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Spatial analysis of Collection and Delivery Points (CDPs) in Madrid (Spain): implications of Last-Mile Logistics for urban retail

Análisis espacial de los puntos de recogida y entrega de paquetería en Madrid (España): implicaciones de la logística de última milla en el comercio urbano

David García-Álvarez

davidg@ucm.es

Sofía Mendoza de Miguel

smendo01@ucm.es

Department of Geography

Universidad Complutense de Madrid (Spain)

Abstract

Traditional urban retail is undergoing a profound transformation due to globalization, digitalization, and shifts in consumer habits, resulting in phenomena such as commercial desertification and changes in store typologies. One of the most significant outcomes of this transition is the rise of online shopping and the associated Last Mile Delivery (LMD) logistics, particularly the proliferation of Collection and Delivery Points (CDPs), including Pick-up Points (PPs) and Automated Parcel Lockers (APLs). This study explores the spatial logic behind the distribution of CDPs and their implications for traditional retail, using the city of Madrid as a case study. To achieve this, data from major logistics companies were first obtained through web

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scraping. Next, a spatial analysis was conducted using QGIS and GEODA software, considering variables such as public transport accessibility, retail and population density. Finally, PPs were categorized into groups according to their main commercial activity. The findings reveal, on the one hand, a clustering pattern of CDPs in central and commercially vibrant city areas, and on the other hand, that most retail shops operating as PPs are either businesses that already offer parcel and courier services, those that match the profile of online customers, or shops involved in daily grocery activities.

Key words: pick up points; automated parcel lockers; parcels.

Resumen

El comercio urbano tradicional atraviesa una profunda transformación debido a la globalización, la digitalización y los cambios en los hábitos de consumo. Estos procesos han generado fenómenos como la desertificación comercial y la modificación en la tipología de los establecimientos. Uno de los efectos más relevantes es el auge del comercio online y la asociada logística de última milla, especialmente a través de los Puntos de Recogida y Entrega (PRE), que incluyen Puntos de Recogida (PR) y Taquillas Automatizadas (TA). Este estudio analiza la lógica espacial de los PRE y su impacto en el comercio tradicional, tomando como caso de estudio la ciudad de Madrid. Para ello se han obtenido datos de las principales empresas logísticas mediante técnicas de *web scraping*. Asimismo, se ha realizado un análisis espacial con QGIS y GEODA, considerando variables como accesibilidad al transporte público, densidad comercial y densidad de población; y se han clasificado los PR según su actividad comercial principal. Los resultados muestran una concentración de PRE en áreas centrales y con una intensa actividad comercial. Además, los comercios que operan como PR suelen ser aquellos que ya ofrecen servicios de mensajería, coinciden con el perfil del consumidor digital o están vinculados al comercio de proximidad.

Palabras clave: taquillas automatizadas; logística de última milla; paquetería.

1 Introduction

In the contemporary landscape of globalization, or arguably, post-globalization (Frago Clols et al., 2023; Carreras i Verdaguer et al., 2020), e-commerce has attained significant prominence and continues to expand. This growth is driven both by major commercial conglomerates (such as Amazon, Inditex, Alibaba, Google, and Apple) and by a multitude of fragmented and individual initiatives on a global scale (Carreras i Verdaguer et al., 2020). At the same time, the globalization and digitalization of consumer markets have led to intense restructuring and transformation of traditional urban retail. The concept of traditional urban retail lacks a rigorous definition: according to Frago Clols (2025) it is used more as a territorial or cultural marketing slogan than as an analytical category capable of specifying the relationship between supply and demand in space and time. This author also clarifies that it is usually associated with small, family-run businesses, accessible without the need to use a car and linked to what has been described as entrepreneurial smallholders. Related to this definition, in this study we will consider traditional urban retail as the opposite of large-scale retail outlets, franchises, or chain branches.

The previously described dynamics are fostering an increasing standardization of consumption patterns, fueled by the rise of oligopolistic tendencies among major retail conglomerates that dominate commercial distribution through extensive advertising campaigns and aggressive pricing strategies (Méndez del Valle, 2004).

This transformation has direct implications for the retail landscapes of contemporary cities, manifesting in phenomena such as retail desertification and significant shifts in the typologies and sizes of businesses. These changes typically drive a transformation of retail environments towards standardized, characterless forms, constituting what has been termed the geography of *non-places* (Augé, 1992). Nonetheless, the widespread adoption of online commerce, despite its well-documented effects on local retail (Frago Clols, 2023), also brings about other significant yet less immediately visible consequences, which do not necessarily result in a profound reconfiguration of the urban landscape.

Logistics has emerged as the central axis of all economic activity, encompassing the entire spectrum from production to the consumption of any product or service (Frago Clols, 2015). Within this context, Last Mile Logistics or Last Mile Delivery (LMD), defined as the final segment of package delivery from the company to the end recipient or consumer (B2C), whether to their residence or a designated collection point, has gained particular significance (Ehmke & Mattfeld, 2012).

The explosive expansion of the logistics sector has triggered substantial changes in city environments. Among these, the rise of alternative and complementary mobility solutions aimed at facilitating urban deliveries stands out. Emerging LMD innovations include crowdsourced collection points or neighbour relays (Morganti et al., 2014; Mommens et al., 2021; Akeb et al., 2018; Zhen et al., 2021). Additionally, experimental delivery models, such as drone or robotbased systems, are currently under exploration (Alvés de Araújo et al., 2020; Mohammad et al., 2023). Nevertheless, Collection and Delivery Points (CDPs), where consumers can both receive and dispatch goods purchased online, represent a well-established and expanding practice that is already reshaping urban landscapes. In addition, they interact closely with traditional retail, which has begun to play a new role within the LMD ecosystem (Mohammad et al., 2023).

CDPs encompass both automated parcel stations, known as Automated Parcel Lockers (APLs) and Pick-Up Points (PPs). APLs are automated delivery machines, typically located inside or outside local shops or other premises, where online shoppers can collect their parcels autonomously. They are usually owned by courier companies. PPs, on the other hand, generally refer to retail businesses that act as intermediary collection points between logistics providers and end consumers.

While APLs work autonomously and represent a commercial activity in themselves, PPs generally serve as auxiliary functions that contribute to a redefinition of traditional retail. Through this role, local retail acting as a PP can assume a new and strategic position within a globalized commercial system that had previously marginalized it in favor of large-scale retail chains.

Most existing studies on LMD and CDPs focus on the operational and transportation-related impacts within urban areas (Viu-Roig & Alvarez-Palau, 2020). However, the implications of these developments for local retail activity remain underexplored. The main objective of this research is therefore to examine, from a geographical and territorial perspective, the spatial logic behind the location of parcel delivery infrastructure as part of LMD, and to assess the role that this infrastructure plays in reshaping traditional retail. In addition, the study seeks to contribute to the expanding field of retail cartography, which has yet to fully exploit the potential of Geographic Information Systems (GIS) in retail studies (Frago Clols et al., 2015).

The starting hypothesis of this research is that the location of CDPs is influenced by three key factors: (i) accessibility, defined as the degree of connectivity with different transport infrastructures and modes (Lagorio & Pinto, 2020; Lachapelle et al., 2018); (ii) population density, understood as a proxy for the concentration of potential online consumers (Fang et al., 2019; Nolmark et al., 2016; Morganti et al., 2014); and (iii) the concentration of urban functions that already attract significant daily pedestrian flows, such as commercial districts or administrative centers. Whereas the first two factors are well-documented in academic literature, the third is introduced as an original contribution of this study.

With that objective in mind, this study focuses on the municipality of Madrid, a capital city where the CDP model is expected to follow patterns similar to other large urban centres, while diverging from trends observed in smaller municipalities. As noted by Mansvelt (2005, cited in Somella & D'Alessandro, 2020), the dynamic nature of retail and consumption implies that empirical findings in this field are inherently partial and highly dependent on the specific context chosen for case study analysis.

This article is structured as follows: Section 2 reviews the relationship between CDPs and urban retail; Section 3 presents the case study; Section 4 describes the research materials and methods; Section 5 presents the results; Section 6 discusses the findings; and Section 7 concludes the study.

2 Collection-and-delivery points (CDPs) and urban commerce

Home delivery is recognized as the least efficient and most costly method of parcel delivery in terms of transportation (Song et al., 2009; Morganti et al., 2014; Xiao et al., 2017). This inefficiency has led to the proliferation of alternative collection points, such as the aforementioned CDPs or the brand's physical store where the online purchase was made, through the click-and-collect option (Viu-Roig & Alvarez-Palau, 2020).

The academic literature on CDPs remains relatively nascent, with approximately 25 years of development. The past decade has been particularly fruitful, as this phenomenon is closely linked to the widespread adoption of online commerce. Research on CDPs has focused on specific topics: consumer use of CDPs, the mobility effects of delivery workers, the spatial distribution of CDPs, the costs associated with lockers, and environmental impacts (Weltevreden, 2008; van Duin et al., 2020), with particular attention to delivery transportation impacts and management (Viu-Roig & Alvarez-Palau, 2020). An important line of research has also focused on demographic characteristics and accessibility (Kedia et al., 2017; Lachapelle et al., 2018), with several studies examining the equity in access to CDPs (Zmuda-Trzebiatowski, 2024; Schaefer & Figliozzi, 2021; Fried et al., 2024), in relation to the "15-minute city" concept, which seeks to restore neighborhood-scale living by ensuring access to essential goods and services within a 15-minute radius (Murphy et al., 2009).

Nevertheless, there is a lack of research on the interactions between LMD, including CDPs, and traditional retail activities, which play an important role in their operation. In this regard, these trends have profound implications not only for urban life and the organization of cities (Carreras i Verdaguer et al., 2020) but also for the commercial configuration of urban spaces.

Following a period during which e-commerce significantly contributed to the closure of both large-scale and local retail establishments, a phenomenon termed the "Retail Apocalypse" (Philipose, 2019), major companies were prompted to adopt strategic reorientations, favoring flagship stores or using physical outlets as showrooms or return centers. Nowadays, a new scenario has emerged, in which e-commerce appears to serve as a lifeline for certain local businesses that operate as CDPs, potentially generating additional customer traffic within their premises (Weltevreden, 2008).

Cárdenas (2019) examined the types of businesses functioning as PPs, categorizing these establishments into major groups such as daily goods, fashion stores, leisure articles, household articles, transport-related businesses, general service providers, and leisure stores. Cárdenas (2019) found that daily goods stores are the ones that stand out as PPs, as they do not require a specific trip to the PP, allowing customers to combine parcel collection with other shopping activities.

On the other hand, the relevance of LMD for the commercial revitalization of urban areas, as well as its territorial implications, underscores the need for spatial analysis of CDPs to understand their distribution patterns and the key factors behind their success. These studies may help to comprehend the interactions between CDPs and retail geographies and how the former impact the latter in different spatial ways.

Research involving spatial analyses of CDPs is limited and, as noted by Fang et al. (2019), often fails to provide a comprehensive view of the distribution of both PPs and APLs. Additionally, much of this research focuses on accessibility analysis and LMD management, with limited attention to the impact of these activities on local commerce.

Morganti et al. (2014) analyse CDPs in urban, metropolitan, and rural areas of the Seine-et-Marne department in France, drawing valuable conclusions about their spatial distribution, which provides a valuable starting point for our investigation. However, the rapid growth of online commerce over the past decade renders this research somewhat outdated, given the substantial increase in the number of operating companies and CDPs. Similarly, Xiao et al. (2017) conduct a spatial analysis of the diversity of CDPs in China's most e-commerce-intensive city, concluding that three spatial effects are observable: an intensification of delivery facilities, a disparity in their urban distribution, concentrated in central districts and newly developed areas, and a clustering of various types of CDPs in specific locations. Likewise, Kang (2025) analyses APLs in London, determining that these are clustered in certain city areas, particularly in the centre. None of the previous contributions have tried to connect those spatial patterns with those of retail to understand the connections and interactions between both activities.

Further contributions go deeper into the previous line of research, providing insights into the spatial analysis of CDPs, but without specifically addressing their connection with urban retail: Leung et al. (2023) and Ding et al. (2023) examined the temporal growth of CDP locations; Wu et al. (2015) and Kedia et al. (2019) developed predictive models to determine optimal CDP locations based on consumer demand; and Oliveira et al. (2019), Beckers and Verhetsel (2021), and Lachapelle et al. (2018) focused on the spatial accessibility of CDPs, finding for example that APLs in Brisbane (Australia) are primarily accessible by car, whereas bicycle parking, taxi stands, and nearby public transportation are present in less than one-third of the cases studied.

Weltevreden (2008) highlighted the gap in empirical studies on CDPs. Moreover, the majority of empirical research and reports have focused on France, the United Kingdom, Germany, and the Benelux countries (Mommens et al., 2021; Buldeo Rai et al., 2021; Weltevreden, 2008; Morganti et al., 2014; van Duin et al., 2020; Song et al., 2011; Parcelmonitor, 2024), and more recently on China (Li et al., 2024; Xiao et al., 2017) and Latin America (Oliveira et al., 2019; Freitas Matinha et al., 2023). In contrast, the scientific literature on CDPs in Spain reveals a significant gap. This focus may be attributed to the early and notable development of CDP systems in these European regions (Augereau et al., 2009).

To date, no empirical studies investigating CDPs within the Spanish context have been identified. This absence is particularly striking given the scale of the phenomenon in the country. According to the report *Out of Home Delivery in Europe 2023* (Różycki and Gal, 2023), Spain has the highest percentage of online retailers in Europe offering delivery to a CDP, with 94% of online businesses providing this option, followed by Italy (84%), France (83%), Germany (72%) and United Kingdom (54%), which shows the importance of this activity in the Spanish market. Furthermore, Spain has one of the densest networks of CDPs in Europe, with 15.15 per 10,000 inhabitants (the ninth densest in the European Union and UK) and 6.69 APLs per 10,000 inhabitants (the eight densest in the European Union and UK) (Różycki & Gal, 2023).

3 Study area

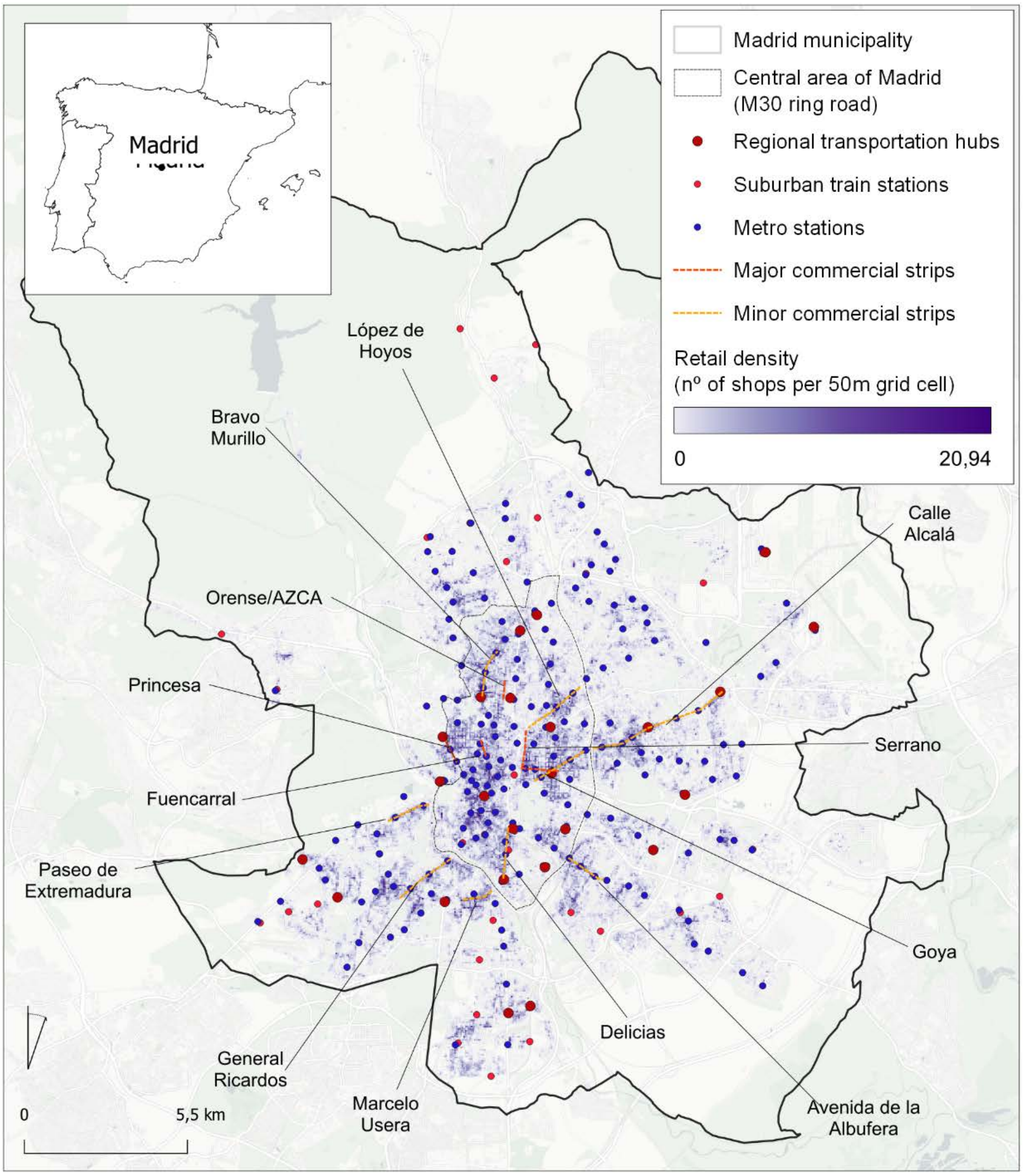
Madrid (Figure 1) is the capital and most populous city in Spain. In addition, it is located at the geographic centre of the country, constituting the core of Spain's radial train and road infrastructure. Accordingly, Madrid has a vibrant retail landscape and plays a key role in the Spanish logistics sector. Because of its size and sociodemographic characteristics (urban and young population), it is one the Spanish cities where contemporary urban dynamics are most prominent, and where online shopping and associated LMD logistics are more developed.

Like other European cities, Madrid's commercial activity has undergone a significant transformation towards centralisation and liberalisation (or deregulation) since the last decades of the 20th century (Sánchez-Tascona Salgado & Hernández Aja, 2022; López de Lucio, 2006). This trend has affected all parts of the city and is therefore not concentrated in any specific area (Carpio-Pinedo, 2020).

Madrid's retail activity is concentrated in the central parts of the city, including the historic city centre and key areas of the first planned urban extension (Ensanche), such as the Serrano, Princesa and Fuencarral strips, as well as the areas of Orense/AZCA and Goya (Figure 1) (Sánchez-Tascona Salgado & Hernández Aja, 2022; López Lucio, 1999). According to Carpio-Pinedo (2014), commercial agglomeration in Madrid is mainly driven by factors such as population and employment density, while accessibility plays a less significant role.

In addition to the central commercial zones, traditional and local retail areas continue to exist in peripheral neighborhoods of the city. These are based on the clustering of a large number of small and medium-sized businesses of local nature. They extend along commercial corridors such as Bravo Murillo, López de Hoyos, Alcalá- carretera de Aragón, Avda. de la Albufera, Delicias, Marcelo Usera, General Ricardos/Oca and Paseo de Extremadura (Figure 1) (López Lucio, 1999). However, these traditional retail areas have become less competitive within the city's retail landscape, gradually losing centrality and relevance compared to the more dominant central commercial zones (Sánchez-Tascona Salgado & Hernández Aja, 2022).

Figure 1. Location map of Madrid, indicating its central area (almendra central) and the location of retail activity / strips and most relevant public transport stops

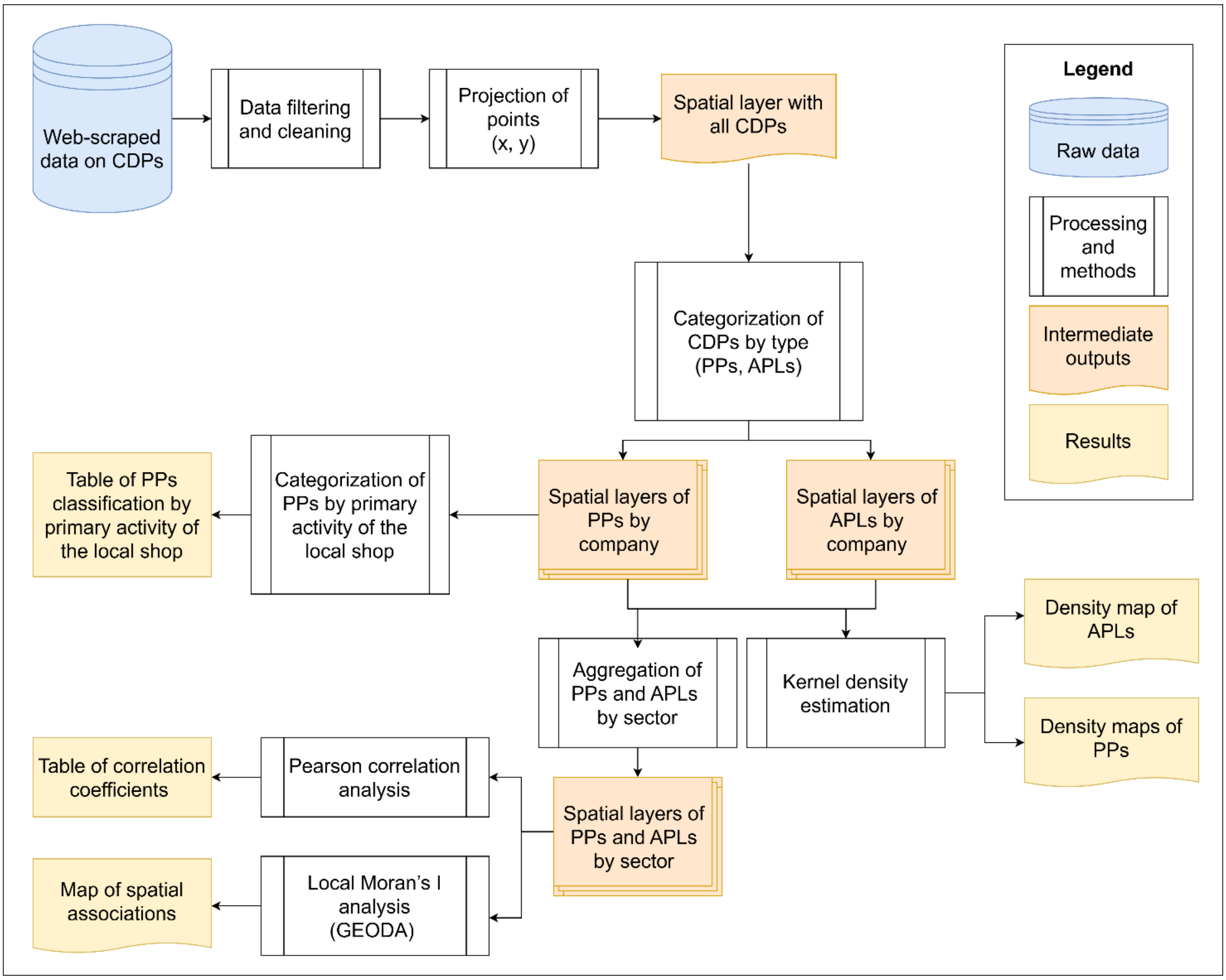


Source: author's own elaboration using ESRI maps, based on data from "Local census" (Ayuntamiento de Madrid, n.d.); "Neighbourhood boundaries" (2025), "Metro stations" (Comunidad de Madrid, n.d.), "Train stations" (Comunidad de Madrid, n.d.), "Platforms interchanges" (Comunidad de Madrid, n.d.)

4 Materials and methods

To understand the spatial distribution of CDPs across the city of Madrid, we collected data through web scraping (section 4.1). The data were subsequently preprocessed and filtered prior to spatial representation and analysis (section 4.2). Figure 2 summarizes the methodological workflow followed in this study.

Figure 2. Methodological workflow



Source: authors' own elaboration

4.1 Collection and preprocessing of CDPs datasets

We obtained the locations of CDPs operated by Amazon, Celeritas, Correos (Citypaq), GLS, Inpost and SEUR in the city of Madrid through web scrapping techniques. We also extracted data on CDPs operated by other major companies in the sector, such as DHL and MRW. However, the datasets obtained for these companies proved insufficiently comprehensive, exhibiting notable data gaps. Therefore, we only selected those datasets that could be properly validated and that accurately reflected the actual distribution of CDPs operated by each company in the city of Madrid (Table 1).

Table 1. List of CDPs analysed by typology (PPs, APLs) and operating company

	PPs	APLs
Seur	436	212
Inpost	506	126
GLS	417	4
Citypack (Correos)	-	128
Amazon	788	349
Celeritas	205	-
Total	2352	819

Source: authors' own elaboration

The companies analysed account for a substantial share of the LMD market in Spain, representing over 50% in the case of PPs and more than 85% in the case of APLs (Różycki & Gal, 2023). Consequently, the location data of their CDPs provides a representative picture of the phenomenon, which enables to drawn meaningful conclusions regarding their distribution and the factors influencing their location. Although readers may refer to other relevant companies operating in the Spanish LMD market, such as Disashop or TIPSA, they often represent brands or subsidiaries of companies already included in our analysis, further confirming the broad coverage of the data used in this study.

We reviewed and validated the datasets obtained for each of the companies analysed, filtering out data errors and other inconsistencies. In a second step, we differentiated, for each company, between standard PPs and APLs. Finally, to further characterize the commercial profile of the premises hosting PPs, each point was classified into one of the following predefined categories: internet café; electronics / IT stores; groceries and convenience stores; tobacco shop; bookstore / stationery shop; courier service; newsstand or press kiosk; clothing store; others (services); others (product sales); and unknown. The classification was based on the name of the PP and was cross-referenced with its location and business description using information available through Google Maps. The categories were defined to ensure an accurate distinction of the commercial activities, while also using a limited set of categories to facilitate comparative analysis.

4.2 Spatial analysis of CDPs

To analyse the distribution of CDPs in the city of Madrid, all obtained datasets were first projected as point vector layers using QGIS. Subsequently, all PPs from different companies were merged into a single layer, and all APLs into a separate one. From these two layers, we generated two raster density maps in QGIS using kernel density estimation (Silverman, 1988), following methods employed in comparable studies (Fang et al., 2019; Oliveira et al., 2019; Ding et al., 2023). The resulting heatmaps help to visualize the concentration of PPs and APLs across the city, and thus the similarities and differences in their spatial distribution. For the kernel density estimation, we applied a quartic kernel function, a 100m search radius and a spatial resolution of 50m, which allowed for the generation of heatmaps that accurately reflect the local variation and spatial patterns of CDPs location.

To assess the spatial agreement between the locations of PPs and APLs, as well as between the location of PPs and APLs operated by different companies, we calculated Pearson correlation coefficients (Pearson, 1895) using Microsoft Excel. These coefficients indicate the degree of association between each pair of distributions: values close to -1 suggest total dissimilarity, whereas values near 1 indicate a high degree of similarity.

Finally, we examined the presence of local spatial clusters and outliers in the distribution of PPs and APLs across Madrid by computing Local Moran's I statistics in GEODA (Anselin et al., 2006), based on a queen contiguity spatial weights matrix. This statistic identifies areas where a variable exhibits significant local spatial autocorrelation, classifying them into four types of spatial association (Anselin, 2024): High-High, Low-Low, Low-High, and High-Low (Table 2). Whereas High-High and Low-Low spatial associations indicate positive local clusters, Low-High and High-Low spatial associations are indicative of spatial outliers. All areas not falling into any of these categories show no statistically significant spatial association.

Both the Pearson correlation coefficients and Local Moran's I were calculated using aggregated counts of PPs and APLs at the sector level. These sectors correspond to architecturally or urbanistically coherent areas of the city, which are typically recognized by a specific name (Dirección General de Economía, 2022). For example, *Gran Vía* constitutes a sector encompassing Gran Vía Street and the surrounding buildings, as well as Callao Square. This is an architecturally, spatially and functionally coherent area that is widely recognized in the collective mindset of Madrid's residents. However, it does not correspond to any administrative boundary within the city. As such, these sectors provide an appropriate spatial scale for analysing the local correlation of urban features, such as the distribution of CDPs. Unlike other spatial units of analysis, these sectors are sufficiently detailed and predominantly cover built-up and inhabited areas, thereby minimizing the issue of zero-count units that frequently affect correlation analyses.

Table 2. Meanings of the types of spatial association provided by local Moran's I statistics

Types of spatial association	Meaning
High-High	Areas with high values surrounded by neighbours also with high values
Low-Low	Areas with low values surrounded by other low-value areas
Low-High	Areas with low values surrounded by high-value neighbours
High-Low	Areas with high values surrounded by low-value neighbours

Source: authors' own elaboration

4.3 Location factors of CDPs

To assess which are the factors that may explain the spatial distribution of CDPs across Madrid, we employed the Spatial Autoregressive (SAR) model implemented in GEODA. This model extends the classical linear regression framework by incorporating a spatially lagged dependent variable as an additional predictor (Anselin & Rey, 2014). Thus, it specifically accounts for the spatial clustering of the variable as a potential driving factor explaining the variability of the dependent variable. That is, the model estimates to what extent the value of the variable in a given area is affected by its value in surrounding areas.

As a baseline, we first estimated an Ordinary Least Squares (OLS) regression model using GeoDa. However, its explanative power was considerably lower, accounting for only 10% of the variance in the dependent variable, compared to 60% explained by the SAR model. Moreover, the OLS residuals exhibited clear violations of key model assumptions: they were not normally distributed and displayed spatial patterns, suggesting non-independence. This was confirmed by the Moran's I statistic computed for the OLS residuals, which yielded a value of 0.498, indicating significant spatial autocorrelation.

We implemented two separate SAR models: one aimed at explaining the distribution of PPs and one aimed at explaining the distribution of APLs. The kernel density maps previously generated

(Section 4.2) were used as the two dependent variables (PPs and APLS). Additionally, we used the same set of independent variables in raster format for both models (Table 3). They were selected to account for the influence of local accessibility (from metro stations, suburban train stations, and regional transportation hubs), population density and economic activity (commercial or institutional) in the location of CDPs.

Table 3. Independent variables included in the SAR models

Independent variable	Obtention method	Source
Distance to suburban train stations (Cercanias)	Euclidian distance to suburban train stations in a 50m raster	(Comunidad de Madrid, n.d.)
Distance to metro stations	Euclidian distance to suburban metro stations in a 50m raster	(Comunidad de Madrid, n.d.)
Distance to regional transportation hubs (Intercambiadores)	Euclidian distance to regional transportation hubs in a 50m raster	(Comunidad de Madrid, n.d.)
Density of administrative, social, cultural, and sport facilities	Kernel density of filtered facilities (quartic kernel function, 100m search radius, 50m spatial resolution)	(Comunidad de Madrid, n.d.)
Retail density	Kernel density of local businesses, excluding restauration and primarily accounting for retail establishments (quartic kernel function, 50m search radius, 50m spatial resolution)	Ayuntamiento de Madrid (n.d.)
Population density	Rasterization of population density per census track in a 50m raster	"National Census 2024" (Instituto Nacional de Estadística, 2024)

Source: authors' own elaboration

These variables were chosen based on their relevance in previous research with similar objectives (Lagorio & Pinto, 2020; Lachapelle et al., 2018; Fang et al., 2019; Nolmark et al., 2016; Morganti et al., 2014). Furthermore, they allow us to test the three main hypothesis regarding the location of CDPs outlined in the introduction of the article.

A regular grid of sampling points spaced every 50 meters across Madrid was used to extract the values of both dependent and independent variables for the regression analysis. This approach addressed the challenges posed by the irregular and discrete distribution of CDPs in a regression model, ensuring spatial continuity and comparability across space. Additionally, it facilitated the construction of spatial weights matrices required for the implementation of the SAR model. In this case, we defined a spatial weights matrix based on a fixed distance band of 50 meters, which ensures that only nearby locations are considered as neighbours, minimizing the influence of distant observations on the estimation of spatial dependence.

To maintain analytical consistency and avoid the influence of irrelevant locations, we retained only those sampling points where at least one of the dependent variables (PPs or APLs) had a non-null density value. Including a large number of zero-density points across the city would have introduced noise and potentially compromised the robustness and interpretability of the regression models.

5 Results

5.1 Spatial distribution of CDPs in Madrid

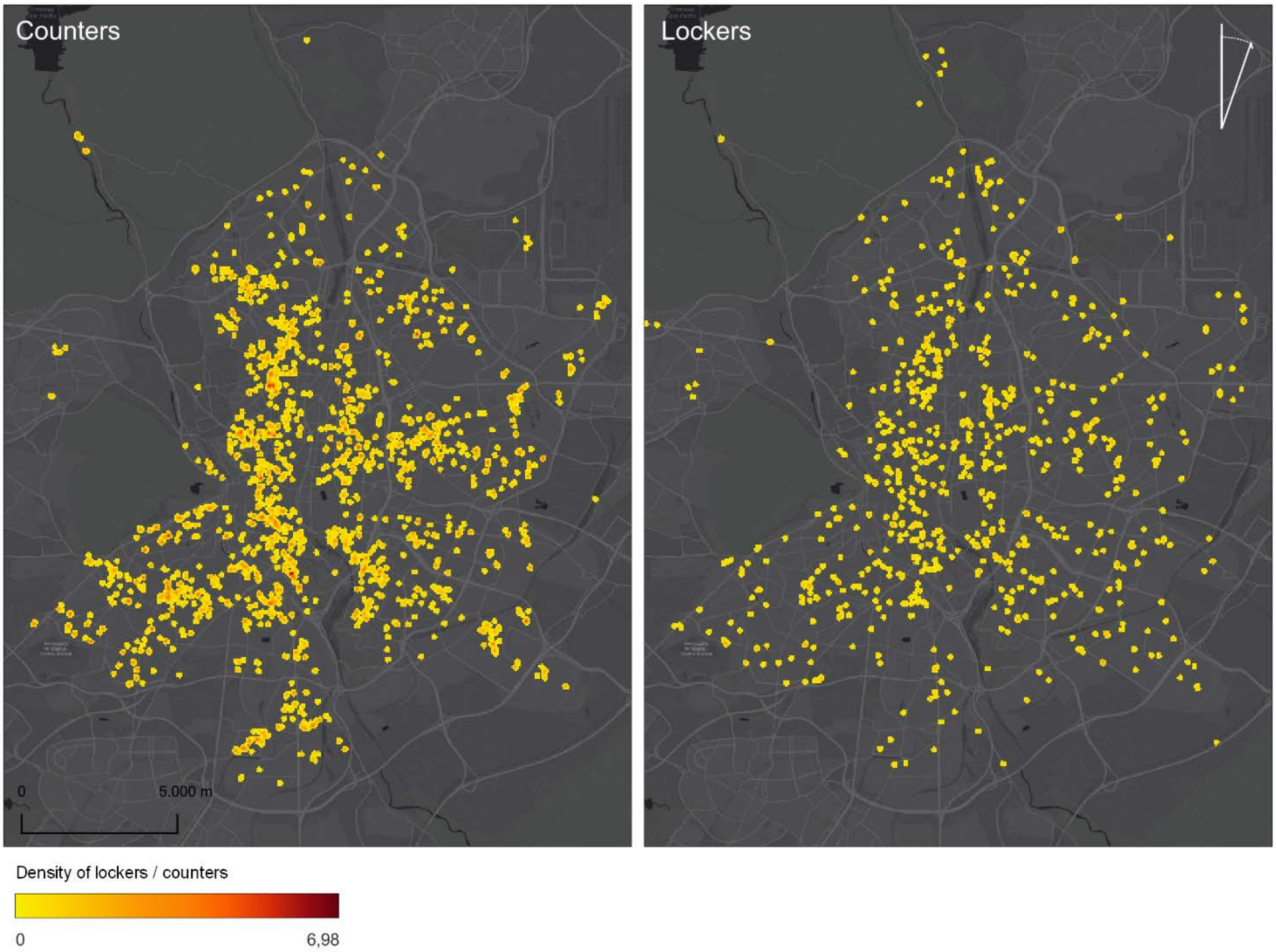
Although CDPs are widespread across all of Madrid, they tend to concentrate in specific areas of the city, as revealed by the kernel density maps (Figure 3) and, in particular, the spatial clusters identified by the Local Moran's I (Figure 4).

Both results confirm that CDPs cluster in certain neighbourhoods, mostly located in central areas of Madrid within the M30 ring road (the city's main ring road). Nonetheless, there are some significant peripherical neighbourhoods, such as Caranbanchel (southwest), around the Oporto metro station, Pueblo Nuevo (east) and Puente de Vallecas (southeast), that also emerge as notable CDPs clusters. All of these correspond to vibrant urban areas with high levels of retail activity that also serve as relevant nodes in Madrid's public transportation network

Within the M30, although CDPs are highly concentrated, the maps reveal important local contrasts. For instance, in the old town, particularly the most central and tourist-oriented areas, such as those close to Sol (the very centre of Madrid), the density of CDPs is lower than in surrounding neighbourhoods. Similarly, one of the most affluent areas of the city, the Barrio de Salamanca, characterised by luxury shops and high-income residents, also exhibits a relatively low number of CDPs.

PPs and APLs show a similar distribution pattern, as observed in the different maps (Figures 3 & 4) and confirmed by the Pearson correlation coefficient (0.60) that was calculated by comparing the distributions of the two types of CDPs. Although some discrepancies exist between their distributions, in general, they tend to be located in the same areas of the city. However, while PPs display significant concentrations in specific areas and along certain commercial strips, APLs appear more uniformly distributed throughout Madrid.

Figure 3. Kernel density maps of Collection-ad-delivery points (CDPs) in Madrid, differentiating between standard Pick-up Points (PPs) and Automated Parcel Lockers (APLs)

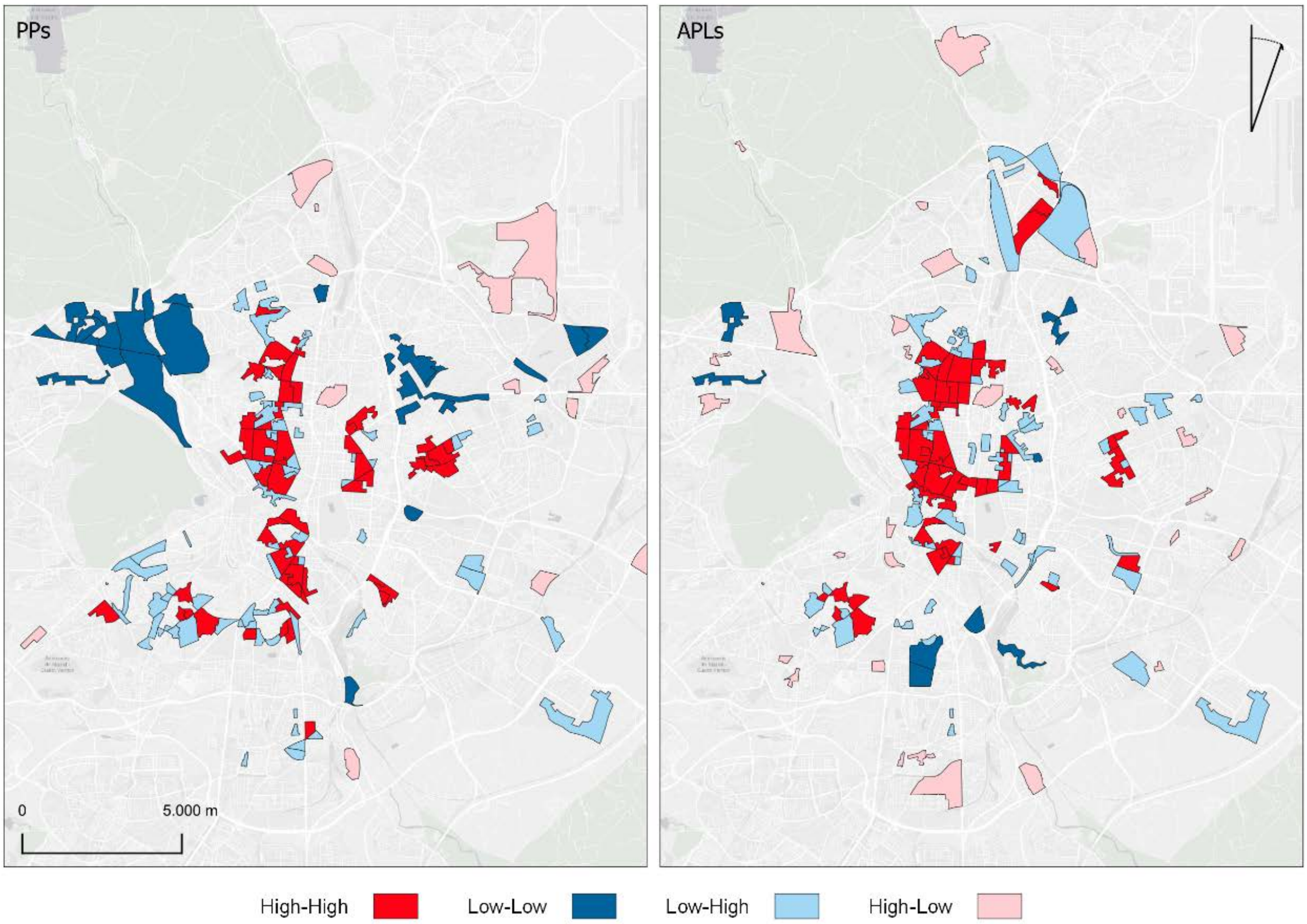


Source: authors' own elaboration using CARTO basemaps

PPs show high and very high intensities in points and along corridors that are locally important, either due to their commercial relevance in the neighbourhoods where they are located, their role as transportation hubs, or both. Examples include Cuatro Caminos – Bravo Murillo, Marcelo Usera, Legazpi, Diego de León – Francisco Silvela, calle Fernández de los Ríos, Vista Alegre, Avenida de la Albufera, Asamblea de Madrid-Entrevías, Calle Alcalá and Canillejas, among many others. APLs, by contrast, tend to appear in small clusters of low-to-moderate density scattered throughout the city.

Finally, the comparison between companies shows how most of them follow a similar location pattern. Table 4 points to high Pearson correlation coefficients between all companies when comparing the distribution of PPs, which makes sense, as this distribution is likely linked to the location of local shops acting as PPs. Nonetheless, the lower coefficients of Celeritas compared to the other three companies (Amazon, Inpost, GLS) may be associated with a slightly different criteria for selecting PPs among these companies.

Figure 4. Local spatial clusters and outliers of Pick-up Points (PPs) and Automated Parcel Lockers (APLs) in Madrid identified using Local Moran's I



Note: N = 13925; R^2 = 0.585; Log-Likelihood = −12,149.8; AIC = 24,315.5; Spatial weights matrix: fixed distance band (50 m). Diagnostics: Breusch-Pagan test for heteroskedasticity: $\chi^2(6) = 325.31$, $p < 0.001$.; Likelihood Ratio Test: $\chi^2(1) = 7403.25$, $p < 0.001$.

More details: High-High and Low-Low areas indicate positive local spatial autocorrelation, while High-Low and Low-High indicate spatial outliers.

Source: author's own elaboration using ESRI basemaps, based on "Neighbourhood boundaries" (Comunidad de Madrid, n.d.)

The correlation between the spatial distribution of APLs operated by different companies is lower than in the case of PPs (Table 5). APLs do not necessarily need to be linked to local shops and therefore may follow more diverse location strategies. The lowest correlations are found between GLS and the other three companies, which is likely due to the small number of APLs operated by GLS (only 4), making the data statistically non-representative (the other companies operate between 126 and 349 APLs). On the other hand, Citypack also shows lower correlation coefficients with the other three companies compared to the correlations among those three. This may indicate a different location strategy. Citypack is the APL provider operated by the state-owned postal company (Correos), which tends to install APLs near post offices or in areas that do not necessarily follow the same concentration patterns as the private companies.

Table 4. Correlation coefficients of PP distribution
at the sector level in Madrid for five different PP providers

	Seur	Inpost	GLS	Celeritas	Amazon
Seur	*1.00*				
Inpost	0.72	*1.00*			
GLS	0.71	0.71	*1.00*		
Celeritas	0.59	0.57	0.56	*1.00*	
Amazon	0.72	0.69	0.73	0.46	*1.00*

Source: authors' own elaboration

Table 5. Pearson correlation coefficients of APL distribution
at the sector level in Madrid for five different APL providers

	Seur	Inpost	GLS	Citypack	Amazon
Seur	*1.00*				
Inpost	0.40	*1.00*			
GLS	0.03	0.02	*1.00*		
Citypack	0.36	0.25	0.10	*1.00*	
Amazon	0.43	0.45	0.06	0.34	*1.00*

Source: authors' own elaboration

5.2 Factors explaining the location of CDPs in Madrid

According to the results of the SAR models we implemented, the spatial distributions of APLs and PPs are explained by similar sets of factors, although some important differences emerge between the two cases. Both models show high explanatory power, with R-squared values of 0.585 for the PPs model and 0.751 for the APLs model. In both cases, the spatially lagged dependent variable is highly significant, with coefficients of 0.767 (PPs) and 0.857 (APLs)

(Tables 6 and 7). This indicates a strong spatial autocorrelation in the distribution of both APLs and PPs. In fact, spatial dependence is the most important explanatory factor for both distributions. That is, APLs and PPs tend to be located close to where other CCPs are, forming clusters throughout the city.

While the kernel density maps show distinct hotspots in the distribution of PPs and a more homogeneous distribution of APLs (Figure 3), the SAR models reveal that spatial dependence is actually slightly stronger for APLs than for PPs (Tables 6 & 7). This suggests that APLs are more systematically influenced by the presence of other APLs in nearby areas, even if they do not concentrate in clearly defined hotspots like PPs do. In other words, while PPs form dense clusters in specific locations, APLs form evenly distributed clusters across the city with similar levels of density.

Retail density is the only independent variable that significantly explains the distribution of both types of CDPs in our models. In both cases, and beyond their spatial dependence, APLs and PPs tend to be located in areas with a higher concentration of retail activity. This reinforces the dynamics of commercial agglomeration in the city, that is, the higher concentration of retail and associated activities in specific areas. However, retail density plays a much stronger role in explaining the location of PPs than that of APLs. The standardized coefficient for retail density in the PPs model is 0.048, compared to only 0.0057 in the APLs model (Tables 6 & 7). This is consistent with the fact that PPs must be hosted by retail businesses, while APLs can be installed in a wider variety of locations, such as parking lots, gas stations, residential buildings, or other non-commercial sites. Still, the positive association found for APLs suggests that many of them are installed as complementary services within or near retail establishments, behaving similarly to PPs.

Accessibility-related variables, such as distance to metro or suburban train stations, do not appear to significantly influence the overall location of CDPs. Nonetheless, the concentration and location of PPs are significatively related to the distance to the city's regional transportation hubs (intercambiadores), with a positive relationship, meaning that greater distances are associated with higher concentrations of PPs. This result is somewhat counterintuitive, given that these hubs function as key nodes in daily commuting flows, attracting high pedestrian traffic, which would typically be expected to favor the location of CDPs. Therefore, this significance may reflect interactions with other model variables and should not be interpreted as a primary explanatory factor. In contrast, APLs are not significantly influenced by the proximity to these transportation nodes.

Table 6. Spatial Autoregressive (SAR) model results for the distribution of PPs in Madrid. Bold indicates statistically significant coefficients ($p < 0.05$)

Variable	Coefficient	Std. Error	Z-value	p-value
Spatial lag of PPs	**0.767**	0.0048	158.80	**<0.001**
Intercept	−0.0716	0.0134	−5.35	<0.001
Distance to suburban train stations	0.00000184	0.00000403	0.46	0.648
Distance to metro stations	0.00000635	0.00001041	0.61	0.542
Distance to regional transportation hubs	**0.0000135**	0.0000047	2.88	**0.004**
Density of facilities	0.00022	0.0077	0.03	0.978
Retail density	**0.0482**	0.0017	28.63	**<0.001**
Population density	0.000037	0.000024	1.54	0.124

Model details: N = 13925; $R^2 = 0.585$; Log-Likelihood = −12,149.8; AIC = 24,315.5; Spatial weights matrix: fixed distance band (50 m). Diagnostics: Breusch-Pagan test for heteroskedasticity: $\chi^2(6) = 325.31$, $p < 0.001$.; Likelihood Ratio Test: $\chi^2(1) = 7403.25$, $p < 0.001$.

Source: authors' own elaboration

The location of CDPs is also not explained by the presence of public facilities, according to our models results. Hence, only central areas with significant retail density may be attractive for the location of CDPs. Finally, the SAR model for APLs found a weak and marginally significant negative relationship between population density and the location of APLs. This suggests that, unlike PPs, APLs are more often found in less densely populated areas. This is plausible, as many APLs are installed in peripheral zones, often associated with gas stations or other facilities that are easily accessible by car.

Table 7. Spatial Autoregressive (SAR) model results for the distribution of APLs in Madrid. Bold indicates statistically significant coefficients ($p < 0.05$)

Variable	Coefficient	Std. Error	Z-value	p-value
Spatial lag of APLs	**0.857**	0.0035	247.84	**<0.001**
Intercept	0.0025	0.0038	0.661	0.509
Distance to suburban train stations	−4.75e−07	1.13e−06	−0.419	0.676
Distance to metro stations	4.24e−07	2.93e−06	0.145	0.885
Distance to regional transportation hubs	−6.19e−07	1.32e−06	−0.468	0.640
Density of facilities	−0.00067	0.0022	−0.309	0.757
Retail density	**0.00575**	0.00046	12.43	**<0.001**
Population density	−1.21e−05	6.72e−06	−1.797	0.072

Model details: N = 13925; **R^2 = 0.751**; Log-Likelihood = 4861.27; AIC = −9706.55; Spatial weights matrix: fixed distance band (50 m). **Diagnostics**: Breusch-Pagan test for heteroskedasticity: $\chi^2(6) = 1458.89$, $p < 0.001$; Likelihood Ratio Test: $\chi^2(1) = 14{,}197.60$, $p < 0.001$.

Source: authors' own elaboration

5.3 Types of businesses operating as PPs

To understand the role that PPs play in the redefinition of traditional commerce and identify which businesses benefit from this activity, we classified the main activity of each previously analysed PP into a set of thematic categories. The results show that more than 70% of the sample can be grouped into 8 categories (Table 8): 1) internet cafés (*locutorios*); 2) electronics and IT; 3) groceries and convenience stores; 4) tobacco shops; 5) bookstores and stationery shops; 6) courier services; 7) newsstands or press kiosk; and 8) clothing stores. The remaining sample was categorized into two additional groups: 1) other (services), referring to local businesses that do not sell products but offer services; and 2) other (product sales), referring to miscellaneous retail shops.

Table 8. Number and percentage of PPs according to the typology of the local businesses where they operate

Bussiness type	Number of PPs	Percentage of PPs
Internet cafe	494	20.99%
Electronics / IT	335	14.24%
Groceries and convinience stores	300	12.75%
Tobacco shop	227	9.65%
Bookstore / Stationery shop	127	5.40%
Courier service	90	3.82%
Newsstand or press kiosk	70	2.97%
Clothing store	54	2.29%
Others (services)	265	11.26%
Others (product sales)	383	16.28%
Unknown	8	0.34%

Source: authors' own elaboration

The results indicate that the most common of establishments are internet cafés (*locutorios*), representing 21% of the sample. These businesses offer, among other activities, communication services, internet access, financial services such as money transfers, and parcel and courier services. In this case, their role as PPs is aligned with their core activities, although it may have increased with the rise of online commerce. Courier services appear in sixth place (3,82%). Combined, these two categories account for nearly 25% of the sample, meaning that 1 in every 4 businesses operating as PPs has parcel and courier services as its main activity. In the second and eighth positions we can find electronicts and IT stores and clothing stores, interestingly both are type of business that sells products closely linked to online commerce so the customer profile that collects packages is potentially the same as the one that buys in those stores. The third (groceries and convenience stores), fourth (tobacco shops) and seventh (newsstands or press kiosk) categories of business correspond to those that are part of the main daily groceries, which aligns with the results by Cárdenas (2019) that defend that some business benefit largely from this activity as costumers do not necessitate a specific trip to the PP but combine visits with other shopping activities. Finally, in the fifth place there are the bookstores and stationery shops, that do not necessarily share online costumers or are part of the daily groceries, but they do usually have a strategic location in residential neighborhoods (close to schools and administrative centers) which make them very accessible to regular users and facilitates their integration into LMD.

6 Discussion

Our analysis has demonstrated how Collection and Delivery Points (CDPs) are a common feature of contemporary urban areas, such as Madrid. Whether in the form of Pick-up Points (PPs) or Automated Parcel Lockers (APLs), CDPs are distributed throughout the city, usually mixing with traditional retail activities and adding new functions to the urban landscape. This shows how Last Mile Delivery (LMD) logistics are prompting continuous adaptation in urban areas, constituting a trend that, although already established, remains ongoing (Morganti et al., 2014; Lachapelle et al., 2018). It is a highly dynamic trend that may impose new changes and challenges on the urban and retail landscapes of the future (Barone & Roach, 2016).

6.1 Spatial patterns of CDP concentration

According to our results, the spatial distribution of CDPs in Madrid shows a clear pattern of concentration, with both PPs and APLs forming significant clusters around specific areas, and new CDPs often locating in close proximity to existing ones, as also observed by Xiao et al. (2017), Fang et al. (2019), and Kang (2025). In addition to their spatial dependence, our results suggest that CDPs tend to be located in areas with high retail density, similarly to what was found in the case of Portland by Schaefer & Figliozzi (2021). Accordingly, CDPs reinforce the urban functions of already vibrant and active areas, which usually refer to mixed used urban areas. In this regard, in Spain, and more generally in Mediterranean and Central European cities, retail activities are usually located in mixed-use areas, often aligned with the 15-minute city model (García-Álvarez, 2024; Murphy et al., 2009).

All companies analysed, except for Citypaq (operated by the national postal service, Correos), exhibit highly correlated CDP location patterns, which suggest market-driven decisions behind their specific distributions. In fact, the location of many CDPs, especially APLs, may be the result of business partnerships between major companies, like Amazon or InPost with Repsol (Repsol, May 28, 2024; Alimarket, September 6, 2023), as also noted in the U.S. context by Fang et al. (2019). In addition, from the user demand perspective, users tend to prefer CDPs in dense and centrally located urban areas that lie mid-way between home and work (Leung et al., 2023; Schaefer & Figliozzi, 2021).

In Australia (Brisbane), Lachapelle et al. (2018) found a similar logic to that observed in Madrid regarding the contrasting geographical patterns between CityPaq and other companies: CDPs operated by Australia Post were located near existing post offices, not following the same market-driven logic as CDPs operated by private companies, whose distributions respond to the drivers discussed above.

6.2 Spatial equity, mobility and efficiency in access to CDPs

Transport and logistics research has consistently highlighted the potential of CDPs to reduce the number and length of trips that customers must make to collect their parcels (Morganti et al., 2014; Lachapelle et al., 2018). According to this line of research, a more equitable spatial distribution of CDPs throughout the city, particularly in proximity to residential areas, can enhance the efficiency of LMD logistics both environmentally, by reducing emissions, and economically, by increasing the rate of successful deliveries to end consumers. However, our results show that, in Madrid, the current trend is the opposite: most CDPs are concentrated in central areas, reinforcing the city's commercial hubs. Russo et al. (2024, 2025) identified the same problem in Thessaloniki (Greece) and Acireale (Italy). Nevertheless, this pattern does not necessarily translate into more trips or emissions, as many customers collect their parcels during commutes or shopping trips (Fang et al., 2019).

A more recent and increasingly relevant body of research links the distribution of CDPs with equitable access to this service and territorial justice. In the context of the rapid and steady growth of online shopping, unequal access to CDPs may reinforce social disparities in terms of who can benefit of this new service and market opportunities (Zmuda-Trzebiatowski, 2024; Fried et al., 2024). In this regard, parcel delivery can be considered a basic service, similar to traditional mail delivery (Schaefer & Figliozzi, 2021). The concentration of CDPs in the central areas of Madrid, typically inhabited by high-income populations and characterized by expensive housing, suggest that their distribution does not align with any equity principle.

Among CDPs, APLs have the greatest potential for a more even distribution throughout the city, decoupling from central locations and commercial hubs and contributing to more equitable and efficient deliveries, at least in terms of transport costs (Song et al., 2009; Morganti et al., 2014; Xiao et al., 2017). In contrast, PPs can only operate where a local business exists, replicating the distribution patterns of urban commerce, which is increasingly uneven, with ongoing declines in traditional and local retail centres and streets (see Schaefer & Figliozzi, 2021). While there is room for a more balanced distribution of PPs, especially in traditional mixed-used compact cities like Madrid, the potential for achieving efficient, close-to-home LMD is greater when installing APLs, particularly in new developed urban areas, which tend to exhibit more functional zoning and a higher concentration of purely residential land uses (García-Álvarez, 2024; Lamíquiz Daudén et al., 2020).

Despite their potential, APLs in Madrid are currently concentrated in central locations and commercial hubs, much like PPs. However, our results suggest that their location is less influenced by accessibility factors, such as proximity to transportation hubs, and may even be negatively associated with population density. While this does not necessarily imply a shift to peripheral residential areas, some of which are densely populated, it does highlight a potential of APLs to decouple from agglomeration economies. Recent initiatives promoting the installation of APLs within newly developed residential areas suggest emerging trends that may reshape the current spatial distribution of these facilities, potentially giving rise to a new urban landscape with distinct implications for city functioning, as already observed in China's Riankin region in the post-pandemic period (Ding et al., 2023) or in Singapore (Guodong & Chung-Piaw, 2022). In this regard, the state-owned Citypaq, whose APL distribution already differs from that of other companies, could help develop a new LMD geography based on alternative, non-market-driven criteria, as suggested by Lachapelle et al. (2018) in the case of Australia Post.

6.3 Interactions between CDPs, urban retail, and place-based economies

Although efficient and relevant from a transport and logistics perspective, these new solutions may have important consequences for urban commercial activities, making online shopping easier and more comfortable, while further weakening its links with traditional retail. This could exacerbate the decline of local businesses and reinforce the concentration of retail in highly competitive, central locations, threatening the diversity and cultural richness of mixed-use urban landscapes, which are unequivocally associated with commerce and retail in European cities (Murphy et al., 2009). Ultimately, such dynamics may contribute to the rise of *non-places* (Augé, 1992).

On the other hand, the mentioned clustering of CDPs in lively and dynamic areas suggest that LMD solutions tend to reinforce already competitive urban zones. Despite marketing narratives that present CDPs as complementary services capable of attracting customers and improving visibility for traditional businesses (Weltevreden, 2008; InPost España, 2023, October 13), our findings indicate that CDPs further amplify market concentration in a few urban zones. Rather than strengthening less competitive retail streets or traditional local businesses and enabling them to assume a renewed role within the contemporary retail landscape, the current spatial allocation of CDPs and the dynamics of LMD logistics may further undermine their competitiveness by excluding them from new urban functions. In fact, in addition to the spatial distribution of CDPs, major retailers, especially in the fashion sector, are adopting commercial strategies that concentrate their activity in fewer, larger stores located in central, symbolic places (flagship stores). These stores simultaneously function as traditional retail spaces and delivery/drop-off points (Viu-Roig & Alvarez-Palau, 2020). This further highlights how these central areas are undergoing a process of reinvention, increasingly positioning themselves as key nodes in the emerging LMD landscape. Research from the field of transport, which emphasizes delivery efficiency and customer coverage, also tends to recommend mobility hubs and local centres as key development sites for LMD (Beckers & Verhetsel, 2021), potentially reinforcing these same concentration dynamics.

Our analysis of the types of businesses participating in the LMD market also reveals that not all retailers benefit equally from operating as CDPs. Almost 25% of PPs analysed were internet cafes (*locutorios*) and courier services stores, indicating that 1 in 4 establishments operating as PPs has parcel delivery as a primary business activity. These cannot be considered traditional businesses using CDPs as a complementary service to boost competitiveness. Apart from these, most PPs are found in electronics/IT stores, tobacco shops, and convenience stores, with very few operating in other sectors. This business profile is consistent with findings from Los Angeles (Fang et al., 2019), Portland (Schaefer & Figliozzi, 2021), Seine-et-Marne (Morganti et al., 2014) and Cárdenas (2019). These results suggest that, by attracting potential customers, LMD primarily benefits businesses that (i) already incorporate parcel services as one of the main components of their operations; (ii) offer goods that do not align with the needs and requirements of online shopping and are part of the daily groceries (e.g., tobacco, beverages, or takeaway food); (iii) provide services like internet access; or (iv) sell goods aligned with typical online shoppers' preferences, such as electronics. The commonly cited potential of local supermarkets and grocery stores to host CDPs aligns with this idea (Beckers & Verhetsel, 2021; Oliveira, 2019; Kedia et al., 2020), a point that has been validated in Belgium and the Netherlands (Beckers & Cárdenas, 2018).

All other businesses may not benefit from operating as CDPs, and may even be harmed, if they effectively support online competitors by delivering their products, potentially losing more customers than they gain. In conclusion, CDPs cannot be considered beneficial complementary services for most struggling local businesses, and may, in fact, contribute more to the problem than to the solution.

7 Conclusions

Collection and Delivery Points (CDPs) tend to cluster, often locating in close proximity to one another, and are concentrated in specific neighbourhoods, mainly in central areas of Madrid and certain peripheral districts characterized by vibrant urban life and high levels of retail activity. Retail activity concentration has been the most relevant factor explaining the distribution of both Pick up Points (PPs) and Automated Parcel Lockers (APLs). In this regard, the two types of CDPs display similar spatial patterns, generally being located in the same areas of the city.

The role of CDPs in reshaping traditional retail remains uncertain. It appears that not all types of businesses benefit equally from this role, with PPs mostly operating in internet cafes, electronics / IT stores, groceries and convenience stores and tobacco shops. Although some hypotheses have been proposed, we are not yet certain about the non-spatial factors that influence the participation of local businesses in this activity. Nor are we sure about the economic benefits it provides. Accordingly, further research is needed to address these questions. A qualitative approach, using interviews and surveys to explore the perspectives and experiences of urban retailers, may represent a promising line of future research.

This study provides a deeper spatial understanding of the phenomenon by offering the first comprehensive cartography of CDPs in Madrid. This information can support more effective management of the process, which could also benefit from complementary lines of research, such as the study of general online consumer behaviour. In addition, the potential future provision of official data on CDPs by Madrid City Council through its open data platform could represent a valuable opportunity to further improve the analysis and characterization of these dynamics.

Last Mile Logistics (LML) is a relevant component of contemporary urban dynamics, with important implications that require careful attention and the adoption of *ad hoc* territorial management policies. The spontaneous and exponential growth of this activity in recent years comes to confirm the sudden need to improve our understanding. Nonetheless, this public policy should not be limited to urban mobility regulation, but should also address the whole impact and interactions of LMD and CDPs with urban contexts, including their relationship with urban retail.

The study is affected by several limitations. First, our data did not include information of important companies working in the field due to the representativeness of the data that was collected. Second, the inherently dynamic and rapidly changing nature of retail activity means that the data collected offers only a static snapshot of a particular moment in time. Accordingly, future directions of work may also be aimed to update the collected data, increase its coverage and analyse the temporal dynamics of evolution of CDPs distribution across Madrid.

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