The Open Transportation Journal
DOI: 10.2174/0126671212391037250827100344, 2025, 19, e26671212391037
ISSN: 1874-4478
1

REVIEW ARTICLE **OPEN ACCESS**

Accessibility and Spatial Location of Parcel Lockers in Last-mile Delivery: A Literature Review

Tiziana Campisi[1] and Irina Di Ruocco[2,*]

[1]*Department of Engineering and Architecture, University of Enna Kore, Cittadella Universitaria, 94100 Enna, Italy*
[2]*Department of Economics, Mathematics and Statistics, University of Trieste, Alfonso Valerio Street, 4/1, 34127 Trieste, Italy*

Abstract:
Parcel lockers (PLs) are gaining recognition for their role in improving last-mile logistics efficiency and sustainability. They provide a reliable, eco-friendly solution by reducing failed deliveries and optimising logistical operations. However, their relationship with accessibility—both in terms of the user's ability to access the parcel (*e.g.*, convenience) and its spatial distribution, a fundamental criterion for companies —remains an area requiring further investigation, particularly across urban, suburban, and rural contexts.

This review examines studies from 2000 to 2024 to evaluate how PLs contribute to accessibility and identify different adoption factors across context, urban and non-urban (*e.g.* peripheral, rural). Total 48 research papers were analysed to assess trends, challenges, and opportunities related to PLs accessibility.

Findings highlight contrasting perspectives between end-users and logistics providers on parcel locker accessibility. While PLs enhance convenience through 24/7 availability, widespread distribution, and on-demand service, challenges remain in peripheral areas due to unequal distribution, digital literacy barriers, and integration issues within logistics networks. Logistics efficiency and user equity must be balanced to ensure sustainable and inclusive last-mile delivery solutions.

It highlights that accessibility and proximity are notably influencing the implementation and acceptance of parcel lockers. Rural accessibility remains a challenge. Digital divides, cultural barriers, and weak logistics integration create significant obstacles. To maximise the benefits of PLs networks, future research should focus on equitable last-mile strategies, enhanced stakeholder collaboration, and integrated urban planning approaches, ensuring that parcel lockers contribute to a more inclusive and sustainable logistics system.

Keywords: Parcel lockers, Urban logistics, Spatial, Literature review, Location, Proximity, Pickup points.

*Address correspondence to this author at the Department of Economics, Mathematics and Statistics, University of Trieste, Alfonso Valerio Street, 4/1, 34127 Trieste, Italy; E-mail: irina.diruocco@deams.units.it

Cite as: Campisi T, Di Ruocco I. Accessibility and Spatial Location of Parcel Lockers in Last-mile Delivery: A Literature Review. Open Transp J, 2025; 19: e26671212391037. http://dx.doi.org/10.2174/0126671212391037250827100344

Received: February 19, 2025
Revised: April 23, 2025
Accepted: May 27, 2025
Published: August 29, 2025

1. INTRODUCTION

The e-commerce sector has significantly transformed consumer shopping and goods transportation [1], with last-mile delivery (LMD) playing a crucial role in this evolution [2]. The COVID-19 pandemic accelerated the adoption of Parcel lockers (PLs), driven by the surge in e-commerce and the demand for contactless delivery. The COVID-19 pandemic has also brought about changes in the spread of so-called weak demand areas, *i.e.*, those areas with low transport demand that often lack public transport services and that have transport needs not only for passengers but also for small quantities of goods [3, 4]. New service management policies and requirements have recently emerged,

particularly regarding the reception of goods that generally do not exceed 20 kg (classifiable as small and medium-sized) [5, 6].

The rise of digital platforms has increased delivery volumes, diversified goods availability, and heightened the demand for faster, more reliable services [7, 8]. However, this expansion has also exacerbated environmental concerns, as more delivery vehicles contribute to congestion and emissions, raising sustainability challenges [9, 10]. Companies are prioritising eco-friendly logistics solutions, investing in route optimisation and innovative last-mile strategies [11].

The term 'last mile' refers to the final stage of delivery, typically from a distribution centre to the consumer. PLs are closely linked to LMD as they offer an alternative to direct-to-door shipping, helping to reduce inefficiencies such as failed deliveries, high transport costs, and urban congestion. By consolidating shipments at fixed locations, PLs allow logistics providers to optimise delivery routes and increase drop density. However, PLs often function as intermediate collection points rather than true end-points, since the consumer must still retrieve the parcel. This distinction is crucial when evaluating their contribution to LMD, as it shifts part of the last-mile burden to the user. PLs have emerged as a key solution to enhance accessibility, efficiency, and sustainability in last-mile logistics [12, 13]. However, as the adoption of PLs expands across urban, suburban, and rural contexts, several critical research questions remain unanswered, including their role as an accessible solution for customers, both in terms of being a digital-friendly tool and providing access to physical lockers. Addressing these gaps is crucial to developing context-sensitive and equitable last-mile delivery strategies [14, 15].

Parcel lockers have experienced rapid global growth, particularly in Europe, with Poland leading the way with over 39,000 units and InPost expanding to 46,000 units across the continent. DHL and DPD also expanded their networks by nearly 50% and 63%, respectively, in 2024 [15].

With DHL operating 12,500 lockers in Germany (reaching 90% of the population), InPost managing more than 23,000 units across Europe, and Amazon offering lockers in major global markets, parcel lockers have become a key component of the evolving last-mile delivery landscape. Public-sector initiatives, such as Croatia's national network and New York City's LockerNYC program, reflect growing interest in their role for inclusive urban logistics [15].

While PLs enhance efficiency, reduce emissions, and offer convenience, limitations such as unequal accessibility, digital literacy requirements, and integration challenges in non-urban *e.g.*, peripheral, rural areas persist. Since PLs act as intermediaries between transport networks and digital systems. Their placement requires strategic planning to balance efficiency, user needs, and equity.

Therefore, the aim of this research is to survey the extant literature pertaining to the intersection of PLs and accessibility in both urban and non-urban contexts, and subsequently, to determine topics of interest among researchers, research gaps, and opportunities for future research.

The transition from human-received boxes (*e.g.*, collection and delivery points, other kiosks for receiving parcels) to non-human-received collection points (such as automated lockers) has introduced not only new technological demands but also modular flexibility in the design and deployment of parcel lockers [16, 17]. In this context, existing literature on LMD has highlighted the role of PLs as well as alternative delivery solutions, such as collection and pickup (C&P) points, emphasising critical gaps in research and implementation [18, 19]. Studies have shown that parcel lockers have the potential to reduce emissions, traffic congestion, and delivery times, while improving customer convenience [20, 21]. However, challenges related to equitable access, network optimisation, and environmental impacts remain underexplored [22, 23].

1.1. The Parcel Lockers in the LMD

Parcel lockers are automated, secure storage units designed to facilitate last-mile delivery by allowing users to collect or return parcels at their convenience. Strategically placed in urban, suburban, and transit-accessible locations, they offer 24/7 access and reduce failed deliveries, making them a flexible alternative to home delivery [24, 25].

Lockers typically consist of modular compartments of varying sizes. A standard configuration may include small lockers (*e.g.*, 10×15×60 cm), medium lockers (*e.g.*, 20×45×60 cm), and large lockers (*e.g.*, 40×60×60 cm), although exact dimensions vary by provider and system. Most lockers accommodate parcels up to approximately 20–25 kg. Oversized items, such as large electronics, furniture, or goods requiring special handling,often fall outside standard locker capacity and must be delivered by other means.

The permitted storage duration ranges from 24 to 72 hours, after which uncollected parcels are returned or incur storage fees. Some systems allow users to extend pickup windows *via* app-based platforms.

Parcel lockers are especially useful for individuals who lack secure home delivery options or who are frequently away during delivery times [26]. While carrying large parcels home may be inconvenient, users often prioritise security and flexibility, particularly if lockers are located near workplaces or transport nodes [27, 28].

Compared to traditional "PO" or "pick-on-off" options, which require access to postal services during limited hours, and supermarket pickup points, which depend on staff availability, parcel lockers offer automated, round-the-clock functionality. They also support multi-carrier delivery in some networks, enhancing interoperability [29, 30].

1.2. Aim and Scope of the Research

Through the analysis of parcel lockers' spatial distribution across various urban environments, this study assesses their impact on user accessibility and evaluates

whether such systems help mitigate or, conversely, reinforce mobility disparities and logistics-related inequalities.

Active accessibility concerns user proximity to lockers, while network accessibility reflects their spatial distribution, impacting service equity, particularly in underserved areas. Digital accessibility has grown in importance with PINs, QR codes, and app-based authentication, potentially excluding less digitally literate users.

Parcel lockers serve as intermediaries between logistics and digital platforms, reshaping supply chains. While traditional accessibility studies focus on transport, digital and communication aspects remain understudied [31, 32]. Logistics firms increasingly integrate accessibility into location strategies, balancing efficiency, users' needs, and equity [33, 34].

This literature review serves as the primary research tool to achieve this aim. This review was conducted using a critical analysis of resources from the Web of Science (WoS) and Scopus databases. Given the critical role of accessibility in last-mile logistics, this study investigates how spatial location affects [35, 36] parcel locker accessibility across different territorial contexts [37]. The paper addresses the two research questions (RQs), following the approach in a previous study [38]:

(1) "How does the accessibility and spatial location of parcel lockers vary across studies and territorial contexts?", and

(2) "What criteria of different domains (socio-economic, environmental, economic, behavioural) influence the implementation of parcel lockers in different urban and non-urban settings?".

The added value of this paper lies in its comprehensive approach to sustainable urban logistics, particularly its focus on accessibility and its identification of trends in the development of LMD. The findings contribute to a broader understanding of how parcel lockers can play a pivotal role in achieving sustainability in logistics. The structure of the paper is as follows: after this introduction, Section 2 describes the methodological procedure. In Section 3, the results are described, following discussion in Sections 3.4 and 3.5. The paper concludes with a section, Section 5, that describes the limitations and further perspectives of the research.

2. MATERIALS AND METHODS

To structure the case study analysis, a review protocol was developed to guide the identification, selection, and analysis of relevant studies according to similar studies in the field [39, 40], as outlined in Fig. (**1**). By analyzing the literature, the study identifies key spatial, social, and technological factors that influence the accessibility of parcel lockers.

To bridge the gap between academic research and the operational perspective of the logistics sector, this study adopts an innovative approach by integrating gray literature, *e.g.*, corporate white papers, policy documents and articles from specialised logistics and transport journals.

The review method is designed to identify, evaluate, and integrate high-quality and relevant studies addressing predefined research questions. This approach enables researchers to tackle broader questions that single empirical studies cannot fully address. To ensure accuracy and reliability, the literature review follows these key stages:

I) Defining the research scope clearly, outlining the thematic focus on accessibility, spatial optimisation, and sustainability in urban and non-urban last-mile delivery contexts, aligning with the study's objectives.

II) Planning the review, developing a detailed plan, including research questions, inclusion/exclusion criteria, and identification of databases (Web of Science and Scopus) for data collection.

III) Identification of relevant works, conducting a thorough search using well-defined keywords, ensuring all potentially relevant studies are captured.

IV) screening and eligibility assessment applying the inclusion/exclusion criteria to filter works based on relevance, quality, and alignment with the study's objectives. Abstracts and full texts are reviewed to ensure the selected studies directly address the research questions.

Literature papers have been collected through an extensive search of electronic databases, including Scopus and Web of Science. The inclusion criteria that have been applied to the search results are in Table **1**.

Table 1. Inclusion criteria adopted for the literature review. Elaboration of authors.

S. No.	Inclusion Criteria
1.	Peer-reviewed articles (Title, abstract, and keywords on a clear focus/object of the research) and Gray literature
2.	English language
3.	Focus on last mile deliveries; parcel lockers (or collection points, delivery, pickup points)
6.	Focus on urban, peripheral, and rural areas.
7.	Focus on spatial location, accessibility (or proximity)
8.	Papers published after 2000 and up to December 2024
9.	Databases: Scopus / Web of Science

Several different keywords/search terms have been used including "parcel locker*", "collection point*", "mobile depot*", "self-collection", "pack-station*", "pick-up point*", "neighbourhood locker*", "click and delivery point*", "spatial location", "proximity", "accessibility". The use of "*" ensures the collection of articles with both the singular and plural terms.

The combination of these keywords has also been applied as a search criterion using Boolean AND (*e.g.*, last mile deliveries AND accessibility) and OR (*e.g.*, parcel locker* OR pickup point*, spatial location OR proximity) operators. The search was limited to English-language articles, and accessibility or proximity (in terms of spatial location); no limitations to the geographic area and time were adopted. Studies have been conducted in various

fields of the databases, including transportation, economics, business and management, environmental and social sciences, and engineering.

To capture the complexity of urban environments across studies, the selected keywords included terms such as *location*, *spatial*, *proximity*, and *accessibility*. Specific terms like *city*, *urban*, or *rural* were intentionally avoided to prevent creating an overly narrow sample. Additionally, we incorporated three different dimensions of accessibility: *spatial location*, which focuses on identifying optimal locker placement to facilitate deliveries for commercial vehicles; *proximity*, which emphasises the user's convenience in accessing the parcel lockers; and *accessibility*, which takes a broader perspective, including aspects like eco-friendly use and overall usability. The review considers studies published after 2000, taking into account the early growth in the e-commerce market.

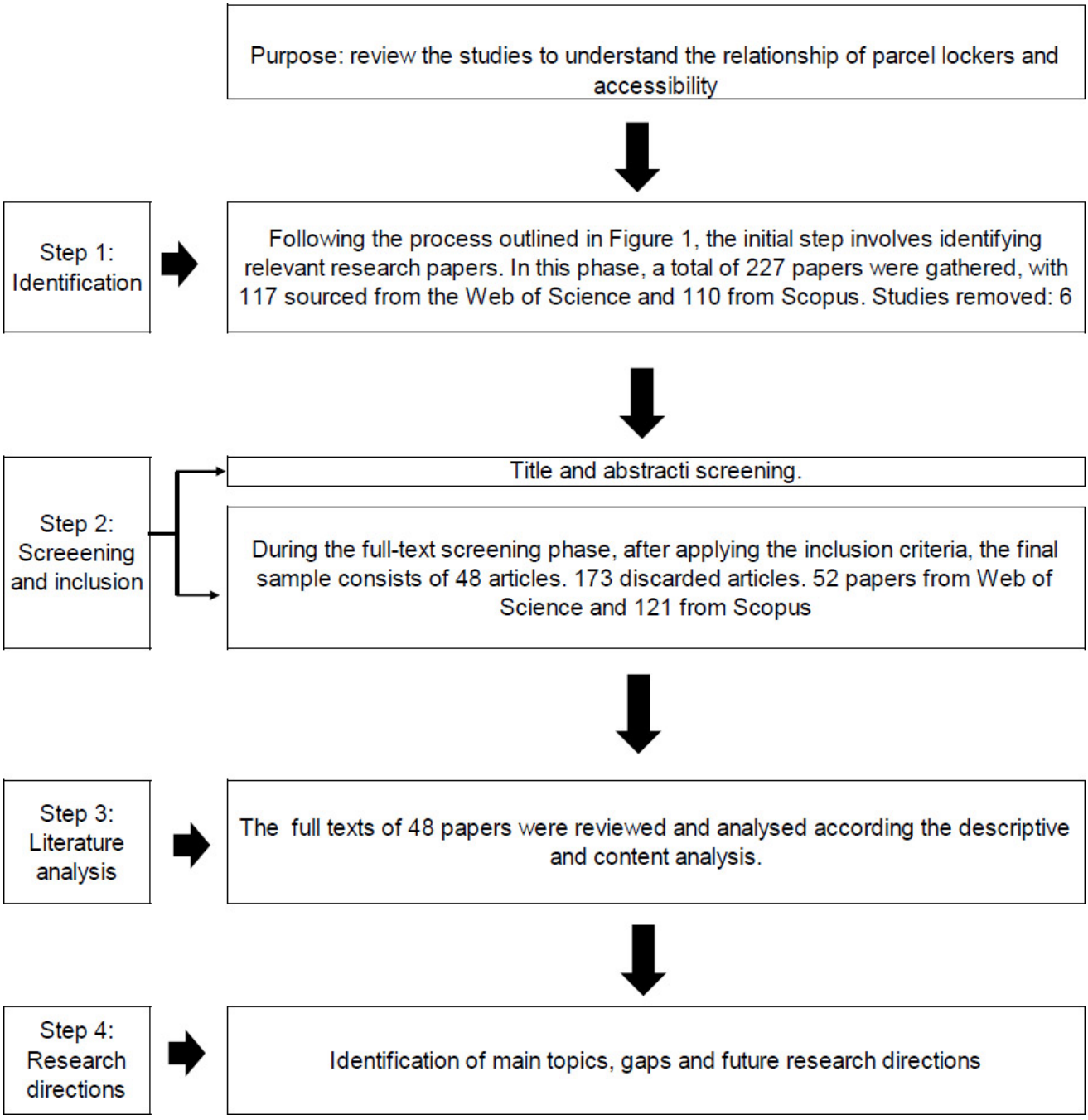

Fig. (1). Literature review flow. Source: Authors owns elaboration.

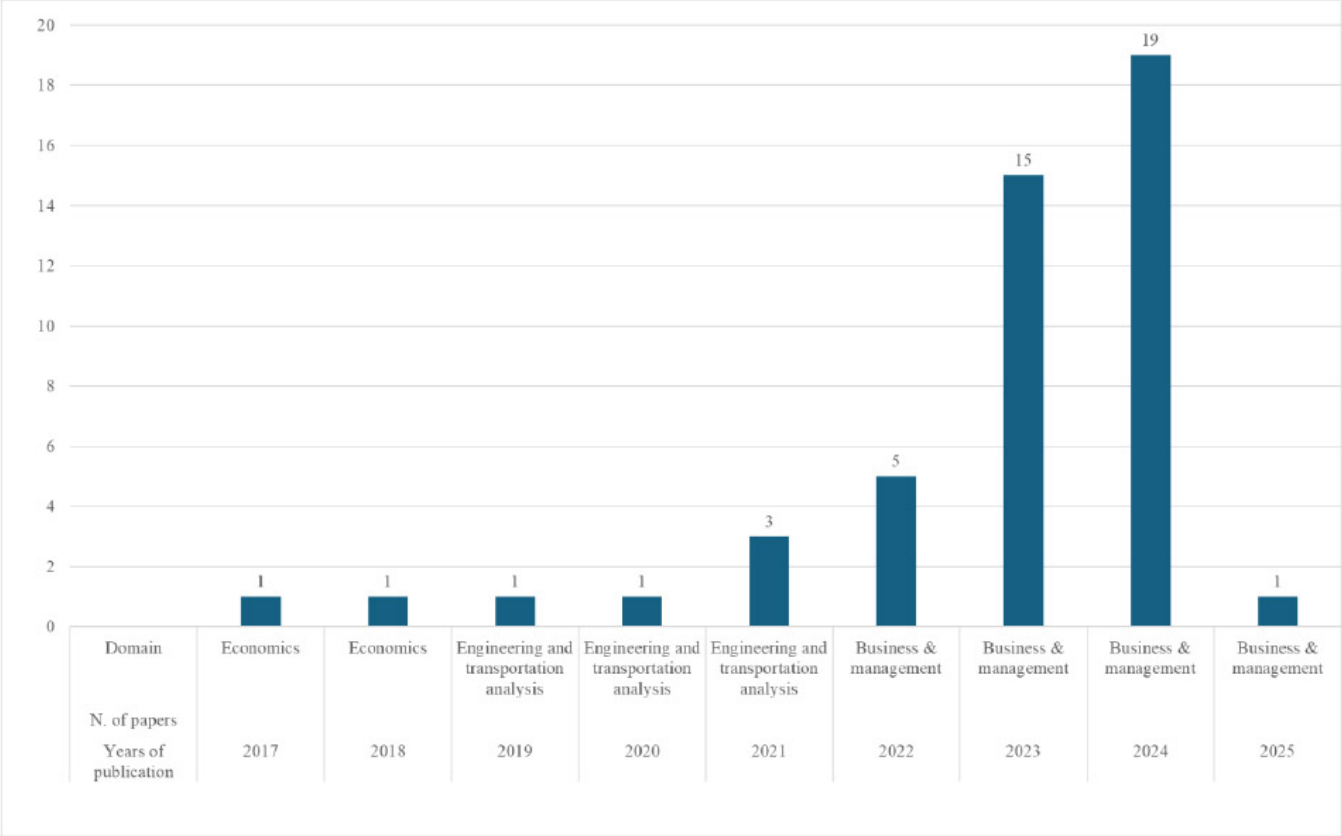

Fig. (2). Number of studies (per domain) and year of publication. Source: Authors owns elaborations.

Following a detailed review of titles, abstracts, and keywords, the initial search yielded a total of 227 articles: 117 publications from WoS and 110 from Scopus. After applying the inclusion criteria during the screening phase, 173 articles were excluded. In the final analysis phase, 96 articles were assessed in-depth, with additional exclusions leading to a final selection of 48 articles. This refined set of studies forms the basis for the insights presented in this review (Fig. **1**).

3. RESULTS

This section presents the results of the literature analysis, which are divided into two main sections: the first part includes the analysis of studies, such as the temporal rise of pickup points, the most frequently used keywords, and the main methodologies adopted in the reviewed studies. The second part focuses on the analysis of studies in terms of findings. Then, the main research areas in line with the RQs have been identified.

3.1. Literature Evidence

The first part of the analysis shows that from 2017 to 2019, the number of publications remained low and relatively stable, with a slight decline around 2018 and 2019. However, from 2020 onwards, research interest began to grow, showing a gradual increase.

Fig. (**2**) illustrates the distribution of publications across different domains. Between 2017 and 2020, output was minimal, with only one paper per year, primarily in economics and engineering, and transportation analysis. A notable upward trend has been observed in 2021, reaching three publications, followed by a further rise to five publications in 2022.

A notable shift occurs in 2023, as research increasingly focuses on business and management, with publications rising sharply to 15, and continuing to grow in 2024, reaching around 19. This upward trend reflects a growing academic interest in PLs, particularly their role in last-mile delivery from the customers' perspective. Recent studies emphasise the spatial distribution and accessibility of PLs, exploring their relationship with urban density, transportation infrastructure, and consumer behaviour. While early research focused on the economic implications of PLs' placement, new works integrate spatial analytics, urban planning, and multimodal transportation. The surge in publications from 2022 onward highlights the expanding relevance of PLs in optimising last-mile logistics, improving accessibility, and advancing sustainable urban mobility. This growth is driven by the convergence of urban sustainability goals, logistical efficiency demands, and social equity concerns.

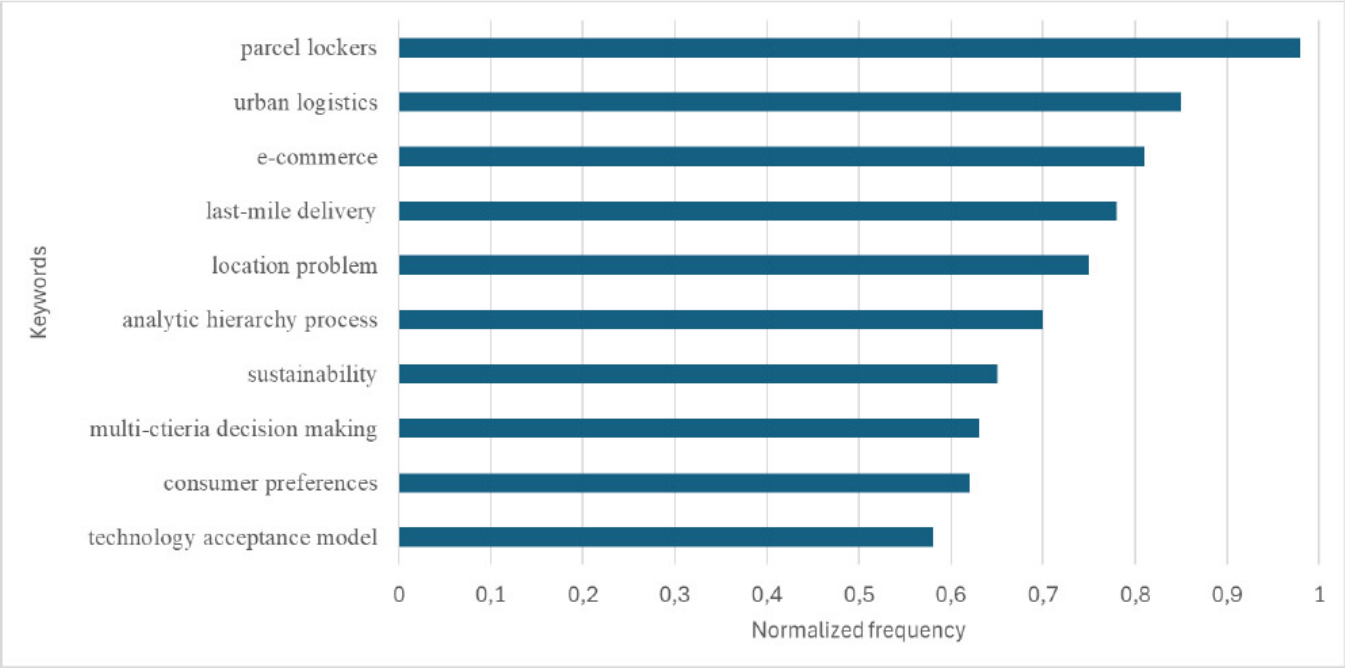

Fig. (3). Frequency of keywords across studies. Source: Author's owns elaboration.

As cities embrace models like the 15-minute city and greener mobility systems, research increasingly examines how PL infrastructure can support these transitions. Furthermore, the rise of data-driven planning, advances in location optimisation tools, and an awareness of spatial inequalities, especially in peripheral and rural areas, have positioned accessibility as a key issue in creating equitable and resilient logistics systems.

Fig. (**3**) describes the common keywords that emerged. It highlights the prominence of key themes in the last-mile delivery research. “Parcel lockers” and “last-mile logistics” dominate, reflecting their central role in optimising urban logistics and e-commerce efficiency. Keywords like “innovation” and “sustainability” emphasize the growing focus on technological advancements and environmental concerns in delivery solutions.

Accessibility plays a significant role in the context of last-mile delivery, particularly in optimising parcel locker locations and urban logistics. While not as prominent as “parcel lockers” or “innovation” in the chart, it is implicitly linked to themes like “spatial accessibility,” “urban freight,” and “sustainability.” Accessibility ensures that delivery solutions are equitable, user-friendly, and strategically placed to benefit diverse populations, underscoring their importance in improving overall logistics efficiency and customer satisfaction.

Table **2** shows the common methodologies used, grouped as qualitative, quantitative, and mixed methods approach.

Qualitative approaches [41] include studies based on case studies, theoretical frameworks, interviews, open-ended surveys, direct observation, or participatory methods (*e.g.*, Delphi). These approaches aim to explore user perceptions, behavioural barriers, decision-making processes, and socio-spatial contexts in depth.

Table 2. Methodology adopted in the studies retrieved for the literature review [13-71].

Methodologies	References
Qualitative	[18, 22, 36, 41]
Quantitative	[13, 14, 16, 17, 19, 20, 21, 25, 26, 27, 28, 29, 34, 42, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 67, 68, 69, 70, 71]
Mixed Methods	[13, 35, 43, 51]

The “Quantitative” approaches involve the use of numerical data and statistical techniques to examine measurable phenomena and relationships between variables. These include regression models, discrete choice models, SEM, GIS analysis, cluster analysis, optimisation models, and simulation tools, which focus on descriptive and exploratory research. These studies analyse behaviours, experiences, and contextual factors in last-mile delivery through non-numerical data. They often rely on methods like interviews, case studies, or observational approaches to provide in-depth insights into user experiences and adoption barriers.

Quantitative research dominates the field [42]. These studies use numerical data and statistical methods, including structural equation modelling SEM, optimisation models, and field experiments. They explore various topics, including spatial optimisation, user adoption, and the environmental impacts of parcel locker systems. By

leveraging measurable data, these studies provide robust evidence for decision-making in logistics. The third category combines both qualitative and quantitative techniques, such as integrating statistical modelling with stakeholder interviews or participatory spatial planning. A detailed summary of the reviewed studies is provided in Table **2** [13-71].

The mixed-methods category combines qualitative and quantitative approaches [43]. These studies integrate numerical data with contextual insights to examine complex phenomena, such as cost-benefit analyses and stakeholder engagement in logistics planning [44]. By blending methods, they offer a comprehensive understanding of the challenges and solutions in urban logistics [45, 46].

This categorization highlights the diversity of methodologies in the field, with quantitative approaches being the most prevalent. It also emphasises the complementary roles of qualitative and mixed methods in capturing user experiences and addressing multifaceted logistics challenges (see Table **2**).

3.2. Research Areas

The second part of this literature analysis focuses on addressing two key research questions: RQ2: "How does the accessibility and spatial location of parcel lockers vary across studies and contexts?" and RQ3: "What criteria influence the adoption of parcel lockers in different urban and non-urban settings?" By examining the final sample, the analysis identifies three thematic areas based on the most frequently discussed topics in the literature: location preferences and accessibility [47], equity and socio-demographics, and location optimisation approaches [48, 49]. These themes highlight how parcel lockers function as both spatial and digital infrastructure while addressing gaps in equity, usability, and distribution strategies across diverse asettings, as shown in Table **3**.

Table 3. Main research areas [13-71].

Research Area	References	No. of Papers
Accessibility Preferences	[19, 20, 21, 25, 29, 36, 37, 47, 48, 49, 50, 51, 58, 59, 62, 69, 70]	17
Equity and Socio-Demographic Aspects	[17, 18, 41, 44, 52, 53, 54, 55, 56, 57, 61, 65, 64, 68, 71]	15
Location Optimisation Approach	[13, 14, 16, 22, 26, 27, 28, 34, 35, 42, 43, 45, 46, 60, 63, 67]	16

3.2.1. Accessibility Preferences

Studies [50, 51] indicate that the optimal placement of parcel lockers depends on a range of spatial characteristics, including proximity to public transportation hubs, the availability of complementary services, and the density of surrounding urban or suburban areas [52].

In urban contexts [53], accessibility is primarily shaped by population density and the availability of multimodal transport systems, emphasising the need to place lockers near transit hubs or high-traffic areas. In contrast, non-urban contexts present unique challenges where proximity to main transport corridors and regional accessibility becomes more critical. For example, lockers placed in suburban or rural areas often require strategic positioning near arterial roads or regional service centres to accommodate lower population densities and ensure accessibility for diverse users [54, 55]. The literature emphasizes the importance of striking a balance between spatial accessibility and logistics efficiency [55], ensuring that parcel lockers are both convenient for users and feasible for delivery operations [56, 57]. Optimal placement must consider walking distance, multimodal integration, and land use compatibility, as shown in studies that apply accessibility indices and simulation-based models [58, 59].

3.2.2. Equity and Socio-demographic Aspects

Equity and socio-demographic factors play a significant role in shaping the accessibility and adoption of parcel lockers. The literature [60-62] highlights how socio-economic conditions, such as income levels, residential patterns, and digital literacy, affect the ability to use parcel locker services. For example, low-income and marginalised communities may face significant barriers if parcel lockers are disproportionately placed in affluent neighbourhoods or high-density urban areas, leaving peripheral or underserved regions without adequate access [63-65].

To address these disparities, equitable distribution strategies are critical. These strategies aim to ensure parcel lockers are accessible to diverse population groups, including individuals in rural or economically disadvantaged areas. The integration of equity into spatial planning is essential to reduce service availability gaps, enabling broader adoption and supporting sustainable last-mile delivery systems [66, 67] that serve all demographics effectively. Additionally, ensuring that digital infrastructure and user interfaces are inclusive is vital for bridging the digital divide [68-70], particularly for populations with lower levels of technological familiarity.

3.2.3. Location Optimisation Approaches

The third thematic issue focuses on the development of advanced quantitative methodologies to optimise the placement of parcel lockers in both urban and non-urban settings. Studies emphasise the use of spatial decision-making models, optimisation algorithms, and Geographic Information Systems (GIS) to address the complex logistical challenges associated with parcel locker placement.

For instance, multi-criteria decision-making tools evaluate factors such as demand patterns, population density, accessibility, and cost-efficiency to identify optimal locations for parcel lockers. These frameworks are designed to enhance user satisfaction, minimise logistical inefficiencies, and integrate parcel lockers seamlessly into broader urban and regional transport systems. Moreover, optimisation models consider environmental impacts, such as reducing delivery-related carbon emissions, by strategically locating lockers to minimise the distance travelled by commercial vehicles.

In rural and suburban areas, location optimisation approaches often focus on overcoming spatial inequities by prioritising connectivity and regional access. For example, GIS-based methods have been used to model underserved areas and identify gaps in parcel locker coverage, enabling planners to address disparities while enhancing overall system efficiency. These approaches align with the broader goal of improving both spatial and digital accessibility, ensuring parcel lockers serve as inclusive infrastructure in last-mile logistics [71].

4. DISCUSSION

This section critically examines the key findings from the literature review, structured around the three thematic areas: accessibility preferences, equity and socio-demographics, and location optimisation for different contexts, to highlight emerging gaps and propose directions for future research.

4.1. Accessibility Preferences

A recurring theme is the importance of spatial characteristics and accessibility in determining the optimal placement of PLs [22]. Proximity to residential areas (*e.g.*, neighbourhoods), transit hubs (*e.g.*, metro and bus stations), and commercial zones plays a key role in enhancing accessibility and encouraging user adoption [42]. Lockers positioned in high-traffic areas, *e.g.*, commuter routes or near shopping centres, significantly improve their utility and convenience for users [46]. Their integration with public transit systems can facilitate trip-chaining, where users combine parcel collection with other daily activities, helping to reduce dedicated trips, improve accessibility [47], and lower emissions.

While studies [46, 47] highlight PL efficiency in urban settings, others [48] reveal challenges in rural areas, where low population density limits economic feasibility and infrastructure gaps hinder accessibility.

High-density urban areas provide an advantageous setting for PL deployment, driven by higher demand and improved operational efficiency [49, 50]. Urban settings often offer the population density required to maximize locker usage and reduce per-unit operational costs. At the same time, safety and usability remain significant considerations in these environments. Features such as proper lighting, clear signage, and clean, well-maintained surroundings contribute to user satisfaction and inclusivity [51].

Sparse population densities in suburban and rural areas, higher operational costs, and a preference for home delivery in these regions limit the widespread adoption of parcel lockers. Additionally, the lack of integration with multimodal transport networks further complicates their deployment in less dense areas.

A study found that Moroccan consumers are motivated to shop online based on factors such as the temporal and spatial flexibility of lockers, competitive pricing, and the quality of retailer websites [52]. However, barriers like delivery risks, privacy concerns, and product security significantly affect online purchasing decisions.

4.2. Equity and Socio-demographic Aspects

A relevant contribution of this study lies in highlighting emerging aspects related to spatial equity within last-mile delivery, as discussed in the second thematic area. While not yet fully established in the literature, these aspects are gaining attention and deserve further exploration. Equity and socio-demographic considerations are fundamental in shaping the accessibility and adoption of parcel lockers. Research demonstrates that factors such as income levels, age, digital literacy, and residential distribution significantly influence user behaviour and access to PL services [19]. As shown in a previous study, the absence of lockers in such areas may reinforce spatial inequities, especially where car ownership is limited [25]. This underscores the need for equitable distribution strategies to ensure that lockers are not disproportionately concentrated in affluent or densely populated neighbourhoods. Communities in underserved or low-income areas, for example, often rely on strategically placed lockers near supermarkets or transit hubs to bridge accessibility gaps [51-54].

The 15-minute city model, for example, can enhance the effectiveness of parcel lockers by promoting sustainable commuting towards these smart warehouses. PLs become more visible, accessible, and frequently used, benefiting from high pedestrian flows and integration into daily routines. This proximity reduces failed deliveries, encourages low-impact collection modes (such as walking, and cycling), and supports a more equitable distribution of last-mile infrastructure, particularly in underserved neighbourhoods. To create a truly inclusive 15-minute logistics network, planning must account for marginalised groups, including individuals with disabilities, older adults, and low-income residents. While progress has been made in improving accessibility to daily services, logistical equity remains a relatively underexplored dimension [55]. The analysis of families in Greece and Italy found that availability, safety, and security are critical factors influencing the use of PLs, particularly for younger demographics. Accessibility is also a behavioural choice. A study [56] has shown how the relative attractiveness of locker services, compared to other delivery options, directly affects user adoption and location preferences. While parcel lockers are often studied in terms of location efficiency [57] and cost reduction, a significant gap remains regarding their potential alignment with the 15-minute city model, which promotes dense, mixed-use, and walkable urban environments. It has been suggested that integrating lockers into this urban planning framework could improve accessibility for a wider demographic and address persistent gaps in underserved communities [58].

Research highlights that income disparities, digital literacy gaps, and limited access to banking or smartphone-based authentication systems can hinder the adoption of PLs among marginalised groups [59-61]. Digital accessibility is acknowledged, but further research should explore usability challenges, especially for less digitally literate users. Dependence on PINs, apps, and authentication systems may create barriers in adopting certain demographics, impacting both accessibility and inclusivity [62, 63].

Additionally, the spatial distribution of lockers may disproportionately favour higher-income areas, exacerbating accessibility inequalities. Addressing these challenges requires targeted strategies, such as integrating PLs into public spaces, transit hubs, or community centres in underserved areas [63]. Future studies should explore how socio-economic factors intersect with digital accessibility and infrastructure planning to ensure a more equitable distribution of parcel lockers across different population groups. While urban areas benefit from high-density placement, rural and suburban regions face significant adoption barriers, including lower population densities, higher infrastructure costs, and limited multimodal transport access, all of which impact deployment feasibility and service equity.

4.3. Location Optimisation Approaches

Decision-making models, such as the Spherical Fuzzy Analytic Hierarchy Process (SFAHP), Real-Time Spatial Delphi (RTSD), and GIS-based tools, are increasingly employed to refine location strategies and address complex logistical challenges. These models prioritise accessibility, operational efficiency, and user satisfaction, enabling planners to identify optimal locations that balance these criteria. It has been found that the quality of customer service provided by self-service technologies for last-mile delivery, which utilize automated parcel lockers, plays a crucial role in shaping user satisfaction and adoption. This suggests that technical performance must be complemented by attention to user experience and service accessibility. This study examines parcel lockers in terms of accessibility and spatial distribution; however, cost-effectiveness is key to their large-scale deployment. Urban PLs benefit from economies of scale, while rural areas face lower demand and higher costs.

Additionally, spatial optimisation methods focus on balancing urban and rural needs by adjusting placement strategies to reflect population density and demand intensity. Dynamic systems, such as mobile parcel lockers (MPLs), further enhance accessibility by adapting to real-time demand variations. Techniques like K-means clustering and location-routing integration have demonstrated success in minimising delivery distances and improving customer satisfaction [59].

4.4. The Spatial Location of Parcel Lockers: Main Factors and Literature Gaps

The placement and accessibility of PLs are determined by several critical factors, which play a central role in their adoption and success. The main factors include:

Proximity to users is consistently identified as a primary factor influencing the adoption of PLs, but rather than being a trivial observation, recent studies offer quantified evidence to support this relationship. From an environmental perspective, positioning lockers in areas that minimise vehicle movements helps reduce traffic congestion and carbon emissions. Locating PLs within high-density urban areas, near public transportation hubs, or integrated into 15-minute city frameworks aligns with broader sustainability objectives by enabling multimodal travel and reducing reliance on private vehicles.

For example, a study has shown that PLs located within 300 to 1500 metres from the residential area or a workplace significantly improve the likelihood of use [27].

4.4.1. Support for Multimodal Transport

Some studies suggest that lockers should also cater to cyclists and pedestrians to encourage sustainable transport modes. However, current implementations often prioritise car accessibility, particularly in suburban areas [36]. Proximity to train stations is positively correlated with higher taxi demand, likely related to the needs of long-distance travellers. This effect is not merely due to distance, but to the alignment of locker locations with users' daily mobility patterns. As illustrated, strategically situating lockers in high-traffic areas such as supermarkets, commercial centres, or transportation hubs enables users to incorporate parcel collection into their regular routines; a phenomenon known as trip-chaining [44, 45]. This integration reduces the need for dedicated travel to collect parcels, thereby enhancing convenience, increasing adoption, and supporting more sustainable travel behaviour. Spatial density and urban characteristics: High-density areas, such as urban centers with higher population density and foot traffic, are preferred for locker placement due to their higher demand and operational efficiency. Lockers in these areas serve larger user bases and minimise last-mile delivery distances. Interestingly, in suburban and rural areas, as lower-density areas, lockers must balance accessibility with cost efficiency. A greater distance between lockers (*e.g.*, 20 kilometres in rural regions) can still provide adequate coverage if they are placed near community hubs or main roads.

Integration with transportation networks: the public transit accessibility, *i.e*. the locations near bus stops, train stations, or park-and-ride facilities (*i.e*. bike according to [61] are particularly effective in urban settings, as they support trip-chaining, where users incorporate parcel collection into their commuting routines.

During the evening peak hours (17:00–19:00), the taxi demand pattern resembles that of the morning peak, with long-distance bus terminals, bus stations, and parking and bike sharing areas remaining key areas of demand. Notably, parking areas frequently serve as pick-up points for passengers during this time, possibly associated with evening activities and entertainment [62].

4.4.2. Accessibility Features

The design and safety show novel interpretation of PLs. Well-located, secure, and easily navigable locker locations enhance user trust and adoption. Accessibility features, such as ramps and disability parking, are essential to ensuring inclusivity. Another relevant aspect is the operating hours. Lockers with 24/7 availability or extended access hours are preferred, as they enable users to collect parcels at their convenience [63].

4.5. Socio-economic and Demographic Factors

In this group, many aspects in common with current studies emerged, such as equity and inclusion in LMD. Younger users and large households exhibit higher usage rates, driven by their greater reliance on e-commerce, technological adaptability, and frequent package deliveries. Previous literature emphasised that factors such as reliability, timeliness, accessibility, and completeness are essential for supporting electronic exchange practices, as they contribute to evaluating both economic benefits (*e.g.*, reduced coordination costs) and environmental advantages (*e.g.*, decreased transportation impact). The spatial location of PLs remains a relevant and complex issue for companies, enhancing their delivery profits. Studies on optimisation focus on dynamic planning. Incorporating real-time data and demand variations into locker placement strategies ensures optimised use, particularly in urban settings with fluctuating delivery volumes.

Ensuring that lockers are accessible to underserved populations (in peripheral or remote areas), including low-income or transit-dependent individuals, addresses disparities in service availability [64]. “Denied proximity” exacerbates logistical service inequalities, particularly when considering that parcel lockers function as decentralised micro-warehouses, designed to provide convenient access to deliveries. This disparity is especially pronounced in low-income neighbourhoods, where car ownership rates are lower, making proximity to lockers even more crucial for daily needs. The spatial distribution of parcel lockers is shaped by multiple urban and socio-economic variables, including population density, land availability, housing prices, urban infrastructure, community layout, and street network proximity [64, 65]. Ensuring equitable accessibility to parcel lockers requires a data-driven approach that accounts for these factors, helping to mitigate disparities and improve logistical inclusion across diverse urban environments.

From an operational standpoint, the cost-effectiveness of PLs is maximized when they are placed in locations that increase delivery density and minimise travel distances for logistics providers. Deploying lockers in transit hubs, commercial centres, and residential clusters facilitates consolidated deliveries, improving efficiency and reducing operational costs. In low-density areas, however, achieving this balance becomes more challenging, requiring a data-driven approach to determine the most effective placement strategy. Future urban logistics planning should prioritise equitable distribution, ensuring that both high- and low-density areas benefit from improved access to sustainable delivery solutions.

However, gaps persist in understanding the role of equity in non-urban areas, where spatial disparities can be more pronounced. There is also limited exploration of how socio-economic characteristics influence the success of PL deployments, particularly in rural settings [65, 66]. Notably, few studies have examined the specific needs of families, with most focusing on middle-aged or working-age populations. Addressing these gaps is crucial for ensuring that parcel lockers serve a broader demographic spectrum, including families and older adults, who may face unique mobility challenges. Despite these innovations, there are gaps in assessing the long-term impacts of these strategies and their integration into broader urban frameworks, such as smart cities. Moreover, the scalability of these solutions for non-urban contexts remains underexplored. Additionally, pick-up points have proven to be effective tools for mass consolidation and pooling, which are readily utilised by e-merchants to streamline operations. Optimal location is one of the inverse factors driving the (economic) choice of couriers [67, 68].

4.6. Comparison Across the Different Location Contexts

The location of parcel lockers varies significantly across studies and contexts, reflecting differences in urban density, user preferences, and logistical goals. Firstly, in urban areas, the PLs are commonly placed in high-traffic areas such as transit hubs, commercial centres, and residential complexes. Studies [25] highlight the preference for locations with high population density, multimodal transport accessibility, and proximity to workplaces. For example, in Vietnam, a study found that lockers near workplaces or residential areas are preferred for convenience and security [29]. In suburban settings, parcel lockers are often placed near shopping centres, community hubs, or park-and-ride facilities [36]. It emerges that cultural factors, as well as distance and accessibility, are the main determinants of choice according to [44], while regional factors shape location choices. While in rural areas, some studies [49, 51] emphasise that rural parcel lockers are typically spaced farther apart, averaging 20 kilometres between units, to accommodate lower population density. In Morocco, it has been noted that accessibility and competitive pricing heavily influence adoption [52]. These locations facilitate trip chaining and reduce last-mile inefficiencies, making them integral to urban logistics. Strategic placement in central community locations ensures coverage while maintaining cost-effectiveness. The placement also reflects regional consumer behaviour and logistical constraints.

4.7. Further Research Recommendations

The analysis highlights that while parcel lockers offer clear benefits in terms of operational efficiency and environmental sustainability, their effectiveness is highly context dependent. Research directions addressing the two RQs on parcel lockers focus on three key points: social sustainability, spatial optimisation, and policy programs.

Regarding RQ1, the analysis shows that accessibility is influenced by a combination of spatial, demographic, and infrastructural factors, which vary significantly between urban, suburban, and rural settings. In dense urban areas, parcel locker usage increases when they are located near transit hubs, aligned with daily commuting routes, and concentrated around commercial centers In suburban and rural contexts, lower population density and car depen-

dency limit access, often requiring innovative placement strategies to ensure coverage. Furthermore, socio-demographic characteristics, such as age, income, and household composition affect users' preferences and their capacity to benefit from parcel locker services. These differences highlight the need for context-sensitive approaches to spatial planning and last-mile logistics. The next points offer an overview of the RQ2:

4.7.1. Spatial Optimisation

Strategic placement near public transport, commercial hubs, and residential areas enhances accessibility and logistical efficiency. However, rural and suburban areas face significant accessibility challenges, as lower population densities reduce the financial viability of widespread locker deployment. The study finds that GIS and AI-driven models can enhance placement strategies, ensuring equitable distribution of services [43]. Additionally, lockers placed along commuter routes and transit hubs increase accessibility while reducing vehicle reliance, strengthening last-mile delivery networks.

4.7.2. Social Sustainability

Parcel lockers reduce emissions and congestion by enabling delivery consolidation, which minimises the number of individual drop-offs. However, their environmental benefits depend on location, as low-density areas require users to travel longer distances for pick-ups, potentially offsetting sustainability gains. Furthermore, energy-efficient solutions such as solar-powered lockers and automated systems could further mitigate the environmental impact.

4.7.3. Policy Programmes

The study finds that regulatory frameworks, financial incentives, and public-private partnerships are essential to expanding locker networks and ensuring their alignment with sustainability and accessibility goals. Emerging technologies, such as IoT-enabled smart lockers and AI-driven optimisation models, offer innovative solutions for enhancing efficiency and addressing user demand fluctuations. Additionally, embedding lockers in urban planning concepts like the "15-minute city" could further improve equitable access to last-mile logistics [58, 63].

Concerning the RQs, the findings of this review reveal that parcel locker accessibility is not a uniform phenomenon but rather a dynamic interplay between urban structure, logistics strategy, and mobility systems. Accessibility, in both its active dimension (user reachability) and its spatial dimension (logistics company placement decisions), exhibits distinct patterns across urban and non-urban environments, shaped by land use, population density, and transport integration.

In high-density urban areas, lockers naturally align with walkable environments. However, in suburban and rural settings, accessibility is fragmented, with car dependency and extended travel distances creating a logistical paradox: while lockers could reduce last-mile inefficiencies, their effectiveness is undermined by dispersed demand and insufficient multimodal access.

Accessibility, spatial equity, and user acceptance vary significantly across different geographical settings, confirming that a one-size-fits-all model is not suitable. For example, user preference in Vietnam tends to favour lockers near residential or work areas for security and convenience, while in Morocco, affordability and accessibility are more influential. Rather than treating these as isolated observations, this study highlights the importance of designing adaptive and inclusive delivery models that reflect socio-spatial realities.

To bridge these gaps, this study calls for further research on a hybrid spatial strategy that moves beyond conventional placement models, combining transit-oriented deployment, predictive analytics for demand forecasting, and adaptive locational clustering to maximize accessibility across diverse urban landscapes. Additionally, integrating parcel lockers into shared mobility ecosystems, leveraging smart-routing algorithms, and introducing flexible, modular locker systems could enhance adaptability in underserved areas.

While PLs are often described as eco-friendly and beneficial for sustainability, these claims lack clear empirical validation [65-68]. Most studies highlight theoretical advantages rather than measurable impacts, making their actual contribution to sustainability uncertain. Factors such as location, user behaviour, and public transport integration play a crucial role in their environmental footprint [69]. To verify PLs as a sustainable innovation, future research should include lifecycle assessments and real-world impact studies, especially on vulnerable users [70, 71]. Future research could explore how public-sector initiatives such as subsidies, partnerships with national postal services, and integrated urban planning strategies can enhance parcel locker accessibility in underserved or low-density areas, as suggested in recent studies. These mechanisms may help address spatial inequalities not typically prioritised by private logistics operators.

CONCLUSION

This study highlights the evolving role of parcel lockers in urban and non-urban logistics, emphasising their impact on accessibility, sustainability, and policy development. Findings suggest that strategic placement near public transportation, commercial hubs, and residential areas enhances accessibility; however, challenges persist in rural and suburban regions, where coverage gaps limit service equity. These insights respond to RQ1, confirming that both spatial and socio-demographic variables shape the accessibility and adoption of parcel lockers. These findings align with previous studies that call for integrating resilience and customer/user-centric approaches into last-mile logistics systems, considering the last-mile delivery into digital-social and equity systems. Sustainability emerges as a key benefit, with parcel lockers reducing last-mile emissions and alleviating congestion through delivery consolidation. However, environmental advantages vary based on urban density and transport integration, highlighting the need for alternative mobility solutions such as cycling and public transit connections. While previous studies have primarily

analysed parcel lockers in dense urban environments, our study expands the discussion by proposing context-sensitive solutions for suburban and rural settings, where accessibility remains limited. However, our study further highlights that digital accessibility, often overlooked in parcel locker adoption, represents an additional barrier, particularly for marginalised user groups.

From a policy perspective, regulatory support, financial incentives, and emerging technologies like IoT-enabled smart lockers and AI-driven optimisation models are essential for improving service efficiency and expanding accessibility. These technologies also respond to RQ2, showing how intelligent systems can support dynamic locker allocation, predict demand fluctuations, and optimise user experience, particularly in high-density environments. While previous research has explored policy -driven deployment strategies, our findings emphasize the necessity of integrating parcel lockers into urban planning frameworks, such as the “15-minute city”, as this could further enhance sustainability and liveability.

Future research should investigate the socio-economic impact of parcel lockers, particularly their role in promoting a circular economy and improving logistics resilience. Additionally, exploring policy incentives for equitable deployment and integrating smart technologies (*e.g.*, IoT-enabled lockers) could enhance sustainability and accessibility. Unlike existing studies that primarily focus on efficiency and environmental benefits, our research suggests that addressing user behaviour, infrastructure adaptation, and digital accessibility will be crucial for optimising their role in sustainable logistics, ensuring the active accessibility for users as a daily-service, aligning with results from Raviv who found that optimising the network design of parcel lockers by balancing location, capacity, and operational costs can further enhance LMD efficiency while maintaining service quality. Looking ahead, the role of Artificial Intelligence (AI) and automation will be central to the future management of parcel lockers. Predictive analytics and machine learning algorithms can forecast peak usage times, enhance routing efficiency, and adjust locker capacity to accommodate seasonal or event-based fluctuations. These innovations, already being piloted in several logistics networks, will be critical for scaling up locker systems, improving user satisfaction, and integrating lockers into intelligent, sustainable, and inclusive last-mile logistics ecosystems. In this way, PLs system highlights the necessity to enhance the supply chain resilience [73-78].

AUTHORS’ CONTRIBUTIONS

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

LIST OF ABBREVIATIONS

PLs	=	Parcel lockers
LMD	=	Last-mile delivery
C&D	=	click and delivery points
C&C	=	click and collection points
AI	=	artificial intelligence
GIS	=	Geographic Information Systems
PO	=	pick-up on/off options

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

Tiziana Campisi is the EIC of the journal TOTJ.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] H.T.K. Le, A.L. Carrel, and H. Shah, "Impacts of online shopping on travel demand: A systematic review", *Transp Rev,* vol. 42, no. 3, pp. 273-295, 2022.
[http://dx.doi.org/10.1080/01441647.2021.1961917]

[2] T. Campisi, G. Tesoriere, A. Russso, and M.A. Al-Rashid, "Spatial distribution and characterization of consumers of E-grocery services in sicily", *Engineering review,* vol. 43, no. 3, pp. 54-67, 2023.
[http://dx.doi.org/10.30765/er.2177]

[3] T. Campisi, G. De Cet, C. Vianello, and C. Garau, "“Exploring economic and ethical challenges of implementing demand-responsive transport systems (DRT) in Italy", *Eur Trans,* no. 98, pp. 1-13, 2024.
[http://dx.doi.org/10.48295/ET.2024.98.7]

[4] R. Gkavra, Y.O. Susilo, and R. Klementschitz, "Determinants of usage and satisfaction with demand responsive transport systems in rural areas", *Transp Res Rec,* vol. 2678, no. 6, pp. 667-680, 2024.
[http://dx.doi.org/10.1177/03611981231198834]

[5] İ. Çelik, E. Aydemir, H. İ. Cebeci, and S. Güner, "Last-mile delivery performance of crowdsourced couriers: Text mining of user comments", *Int J Logist Res Appl,* pp. 1-22, 2025.
[http://dx.doi.org/10.1080/13675567.2025.2472745]

[6] A.S. Shuaibu, A.S. Mahmoud, and T.R. Sheltami, "Last-mile delivery optimization: Recent approaches and advances", *Transp Res Procedia,* vol. 84, pp. 299-306, 2025.
[http://dx.doi.org/10.1016/j.trpro.2025.03.076]

[7] A. Muñoz-Villamizar, J.C. Velazquez-Martínez, and S. Caballero-Caballero, "A large-scale last-mile consolidation model for e-commerce home delivery", *Expert Syst Appl,* vol. 235, p. 121200, 2024.
[http://dx.doi.org/10.1016/j.eswa.2023.121200]

[8] J. Kim, S.J. Kweon, S.W. Hwang, and S. Lee, "Crowdsourcing integration on the last mile delivery platform considering floating population data", *Expert Syst Appl,* vol. 248, p. 123312, 2024.
[http://dx.doi.org/10.1016/j.eswa.2024.123312]

[9] S.T. Peinkofer, M.A. Schwieterman, and J.W. Miller, "Last-mile delivery in the motor-carrier industry: A panel data investigation using discrete time event history analysis", *Transp J,* vol. 59, no. 2, pp. 129-164, 2020.
[http://dx.doi.org/10.5325/transportationj.59.2.0129]

[10] O. Rotem-Mindali, and J.W.J. Weltevreden, "Transport effects of e-commerce: What can be learned after years of research?",

Transportation, vol. 40, no. 5, pp. 867-885, 2013. [http://dx.doi.org/10.1007/s11116-013-9457-6]

[11] A. Russo, S. Basbas, E. Bouhouras, G. Tesoriere, and T. Campisi, "The study of the 5-min walking accessibility for pickup points in Thessaloniki: Enhancing logistics' last mile sustainability", *Proc Int Conf Comput Sci Appl,* , 2024pp. 41-53 [http://dx.doi.org/10.1007/978-3-031-65308-7_4]

[12] Y. Deutsch, and B. Golany, "A parcel locker network as a solution to the logistics last mile problem", *Int J Prod Res,* vol. 56, no. 1-2, pp. 251-261, 2018. [http://dx.doi.org/10.1080/00207543.2017.1395490]

[13] M. Peppel, and S. Spinler, "The impact of optimal parcel locker locations on costs and the environment", *Int J Phys Distrib Logist Manag,* vol. 52, no. 4, pp. 324-350, 2022. [http://dx.doi.org/10.1108/IJPDLM-07-2021-0287]

[14] L. Bell, S. Spinler, M. Winkenbach, and V. Müller, "Assessing economic, social and ecological impact of parcel-delivery interventions in integrated simulation", *Transp Res Part D Transp Environ,* vol. 121, no. 103817, p. 103817, 2023. [http://dx.doi.org/10.1016/j.trd.2023.103817]

[15] "20 years of DHL Packstation parcel lockers", Available from: https://www.thepostalhub.com/blog/dhl-deutsche-post-packstation-parcel-locker-20-years

[16] S. Sina Mohri, N. Nassir, R.G. Thompson, and H. Ghaderi, "Last-Mile logistics with on-premises parcel Lockers: Who are the real Beneficiaries?", *Transp Res, Part E Logist Trans Rev,* vol. 183, p. 103458, 2024. [http://dx.doi.org/10.1016/j.tre.2024.103458]

[17] S. Jang, D. Hong, and C. Lee, "Exploring the behavioral adoption of automated parcel locker systems under COVID-19", *Transp Policy,* vol. 151, pp. 1-11, 2024. [http://dx.doi.org/10.1016/j.tranpol.2024.03.016]

[18] M. Cebeci, M. De Bok, and L. Tavasszy, "The changing role and behaviour of consumers in last mile logistics services: A review", *J Supply Chain Manag Sci,* vol. 4, no. 3-4, pp. 114-138, 2023. [http://dx.doi.org/10.59490/jscms.2023.7265]

[19] R. Villa, and A. Monzón, "A metro-based system as a sustainable alternative for urban logistics in the era of e-commerce", *Sustainability,* vol. 13, no. 8, p. 4479, 2021. [http://dx.doi.org/10.3390/su13084479]

[20] D.R. Pinchasik, I.B. Hovi, and B. Dong, "Replacing home deliveries by deliveries to parcel lockers: Cost, traffic, emissions, and societal cost effects of locker network expansions in greater Oslo", *Int J Logist Res Application,* vol. 1, pp. 1-26, 2023. [http://dx.doi.org/10.1080/13675567.2023.2286006]

[21] M. Peppel, S. Spinler, and M. Winkenbach, "Integrating mobile parcel lockers into last-mile delivery networks: An operational design for home delivery, stationary, and mobile parcel lockers", *Int J Phys Distrib Logist Manag,* vol. 54, no. 4, pp. 418-447, 2024. [http://dx.doi.org/10.1108/IJPDLM-01-2023-0055]

[22] A. Ranjbari, C. Diehl, G. Dalla Chiara, and A. Goodchild, "What is the right size for a residential building parcel locker?", *Transp Res Rec,* vol. 2677, no. 3, pp. 1397-1407, 2023. [http://dx.doi.org/10.1177/03611981221123807]

[23] E. Rosca, F. Rusca, M.A. Rosca, and A. Rusca, "Performance analysis of automated parcel lockers in urban delivery: Combined agent-Based–Monte Carlo simulation approach", *Logistics,* vol. 8, no. 2, p. 61, 2024. [http://dx.doi.org/10.3390/logistics8020061]

[24] K. Hofer, S. Flucher, M. Fellendorf, M. Schadler, and N. Hafner, "Estimation of changes in customer's mobility behaviour by the use of parcel lockers", *Transp Res Procedia,* vol. 47, pp. 425-432, 2020. [http://dx.doi.org/10.1016/j.trpro.2020.03.118]

[25] K.L. Keeling, J.S. Schaefer, and M.A. Figliozzi, "Accessibility and equity analysis of transit facility sites for common carrier parcel lockers", *Transp Res Rec,* vol. 2675, no. 12, pp. 1075-1087, 2021. [http://dx.doi.org/10.1177/03611981211032214]

[26] J. Chen, R. Li, J. Ma, and Q. An, "Stationary versus mobile parcel lockers: Which self-service technology moves the consumers in the last mile of urban areas?", *Travel Behav Soc,* vol. 35, no. 100742, p. 100742, 2024. [http://dx.doi.org/10.1016/j.tbs.2024.100742]

[27] S. Moslem, and F. Pilla, "Planning location of parcel lockers using group analytic hierarchy process in spherical fuzzy environment", *Transp Res Interdiscip Perspect,* vol. 24, p. 101024, 2024. [http://dx.doi.org/10.1016/j.trip.2024.101024]

[28] Y.T. Tsai, and P. Tiwasing, "Customers' intention to adopt smart lockers in last-mile delivery service: A multi-theory perspective", *J Retailing Consum Serv,* vol. 61, p. 102514, 2021. [http://dx.doi.org/10.1016/j.jretconser.2021.102514]

[29] N. Nguyen, M. Trang Nguyen, T. Thuy Chung Nguyen, and M. Hung Nguyen, "Customer switching intention from home delivery to smart locker delivery: Evidence from Vietnam", *Innovative Marketing,* vol. 20, no. 2, pp. 140-151, 2024. [http://dx.doi.org/10.21511/im.20(2).2024.12]

[30] T. Litman, *Evaluating accessibility for transport planning: Measuring people's ability to reach desired services and activities,* Victoria Transport Policy Institute, 2024.

[31] Q. Shen, "Spatial technologies, accessibility, and the social construction of urban space", *Comput Environ Urban Syst,* vol. 22, no. 5, pp. 447-464, 1998. [http://dx.doi.org/10.1016/S0198-9715(98)00039-8]

[32] H.J. Miller, "Place-Based Versus People-Based Accessibility", In: D.M. Levinson, K.J. Krizek, Eds., *Access to Destinations,* Emerald Group Publishing Limited: Leeds, 2005, pp. 63-89. [http://dx.doi.org/10.1108/9780080460550-004]

[33] A. Holl, and I. Mariotti, "The geography of logistics firm location: The role of accessibility", *Netw Spat Econ,* vol. 18, no. 2, pp. 337-361, 2018. [http://dx.doi.org/10.1007/s11067-017-9347-0]

[34] G. Calabrò, M. Le Pira, N. Giuffrida, M. Fazio, G. Inturri, and M. Ignaccolo, "A spatial agent-based model of e-commerce last-mile logistics towards a delivery-oriented development", *Transp Res Interdiscip Perspect,* vol. 21, no. 100895, p. 100895, 2023. [http://dx.doi.org/10.1016/j.trip.2023.100895]

[35] A. Seghezzi, C. Siragusa, and R. Mangiaracina, "Parcel lockers vs. home delivery: A model to compare last-mile delivery cost in urban and rural areas", *Int J Phys Distrib Logist Manag,* vol. 52, no. 3, pp. 213-237, 2022. [http://dx.doi.org/10.1108/IJPDLM-03-2020-0072]

[36] U. Lachapelle, M. Burke, A. Brotherton, and A. Leung, "Parcel locker systems in a car dominant city: Location, characterisation and potential impacts on city planning and consumer travel access", *J Transp Geogr,* vol. 71, pp. 1-14, 2018. [http://dx.doi.org/10.1016/j.jtrangeo.2018.06.022]

[37] M. Cieśla, "Perceived importance and quality attributes of automated parcel locker services in urban areas", *Smart Cities,* vol. 6, no. 5, pp. 2661-2679, 2023. [http://dx.doi.org/10.3390/smartcities6050120]

[38] F.R. Ashik, S.A. Mim, and M.N. Neema, "Towards vertical spatial equity of urban facilities: An integration of spatial and aspatial accessibility", *J Urban Management,* vol. 9, no. 1, pp. 77-92, 2020. [http://dx.doi.org/10.1016/j.jum.2019.11.004]

[39] V. Dohale, M.M. Akarte, and P. Verma, "Systematic review of manufacturing strategy studies focusing on congruence aspect", *Benchmarking,* vol. 29, no. 9, pp. 2665-2690, 2022. [http://dx.doi.org/10.1108/BIJ-02-2021-0103]

[40] W.A.M. Mohammad, Y. Nazih Diab, A. Elomri, and C. Triki, "Innovative solutions in last mile delivery: Concepts, practices, challenges, and future directions", *Supply Chain Forum: An International Journal,* vol. 24, no. 2, pp. 151-169, 2023. [http://dx.doi.org/10.1080/16258312.2023.2173488]

[41] A. Kokkinou, H. Quak, O. Mitas, and A. Mandemakers, "Should I wait or should I go? Encouraging customers to make the more sustainable delivery choice", *Res Transp Econ,* vol. 103, p. 101388, 2024. [http://dx.doi.org/10.1016/j.retrec.2023.101388]

[42] F.M. Ottaviani, G. Zenezini, A. De Marco, and A. Carlin, "Locating Automated Parcel Lockers (APL) with known customers' demand:

A mixed approach proposal", *Eur J Transp Infrastruct Res,* vol. 23, no. 2, pp. 24-45, 2023.
[http://dx.doi.org/10.18757/ejtir.2023.23.2.6786]

[43] N. Giuffrida, Y. Calleo, S. Di Zio, F. Pilla, and M. Ottomanelli, "Spatial participatory planning for urban logistics: A GIS-enhanced real-time spatial Delphi approach", *Res Transp Econ,* vol. 108, no. 101488, p. 101488, 2024.
[http://dx.doi.org/10.1016/j.retrec.2024.101488]

[44] G. Iannaccone, E. Marcucci, and V. Gatta, "What young e-consumers want? Forecasting parcel lockers choice in Rome", *Logistics,* vol. 5, no. 3, p. 57, 2021.
[http://dx.doi.org/10.3390/logistics5030057]

[45] A. Fessler, P. Cash, M. Thorhauge, and S. Haustein, "A public transport based crowdshipping concept: Results of a field test in Denmark", *Transp Policy,* vol. 134, pp. 106-118, 2023.
[http://dx.doi.org/10.1016/j.tranpol.2023.02.014]

[46] L. Zhou, C. Li, C. Hu, and J. Du, "Parcel locker location problem with selectable volume sizes and heterogeneous customers in the last mile delivery", *Transp Lett,* vol. 16, no. 9, pp. 1140-1154, 2024.
[http://dx.doi.org/10.1080/19427867.2023.2277013]

[47] B. Ma, C.C. Teo, and Y.D. Wong, "Location analysis of parcel locker Network: Effects of spatial characteristics on operational performance", *Transp Res, Part E Logist Trans Rev,* vol. 192, p. 103776, 2024.
[http://dx.doi.org/10.1016/j.tre.2024.103776]

[48] E. Molin, M. Kosicki, and R. Van Duin, "Consumer preferences for parcel delivery methods", *Eur J Transp Infrastruct Res,* vol. 22, no. 2, pp. 183-200, 2022.
[http://dx.doi.org/10.18757/ejtir.2022.22.2.6427]

[49] M. Schnieder, "Visualising carrier consolidation and alternative delivery Locations: A digital model of last-mile delivery in England and Wales", *Logistics,* vol. 8, no. 3, p. 77, 2024.
[http://dx.doi.org/10.3390/logistics8030077]

[50] X. Yang, C. Wang, X. He, H. Zhang, and G. Xu, "Location optimization for community smart parcel lockers based on bilevel programming", *J Adv Transp,* vol. 2023, no. 1, pp. 1-18, 2023.
[http://dx.doi.org/10.1155/2023/1998188]

[51] T. Encarnación, and J. Amaya, "Determinants of parcel locker adoption for last-mile deliveries in urban and suburban areas", *Transp J,* vol. 64, no. 1, p. 12031, 2025.
[http://dx.doi.org/10.1002/tjo3.12031]

[52] A.E. El Moussaoui, B. Benbba, A. Jaegler, T. El Moussaoui, Z. El Andaloussi, and L. Chakir, "Consumer perceptions of online shopping and willingness to use pick-up points: A case study of Morocco", *Sustainability,* vol. 15, no. 9, p. 7405, 2023.
[http://dx.doi.org/10.3390/su15097405]

[53] V. Gatta, E. Marcucci, M. Nigro, and S. Serafini, "Sustainable urban freight transport adopting public transport-based crowdshipping for B2C deliveries", *Eur Trans Res Rev,* vol. 11, no. 1, p. 13, 2019.
[http://dx.doi.org/10.1186/s12544-019-0352-x]

[54] L. Guarino Neto, and J. Geraldo Vidal Vieira, "An investigation of consumer intention to use pick-up point services for last-mile distribution in a developing country", *J Retailing Consum Serv,* vol. 74, p. 103425, 2023.
[http://dx.doi.org/10.1016/j.jretconser.2023.103425]

[55] E. Bouhouras, S. Ftergioti, A. Russo, S. Basbas, T. Campisi, and P. Symeon, "Unlocking the potential of pick-up points in last-mile delivery in relation to Gen Z: Case studies from Greece and Italy", *Appl Sci,* vol. 14, no. 22, p. 10629, 2024.
[http://dx.doi.org/10.3390/app142210629]

[56] Y. Lin, Y. Wang, L.H. Lee, and E.P. Chew, "Profit-maximizing parcel locker location problem under threshold Luce model", *Transp Res, Part E Logist Trans Rev,* vol. 157, p. 102541, 2022.
[http://dx.doi.org/10.1016/j.tre.2021.102541]

[57] S. Moslem, and F. Pilla, "A hybrid decision making support method for parcel lockers location selection", *Res Transp Econ,* vol. 100, p. 101320, 2023.
[http://dx.doi.org/10.1016/j.retrec.2023.101320]

[58] M. Kahalimoghadam, R.G. Thompson, and A. Rajabifard, "Determining the number and location of micro-consolidation centres as a solution to growing e-commerce demand", *J Transp Geogr,* vol. 117, p. 103875, 2024.
[http://dx.doi.org/10.1016/j.jtrangeo.2024.103875]

[59] Y. Liu, Q. Ye, J. Escribano-Macias, Y. Feng, E. Candela, and P. Angeloudis, "Route planning for last-mile deliveries using mobile parcel lockers: A hybrid q-learning network approach", *Transp Res, Part E Logist Trans Rev,* vol. 177, p. 103234, 2023.
[http://dx.doi.org/10.1016/j.tre.2023.103234]

[60] L.K. Oliveira, E. Morganti, L. Dablanc, and R.L.M. Oliveira, "Analysis of the potential demand of automated delivery stations for e-commerce deliveries in Belo Horizonte, Brazil", *Res Transp Econ,* vol. 65, pp. 34-43, 2017.
[http://dx.doi.org/10.1016/j.retrec.2017.09.003]

[61] S. Santiago-Montaño, D.F. Silva, and A.E. Smith, "Sustainable last mile logistics employing drones and e-bikes", *Int J Sustain Transport,* vol. 18, no. 10, pp. 887-902, 2024.
[http://dx.doi.org/10.1080/15568318.2024.2419378]

[62] M. Zhang, and H. Zhang, "The use of smart lockers in China's smart villages construction: Expanding UTAUT with price value and technical anxiety", *SAGE Open,* vol. 14, no. 4, p. 21582440241287593, 2024.
[http://dx.doi.org/10.1177/21582440241287593]

[63] H. Karlı, and M. Tanyaş, "Innovative delivery methods in the last-mile: Unveiling consumer preference", *Future Transportation,* vol. 4, no. 1, pp. 152-173, 2024.
[http://dx.doi.org/10.3390/futuretransp4010009]

[64] M. Kiba-Janiak, K. Cheba, M. Mucowska, and L.K. De Oliveira, "Segmentation of e-customers in terms of sustainable last-mile delivery", *Oeconomia Copernicana,* vol. 13, no. 4, pp. 1117-1142, 2022.
[http://dx.doi.org/10.24136/oc.2022.032]

[65] E. Boom-Cárcamo, S. Molina-Romero, C. Galindo-Angulo, and M. del Mar Restrepo, "Barriers and strategies for digital marketing and smart delivery in urban courier companies in developing countries", *J Knowl Econ,* vol. 1, pp. 1-30, 2024.
[http://dx.doi.org/10.1007/s13132-024-01823-1]

[66] Y. Wang, M. Bi, and Y. Chen, "A scheduling strategy of mobile parcel lockers for the last mile delivery problem", *Promet-Traffic Transp,* vol. 32, no. 6, pp. 875-878, 2020.
[http://dx.doi.org/10.7307/ptt.v32i6.3531]

[67] P. Ozyavas, P. Buijs, E. Ursavas, and R. Teunter, "Designing a sustainable delivery network with parcel locker systems as collection and transfer points", *Omega,* vol. 131, p. 103199, 2025.
[http://dx.doi.org/10.1016/j.omega.2024.103199]

[68] J.F. Tsai, H.N. Ngo, and Z.H. Che, "Last-mile delivery during COVID-19: A systematic review of parcel locker adoption and consumer experience", *Acta Psychol,* vol. 249, p. 104462, 2024.
[http://dx.doi.org/10.1016/j.actpsy.2024.104462] [PMID: 39216341]

[69] A. Leung, U. Lachapelle, and M. Burke, "Spatio-temporal analysis of Australia Post parcel locker use during the initial system growth phase in Queensland (2013–2017)", *J Transp Geogr,* vol. 110, p. 103634, 2023.
[http://dx.doi.org/10.1016/j.jtrangeo.2023.103634]

[70] A. Rossolov, "A last-mile delivery channel choice by E-shoppers: Assessing the potential demand for automated parcel lockers", *Int J Logist,* vol. 26, no. 8, pp. 983-1005, 2023.
[http://dx.doi.org/10.1080/13675567.2021.2005004]

[71] T. Raviv, "The service points' location and capacity problem", *Transp Res, Part E Logist Trans Rev,* vol. 176, p. 103216, 2023.
[http://dx.doi.org/10.1016/j.tre.2023.103216]

[72] B. Murgante, and I. Di Ruocco, "Public participation in the 15-minute city: The role of ICT and accessibility to reduce social conflicts", *Computational Science and Its Applications – ICCSA 2024 Workshops*
[http://dx.doi.org/10.1007/978-3-031-65238-7_6]

[73] B. Sawik, "Optimizing last-mile delivery: A multi-criteria approach with automated smart lockers, capillary distribution and

crowdshipping", *Logistics,* vol. 8, no. 2, p. 52, 2024. [http://dx.doi.org/10.3390/logistics8020052]

[74] D. Ivanov, "When is the supply chain resilient? Customer and operational perspectives", *Int J Prod Res,* vol. 1, pp. 1-16, 2025. [http://dx.doi.org/10.1080/00207543.2025.2454331]

[75] "Smart parcel lockers: The future of secure package delivery", Available from: https://parcelhive.net/smart-parcel-lockers- the-future-of-secure-package-delivery/

[76] D. Thomas, "Delivery groups rush to open parcel lockers as demand surges", Available from: https://www.ft.com/content/e896727f-0a20-4256-83d8-c46fc3535771

[77] A. Bhutani, S. Mall, A. Dubey, and S.A. Zade, "FetchAid: Making parcel lockers more accessible to blind and low vision people with deep-learning enhanced touchscreen guidance, error-recovery mechanism, and AR-based search support", *arxiv,* vol. 2024, 2024.

[78] A. Wasilewski, "Analysis of accessibility from collection and delivery points", Available from: https://scispace.com/pdf/analysis-of-accessibility-from-collection-and-delivery-3l8uqo2oap.pdf