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Research paper

Urban Logistics and the Challenge of Smart Cities*

Sanaa Kabbassi[1,*], Aziz Babounia[2], Issam Kabbassi[2]

Ibn Tofail University of Kenitra Morocco

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ABSTRACT

This article provides an in depth analysis of the intersection between urban logistics and the smart city concept, in a context marked by rapid urbanization, the growth of e-commerce, and the pressing need to reduce the environmental impact of freight flows. It highlights the integration of emerging technologies—the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), and blockchain—as key drivers for improving efficiency, sustainability, and resilience in urban logistics systems. The study begins by clarifying the concepts of urban logistics (management of physical and reverse flows within urban areas) and smart cities (interconnected integration of physical infrastructures, digital technologies, and human actors). The key challenges are grouped into four categories: Economic (cost control, resource pooling, new models such as crowdshipping), Environmental (reduction of GHG emissions, electromobility), Social (acceptance of innovation, improved quality of life, equitable logistics accessibility), and Technological (interoperability, cybersecurity, system resilience).

A set of Key Performance Indicators (KPIs) is proposed: Operational (unit logistics cost, load factor, on time delivery rate), Environmental (CO_2 emissions, energy consumption, noise pollution), and Social (user satisfaction, accessibility, job creation). The article proposes an Integrated Smart Urban Logistics System (ISULS) built on five interconnected pillars: Central digital platform, Network of urban hubs, Clean and diversified fleets, Secure traceability and Collaborative governance.

1. Introduction

Rapid urbanization and the globalization of trade have profoundly transformed how cities organize and manage logistics flows. According to UN Habitat's 2023 World Cities Report, more than 56% of the global population now lives in urban areas, and this proportion is expected to approach 70% by 2050. This concentration of people, combined with the rise of online commerce and intensifying international exchanges, exerts considerable pressure on transport infrastructure, energy resources, and the urban environment.

In this context, urban logistics is no longer limited to an operational function of moving goods from point A to point B. It has become a strategic lever that reconciles economic performance, fluidity of exchanges, and environmental sustainability. Mastery of physical and informational flows is now decisive for ensuring a city's competitiveness and its residents' quality of life.

At the same time, the emergence of smart cities offers new perspectives for logistics management. Built on advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and blockchain, smart cities enable real time planning, coordination, and monitoring of logistics operations. Integrating these tools paves the way for more agile, responsive, and environmentally respectful logistics.

However, this transformation comes with constraints. Smart urban logistics projects raise complex questions concerning cybersecurity (to protect sensitive data and connected infrastructure), interoperability (to ensure

*Sanaa Kabbassi. Email: sanaa.kabbassi@uit.ac.ma

compatibility between public and private systems), economic viability (given the investments required), and social acceptability (to secure citizen and business buy in).

The aim of this article is twofold: first, to analyze interactions between urban logistics and the smart city paradigm, highlighting the contributions of technological and organizational innovations; and second, to propose a conceptual model—an Integrated Smart Urban Logistics System (ISULS)—applicable both to global metropolitan contexts and to Morocco's specific context, together with a phased roadmap for implementation.

2. Conceptual and Terminological Framework

2.1. Urban Logistics

Urban logistics encompasses all activities dedicated to organizing, managing, and optimizing the transport, storage, and distribution of goods within an urban area. It also includes reverse flows such as product returns, waste collection, and recycling.

As Taniguchi and Thompson (2018) note, the primary objective of urban logistics is to minimize environmental impacts while improving the efficiency of transport services and residents' quality of life. This takes place in a constrained environment marked by road congestion, regulatory restrictions (low emission zones, time windows), and rising expectations in terms of sustainability.

2.2. Smart Cities

The smart city concept, as defined by Nam and Pardo (2011), refers to an urban ecosystem that interconnects physical infrastructure, digital technologies, and human actors. The objective is to optimize urban service management and enhance residents' quality of life through real time data exploitation.

Three fundamental dimensions structure this model: technological (deployment of connected sensors; exploitation of IoT, AI, and Big Data for data collection and analysis); environmental (carbon footprint reduction and sustainable resource management); and governance (effective cooperation among public authorities, firms, and citizens).

2.3. Convergence Between Urban Logistics and Smart Cities

The articulation between urban logistics and smart cities relies on increasingly deep digital integration in flow management. This convergence appears through: the digitization of logistics chains for more precise planning and improved traceability; the real time management of traffic, delivery, and storage data; and the development of multimodal solutions combining electric vehicles, cargo bikes, tram freight, river barges, and, in the future, delivery drones. This integrated approach enables more efficient, resilient, and sustainable urban logistics capable of responding to the challenges of contemporary urban mobility.

3. Literature Review

3.1. Historical Evolution of Urban Logistics

The notion of urban logistics emerged in the 1970s and 1980s, mainly in Europe and Japan, amid growing city center congestion and environmental concerns tied to road transport. Taniguchi et al. (2001) were among the first to propose an integrated approach associating urban planning with logistics flow management to mitigate the impact of freight transport on urban mobility.

In the 2000s, the boom in e commerce and rising expectations for fast delivery profoundly changed the nature and frequency of flows. City center deliveries increased—often in small quantities—exacerbating congestion and pollutant emissions (Dablanc, 2013).

3.2. Urban Logistics Models

The literature identifies several structuring approaches: centralized models (consolidation in peripheral hubs before redistribution to the city center; Browne et al., 2012); decentralized models (use of micro distribution platforms located close to end customers); and collaborative logistics (mutualization of logistics assets—vehicles, warehouses, data—across operators to reduce empty runs and optimize load factors; Gonzalez Feliu et al., 2013).

3.3. Technologies for Smart Urban Logistics

Integrating urban logistics into the smart city paradigm rests on several key technologies: the Internet of Things (IoT), with embedded and fixed sensors for real time monitoring of vehicles, goods, and infrastructure (Perboli et al., 2018); Big Data, for processing massive data to forecast demand, adjust delivery capacity, and analyze mobility behavior (Marcucci et al., 2017); Artificial Intelligence (AI) for dynamic route optimization and automated resource allocation (Gatta et al., 2019); and blockchain for securing and tracing information exchanges, especially for sensitive flows (Queiroz et al., 2020).

3.4. Performance Indicators

The literature emphasizes the need to track KPIs to evaluate the effectiveness of smart urban logistics policies and systems: environmental indicators (CO_2 per tone kilometer, noise pollution, energy consumption; European Commission, 2021); operational indicators (cost per delivery, load factor, on time rate); and social indicators (user satisfaction, service accessibility, road safety; Allen et al., 2017).

3.5. Identified Gaps

Despite abundant research, several gaps remain a scarcity of longitudinal studies to assess long-term effects; an excessive focus on large metropolitan areas in developed countries to the detriment of mid-sized cities and developing country contexts; and a lack of work that simultaneously integrates economic, environmental, and social dimensions in a systemic manner.

4. Challenges of Smart Urban Logistics

4.1. Economic Challenges

The pressure from e commerce, fragmented orders, and expectations for rapid delivery has driven logistics costs upward. Smart urban logistics therefore seeks to: optimize resource use through AI and asset sharing among operators; reduce empty kilometers via better route planning and flow consolidation; and develop new business models—such as crowd shipping and multi service hubs—that combine urban logistics, local commerce, and citizen services. These approaches aim to improve operational profitability while boosting local competitiveness.

4.2. Environmental Challenges

Urban freight is a major source of greenhouse gas emissions and air pollution. Smart urban logistics mitigates these impacts by electrifying vehicle fleets to reduce direct CO_2 emissions; promoting low impact modes (cargo bikes, walking deliveries, river freight); and piloting solutions such as quiet night deliveries to decongest daytime traffic while reducing noise. These strategies align with carbon neutrality objectives and local sustainable mobility policies.

4.3. Social Challenges

Smart urban logistics must also meet societal expectations: improving residents' quality of life by reducing congestion, noise, and visual pollution; ensuring social acceptability of innovations, particularly amid concerns about security, privacy, and employment; and guaranteeing equitable logistics accessibility so all neighborhoods benefit from reliable and affordable delivery services.

4.4. Technological Challenges

The transition relies on digital infrastructure and advanced management systems, which raises challenges of interoperability among heterogeneous public and private sector systems; cybersecurity to safeguard sensitive data and prevent malicious intrusions; and technological resilience to maintain service continuity in the face of outages, power cuts, or cyberattacks.

5. Innovations and Technological Solutions

5.1. Internet of Things (IoT)

IoT plays a central role in smart urban logistics. Sensors on vehicles, in infrastructure, or embedded in packaging enable real time tracking of goods; precise geolocation of delivery vehicles; and anomaly detection (delays, incidents, temperature excursions). Continuous connectivity enhances responsiveness and resource optimization.

5.2. Big Data and Predictive Analytics

Processing data from multiple sources (sensors, GPS, weather, traffic flows) supports proactive delivery planning. Predictive analytics enables dynamic route management, instant adaptation to demand variations, and optimization of vehicle load factors.

5.3. Artificial Intelligence (AI)

AI automates decision making in tour optimization, resource allocation, and disruption management. It helps reduce operating costs, shorten delivery times, and improve reliability and customer satisfaction.

5.4. Blockchain and Traceability

Blockchain ensures integrity and security of information exchanges among logistics stakeholders. In a smart city context, it provides end-to-end product traceability, secures sensitive data (notably for critical flows such as medicines and food), and increases transaction transparency.

5.5. Autonomous Vehicles and Drones

Autonomous vehicles and drones are emerging solutions for last mile transport. They can reduce dependence on human labor for certain deliveries, accelerate deliveries in congested areas, and lower operating costs in the longer term.

5.6. Low Impact Modes and Multimodality

Smart urban logistics integrates less polluting modes tailored to dense urban cores—electric cargo bikes, tram freight, and river shuttles. Combined with well-located logistics hubs, these modes reduce heavy vehicle circulation, improve traffic fluidity, and strengthen the social acceptability of deliveries.

5.7. Urban Logistics Hubs

Urban hubs act as consolidation and redistribution points that enable delivery pooling across operators, last mile optimization, and fewer nuisances linked to multiple deliveries.

6. Key Performance Indicators (KPIs)

6.1. Operational Indicators

• Unit logistics cost (ULC): total cost relative to delivered volume;

ULC = Total cost / Delivered volume (Target: 10–20% reduction over 5 years).

• Load factor (LF): occupied volume / total vehicle capacity;

LF = (Transported volume / Total capacity) × 100 (Target: ≥ 85%).

• Average delivery time: mean duration from order to receipt (Target: 15% reduction).

• On time delivery rate: deliveries within the planned window;

(On time deliveries / Total deliveries) × 100 (Target: ≥ 95%).

6.2. Environmental Indicators

• CO_2 per tonne kilometer: kg CO_2 / t km (Target: ≤ 0.1 kg/t km).

• Energy consumption: kWh or L per km (Target: 30% reduction).

• Noise pollution: average dB level in residential zones (Target: < 55 dB).

6.3. Social Indicators

• User satisfaction: measured via surveys (Target: ≥ 80%).

• Logistics accessibility: share of the population served (Target: ≥ 95%).

• Job creation: employment generated by the system (Target: positive annual growth).

7. International Case Studies

7.1. Barcelona — Toward Sustainable, Collaborative Urban Logistics

Barcelona has implemented a network of urban micro hubs and shared platforms, supported by public policies favoring electric vehicles and low impact modes. The Cargo bike project, for instance, replaces combustion vans with electric cargo bikes for last mile deliveries, thereby cutting CO_2 emissions and congestion in the city center.

7.2. Singapore — End to End Supply Chain Digitalization

Singapore is pursuing comprehensive digitalization of logistics operations through a national integrated platform connecting carriers, warehouses, customs, and customers in real time. This digital infrastructure reduces waiting times, optimizes routing, and guarantees full traceability.

7.3. Amsterdam — Multimodality and Urban River Logistics

Amsterdam has developed a multimodal system that combines waterborne transport, consolidation centers, and electric vehicles for urban deliveries. The City Logistics by Water initiative uses barges to bring goods into the urban core, limiting truck traffic and lowering the city's carbon footprint.

7.4. Comparative Snapshot of Good Practices

• Barcelona: micro hubs, shared assets, electric cargo bikes → ~30% CO_2 reduction in the city center; lower noise; ~20% efficiency gain in last mile deliveries.

• Singapore: national logistics platform, real time traceability → emission reductions via optimized routing; ~25% shorter order processing times.

• Amsterdam: water transport, consolidation centers, electric vehicles → ~40% CO_2 reduction; less congestion; ~15% higher delivery punctuality.

7.5. Lessons Learned

Common levers include centralized digital platforms and IoT for traceability; shared infrastructure to optimize routes; energy transition via fleet electrification and soft modes; and smart combinations of multiple transport modes.

8. Conceptual Model Proposal: Integrated Smart Urban Logistics System (ISULS)

8.1. Objectives of ISULS

Improve logistics fluidity through integrated, real time flow planning; reduce environmental footprint by prioritizing clean modes and resource sharing; strengthen urban resilience to shocks (health, climate, economic); and foster collaboration among public authorities, private operators, and citizens.

8.2. Components of ISULS

• Central digital platform: a shared interface for all stakeholders (carriers, local authorities, retailers, citizens) integrating IoT, Big Data, and AI for dynamic flow management.

• Network of urban hubs: strategically located consolidation centers to shorten delivery routes.

• Clean, diversified fleets: electric vehicles, cargo bikes, river and urban rail freight.

• Tracking and traceability: block chain and connected sensors to ensure delivery security and transparency.

• Collaborative governance: decision-making mechanisms aligning stakeholders with public policy.

8.3. Schematic Overview of ISULS (description)

At the center sits the digital platform that aggregates data and coordinates operations. Upstream suppliers and carriers feed logistics data into the system; downstream, urban hubs distribute flows via the most appropriate modes (clean vehicles, bikes, barges). A KPI dashboard encircles the system to monitor operational, environmental, and social performance.

8.4. Expected Benefits

• 25–40% CO_2 reduction in urban areas.

• 15–25% improvement in delivery punctuality.

• 10–20% decrease in operating costs.

• Greater social acceptability via reduced nuisances.

9. Implementation Challenges and Risks

9.1. Technical Challenges

• System interoperability: common standards and robust communication protocols are needed to integrate data from many actors.

• Cybersecurity: centralized digital platforms are vulnerable to attacks that could compromise confidentiality and availability.

• Maintenance: connected sensors, vehicles, and AI systems require regular upkeep and costly updates.

9.2. Economic Challenges

• High upfront investments: electric fleets, urban hubs, and digital infrastructure require significant capital.

• Uncertain short-term returns: financial gains may take years to materialize, dampening investor appetite.

• Operating costs: maintaining connected equipment and renewing technology entail ongoing expenses.

9.3. Social Challenges

• Citizen acceptance: innovations (night deliveries, sensor based monitoring) may trigger privacy or nuisance concerns.

• Employment impacts: automation and autonomy could displace some roles, calling for reskilling policies.

• Territorial equity: peripheral areas risk being less well served than city centers.

9.4. Regulatory and Institutional Challenges

• Standards harmonization: lack of uniform rules can hinder interoperability at national or international scales.

• Multi actor governance: coordinating local authorities, private operators, and national institutions is complex.

• Data governance: massive data collection raises compliance questions (e.g., GDPR and similar privacy laws).

9.5. Proactive Risk Management

• Deploy robust cybersecurity protocols;

• Develop public–private partnerships to share costs and risks;

• Involve citizens in co design to build social buy in;

• Adapt regulation progressively via pilot projects.

10. Roadmap for Morocco

10.1. Phase 1 — Preparation and Diagnosis (Years 1–2)

• Needs assessment: conduct logistics audits in Casablanca, Rabat, Tangier, and Marrakech.

• Regulatory framework: adapt laws governing urban logistics, data protection, and sustainable mobility.

• Strategic partnerships: establish agreements among the State, local authorities, logistics operators, and specialized startups.

• Training and awareness: develop programs for logistics stakeholders and local authorities.

10.2. Phase 2 — Pilot Deployment (Years 3–5)

• Launch pilots in 2–3 large cities with urban hubs and clean fleets.

• Technological integration: deploy a national digital platform connected to IoT, Big Data, and AI.

• Monitoring: set up a national logistics KPI dashboard.

• Citizen communication: inform the public about environmental and economic benefits.

10.3. Phase 3 — Rollout and Optimization (Years 6–10)

• Extend ISULS to large and mid-sized cities nationwide.

• Optimize multimodal flows: integrate rail, river, and maritime legs into urban logistics.

• Continuous improvement: use predictive analytics to adapt operations to demand.

• Climate alignment: track progress against national GHG reduction commitments.

10.4. Implementation Timeline (narrative)

Three segments: (1) Years 1–2: diagnosis, regulation, partnerships, training; (2) Years 3–5: pilots, tech integration, KPI tracking, communication; (3) Years 6–10: generalization, multimodality, continuous improvement, climate targets.

11. Conclusion

Urban logistics now sits at the core of city transformation. Faced with rising freight flows, environmental pressure, and growing social expectations, integrated systems such as ISULS represent a pertinent and necessary

response. Our analysis shows that combining digital technologies (IoT, Big Data, AI, blockchain) with collaborative governance and suitable infrastructure (urban hubs, clean fleets, multimodality) improves operational performance while significantly reducing environmental footprints.

International case studies demonstrate that pioneering cities reconcile economic efficiency, sustainability, and social acceptability by adopting hybrid, adaptive approaches. Transferred to the Moroccan context, these experiences can guide an ambitious national strategy structured in phases—from diagnostic to wide scale deployment.

Success nonetheless depends on overcoming several challenges: technological resilience and data security; long term economic viability through robust public–private partnerships; and social balance via citizen acceptance and territorial equity. Future avenues include regional and cross border scaling; deeper integration of rail and river freight; advanced AI for real time anticipation and regulation of flows; and circular economy models to reduce waste and valorize reverse flows.

Transforming urban logistics in the smart city era is no longer optional. Integrating advanced technologies within a coherent operational framework enables cities to markedly improve the efficiency, sustainability, and resilience of logistics systems.

The proposed ISULS embodies a forward looking vision that combines technological innovation, multimodal infrastructure, and collaborative governance. Its implementation can reduce environmental footprints, optimize operating costs, and enhance residents' quality of life by creating urban environments that are more fluid, equitable, and environmentally respectful.

Achieving this transition hinges on addressing major challenges—interoperability, data security, stakeholder engagement, and investment viability. Public–private partnerships, active citizen participation, and adaptive regulation will be essential to ensure effective and equitable deployment.

Ultimately, when embedded in the smart city paradigm, urban logistics becomes a strategic lever of sustainable development. For Morocco and similar contexts, ISULS provides a clear roadmap for building competitive, inclusive, and environmentally respectful cities ready to meet the mobility and supply chain challenges of the 21st century.

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