods are sorted and transferred to electric vans, cargo bikes, or other low-emission vehicles for final delivery. This last-mile delivery model minimizes freight carbon footprint while maintaining commercial viability [20]. Digital scheduling tools further optimize delivery windows and coordinate operations in real time.

This integrated approach demonstrates how emission regulations, infrastructure investments, and technological advancements can work together to foster sustainable urban logistics ecosystems. Cities such as Ljubljana and Copenhagen, as well as Vienna, share key characteristics: the implementation of alternative mobility solutions, the functional separation of freight and passenger transport, and the maintenance of integrated urban functionality [21].

3.5. Pilot projects: digital technologies in urban logistics

Selected projects that apply digital technologies to urban logistics are analyzed below. Table 3 presents the main characteristics and benefits of the projects.

Table 3. Selected European pilot projects using digital technologies for smart urban logistics.

Project	City/area	Core digital technology	Benefits
DUET	Rotterdam	Local Digital Twins integrating open data	Improved simulation and optimization of traffic and freight flows (qualitative evidence of reduced congestion and better routing)
SENATOR	Zaragoza	AI-based optimization and digital platform	Reduction of van travel distances by up to 32%, leading to lower CO_2 emissions, fuel consumption, and vehicle-kilometers travelled
URBANE	Multiple EU cities	Digital Twins, data-driven assessment, Blockchain-based smart contracts	Potential to reduce emissions and improve last-mile efficiency through scalable green delivery models

The DUET (Digital Urban European Twins for Smarter Decision Making) project, supported by the EU Horizon Programme, develops local Digital Twins for European cities to support evidence-based urban policy and planning. For example, Rotterdam uses Digital Twins technology to integrate open data, simulate traffic and logistics flows, and enhance decision-making processes. The system supports the optimization of freight routing, curb-space management, delivery operations, and overall urban logistics strategies [22].

Under EIT Urban Mobility's Rapid Applications for Transport (RAPTOR) program, the Scottish startup Digiflec is piloting a solution to optimize last-mile deliveries in Trondheim, Norway. The LiDAR sensors and AI-based analytics monitor loading bays in real time, detect occupancy, classify vehicle types, and track parking durations. By providing live operational data to city planners and logistics operators, deliveries can be scheduled more efficiently, and freight operations can be dynamically adjusted [23,34].

The SENATOR (Smart Network Operator Platform Enabling Shared, Integrated, and More Sustainable Urban Freight Logistics) project, also funded by the EU Horizon

Programme, established an Urban Living Lab in Zaragoza, Spain. The platform improved operational efficiency and was integrated into the city's Sustainable Urban Logistics Plan (SULP). It also supported the training of new delivery staff through depot-based simulations and real-time navigation tools [24]. AI-driven optimization algorithms were applied to last-mile deliveries, enabling dynamic route planning and rebalancing, load consolidation across operators, and optimized loading-bay allocation. As a result, van travel distances were reduced by up to 32%, leading to lower CO_2 emissions, reduced fuel consumption, and fewer vehicle kilometers traveled, demonstrating the measurable environmental benefits of AI-enabled logistics coordination [25].

The URBANE (Upscaling Innovative Green Urban Logistics Solutions Through Multi-Actor Collaboration and PI-Inspired Last Mile Deliveries) project, also funded by the EU Horizon Programme, focuses on scaling sustainable last-mile solutions across multiple European cities. It integrates Digital Twins, data-driven impact assessments, Blockchain-based smart contracts, and open-model sharing to support greener urban freight systems. Its "Lighthouse Living Labs" operate in cities including Helsinki, Bologna, Valladolid, and Thessaloniki, with later phases extending to Barcelona and Karlsruhe [26]. The project explores innovative delivery models, including autonomous and light electric vehicles, micro-hubs, intermodal transport systems, smart routing, and dynamic infrastructure, by integrating digital technologies with physical logistics solutions to reduce emissions, alleviate traffic congestion, and improve last-mile efficiency [26].

4. Crucial challenges for smart urban logistics

4.1. Infrastructure and investment challenges

Infrastructure gaps present a fundamental barrier to smart urban logistics. Transitioning to sustainable technologies and establishing smart infrastructure requires substantial capital investment. Smaller logistics firms frequently lack access to credit or financial incentives to modernize fleet operations [27]. Electric vehicles require dependable charging networks to operate efficiently, where they are most in demand; inadequate charging coverage can aggravate smart urban logistics solutions [27]. Similarly, cargo bikes and active mobility modes require proper infrastructure and designated consolidation centers. Without these foundational elements, delivery faces delays, safety risks, and reduced operational efficiency of last-mile deliveries [28].

4.2. Regulatory and governance challenges

Fragmented or inconsistent policy standards can lead to monetary penalties for vehicles entering urban areas, depending on their weight, class, and function [29]. An effective governance structure should align public values with societal expectations, promote sustainable stakeholder initiatives, and encourage cross-sector collaboration to mobilize the resources needed for successful implementation [30]. Land-use restrictions may influence the placement of micro-hubs or the development of critical infrastructure.

4.3. Technological integration, security, and privacy

The implementation of advanced technologies requires complex IT infrastructure and specialized expertise [27]. Smaller logistics operators often lack the technical capacity to adapt. Smart systems comprising numerous interconnected stakeholders require complex network management and continuous monitoring. The rapid transfer of sensitive personal and operational data raises serious privacy concerns regarding device-to-device and user data sharing [27]. Furthermore, highly interconnected networks increase vulnerability to cyberattacks and data breaches, necessitating robust security protocols and governance frameworks [27].

4.4. Stakeholder resistance and social acceptance

Retailers, logistics operators, and consumers may resist changes that increase costs. Traditional logistics operators often hesitate to share networks or participate in consolidation schemes [27]. Users and operators may resist the systematic transformation of urban logistics, particularly regarding unfamiliar delivery methods and route changes that disrupt established patterns [32]. However, this should not prevent implementation. Through proactive engagement, transparent communication, and participatory design processes, stakeholders can perceive innovations as a contribution to more efficient and sustainable urban logistics [32].

5. Discussion

Across European cities, micro-hubs are most effective when combined with complementary regulatory measures such as low-emission zones and vehicle access restrictions, rather than when implemented as isolated interventions [33]. In addition to the previously discussed examples, Hamburg underscores the importance of strategic location selection. Micro-hubs should support local business logistics needs while being situated near residential areas and retail centers [33]. The Hamburg feasibility study identifies blue and orange priority zones based on population density and commercial activity, revealing several interrelated challenges, including demand quality, stakeholder cooperation, potential additional traffic generation, customer behavior, and environmental impacts. These findings show that even well-designed micro-hubs may fail to deliver expected benefits if they are not integrated into a broader regulatory and spatial framework that manages vehicle access and freight flows. Projects lacking integrated planning, such as standalone micro-hubs without complementary access restrictions, have demonstrated limited scalability and reduced operational effectiveness [33].

London's experience with clean air zones shows that regulatory mechanisms should be accompanied by economic incentives to support fleet modernization [13]. Without financial assistance, many logistics operators, especially small and medium-sized enterprises, struggle to replace high-emission vehicles with cleaner alternatives. Estimated healthcare savings of approximately $2 billion from reduced air pollution highlight the broader socio-economic value of these integrated policy packages [14]. These benefits go beyond environmental improvements. However, citizen acceptance of alternative mobility options remains critical, as public resistance can undermine even technically sound policy measures.

Digital technologies are primarily enablers rather than drivers of transformation. While enhancing the effectiveness of physical infrastructure and regulatory frameworks, they cannot compensate for weak or fragmented governance structures [6]. In Ljubljana, for example, digital scheduling tools optimize delivery windows and fleet coordination; however, the core transformation results from the physical logistics terminal and strict vehicle restrictions that structure freight flows into the city center [34]. Similarly, in Paris, interactive mapping platforms and smart dashboards support the 15-minute city objectives [17]. These instances show that while IoT and AI enhance operational efficiency, they do not replace the need for infrastructure or well-structured planning frameworks. Ljubljana's achievements largely stem from its integrated logistics infrastructure and methodical access restrictions, rather than just from advanced technology [34]. This supports the conclusion that technology acts as a multiplier of effective policy and infrastructure, not as a prerequisite for sustainable urban logistics transformation [35].

The transition to smart urban logistics represents more than a technical upgrade; it requires a fundamental restructuring of how urban mobility systems and public space are organized. Freight transport must be reconciled with the needs of citizens. In this context, cities should prioritize:

- ◊ Public-private partnerships that align strategic visions and distribute investment costs,
- ◊ The gradual introduction of clean air zones accompanied by social support measures for businesses and citizens,
- ◊ Citizen engagement through transparent communication and participatory design processes,
- ◊ Integrated zoning that positions micro-hubs within mixed-use urban areas close to demand centers.

These principles reflect the need to balance environmental objectives, economic viability, and social acceptance in the implementation of smart urban logistics. Rather than deploying digital technologies prematurely, cities should first create the institutional and infrastructure foundations. Therefore, a phased implementation is recommended:

Phase 1: **Establish a regulatory framework** for clean air zones, vehicle access regulations, and micro-hub zoning rules. This phase provides legal certainty, defines environmental targets, and shapes market behavior, ensuring that low-emission and shared logistics models become economically viable.

Phase 2: **Build foundational physical infrastructure**, including charging networks for electric vehicles, cargo bike lanes, consolidation centers, and loading zones. This phase enables logistics operators to comply with regulations and adopt new delivery models in practice, reducing operational risk and improving reliability.

Phase 3: **Integrate digital technologies**, including IoT, Digital Twins, AI, and Blockchain. Once regulatory and physical systems are in place, digital technologies can be deployed to optimize routing, manage curb space, coordinate stakeholders, and support evidence-based planning and decision-making.

The phased implementation ensures that technology investments are supported by enabling policy frameworks and functional physical infrastructure, thereby maximizing the probability of successful, scalable, and socially accepted smart urban logistics solutions.

6. Conclusion

This research demonstrates that smart urban logistics can play a pivotal role in creating more sustainable cities when digital technologies are integrated with supportive public policies and strong multi-stakeholder governance frameworks. Rather than functioning as stand-alone solutions, technologies such as IoT, AI, Blockchain, and Digital Twins act as enablers that enhance the effectiveness of physical infrastructure, regulatory measures, and coordinated urban planning.

The analysis of European case examples shows that micro-hub-based delivery systems, when combined with low-emission vehicles and access regulations, can reduce urban freight emissions by up to 80%, preventing significant amounts of CO_2 from being released into urban areas. These systems also improve last-mile efficiency, reduce congestion, and free valuable public space in dense city centers. However, their long-term success depends on adequate investment in charging networks, cargo bike infrastructure, and logistics terminals, as well as coherent land-use and transport policies that facilitate the integration of freight into the urban fabric.

The findings further confirm that digital technologies are essential for optimizing routing, managing curb space, increasing data transparency, and supporting evidence-based decision-making. Nevertheless, without robust regulatory frameworks, financial incentives, and appropriate physical infrastructure, digital solutions alone cannot achieve meaningful sustainability outcomes. Public-private partnerships and active stakeholder engagement are therefore critical for overcoming institutional fragmentation, reducing resistance to change, and ensuring broad social acceptance of innovative logistics models.

From a policy perspective, cities should move beyond isolated pilot projects and adopt coordinated, long-term strategies for smart urban logistics. A phased approach, combining regulatory implementation, infrastructure development, and digital integration, can reduce implementation risks while building trust among logistics operators, citizens, and other stakeholders. Furthermore, it enables urban authorities to adapt solutions rather than applying uniform models.

Future research should focus on comparative and quantitative evaluations of urban logistics performance across different governance and spatial settings, particularly in emerging and rapidly urbanizing economies. Future research is also needed into the long-term scalability of micro-hub models and the potential rebound effects associated with continued e-commerce growth, ensuring that efficiency gains are not offset by increasing freight demand.

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