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Sustainable and Smart City Logistics

Innovations, Challenges and Future Directions



Edited by Sudhanshu Joshi, Anjali Awasthi, M. Ali Ülkü and Manu Sharma

Sustainable and Smart City Logistics

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Sustainable and Smart City Logistics:
Innovations, Challenges and Future Directions

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Preface

The urban logistics imperative

The 21st century's habitat is the city. Nearly 7 out of 10 people are forecast to be living in urban areas by 2050, making the systems that transport goods through cities a key part of urban life. Cities are engines of growth and innovation, but they are subjected to extreme pressure from the same factors: density, connectivity and an increasingly high rate of consumption. E-commerce, omnichannel retail, quick commerce and on-demand delivery have led to an unprecedented acceleration in the volume, frequency and complexity of urban deliveries, while citizens, regulators and businesses are demanding that they are faster, cleaner and more equitable simultaneously. Urban logistics is thus at a challenging crossroads. It needs to be economically efficient and environmentally responsible, and it needs to accommodate both global e-commerce giants and informal street-based operations, as well as the physical limits of streets, kerbs, warehouses and emissions budgets. The traditional approach to urban freight based on efficiency is no longer sufficient to meet these needs. The new paradigm is one that is smarter, powered by the Internet of Things, artificial intelligence, big data analytics, blockchain, digital twins and intelligent transportation systems, and more sustainable, grounded in the economic, environmental and social aspects of the triple bottom line. However, technology is the answer to few problems. Logistics for smart and sustainable cities is not just a technological issue but also an institutional and governance challenge, and new modes of cooperation between public authorities, industry, technology providers and citizens are needed.

This volume was conceived to bring coherence to that challenge. The number of research projects in the field of urban freight, smart cities and sustainable logistics has grown rapidly, but the research is still fragmented by discipline and by geography, and by the lack of an integrated approach to technological, operational, environmental and policy issues. This yields an insightful field that suffers from a lack of structure. As editors, our goal is to bring these threads together – from basic concepts to enabling technologies, industry applications to low-carbon pathways, and finally forecasting capabilities driven by data that will define the future of the field.

Aim and scope of the book

Sustainable and Smart City Logistics: Innovations, Challenges and Future Directions examines how cities can design, govern and

operate urban freight and mobility systems that are simultaneously efficient, intelligent, environmentally responsible and socially inclusive.

The book is designed to have three general goals. First, it provides the conceptual and theoretical basis of smart and sustainable city logistics, explaining the evolution of the city logistics field from purely cost-oriented freight management to integrated (sociotechnical and governance) systems. Second, it examines the technologies that are making urban supply chains possible, including electric and multi-compartment fleets, sharing-economy applications, GeoAI, predictive analytics and much more. Third, it highlights implementation issues and future research avenues, with a particular focus on the issues of developed against developing economies and the growing data-driven forecasting capabilities of cities that are now able to look ahead, not just towards, change.

The collection is intentionally international and interdisciplinary. It features contributors from India, Canada, Botswana, South Africa, Tunisia and the Maldives who have a background in logistics and supply chain management, operations research, urban and transport planning, public policy, information systems and sustainability science. The cases they study cover a wide range of urban settings from experience – from the old to the new – from Amsterdam to London, to Singapore, to Tokyo – from Delhi to Bengaluru, from Montréal to the Indian Himalaya and small island states – and the editors believe that solutions that work in one context cannot be copied in another. In all, the methodological spectrum is wide, ranging from conceptual frameworks to systematic and bibliometric-based literature reviews, comparative policy analysis, optimisation modelling, to surveys and machine-learning based forecasting.

Structure of the book

The book is structured around six thematic sections with sixteen chapters. By design, the sections progress from foundations, systems, technologies and applications to green pathways and finally to forecasting and directions for the future, ushering the reader from the conceptual beginning of the field to its emerging research frontier. This architecture is summarised in Table 1.

Table 1 Structure of the book

Section	Focus	Chapters
I	Foundations of smart and sustainable city logistics	1–4
II	Urban mobility, freight systems and city-level planning	5–7
III	Smart technologies, decision systems and digital transformation	8–10
IV	Sustainable supply chains and industry applications	11–13
V	Green logistics, low-carbon pathways and urban resilience	14–15
VI	Data-driven forecasting and future directions	16–17

Section I: Foundations of smart and sustainable city logistics

The first section lays the conceptual and policy foundations for the rest of the book. Chapter 1 by Singhal and Sharma provides easy access to the field by outlining the trends and enabling technologies that are transforming urban logistics – from the growth of eCommerce demand at the last-mile to decarbonisation, Internet of Things (IoT), artificial intelligence (AI), blockchain, electric vehicles (EVs) and digital twins. In Chapter 2, Kanyepe and Chisungo conduct a systematic literature review to summarise the challenges that urban freight logistics face in achieving sustainability and sketch the lines of the existing scholarship on the subject of sustainable urban freight logistics. In Chapter 3, Prajapati focuses on the policy domain and compares the urban logistics sustainability of major Indian cities to the aspirations of Sustainable Development Goal 11. The section is rounded off with Joshi, Pant and Joshi's smart-governance framework, which combines policy, technology and stakeholder cooperation, anticipating a theme that is revisited throughout the volume: governance, not technology, is what matters.

Section II: Urban mobility, freight systems and city-level planning

The second section moves beyond the foundations to the planning of mobility and freight at the level of specific cities and territories. Dhaundiyal presents a critical analysis of the Comprehensive Mobility Plan and metro rail proposal for Dehradun in Chapter 5, based on the city's vision for mobility and sustainability in the context of the sustainable mobility paradigm. In Chapter 6, Joshi, Awasthi, Ülkü and Sharma explore the experiences of smart urban mobility across different countries through the sharing economy, and suggest a governance framework that would view the platform as a part of the urban infrastructure instead of a business. In Chapter 7, Joshi, Pandey and Pathak further explore the challenging landscape of mountain cities, building on these concepts to create GeoAI-driven approaches to sustainable and resilient urban freight transport where topography, fragility and climate risk amplify every transport move.

Section III: Smart technologies, decision systems and digital transformation

The third section focuses on the technologies and decision support systems for implementing smart logistics. Dhiman and Madan in Chapter 8 provide an overview of trends, tools and transformation for smart logistics systems for sustainable urban supply chains, which places digital technologies in a wider institutional and operational transformation programme. The chapter on dynamic urban waste collection using electric multi-compartment vehicles by Yahia, Larbi, Bahria and Chaabane presents one of the most technically detailed chapters in the book: a decision-support framework based on a combination of mixed-integer programming and a hybrid metaheuristic and validated on a case-study from Montréal. Chapter 10, written by Khan, Shah, Afsar, Jaleel and Abdulla sets the foundations for the technology discussion by taking a unique and informative look at the adoption of smart technologies in landscape construction in the context of resort development in the Maldives and how often the gap between awareness and actual use of technology exists.

Section IV: Sustainable supply chains and industry applications

The fourth section widens the perspective from city logistics to sustainable supply chains and industries in which urban freight is embedded. Shah and Gupta (Chapter 11) make a case for information

systems in the restructuring of manufacturing supply chains for sustainability, suggesting information systems be treated as strategic resources instead of just tools. Goel and Madan present a new conceptual and theoretical framework for smart city logistics, which integrates urban planning, supply chain management, omnichannel logistics and digital transformation to emerge as a unified smart city supply system that is data-driven and intelligent.

Section V: Green logistics, low-carbon pathways and urban resilience

The overall theme of the volume is the environmental imperative, which is highlighted in the fifth section. Chapter 13, by Thakur and Kalra, traces an urban strategic agenda towards urban resilience and low-carbon mobility, drawing lessons from exemplary cities like Singapore, London, Tokyo and Amsterdam, in the context of the Sustainable Development Goals, and finally shows the importance of sustainable logistics as a key component of urban climate-resilience transformation. Complementing this is Chapter 14 by Mandal and Dhani, which looks at sustainable logistics pathways for smart urban ecosystems with a focus on green mobility, stakeholder cooperation and the integration of technology and physical infrastructure to achieve lower-carbon urban delivery.

Section VI: Data-driven forecasting and future directions

The final section provides a glimpse into the future, the possibilities for prediction and future research in the field. In Chapter 15, Sharma, Kumar, Laxmi and Chauhan show how forecasting based on data can make a difference in practice, combining the random forest feature selection with long short-term memory networks for forecasting tourism demand, a technique that can easily be adapted to forecasting urban freight. In Chapter 16, Joshi ties together the threads of the book through a multistakeholder perspective and introduces a Multistakeholder Smart Urban Logistics Framework that integrates public policy, industry innovation and citizen expectations, and outlines a roadmap for the future, where data-driven forecasting and trustworthy artificial intelligence and collaborative governance play a prominent role.

Cross-cutting themes

The chapters are very diverse in method and setting, but there are several themes that recur throughout the book, and together, they

form the main argument of the book. The first is that the solution of sustainable smart city logistics is not just a technical but a sociotechnical and governance solution as well. The contributors repeatedly discover that what holds them back from progress is not technology but the quality of governance, the interest of the parties and the ripeness of the institutions – making collaborative governance, public–private partnership and citizen-centred design first-class design principles.

The second theme is that of context. The priorities of developed economies repeatedly appear in contrast to those of developing economies, which are characterised by rapid urbanisation, lack of infrastructure, informal logistics and a high level of resource scarcity and therefore require more adaptive and inclusive approaches. The implication, made explicit in several chapters, is that good practice needs to be translated not transplanted. The third theme is that of the rise of data-driven forecasting. The contributors illustrate how predictive analytics, machine learning and digital twins are transforming urban logistics from being reactive to anticipatory in the areas of waste collection, tourism demand, freight flows and traffic, warning that these tools will add value only if the data quality and interoperability, the institutional capacities and the explanatory and trustworthy design are ensured.

The constant focus on sustainability and resilience will be a fourth theme. The chapters all approach the triple bottom line, the circular economy and the Sustainable Development Goals from a perspective of the interdependence of economic, environmental and social performance and increasingly also resilience – the ability to absorb and recover from disruption – in a world of pandemics, climate shocks and supply-chain volatility. Lastly, the volume is bound together by a focus on theory, policy and practice: nearly all the chapters combine a conceptual or analytical chapter with practical recommendations for planners, operators and policy-makers who are ultimately responsible for sustainable urban logistics.

Intended audience and contribution

This book has been written for a general audience. For researchers and graduate students, it provides a comprehensive illustration of a rapidly developing, multifaceted field and frameworks, reviews and methods that can provide a basis for further research. It offers comparative evidence, governance models and a phased roadmap for the

design of resilient, inclusive and low-carbon logistics systems for urban planners, transport authorities and policy-makers. It explores the tools, solutions and forecasting tools available in the market and candidly discusses the challenges in their adoption for logistics enterprises, technology companies and supply chain managers. The aim of the volume is not just to provide new knowledge, but also to establish a common language for the sustainable and smart transformation of urban logistics in bringing these audiences together.

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Section I

Foundations of smart and sustainable city logistics

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Sustainable and Smart City Logistics: Innovations, Challenges and Future Directions

Sudhanshu Joshi, Anjali Awasthi, M. Ali Ülkü and Manu Sharma
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Chapter 1
Emerging trends in urban logistics: reviews and transitions

Ishika Singhal and Nagendra Sharma

Graphic Era (Deemed to be University), India

Abstract

Purpose: This chapter explores the new trends and technologies transforming urban logistics and outlines what could constitute the future of last mile delivery, freight transport and urban design in the era of hyperurbanisation, population growth and e-commerce growth.

Design/methodology/approach: The chapter takes a conceptual and forward-looking approach and discusses the key actors for urban logistics change and brings them together in an integrated end-to-end view that combines technology, urban planning and sustainability.

Findings: Conventional logistics systems are under increasing pressure due to congestion, higher carbon emissions, inefficiency in deliveries and limited space access. In addition to shared, electric and automated delivery channels, digitalisation, artificial intelligence, the Internet of Things and big data analytics are paving the way for new service models which enhance the efficiency of operations and offer environmental, traffic and resource optimisation advantages. Achieving these benefits requires as much a public–private alliance, innovation in policies and enabling regulations as it does the technologies themselves.

Practical implications: The chapter shows how cooperation between local governments, urban planners, logistics operators and technology companies in redesigning urban space and creating smart mobility corridors is an essential element of their success, and how the integration of urban planning, smart technologies, data-driven decision-making and sustainability into one coherent strategy is the best approach for developing resilient and future-proof logistics networks.

Originality/value: It provides a future perspective on the reconfiguration of urban logistics, and provides academics, practitioners, policy-makers and urban innovators with a combined perspective on the technology–sustainability interface, which is influencing the urban logistics of tomorrow.

Keywords: artificial intelligence; e-commerce logistics; last-mile delivery; micro-fulfilment; smart mobility; sustainable freight; urban consolidation centres; urban logistics

1.1. Introduction

Rapid urbanisation, population growth and the sustained boom in e-commerce have fundamentally reshaped the structure and operation of urban freight and logistics systems worldwide. The United Nations projects that over 68% of the global population will live in cities by 2050, sharply increasing the demand for efficient and reliable movement of goods within urban areas (UN DESA, 2018). Meanwhile, the evolution of consumer expectation for fast, flexible and even same-day delivery has led to an increase in freight movement in already clogged urban environments (Allen *et al*., 2015). Urban logistics has become an integral part of smart city development and a key element in the sustainability agenda, as timely delivery of goods to companies and households is essential to ensure economic competitiveness and urban liveability. Traditional urban freight transport, which is usually dominated by fossil fuel-powered transport vehicles, is characterised by a lack of coordination between stakeholders, inefficient use of scarce urban space, traffic congestion, high greenhouse-gas emissions (Taniguchi *et al*., 2016). Freight vehicles account for a disproportionate share of urban transport emissions relative to the vehicle-kilometres they travel. As cities set ambitious climate and sustainability goals, the shortcomings of traditional logistics models have become increasingly visible, prompting a shift toward smart and sustainable urban logistics paradigms marked by digital technologies, new delivery models and more integrated governance (He and Haasis, 2020).

Urban freight decision-making is being transformed by real-time tracking, predictive demand forecasting and dynamic route optimisation enabled by artificial intelligence (AI), the Internet of Things (IoT) and big data analytics (He and Haasis, 2020). These digital capabilities are supported by new operational patterns – micro-fulfilment centres, urban consolidation centres, cargo bikes, electric delivery vehicles, crowd-shipping and autonomous delivery – that aim to reduce last-mile inefficiency and emissions (Boysen *et al*., 2021). Digitalisation and sustainability have thus converged into an integrated urban logistics ecosystem in which freight transport is increasingly aligned with wider urban mobility and land-use planning. While the field has received significant academic interest, much existing research still considers the different elements of the field separately, and more complete frameworks that integrate the interdependencies between drivers, enabling technologies, operational innovations, governance and socioenvironmental outcomes are still limited (Savelsbergh and Van Woensel, 2016). To fill this lack, this chapter introduces an Integrated Smart and Sustainable Urban Logistics Framework, which is based on the theoretical concept of urban logistics as a multi-layered system. The framework identifies the principal drivers (urbanisation and e-commerce growth), the enabling power of digital technologies, the role of innovative operational models, and governance and policy coordination as decisive success factors, linking these to measurable outcomes such as emission and congestion reduction, operational efficiency and improved urban liveability. This integrated structure is illustrated in Figure 1.1.

This chapter also adopts a maturity-oriented perspective to characterise how cities progress from traditional freight systems toward digitally enabled, smart and ultimately sustainable urban logistics. This view allows cities to benchmark their current position and identify incremental improvement pathways suited to their institutional and technological readiness (Golinska-Dawson and Sethanan, 2023). The progression is summarised in Table 1.1.

Figure 1.1 Integrated smart and sustainable urban logistics framework

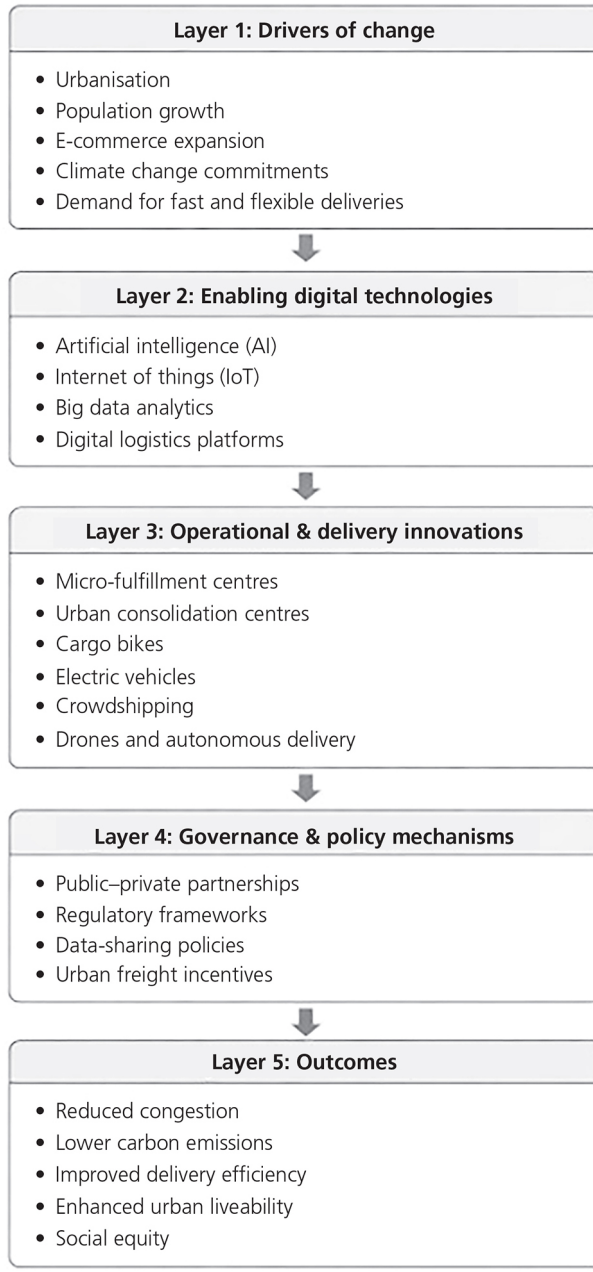


Table 1.1 Urban logistics maturity levels and characteristics

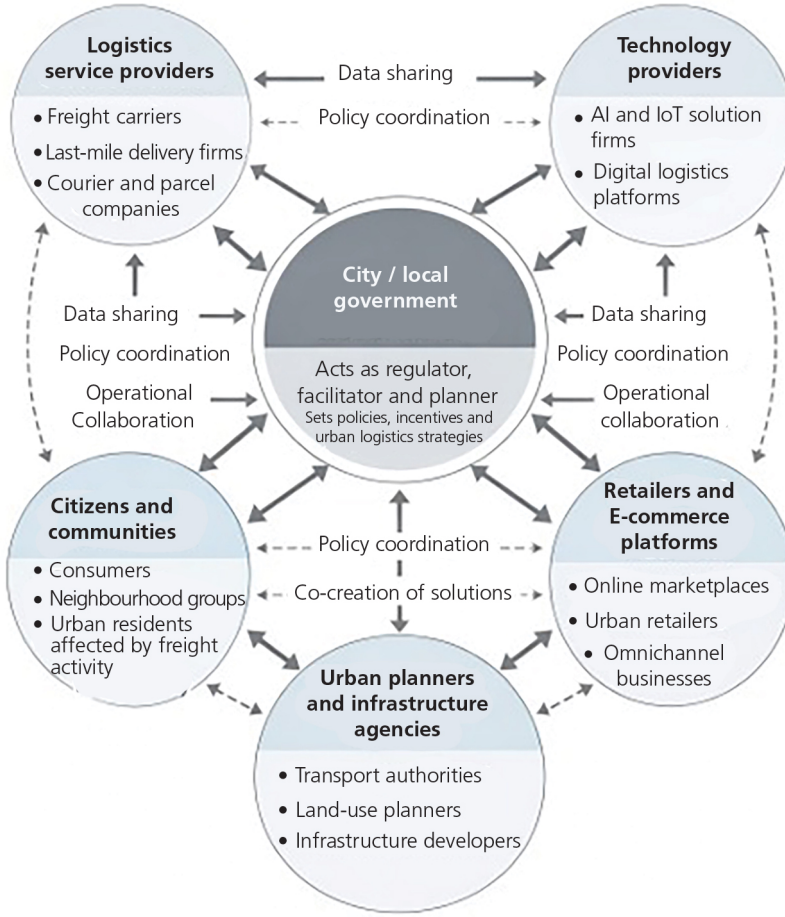
Maturity level	Key characteristics	Technology adoption	Delivery models	Governance approach
Traditional city	Fragmented logistics, diesel fleets, low coordination	Minimal	Conventional vans	Limited regulatory involvement
Digitally enabled city	Route optimisation, global positioning system (GPS) tracking, basic data use	Moderate	Optimised deliveries	Reactive policy measures
Smart logistics city	Integrated platforms, real-time data sharing	High	Micro-hubs, electric vehicles (EVs), cargo bikes	Collaborative governance
Sustainable and resilient city	Zero-emission zones, integrated urban planning	Very high	Multimodal, shared systems	Proactive and strategic policies

Because urban logistics is a multi-actor process, this chapter also incorporates a stakeholder-interaction perspective in which cooperation and data sharing between local governments, logistics providers, technology firms, retailers and urban communities are central. Effective coordination between these actors is needed to ensure that technological innovation is socially inclusive and environmentally sustainable rather than aggravating inequality and congestion (Quak *et al*., 2016). These interactions are conceptualised in Figure 1.2, which illustrates the central role of local governments in facilitating collaboration, data sharing and policy alignment.

This chapter draws on both conceptual and illustrative evidence from major smart cities, such as Amsterdam, Singapore and Barcelona, which have implemented a range of urban logistics initiatives – zero-emission delivery areas, smart freight corridors and urban consolidation centres – that offer insights into how emerging solutions can be scaled and adapted to different regulatory and socioeconomic contexts. Beyond operational performance, the chapter also reflects critically on the wider socioenvironmental implications of these trends, including equity of service access, automation-driven workforce change and urban liveability.

The remainder of the chapter is organised as follows. Section 1.2 discusses the evolution of urban logistics systems and the forces driving their transformation. Section 1.3 examines digital transformation and enabling technologies. Section 1.4 considers emerging delivery models and last-mile innovations and Section 1.5 addresses infrastructure and urban-planning considerations. Section 1.6 turns to governance, policy innovation and public–private partnerships and Section 1.7 concludes with cross-cutting implications and future directions for policy-makers, practitioners and researchers.

Figure 1.2. Stakeholder interaction model in smart urban logistics



1.2. Evolution of urban logistics systems

Urban logistics systems have developed significantly over the past decade as cities have faced accelerating urbanisation, expanding e-commerce and intensifying sustainability pressures. Historically a low-profile element of urban mobility with limited strategic attention in transport and land-use planning, urban freight has been exposed by the rapid growth of goods flows in large urban areas which has revealed the inefficiencies and externalities of traditional systems and prompted more holistic, technology-enabled and sustainability-focused solutions.

1.2.1 The traditional urban logistics paradigm

In the conventional urban logistics paradigm, freight transport was characterised by non-integrated supply chains, low coordination between actors and heavy reliance on internal-combustion-engine vehicles. Optimisation was pursued primarily at the level of the individual firm, with limited attention to system-wide efficiency or urban externalities (Silva *et al*., 2023).

Land-use constraints that pushed warehousing and distribution to the urban periphery often increased delivery distances and the vehicle-kilometres travelled within cities (Viu-Roig and Alvarez-Palau, 2020). These patterns contributed to congestion, air pollution and greenhouse-gas emissions, even though freight vehicles represent a comparatively small share of total traffic volumes. Cities at this stage correspond to the lowest maturity level in Table 1.1, with minimal technology adoption, conventional delivery models and limited regulatory engagement.

1.2.2 Forces driving change in urban logistics

Several interconnected drivers have magnified the deficiencies of existing urban logistics systems. Rapid urbanisation has concentrated populations and intensified demand for goods and services within limited urban space. E-commerce has experienced a dynamic expansion, which has been further boosted by the COVID-19 pandemic, leading to an increase in last-mile deliveries of smaller, more frequent and more time-sensitive consignments (Viu-Roig and Alvarez-Palau, 2020). Consumers have come to expect quicker, easier and contactless delivery, which puts greater pressure on providers to deliver better service performance. The policy dimension has also resulted in the adoption of low-emission zones, zero-emission targets and public-health and climate-oriented freight policies by cities (European Commission, 2020). Together, these drivers – urbanisation, e-commerce growth, sustainability demands and technological development – constitute the drivers layer of the Integrated Smart and Sustainable Urban Logistics Framework in Figure 1.1.

1.2.3 From smart to sustainable urban logistics: a maturity perspective

Urban logistics systems are shifting towards smart and green models in the face of increasing pressures of urbanisation, e-commerce and environmental protection. Smart urban logistics emphasises integration, coordination and data-driven decision-making using digital technologies including AI, IoT, real-time analytics and autonomous systems; these enable visibility, route optimisation and demand forecasting, improving operational efficiency and reducing resource use (He and Haasis, 2020). Smart technologies also help city authorities and logistics providers to plan freight movements more effectively, integrate infrastructure planning and contribute to broader urban sustainability (Golinska-Dawson and Sethanan, 2023).

Adopting smart technologies is not, however, sufficient for sustainability. Sustainable urban logistics seeks a balance between economic effectiveness, environmental protection and social welfare. Electric delivery vehicles, cargo bikes, urban consolidation centres, shared delivery services and low-emission zones are among the measures expected to reduce congestion, emissions and urban externalities (Boysen *et al*., 2021; Perboli and Rosano, 2019). Sustainable logistics also depends on governance coordination, policy instruments and stakeholder relationships that align freight behaviour with climate and urban-development goals (European Commission, 2020). Empirical evidence suggests that electric fleets, collaborative delivery and spatial-planning interventions can substantially reduce emissions and enhance liveability (Viu-Roig and Alvarez-Palau, 2020).

To reflect the variation in technological readiness, governance capacity and infrastructure across cities, a growing body of work adopts a maturity-based approach, classifying cities along a path from traditional, fragmented systems to smart and fully integrated sustainable