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Assessing the spatial patterns of Amazon warehouse network in the United States

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Abstract

E-commerce is simultaneously creating a new retail landscape through digitalization and new consumption and distribution practices (virtual access to a wide range of products, instantaneity, omnichannelity) and a new *freight landscape* in terms of the structuring of demand, the location characteristics of warehouses and distribution centers, transport strategies (modal choices and nodal facilities) and the handling of the last mile in central urban areas. The company Amazon embodies all of these developments in retail and e-commerce, being a dominant player in the e-commerce sector. This research therefore focuses on the evolution of Amazon's logistics system and in particular the geography of Amazon's warehouses, marked by an expansion of the spatial coverage of the warehouses and by a functional specialization of this logistics system. From the analysis of Amazon's logistics system, we understand how strong the spatial footprint of e-commerce is and we can confirm some of the major processes affecting the e-commerce sector and more broadly the retail sector. This empirical spatial analysis makes it possible to identify through cartographic representations several spatial logics for the establishment and extension of Amazon's logistics system: 1) a dual spatial rationale of networking and concentration of logistics warehouses, with the development of clusters of warehouses around major transport infrastructures and the creation of a more or less fine mesh of warehouses, particularly urban logistics areas; 2) a dual spatial rationale that focuses both on the outskirts of metropolitan areas and on dense urban centers; 3) an emergence of regionalized logistics strategies are being deployed that reveal differentiated systems, apparently taking into account territorial arrangements and socio-economic and urban dynamics.

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Keywords: Warehouse; logistics; Amazon; logistics sprawl; urban logistics; United States

1. Introduction: research objective and state of the art on logistics spatial patterns

This research looks at the evolution of Amazon supply chains and in particular the geography of its warehouses, marked overtime by an expansion in spatial coverage and by functional specialization. The objective of the research is threefold: to map these changes in space and time and identify the logics of Amazon spatial coverage, notably with respect to markets of different sizes; to identify spatial patterns according to warehouse type; to analyze the company's strategy at the regional scale in three large US consumer markets: New York, Los Angeles, Chicago.

Research on the geography of warehouses has been developing since the early 2000s, following a first wave of rapid growth of warehousing throughout the US, in particular in large megaregional areas of the country (Dablanc and Ross, 2012). A pattern of spatial decentralization of warehouses and growth in the number of warehouses on the outskirts of large cities, particularly in peripheral areas where densities are low, land is available and cheap, and plots are large, was identified in the US and in other urbanized regions around the world (Bowen, 2008, Cidell, 2010, Dablanc and Rakotonarivo, 2010, Giuliano et al., 2013). Urban renewal, land pressure and competition with other activities have created conditions that are increasingly unfavorable to the development of logistics activities in dense areas (Heitz, 2017), while peripheral areas offer large plots for logistics activities and access to big consumer markets thanks to good road and highway connections, favoring 'logistics sprawl'. In fact, the availability of transportation infrastructure offers good access at two scales: first, local access (to delivery areas) and secondly, regional or inter-regional access (to other cities or to other countries for logistics facilities that have an extended hub role). Local public policies in favor of logistics activities – such as the creation of dedicated logistics zones on the outskirts of cities – also influence the location of warehouses. The lack of spatial planning regulation in suburban areas has encouraged the construction of warehouses, fueling a process of logistics sprawl (Dablanc et al., 2014) in which warehouses become concentrated in sparsely populated peri-urban areas (Bowen, 2008; Cidell, 2010). The intensity of logistics sprawl varies with the type of warehouse (greater for distribution centers, lower for parcel sorting facilities) and according to the type of strategy pursued by logistics actors. Other factors contributing to logistics sprawl are changes in supply chains and the demand for logistics real estate and increasingly larger warehouses (Hesse, 2008).

Because of the lack of regulatory oversight of logistics by regional and metropolitan authorities, leaving isolated ex-urban municipalities negotiate with real estate developers integrated into international financial markets (Raimbault, 2014), logistics facilities have grown on the margins of cities, contributing to logistics sprawl. The main negative impacts of this sprawl (congestion, pollution, the artificialization of land) run counter to the objectives of sustainable cities, which typically include densification, mixed functions, reductions in congestion and CO₂ emissions, control of land artificialization. Sustainability agendas have shifted the focus on last mile logistics and urban warehouses as a way to offset logistics sprawl. At the same time, private demand for warehouses in dense areas has emerged. Some logistics sectors, particularly those linked to e-commerce, have started to look for warehouse capacity within cities. This new demand for real estate also coincides with the desire of public authorities to revive logistics activities in city centers in order to limit logistics sprawl. We are in the presence of a two-way movement: on the one hand, the development of peripheral logistics activities characterized by the rise of large, standardized logistics buildings, intended for logistics service providers, mass retail or manufacturing (Heitz et al., 2017); on the other hand, the emergence of urban logistics reliant on buildings that are still largely "made-to-measure" and subject to difficult urban integration.

E-commerce is simultaneously creating a new retail landscape through digitization and new consumption and distribution practices (virtual access to a wide range of products, instantaneity, omnichannelity) (Ramcharran, 2013; Hagberg et al, 2016), and a new freight landscape with respect to the structuring of demand, the location patterns of warehouses and distribution centers, transportation strategies (modal choices and nodal facilities), and the handling of the last mile in central urban areas (Bowen, 2012; Rodrigue, 2020). As the main player in US e-commerce, and one of the main players in e-commerce in many regions around the world, Amazon offers a good example of the effects of e-commerce on the organization of the supply chain, on the warehouse sector and on urban spaces. Jean-Paul Rodrigue (2020) in his paper on Amazon logistics system has identified four major effects of e-commerce on the distribution of goods: effect on distribution structures (growth of B2C deliveries); effect on the real estate market (shrinkage of the land footprint associated with retail activity, and expansion in the footprint of warehouse facilities); effect on logistics facilities (development of new types of warehouses – e-fulfillment centers, sorting facilities, urban logistics hubs); effect on business strategies (vertical integration, development of 3PL and 4PL services or own transportation services by pure e-commerce players). E-commerce players are seeking to maximize access to urban markets and minimize

delivery times by achieving significant economies of scale and density, particularly for their distribution centers (Houde et al., 2017), developing their own urban logistics strategies for last-mile deliveries (Browne et al., 2019), and promoting vertical integration, where Amazon is a pioneering player (Lieb and Leib, 2016). Most of the scientific works on logistics sprawl are interested in the spatial dynamics of warehouse location, in an undifferentiated way, without distinguishing the types of warehouses (distribution centers, cross-docking warehouses), or the companies (logistics providers, parcel and express operators, e-retailers), or the catchment areas of each warehouse (to understand which warehouse serves which area). This is primarily due to the lack of reliable and available data. A few studies are beginning to address this issue (Heitz, Launay and Beziat, 2019), particularly on Amazon logistics system in the United States (Rodrigue, 2020; Schorung and Lecourt, 2021) or on the terminals of a carrier like DB Schenker (Robichet and Nierat, 2021).

This paper examines the deployment of Amazon warehouses in the United States through an empirical spatial analysis. This research is based on quantitative approach to generate maps and barycenters and a qualitative approach to situate the evolution of Amazon's warehouse network within its overall business and logistics strategy and present current information about Amazon from the press. This approach allows us to identify the spatial patterns, at different scales (national scale, regional scale, metropolitan scale), that underlie this deployment. This research complements recent work, notably an article by Rodrigue (2020) that analyzed Amazon's logistics development overtime. We focus on three items of interest: the specialization of Amazon warehouses, the development of differentiated regional spatial patterns, and the analysis of the spatial distribution of warehouses according to type and size. The research on the size of warehouses develops the work done by Kang (2020b) who analyzed the differential of logistic sprawl in US cities based on size levels. The paper is structured as follows. In the first part we present the methodology used to analyze the database and to carry out the maps; then we briefly present Amazon and the organization of its supply chain; then we analyze the spatial patterns of Amazon warehouses overtime at the scale of the United States before looking at the functional specialization and the diversification of Amazon warehouses. A penultimate section is dedicated to a regional and metropolitan approach to the Amazon system, based on the cases of the Northeast region, Los Angeles and Chicago. The final section presents and discusses the findings and outlines perspectives for further research. This analysis aims to represent and understand the spatial footprint of Amazon's warehouse network, as well as the spatial patterns according to different territories and according to different types of warehouses. The Amazon business contributes to logistics sprawl, especially for fulfillment and sortation centers. Nevertheless, this analysis could be deepened by an environmental approach in order to understand if the development of this network of warehouses, in particular those in dense spaces, increases or manages to reduce negative externalities (congestion, emissions of pollutants and CO₂).

2. Data and methodology

The analysis of Amazon's warehouses in the United States was based on an inventory of logistics facilities maintained by MWPVL International¹, a logistics and supply chain consulting firm. This inventory is regularly updated. It is accessible from the company's dedicated website and, though protected, is authorized for use for purposes of research. This inventory is the most complete one available but it is possible that some projects are not referenced or that the information on smaller logistics facilities (especially *Prime Now* hubs) is fragmented.

This research was conducted from April to July 2021, and is based on the May 2021 inventory, so some information (particularly on planned warehouses) may have changed since then. In order to represent the spatial processes in 2021 as simply as possible, it was decided to include all facilities, including projects with opening dates up to December 2021. This database contains information about the location, with for each facility: a specific code (usually 3 letters and 1 number), the location by U.S. state and then by address (precise or approximate, especially in the case of planned facilities), the function and type of warehouse, the surface area (expressed in square feet), the year of opening (estimated opening for projects), the status of the warehouse (open, closed, planned), the co-presence, if any, of any other logistics or transportation facility. Other information subject to cartographic processing may feature in the description of warehouse function, for example whether it has been extended or is totally or partially automated.

After recovering the database, which had to be transcribed in its entirety to Excel spreadsheets by OCR processing because of its size, and since the website of MWPVL International is protected against automatic copying, despite the

¹ https://www.mwpvl.com/html/amazon_com.html [accessed on 05/15/2022].

authorization to use the data for research purposes, the task of standardizing the database was undertaken as well as extracting certain characteristics in the description of functions, in particular the automation of certain facilities or the distinction between warehouses that specialize in handling “sortable” and “non-sortable” products. The tables included in the data retrieved from the website were scanned. Each facility address was geocoded from the address provided or the approximate location (in which case we chose either to represent the middle of the facility or to indicate a location in the nearest industrial zone) via OpenStreetMap and Nominatim. This entailed a degree of approximation in the location of some warehouses and we undertook manual relocation for the outliers using the GIS software QGIS. The maps presented in the following study were produced using QGIS, supplemented by processing in R software for statistical representations.

3. Amazon: an e-commerce logistics powerhouse and the sprawling growth of its building footprint

As the dominant player in the e-commerce sector, Amazon embodies every development in retail and e-commerce: in 2017, Amazon accounted for 37% of the total online shopping market in the United States, rising to 38.7% in 2020. Its share is expected to exceed 40% in 2022. In the United States, Amazon’s supremacy is clear: 39.5% of the e-commerce market in 2021, compared with 7.1% for Walmart (2nd), 4.3% for eBay (3rd), 3.7% for Apple (4th), and 2.2% for Best Buy (5th)². In the retail sector as a whole, Amazon is the second biggest market player behind Walmart. The Covid-19 pandemic has had the effect of accelerating Amazon’s already spectacular growth, with sales in 2020 rising by 44.1% and by 22% in 2021. This performance is based on a particularly successful vertical integration and recognized efficiency in supply chain management, particularly in the last mile³. This effectiveness relies on a logistics system organized around an interlocking network of warehouses and logistics facilities of different sizes and types, emerging proprietary 3PL and 4PL services, and emerging proprietary transportation services (air and road freight). At the beginning of 2021, Amazon purchased eleven Boeing 767 aircraft converted to cargo planes. Amazon cargo fleet operates as of October 2022 110 aircrafts and is expected to add 10 Airbus planes by the end of 2023⁴. For several years, Amazon has been shifting its strategy towards direct ownership and control of most aspects of the supply chain, in order to reduce its dependence on third-party service providers (UPS, FedEx). This enabled the company to reduce its click to door time in 2020 from an average of 3.4 days to 2.2 days (industry average: 5.1 days)⁵.

For the United States, the database lists a total of 302.6 million square feet (28.1 million square meters) of logistics facilities and warehouses for 2021, and more than 144.6 million square feet (13.4 million square meters) of planned projects (2021-2024). The Amazon warehouses listed are divided into nine categories (Schorung and Lecourt, 2021):

- Fulfillment and Distribution Centers are large distribution centers that handle consumers’ online orders, generally ranging in size from 500,000 to 2 million square feet. Many of these centers are undergoing full or partial automation as well as expansion (either through the reorganization or optimization of existing structures or through extensions). Large distribution centers may also specialize: according to product type (clothing, jewelry, electronics, perishables, all information that may be mentioned in the description of the functions in the database but has not been the subject of a cartographic processing); or according to the nature of the handling and packaging (“small sortable” for small sortable products that can fit in packages weighing less than 10 kilos, “large sortable” for sortable products weighing 10 to 25 kilos; “large non-sortable” for heavy and/or bulky products such as furniture or televisions that cannot be sent in standardized packages).
- Pantry/Fresh Food Fulfillment Centers are the same types of warehouses as the previous category, i.e. large distribution centers, but specialize in handling orders for perishable and/or fresh food products as well as cleaning products.
- Whole Foods Retail Grocery Delivery Centers constitute a very specific category with a limited number of facilities, catering for the stores of the Whole Foods chain acquired by Amazon in 2017 for \$13.7 billion. These supermarkets also act as distribution and delivery centers for the chain and for online orders.
- Prime Hubs are local fulfilment and picking hubs dedicated to express deliveries and Amazon’s fast delivery service. These urban hubs serve very fast deliveries, in less than 48 hours, and instant deliveries, in less than

² <https://www.emarketer.com/content/amazon-dominates-us-ecommerce-though-its-market-share-varies-by-category> [accessed on 06/12/2022].

³ <https://www.forbes.com/sites/shelleykohan/2021/02/02/amazons-net-profit-soars-84-with-sales-hitting-386-billion/?sh=69d546a41334> [accessed on 06/12/2022].

⁴ <https://www.aboutamazon.com/news/transportation/amazon-air-adds-10-airbus-a330-300s-to-its-global-fleet> [accessed on 06/11/2022]

⁵ <https://www.forbes.com/sites/shelleykohan/2021/02/02/amazons-net-profit-soars-84-with-sales-hitting-386-billion/?sh=69d546a41334> [accessed on 06/13/2022].

two hours. These small and medium-sized warehouses are located in dense parts of major metropolitan areas in order to be as close as possible to demand and to cover the catchment zones in central and peri-urban areas.

- Inbound Cross Dock Centers (IXD) are processing centers for maritime containers carrying goods imported into the United States, generally located near major multimodal hubs (ports, logistics parks, rail hubs): “IXDs are the point of entry for the fulfillment process in e-commerce by synchronizing inbound procurement logistics with the distributional capabilities of e-fulfillment centers” (Rodrigue, 2020).
- Regional Sortation Centers are the intermediate regional links between several large distribution centers. They are used to sort packages for a given region from multiple Amazon distribution centers. Packages are sorted by zip code and then redistributed to local links in the supply chain, either to third-party carriers (e.g. UPS) or to smaller delivery and last-mile distribution centers.
- Delivery Stations (Packages) and Delivery Stations (Heavy/Bulky) are small last-mile delivery centers that serve either as distribution locations for delivery drivers picking up packages or as final delivery pick-up points. These small facilities are the most local link in Amazon’s logistics system and there are large numbers of delivery and collection points in urban and suburban areas. Some of these delivery and distribution points correspond to pick-up points, in particular “Amazon locker banks”. The database divides these “stations” into two sub-categories: delivery points for small packages and delivery points for unpackaged bulky or heavy objects.
- Air Gateways are facilities located near or within an airport space that handle the cargo pallets of air cargo services from or to major distribution centers and large pooling centers. These services are organized according to a hub-and-spoke principle (Rodrigue, 2020).

The most commonly represented type of warehouse is the Delivery Stations Packages & Heavy/Bulky, of which the database lists 454 across the country and another 275 planned facilities, reflecting the exceptional growth of Amazon business in the United States and in particular its spatial coverage. The second commonest type is the distribution center, of which the database listed 264 facilities and 106 planned facilities as of September 2021. Distribution centers account for the bulk of Amazon’s spatial footprint: 184.8 million square feet (17.1 million square meters), or nearly 61% of Amazon’s total warehouse space. They also account for 49.4% of total planned space.

4. Amazon’s US-wide logistics system rollout strategy

4.1. From a niche business to a multinational firm

The exceptional spread of Amazon logistics system reflects the equally exceptional growth of the company’s business. Rodrigue (2020) has identified four phases of growth since the 1990s:

- The first phase corresponds to Amazon’s entry into a niche market from 1995 onwards, at a time when the Internet economy was in its infancy and e-commerce represented a tiny niche business. At that time, the company had only a very limited number of medium-sized distribution centers. The business was limited to digital products.
- The second phase, starting in the mid-2000s, marks a shift in Amazon’s business strategy with rapid diversification in the types of products sold (electronics, toys, cosmetics, clothing). As a result, a first wave of expansion in Amazon’s logistics system took place from 2005 to 2008, ensuring Amazon’s emergence as an e-commerce platform: in particular the increase in the number of distribution centers and the opening of the first Inbound Cross Dock for imported goods.
- From 2010, the company pursued a very active growth strategy, particularly through greater horizontal integration, in response to the rapidly growing demand for online shopping, especially in the United States. To achieve this, Amazon began opening a large number of distribution centers throughout the country, followed by a gradual process of warehouse specialization with the opening of Sortation Centers, Delivery Stations, and the first local hubs for the Prime Now premium service.
- Finally, since 2016, Amazon’s logistics system has undergone three major changes: a change of scale with the opening of a very large number of warehouses, especially large distribution centers, enabling the company to assert itself as the dominant player in the U.S. e-commerce sector; the move towards increasing warehouse specialization; and a strategy of vertical integration that has reinforced Amazon’s control over the entire distribution and transportation chain and reduced its dependency on third-party carriers (UPS, FedEx).

4.2. Exponential development and a strategy of diversification

An analysis of the MWPVL International database shows Amazon's deployment strategy over time. The first graph below (Fig. 1 (a)) situates the opening of Amazon warehouses in time (from 1997 to the projects planned up to 2024). Through this representation, we can identify the multiple phases of expansion, especially the massive business expansion and the reinforcement of the spatial coverage of the warehouses between 2015 and 2020. However, the most interesting lesson from this graph is the reduction over time in the average size of the warehouses opened, especially in the years 2014-2015. Each point represents the creation of a warehouse (all categories combined) classified by date (x-axis) and surface area (y-axis). The concentration of points on the right shows the surge in the number of warehouses from 2013 to 2014, and also shows the proliferation of very large warehouses from 2010 onwards. We also provide the curve and the linear regression line, which show the downward trend in the average surface area of warehouses (the curve shows that it rose until 2010, then fell until 2015 and has remained stable since). The straight line and regression curve express this gradual decrease over time after a period of continuous growth from 1997 until 2013, with a short period of large warehouse openings between 2009 and 2013. This represents a shift in Amazon's logistics strategy, with a gradual move towards the coverage of urban spaces, which require small urban warehouses (e.g. for fast delivery services) and many small delivery and parcel distribution points. It is also interesting to note that only a small number of large distribution centers are planned for the period 2021 to 2024.



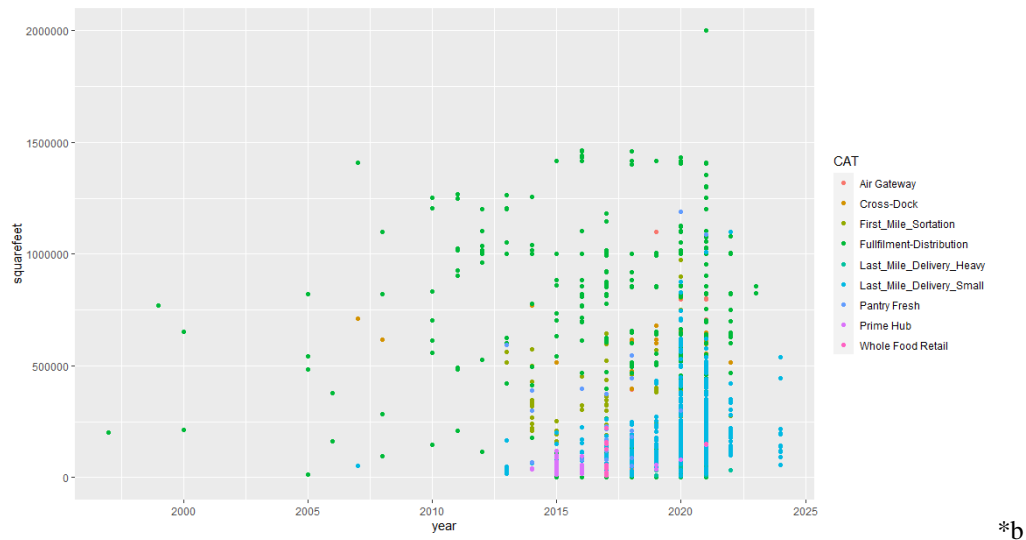


Fig. 1. *(a) Opening of Amazon's US warehouses over time by size (sq ft) and the right and left-hand regression curve; *(b) Opening of Amazon's US warehouses over time according to size (sq ft) and the right and left-hand curve of regression. Data source: MWPVL©. Lecourt, Schorung, 2022.

When looking at warehouse types, the process of functional specialization and the location of logistics centers in metropolitan areas for last-mile distribution are confirmed. Several observations can be made on the basis of this graph:

- Amazon's logistics development has taken place in a short period of time, an extraordinary process of exponential development over a timespan of only 7 to 8 years (2014-2021).
- Amazon's strategy is based on diversification and functional specialization with respect to both the size and the type of warehouse. From 2013 to 2016, the number of warehouses – whether large, medium, or small – increased. Although after 2018 Amazon mainly focused on small warehouses and last-mile logistics facilities, very large distribution and fulfillment centers continued to be established, several dozens of them measuring almost 1.5 million square feet (130,000-140,000 sq m), some are multistorey warehouses.
- Distribution centers constitute the backbone of Amazon's logistics system, and their spatial coverage is expanding, including DCs planned for 2022 to 2024. This skeleton connects to a specialized regional framework (*Sortation Centers, Inbound Cross Docks, Air Gateways*) and by a relatively narrow local framework (*Last Mile Delivery, Prime Hubs*).

The graph above (Fig. 1 (a)) provides an additional representation of this spatial expansion over time based on warehouse type. This graph firstly illustrates the relative influence of each type of warehouse in Amazon's global logistics system: the large distribution centers (*Fulfillment Centers*) represent the bulk of the system, confirming the exceptional spatial coverage of US territory, in particular from 2014-2015 onwards, with growing diversity in the size of distribution centers, especially medium-sized centers.

The functional specialization of Amazon's warehouses can be clearly seen in this graph, with numerous specific warehouse openings between 2015 and 2020: *first-mile sortation centers, last-mile delivery centers, Prime hubs, pantry/fresh centers*. This specialization also signals Amazon's strategy of vertical integration to reduce its dependence on third-party operators, as shown by the very rapid opening of air hubs (*Air Gateways*) and cross-dock terminals.

4.3. A global geography of Amazon's logistics system

The map below provides a spatial representation of Amazon's logistics system according to the type of warehouse or logistics facility: "air gateway", "inbound cross dock", "regional sortation center", "pantry and fresh distribution center", "whole foods retail or distribution center" (Fig. 2). Several observations suggest themselves:

- Air Gateways are few in number. They are generally not located in major airport hubs (except Dallas and Los Angeles). Instead, Amazon appears to set up facilities either at medium-sized airports or at large airports that do not serve previously as a hub for a carrier or express carrier. As of 2021, Amazon's largest hub is located near Cincinnati in the city of Wilmington, while Atlanta (the largest US airport) or Memphis (FedEx territorial base) do not host a hub. The situation in the Northeast region is enlightening on this point: the two Amazon hubs are located outside the major metropolises.
- IXDs ("Inbound Cross Docks") are processing centers for maritime containers loaded with goods imported into the United States, generally located near major multimodal hubs (ports, logistics parks, rail hubs).
- Regional Sortation Centers are the intermediate regional links between several large distribution centers. They are used to sort packages for a given region from several Amazon distribution centers. There are a large number of them, and each major or intermediate metropolitan area is served by one or more of these intermediate sorting and distribution centers.
- Pantry and Fresh Distribution Centers cater to developing markets, and so far have a modest logistics footprint with few warehouses. These are generally small – with two exceptions in the east – and close to major urban centers so that they can meet demand from urban customers for fresh/perishable and household goods.

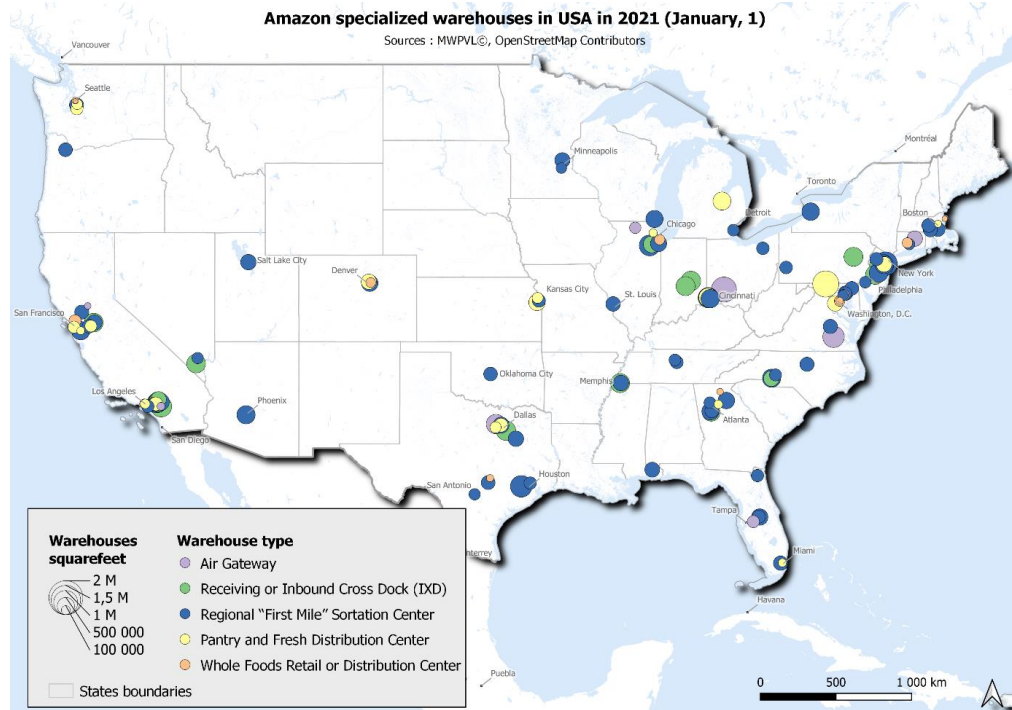


Fig. 2. Opening of Amazon warehouses in the United States in 2021 by warehouse type. Data source: MWPVL©. Lecourt, Schorung., 2022.

Finally, to complete this national overview of Amazon's logistics organization, we represented the spatial distribution of all distribution centers (Fig. 3), regardless of category.

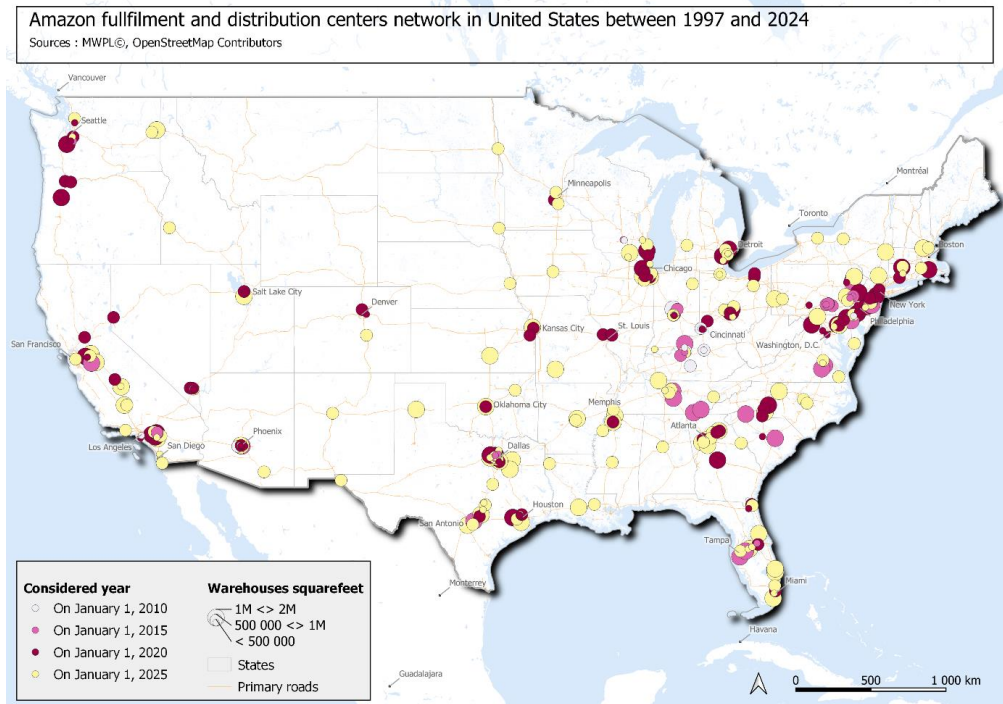


Fig. 3. Evolution over time (at four selected time steps) of fulfillment and distribution centers in all categories across the United States. Data source: MWPVL©. Lecourt, Schorung,, 2022.

To do this, we chose four time steps, including one in the future to include all the listed projects, in order to visualize the spatial distribution of Amazon warehouses. Three remarks can be made:

- Until 2015, the establishment of large distribution centers is geographically very selective, concentrated in a few major economic regions in the country (California, Atlanta region, the Northeast). It is interesting to note that, before 2015, distribution centers are not established in other major regions and metro areas of national importance, or else are modest in size (Texas metro areas, Chicago, St. Louis, Miami, Detroit, Boston). This may reflect Amazon’s strategy of setting up in a few key areas with a mature or strong e-commerce market and favoring locations near major “gateways”, as illustrated by the situation in the South-East around Atlanta.
- From 2015 to 2020, Amazon’s spatial expands very significantly, reflecting the proliferation of its activities and its dominant position in the e-commerce sector. All major metropolitan areas now have one or more large distribution centers, forming clusters of warehouses in the most urbanized regions (North East, Great Lakes region, Atlantic Piedmont, Texas Triangle, California). In addition, fulfillment centers start to arrive in previously neglected inland regions and mid-sized cities (Salt Lake City, Denver, Las Vegas, Phoenix, Kansas City, Oklahoma City, Portland, Minneapolis etc.). This global trend signals the horizontal integration strategy implemented by the company in the 2010s in order to achieve economies of scale and cut costs through the proliferation of warehouses and the development of a tight network of large distribution centers and specialized warehouses.
- The projects listed from 2021 to the end of 2024 reflect a threefold strategy: continued horizontal integration with a sharp increase in the number of distribution centers in the United States; tightening of the network in the best-served megaregions (Great Lakes, Northeast, Texas Triangle, California, Florida, Atlantic Piedmont, Northwest region); the implementation of an interstitial strategy to fill the “gaps” in less densely populated territories, with projects planned for medium-sized cities and in states or regions without a major metropolis (Idaho, North Dakota, South Dakota, New Mexico) as well as in smaller cities in states where they are already present.

4.4. Amazon: a network logic favouring urban logistics

For several years, Amazon has been offering fast (less than 48 hours), very fast (less than 24 hours) and even same day delivery services for certain types of products – until May 2021 Amazon gave access to a dedicated service (dedicated app and website) for its *Prime Now* members for less-than two hours deliveries⁶. Providing these new services to consumers requires specially designed and dedicated logistics facilities, in particular for the premium *Prime Now* service. In line with its overall strategy of horizontal and vertical integration, the company is therefore developing small urban warehouses through which it can control the various links in the logistics chain, particularly the last mile (Fig. 4). These urban *Prime Now* warehouses are very small compared with the other warehouse categories and have a coverage that is still largely limited to the major metropolitan markets where demand for this type of service is highest – there are several warehouses in the Los Angeles, San Francisco, Dallas and New York City areas.

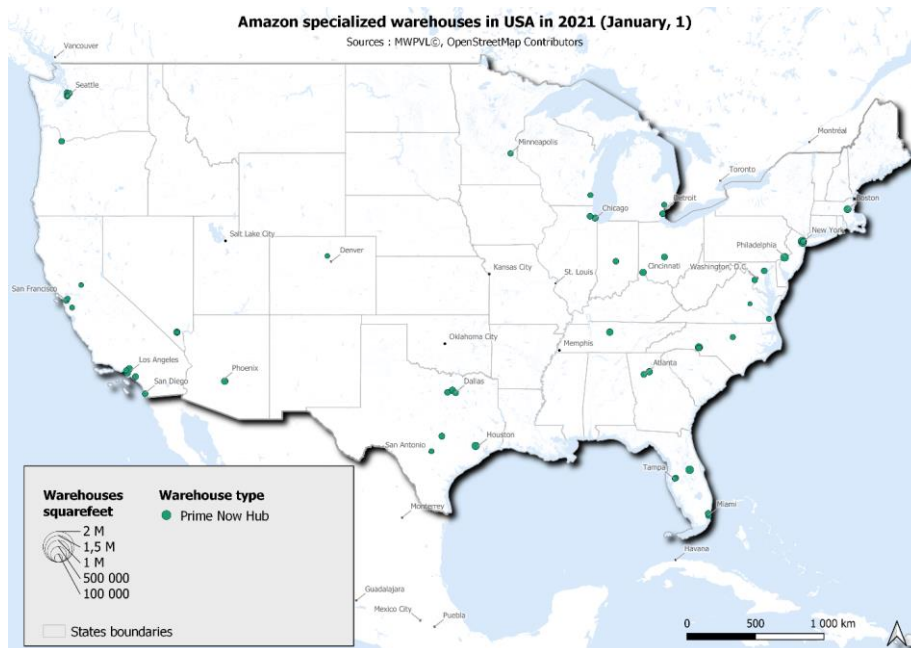


Fig. 4. Location of small urban Amazon warehouses dedicated to *Prime Now* service as of January 1, 2021. Data source: MWPVL©. Lecourt, Schorung, 2022.

These dedicated urban warehouses are currently concentrated in metropolitan areas at the top of the American urban hierarchy, although some intermediate areas are now included (San Diego, Sacramento, Portland, Tampa, etc.). In 2016, 44.8 million U.S. households signed up for Amazon Prime. That number is expected to grow to 81.4 million by 2021 and 90.2 million by 2025, according to projections by consulting firm Insider Intelligence.⁷

⁶ <https://www.cnn.com/2021/05/21/amazon-is-shutting-down-its-prime-now-fast-delivery-app.html> [accessed on 11/06/2022].

⁷ <https://www.emarketer.com/content/forecast-just-how-big-amazon-prime-how-fast-will-grow> [accessed on 12/11/2022].

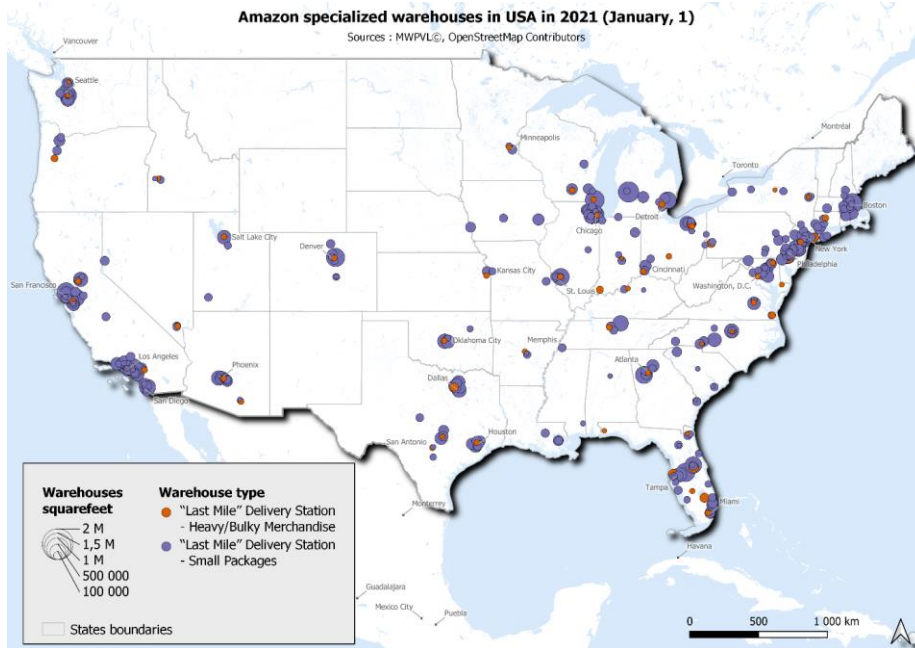


Fig. 5. Location of *last mile* delivery stations in the United States as of January 1st 2021. Data source: MWPVL©. Lecourt, Schorung., 2022.

Last-mile delivery stations are the most developed type of logistics installations in Amazon's logistics system⁸. They handle the final stage of delivery to the end customer, and their spatial coverage must be as extensive as possible to facilitate access to distribution and delivery points for carriers, delivery personnel, or consumers. There are two types of delivery point, for different product types: points for small parcels, which are the most numerous, and points for heavy or bulky goods. The map indicating the location of these sites as of January 2021 shows the extent of this spatial coverage (Fig. 5). Several observations can be made:

- A few megaregions contain the bulk of these last-mile delivery points: the Northeast region, the Great Lakes region, Florida, Piedmont Atlantic, the Texas Triangle, Northern and Southern California, and the Northwest region.
- In some metropolitan areas, the density of delivery points is very high, reflecting the adjustment of the logistics system to the most dynamic urban markets (New York, Los Angeles, Chicago).
- All major metropolitan areas and most intermediate metropolitan areas have this type of logistics facility, even mid-sized cities like Boise, Idaho, where Amazon's market developed the latest.
- The very strong dissymmetry in numbers between delivery points for small packages and delivery points for heavy/bulky merchandises testifies to the dominance of small packages in Amazon's sales activity.
- The delivery points vary extensively in size: from small, intermediate-sized urban warehouses serving as collection and redistribution points for delivery personnel and third-party carriers to automated delivery points (e.g., *locker* type) in small, dedicated, covered spaces.

5. Diversification, functional specialization and regionalization of Amazon's warehouses

5.1. A combined process of specialization and concentration within the main megaregions

The analysis of the spatial location strategies for distribution centers can also provide insight into the process of functional specialization for warehouses. In the period 2014–2015, Amazon pursued a vertical integration strategy to gain control of several components of the global supply chain, from importing goods, to chartering air assets for distribution over continental distances, to last-mile delivery (Rodrigue, 2020). This diversification strategy is

⁸ Automated lockers are not included in the database and are not represented on the maps below.

represented in the map below (Fig. 6) in which the distribution centers are listed according to the main characteristic specified in the database: “sortable” (for sortable goods that can be sent in parcels), “non-sortable” (for non-sortable goods that cannot be sent in parcels), “specialized or seasonal” (for warehouses that handle a specific type of goods or that are used only for particular periods such as Thanksgiving), “other or unknown” (for warehouses for which no specific characteristic is mentioned). It should be noted that some of the information contained in the database was not mapped, in particular the specialization of certain warehouses in particular types of goods (e.g. toys, furniture, jewelry).

This mapping confirms the rather late, but very effective, move to specialization in Amazon’s logistics system. The map (Fig. 6) shows an intensification of this strategy of diversification and specialization. Several observations can be made:

- The eastern United States has a higher number of warehouses, of varying size but large in many cases, spread over a much larger number of locations. In the western United States, there are fewer locations and they are concentrated in the largest metropolitan areas, which also serve as gateways for goods (ports, airports) (Seattle-Tacoma, Portland, San Francisco-Oakland, Los Angeles-Long Beach-Riverside).
- Several regions contain the bulk of warehouses in all categories (North-East, Midwest, Atlantic Piedmont, California). These regions are home to many “sortable”, “non-sortable”, and “specialized or seasonal” warehouses.
- *Non-sortable* warehouses are generally large, with locations near urban centers (Los Angeles, New York, Chicago), in the inner suburbs of metropolitan areas (San Francisco, Seattle, Phoenix), or in exurban areas within megaregions (Piedmont Atlantic, Northeast).
- *Sortable* warehouses are generally of intermediate size and are located relatively close to urban centers, sometimes forming clusters of warehouses within a single metropolitan area (Los Angeles, Chicago, Tampa, Northeast).
- *Seasonal* warehouses are fewer in number and more selectively located throughout the United States, with two main areas of concentration (Midwest and Northeast).

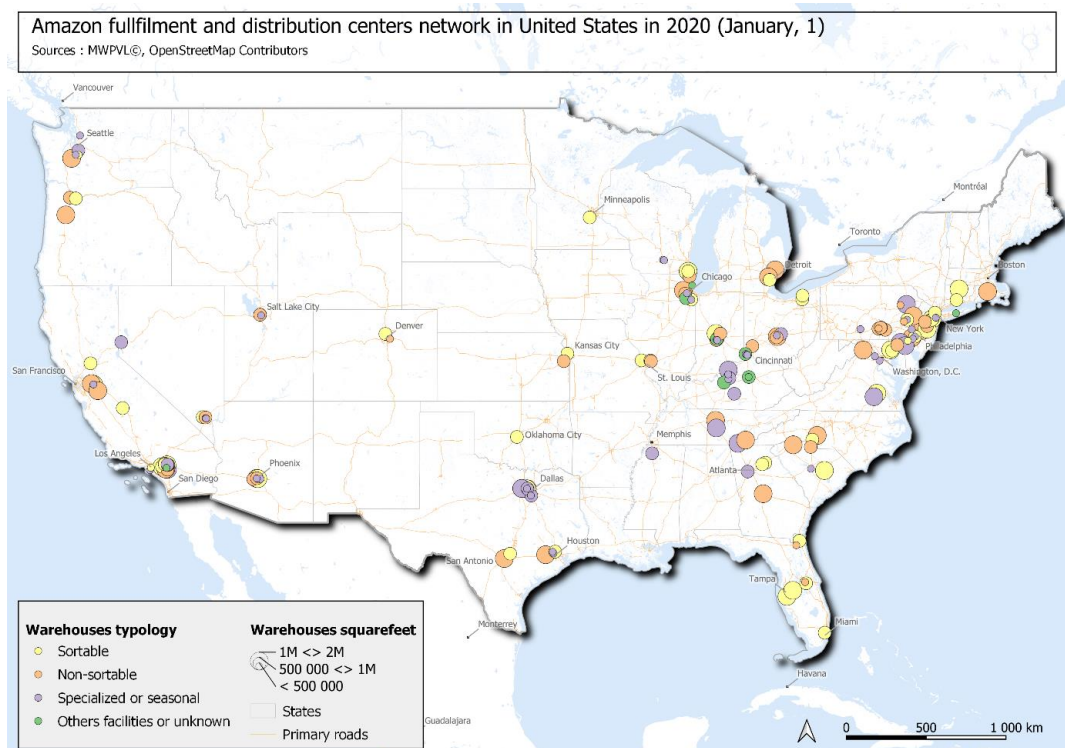


Fig. 6. Location and specialization of *fulfillment and distribution centers* across the United States as of January 1st 2021. Data source: MWPVL©. Lecourt, Schorung., 2022.

In addition, the company has embarked on a strategy of diversifying its logistics stock to incorporate the latest warehousing innovations (multi-story warehouses, automated warehouses) (Fig. 7). This map shows the spread of these innovations: several robotized (totally or partially) warehouses are open (in some cases apparently conversions of traditional warehouses rather than new structures). These robotized warehouses are located in major metropolitan markets (Los Angeles, New York) as well as, more surprisingly, in the Midwest (St. Louis) and in Columbus, Ohio. As of January 1st 2020, only one multi-story warehouse is shown in Riverside in the Los Angeles metropolitan area. As of mid-2022, the database lists 29 multi-story warehouses across the United States (some are not yet confirmed projects).

5.2. *Toward regional models of logistics development: a regional and metropolitan approach with three case studies (Northeast, Los Angeles, Chicago)*

The analysis of the spatial footprint of Amazon's warehouses on a national scale demands a cross-section of scales in order to understand how Amazon's regional and metropolitan network is organized. We considered a relatively large regional space (the Northeast region, in particular the region between Washington D.C. and New York City) and two wider metropolitan areas (Los Angeles-Riverside and Chicago). New York, Los Angeles, and Chicago are among the three largest consumer markets for e-commerce and are the top three metropolitan areas for the number of logistics warehouses (493 NAICS code) according to the US census Bureau's County Business Patterns data. Los Angeles and New York, and secondarily Chicago especially as a rail hub, are major gateways for international and domestic trade as well as powerful multimodal trade and logistics hubs (Rodrigue et al., 2017).

In the case of the Northeast megalopolis, our analysis focused on the central and southern part, from New York to Washington D.C., taking into account the warehouses in the hinterland in relative proximity to the major maritime, air, and logistics gateways. Based on the map of Amazon's network of logistics operations in the region on January 1, 2021 (Fig. 7), most of the warehouses are located in the urban continuum of the Northeast region following a linear pattern and the region's major transportation corridors. Several observations stand out:

- The large distribution centers are mainly located in the outskirts of the major metropolitan areas (Baltimore, Philadelphia, New York). Moreover, several of the biggest centers are located in exurban areas, such as the three between Baltimore and Wilmington and the four between Philadelphia and New York at Trenton.
- In addition, a second hinterland arc would appear to play a supporting role with a cluster of several distribution centers in the Harrisburg and Allentown suburbs and a large warehouse to the southwest in Winchester. The mismatch between the size of the logistics location and the size of the surrounding market might suggest that these hinterland warehouses either service logistics facilities for the core consumer markets, or are facilities that mesh with many intermediate-sized inland markets.
- Many warehouses are located on the fringes of the metropolitan area, on the edge of the urban areas shown on the map: there is a correlation between the size of the warehouse and its location in the urban area, confirming the search for low-cost land available for large warehouses.

The large logistics warehouses that do not fall into the "fulfillment and distribution centers" category – Inbound Cross Dock, Regional Sortation Center, Pantry and Fresh Distribution Center – are located in the region in two ways: either on the periphery of the metropolitan fringe or in a pericentral position relatively close to urban centers (Trenton, Newark, Baltimore). This pericentral position could confirm the role of these warehouses as intermediate links in Amazon's global logistics chain.

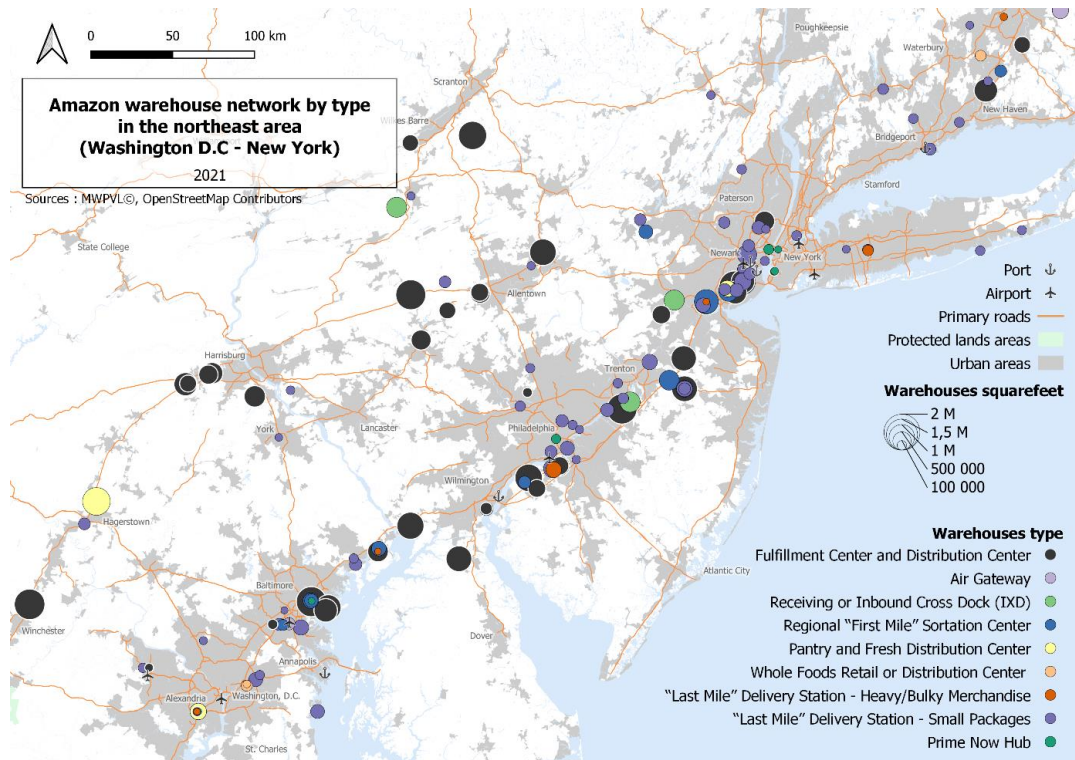


Fig. 7. Amazon's logistics network in the Northeast region (Washington D.C.-New York City) in 2021. Data source: MWPVL©. Lecourt, Schorung, 2022.

Finally, there is a second level in this logistics network, an urban and local network with a multitude of small urban logistics spaces (“last mile delivery stations” and “Prime hubs”). There is a fine network of urban delivery points that is particularly well developed in the two major cities considered in the study area: Philadelphia and especially New York. The other two cities further south have a much looser network, reflecting the relatively strong geographical selectivity of e-commerce and urban deliveries. The other urban logistics areas appear to be scattered throughout the region under consideration, with a multitude of points in suburban areas, illustrating the strategy of penetrating suburban consumer markets. The Prime Hub service and its small urban hubs dedicated to these rapid delivery services are marked by selectivity for an even larger geographic area, with a single deployment market in New York City, apart from a small Prime warehouse in Philadelphia.

When we look at the full scope of the Los Angeles metropolitan area (Fig. 8) (including Long Beach, Irvine, Anaheim, Riverside, San Bernardino), there is a very sharp dualization in Amazon's logistics network, with large warehouses (*fulfillment centers*, *IXDs*, *regional sortation centers*) in the east around Riverside and San Bernardino (in the ‘Inland Empire’), and small warehouses and urban logistics facilities in the west, both in the urban center and on the coastline. Beyond these two nuclei, a few scattered logistics facilities exist in the area's other peripheral centers (Irvine to the south and Burbank to the north-west). The Los Angeles-Riverside metropolitan area is one of the main markets for Amazon and one of the cornerstones of its logistics system. The logistics infrastructure is particularly well developed there, with a particularly visible concentration effect in Riverside and especially San Bernardino, which are areas marked by transportation activities (airport, rail terminal or depot), logistics (exceptional concentration of warehouses), and trade. The area around Ontario International Airport and the Interstate 15 and 10 interchanges, and the area around San Bernardino International Airport and the Interstate 10 and 215 interchanges, are urban landscapes deeply marked by logistics, with hundreds of warehouses. These areas enjoy excellent access (airports, federal highways, expressways, rail network for freight serving the more distant hinterland and the connection with the port of Long Beach).

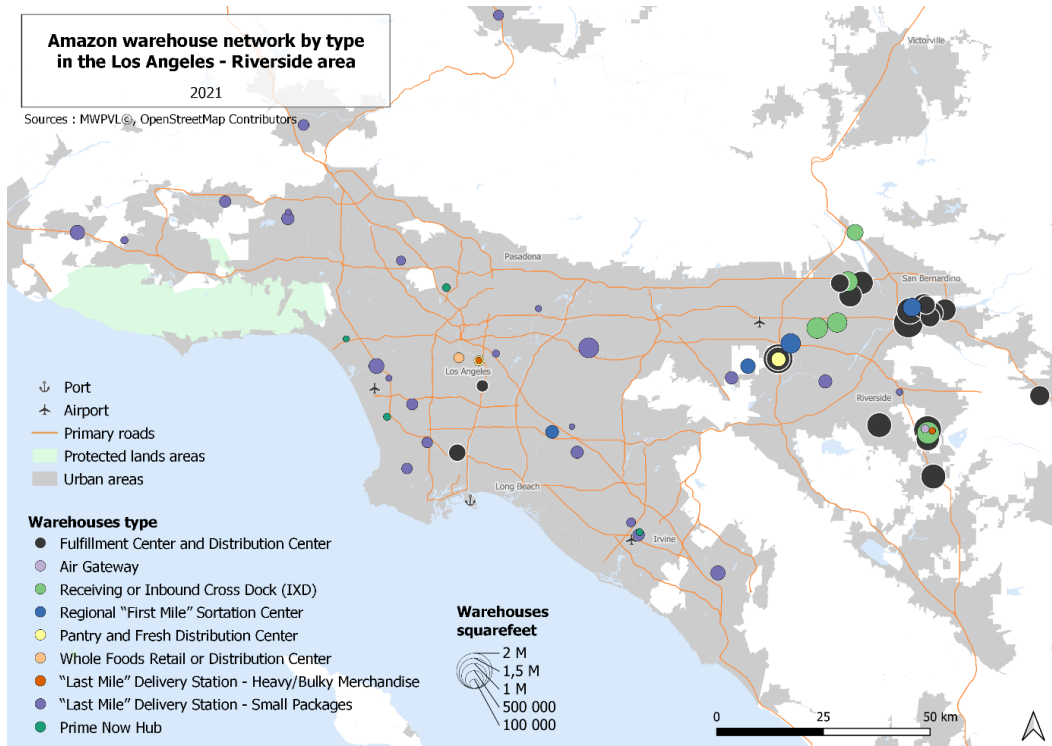


Fig. 8. Amazon’s logistics network in the Los Angeles CSA (Inland Empire) metropolitan area (Los Angeles-San Bernardino-Riverside) in 2021. Data source: MWPVL©. Lecourt, Schorung, 2022.

This part of the metropolitan area serves all territorial scales. There are more than ten distribution centers, some of which are considered XXL (over 1.5 million sq ft), especially around San Bernardino airport and south of Riverside. These large distribution centers are themselves complemented by an extensive logistics network with several Inbound Cross Docks (IXDs) and several Regional Sortation Centers, as well as by an extensive specialist network, as demonstrated by the existence of a big Pantry and Fresh Distribution Center. In the east of the conurbation, there are in fact only four small urban logistics areas. The network becomes more distant when we leave this eastern zone, where the warehouse map reveals the importance of the Los Angeles urban market, with a large but not completely polarized network of local delivery points and three Prime Now hubs in the high-income residential areas of the west near the coast (Gardena, Inglewood) and near this Los Angeles International Airport.

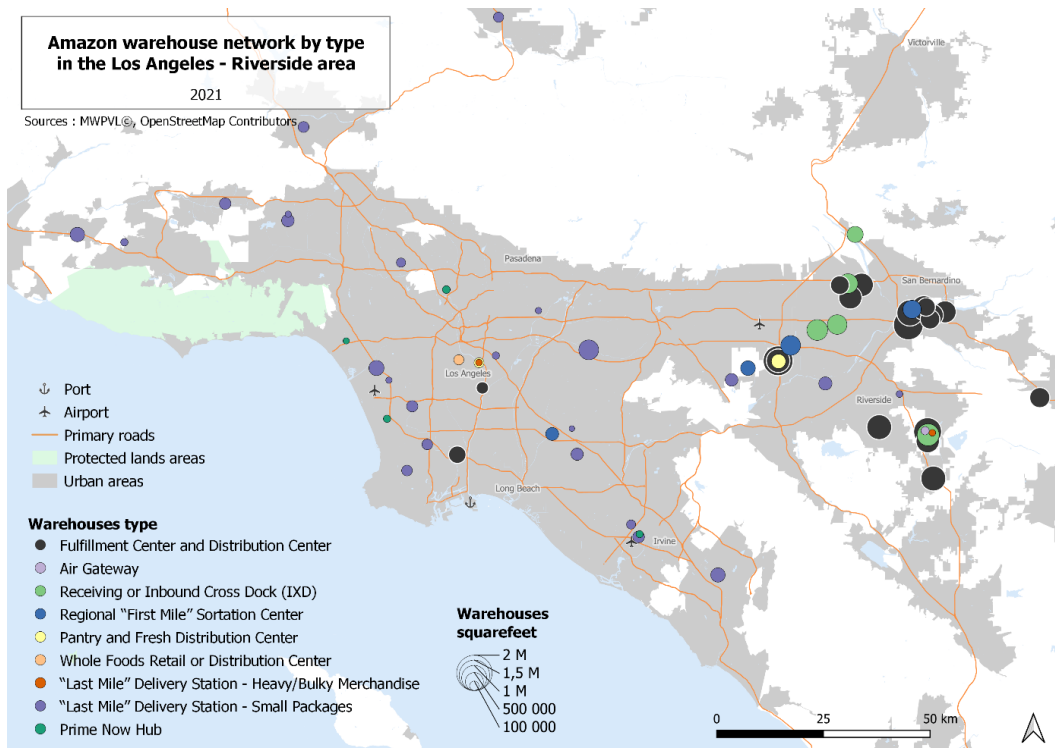


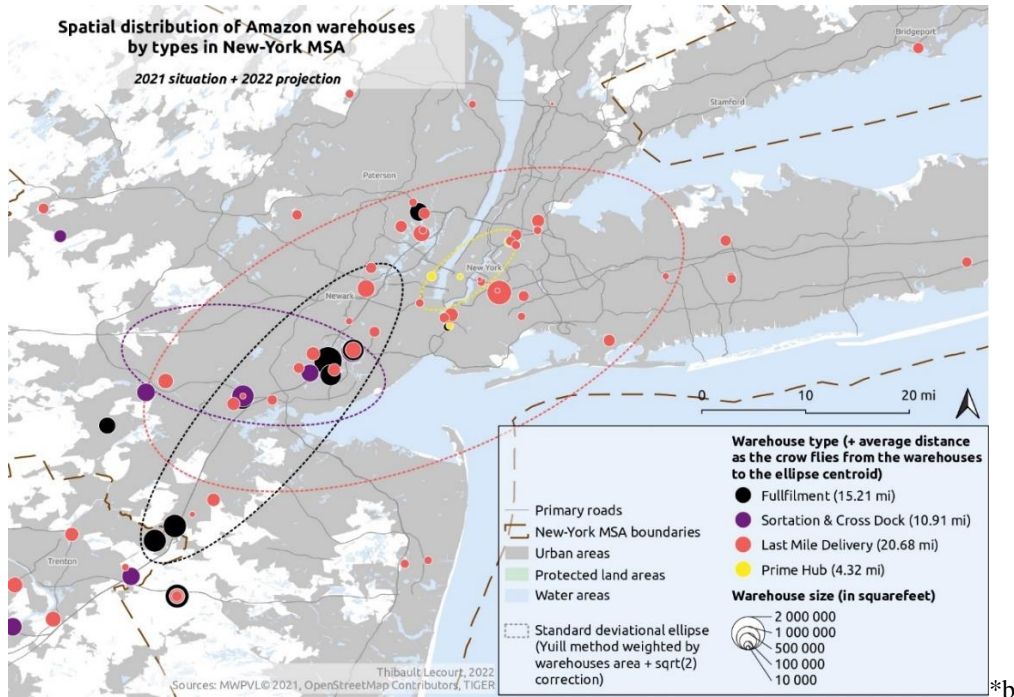
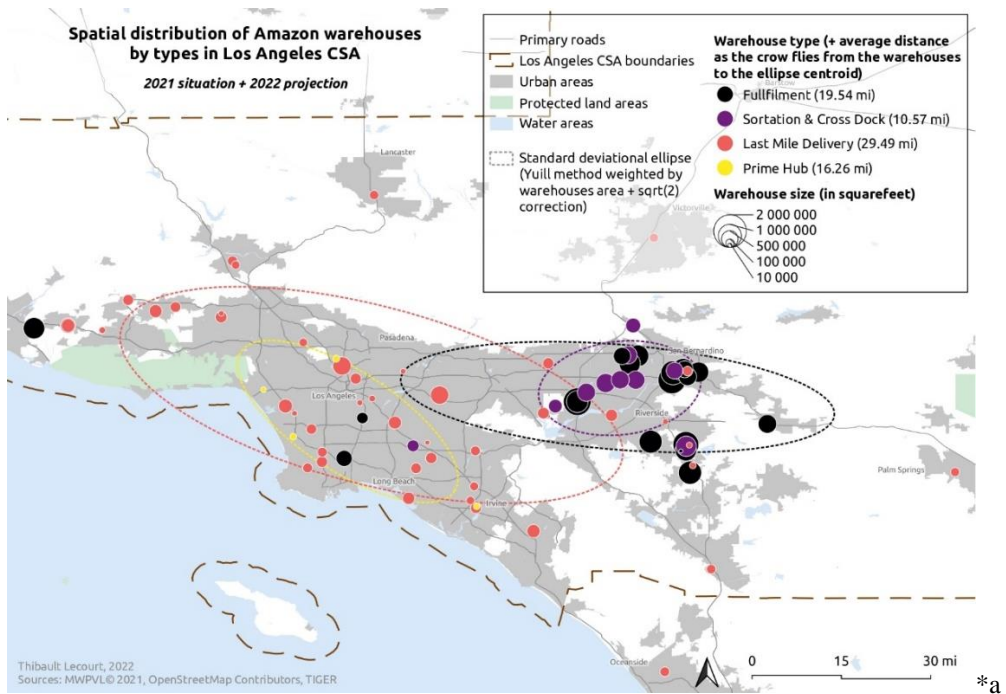
Fig. 9. Amazon's logistics system in the Chicago metropolitan area in 2021. Data source: MWPVL©. Lecourt, Schorung., 2022.

Amazon's logistics network in the Chicago area extends as far north as Milwaukee since there is an urban continuum between the two metro areas. It presents a different picture from the other two metropolitan areas studied (Fig. 9). Indeed, the concentration effect around a few main logistics centers does not seem to exist or to be clearly visible in Chicago. The structure of the network here is conventionally based on the polycentric city with small logistics facilities in the center and large facilities in peripheral areas.

Last-mile local distribution centers are concentrated in the city center (plus a few structures in some suburban areas in the north and north-west) and large distribution and processing warehouses are located in the western, southern, and northern periphery. Large distribution centers, as well as a large IXD and two regional sortation centers, are concentrated in the south-western part. Another area of concentration is to the north of the Chicago metropolitan area and to the south of the Milwaukee metropolitan area around the city of Kenosha, with several large warehouses near an Interstate 41 interchange and Kenosha Regional Airport.

5.3. Refine spatial patterns of logistics sprawl by size and type of warehouse (Northeast, Los Angeles, Chicago)

In this last section, we make the hypothesis that with multifaceted data on Amazon warehouses (by size, by type of warehouse), we could identify different spatial patterns for diverse logistics facilities and show that the location of logistics facilities and logistics sprawl depends on the size and the type of facilities. This approach has been explored in previous studies. For example, Kang (2020b) examined the spatial distribution of warehouses relative to the distribution of logistics businesses, goods movement businesses and the consumer demand in 64 major US metropolitan areas. He distinguished the warehouses by two sizes (large and small). Raimbault et al. (2012) have differentiated logistics facilities in the Paris Region (between the parcel industry, distribution centers and inland ports). Heitz and Beziat (2016) have illustrated this heterogeneity through a comparison of the location of the parcel industry facilities and that of other logistics activities. Heitz, Launay and Beziat (2019) propose a new methodology for the Paris region to census and classify logistics facilities in order to observe the spatial pattern of the different logistics facilities, according to logistics sectors.



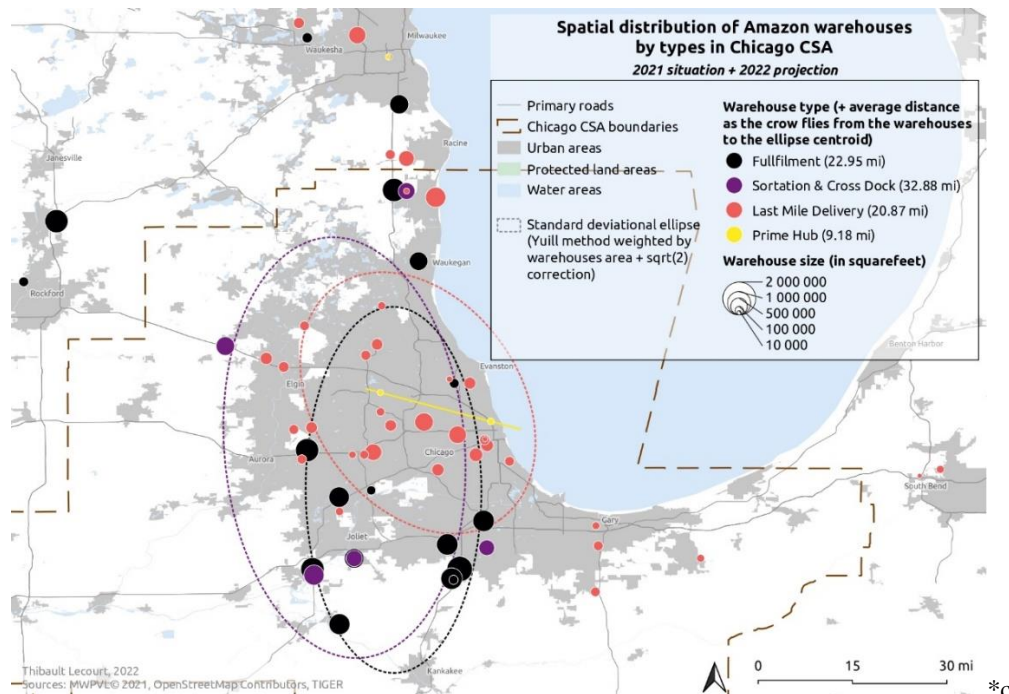


Fig. 10. *(a) Spatial distribution of Amazon warehouses by types in Los Angeles CSA; *(b) Spatial distribution of Amazon warehouses by types in New York MSA, *(c) Spatial distribution of Amazon warehouses by types in Chicago CSA. Data source: MWPVL©. Lecourt, Schorung, 2022.

The case of Los Angeles presents a fine network (and therefore the largest ellipse⁹) of last mile delivery sites across the agglomeration, while the largest facilities are concentrated in the eastern part of the agglomeration. This configuration is similar in the case of New York – we chose to use the MSA and not the CSA to have a more readable display, especially in the core area. In the case of New York, the largest fulfillment warehouses are concentrated in the southern part of the metropolitan area; last mile delivery sites are very numerous around Manhattan. Smaller *Prime Now* warehouses are found only in the central part of the city. The case of the Chicago CSA differs in part with larger dispersion ellipses for fulfillment and crossdock.

First, we observe that a significant concentration of small warehouses and logistics facilities (last mile delivery and Prime Now) in dense urban areas, located in core areas and their closest suburbs. In contrast, large facilities have spread to the fringes of the urban areas. We have analyzed four specific types of warehouses, to identify their different location patterns. The storage industry is very heterogeneous and warehouses do not share the same spatial pattern. With this case study focused on Amazon we show a complex freight landscape and a specific spatial pattern for each type of logistics facilities thereby complicating the understanding of the geography of logistics facilities in major urban areas. Finally, we show consistency across warehouse sizes and types, along a center-periphery geographic gradient. A further step in this research would be to compare the barycenters and dispersion ellipses as a function of the type of warehouse associated with the size, with a diachronic dimension.

6. Conclusion and discussion. Does Amazon contribute to logistics sprawl?

From the analysis of Amazon logistics infrastructure, we can see the magnitude of the spatial footprint of e-commerce and we can confirm some characteristics of the e-commerce sector and more broadly the retail sector:

⁹ These maps also offer a representation of the standard deviation ellipse, and its barycenter, of the three MSAs studied, for the years 2021 and 2022. This method can make it possible to observe a phenomenon of extension in a geographical direction around the barycenter. In this case, it helps to visualize the spatial distribution of Amazon warehouses by types and to identify specific development patterns for each type.

- Increasingly specialized logistics facilities to support the company's vertical integration strategy (distribution centers and local delivery points for products that can be packaged and for products that cannot be packaged, robotized warehouses, multi-story warehouses, Amazon's own airport hubs, small logistics spaces for the *Prime* service or for last-mile delivery).
- Diversification in both the size and location characteristics of warehouses (location in dense urban or dense suburban zones, versus location in ex-urban areas, or even on the metropolitan fringes);
- Complexifying logistics and warehousing sectors, with increasingly large peripheral warehouses (*fulfillment centers, inbound cross docks, regional sortation centers*) on the one hand, and a new market of intermediate or small urban logistics facilities (*last mile delivery stations, Prime hubs*) on the other.
- Direct control of the various links in the global logistics chain, increasing control over flows and distribution routes and reducing dependence on third-party carriers or shippers, for long and medium-distance operations as well as for last mile operations.

This cartographic analysis makes it possible to identify several spatial patterns for the establishment and extension of Amazon's logistics system:

- A dual pattern of networking and concentration of logistics warehouses, with the development of clusters of warehouses around major transportation infrastructures (highway interchanges, regional or international airports, ports, rail freight network) and the creation of a mesh of warehouses of varying density, particularly urban logistics areas. This dual pattern makes it possible to achieve broad market coverage even in secondary markets and to reduce processing and delivery times, while at the same time realizing economies of density. This dual logic can be found both at the national level (concentration in the main megaregions and gradual networking in new market areas) and at the metropolitan level (concentration in clusters of peripheral warehouses and deployment of a network of urban logistics spaces);
- A dual spatial pattern that focuses both on the outskirts of metropolitan areas and on dense urban centers. This work confirms the emergence of a double logistics real estate market, with on the one hand large peri-urban or even exurban warehouses that structure logistics chains on an international, national, and regional scale (Heitz *et al.*, 2017), and on the other hand small urban warehouses or urban logistics spaces designed to serve metropolitan areas and the last mile and final delivery chain. In this last-mile chain, new logistics spaces are constructed to support the development of new market segments, in particular fast deliveries (one day, same day, instant deliveries). The growth of e-commerce and the increase in goods flows that it brings with it have created an interest in developing urban logistics facilities. E-commerce *pure players* are one of the drivers of the logistics real estate sector, seeking to meet their growing needs for logistics space by turning to new asset classes, ranging from XXL warehouses of hundred thousand square feet to small urban warehouses of a few hundred or thousand square feet. This dual entry into the logistics real estate market is well illustrated by developments in Amazon's US locations.
- The process of expanding the spatial coverage of warehouses, which contributes to the phenomenon of logistics sprawl through the proliferation of warehouses in peri-urban zones and more broadly in low-density areas (Giuliano *et al.*, 2013; Dablanc *et al.*, 2014). Several location-related relationships already identified (Dablanc *et al.*, 2020) are confirmed by this empirical study on the case of Amazon: logistics sprawl is positively correlated with the availability of large parcels in peripheral areas; and the intensity of logistics sprawl varies with the type of warehouse (higher for large distribution and processing centers, more limited for parcel sorting terminals). Amazon therefore contributes to logistics sprawl in the United States, both through the location of large distribution warehouses in suburban areas and even on the outskirts of cities, and through an increasingly dense network of warehouses that amplify Amazon's land and real estate footprint, which is some distance from urban centers. The strong growth in the number of peri-urban warehouses is coupled with strong growth in urban logistics facilities, thereby amplifying Amazon's urban footprint. One can therefore speak of logistics sprawl as a two-way process, both centrifugal and centripetal and also contributing to an expansion in the urban footprint of the logistics sector. This raises regulatory, land, real estate, and environmental issues in terms of urban spatial planning, as well as in terms of the management of vehicle flows and of the negative externalities of urban logistics.

The spatial patterns of Amazon warehouses can be explained first by a change in the scale of Amazon's business (fast growth of e-commerce, further accelerated by the Covid-19 pandemic), Amazon's dominant position on the US market), and second by the general evolution of global supply chains (Hesse, 2008). Indeed, Amazon's logistics real

estate strategies mirror the major trends observed in the global logistics real estate market: development of a logistics real estate supply that meets the needs of logistics operations (adaptability, automation, need for space and large land parcels, modern equipment); recognition of logistics buildings as financial and real estate assets (Fender et al., 2016); a process of vertical integration that relies on direct control of several links in the supply chain in order to reduce dependence on third-party actors (3PLs, shippers, carriers) and on the development of a real estate system that exploits this dual but potentially complementary logistics real estate market and generates economies of scale and density.

Finally, Amazon's warehouse location strategies need to be observed on a finer scale in order to fully understand their spatial logic. From the analysis of the three case studies, it appears that regionalized logistics strategies are being implemented, with several significant common characteristics (concentration of large warehouses on the outskirts of metropolitan areas, deployment of a fine network of urban logistics facilities, development of intermediate logistics links, particularly *regional sortation centers*, importance of access and location near transportation infrastructures). Nevertheless, it would also seem that there are local variations on these regionalized strategies, apparently adapted to specific territorial arrangements and socio-economic and urban dynamics: the case of the Chicago metropolitan area shows a logistics system built according to a pattern of distinct radio-concentric areas (large warehouses on the outskirts, urban logistics spaces in the city center, with the exception of a few rare urban logistics facilities in peri-urban areas). The case of Los Angeles, on the other hand, reveals a polycentric logistics system reflecting the polycentric organization of the metropolitan area, with several major clusters of peri-urban warehouses along way from the city center, another cluster near the port infrastructures of Los Angeles/Long Beach, and a scattering of urban logistics spaces in the primary and secondary residential and employment centers which structure this vast metropolitan area. Finally, the case of the southern part of the Northeast region, from the New York metropolitan area to Baltimore and Washington D.C., suggests a new form of spatial organization, this time linear, which tracks the long urban and infrastructural corridor that structures the megalopolis with, for example, several clusters of peri-urban and exurban warehouses on the outskirts of the major cities, but also in the secondary centers and in the interstitial spaces. Moreover, a split in this linear logic is beginning to appear further north, with a second arc of warehouses beginning to form in the hinterland. These initial findings require further study, particularly in other US urban regions, in order to understand whether the spatial rationale of Amazon's location strategies indicates adaptation to pre-existing territorial arrangements and legacies as well as (or in parallel with) market logic (availability and cost of land, etc.).

This work could be complemented by further research in a context of rapid development in Amazon's logistics system and continued growth in the e-commerce sector, particularly during the Covid-19 crisis. Other analyses of Amazon's locations in other urban regions and large agglomerations could be conducted in order to refine the initial findings on the regionalization of Amazon's logistics system and to identify other regionalized processes. In addition, two other lines of research could be pursued: first, a multifactorial analysis (transportation, land, traffic flows and congestion, socio-demographic and economic factors, environment, size of facilities (Kang, 2020a), etc.) on the location logic of Amazon warehouses in order to assess its urban footprint and negative impacts; second, an analysis of land and real estate costs in order to understand the impact of these costs on the location of warehouses and the growth of the warehouse network and to arrive at a deeper understanding of the differential relationship between warehouse location (in urban areas and in peripheral areas) and real estate and land costs (Oliveira, Dabanc, Schorung, 2022).

Acknowledgements

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RESPONSES TO REVIEWERS

Reviewer 1

The geographic distribution of Amazon's warehouses is evaluated and the characteristics of the logistics network are summarized. The paper analyzes the current geographic distribution of warehouses using interesting data, but the method is qualitative, and a quantitative analysis is needed to draw robust conclusions. However, this is an interesting proposal that points the way to a new research direction.

Response

Some elements added in the introduction. We definitely use a hybrid approach : quantitative with the database, the use of GIS for the maps and the barycenters ; qualitative with the press and the current literature.

Reviewer 2

The manuscript "Multiscalar approach to the analysis of the spatial patterns of Amazon warehouses in the United States" describes a very interesting data analysis of Amazon warehouses. Given the limited information that is commonly available for freight logistics, this article provides a valuable insight how warehousing of a dominant online seller works.

Be careful to not state normatively the negative impacts of Amazon. While I imagine that many negative impacts are true, the part on sprawl of distribution centers appears to be mostly anecdotal. With a fairly harsh criticism of Amazon I feel I need to read more evidence that these negative impacts are true. Maybe suburban distribution centers help reduce the amount of heavy duty trucks in cities, as the longer distance shipment by heavy duty truck ends in the suburbs, and the delivery to smaller distribution centers or the customers is done with smaller trucks, sometimes even electric trucks. I am not trying to defend Amazon, but I would like the authors to avoid normative criticism in a scientific paper. Likewise, I am not sure what it means to call Amazon's growth strategy "aggressive". One can argue without doubt that they grew fast, but whether this growth was aggressive or not seems to be a normative statement.

Response

We have added some elements on these aspects. Indeed, it is not a paper assessing the negative impacts of Amazon (on truck congestion or GES emissions for example) and it should be made clear in the paper. Nevertheless, this paper shows the massive spatial footprint of Amazon and its warehouses – which has almost no equivalent in the US or in the world.

We have changed the word ‘aggressive’ : a difference of meaning between the French (aggressive is also a metaphor for a very ambitious and very active/fast strategy or phenomenon. Totally agree with the reviewer to be careful not to be judgemental.

Reviewer 3

The paper is aligned with the aims of the conference. The paper analyzes the historical development of the logistics facilities of a big e-commerce company (Amazon).

Following points can be considered to improve the paper:

- 1)- *Although Amazon holds a large share of e-commerce market (about 40% as mentioned in paper), the overall logistics facility location trends can be more complexed, especially considering the smaller actors. A brief discussion on a more general overview (preferably by considering few more companies' data) would make the outcomes of the paper more valuable.*
- 2)- *The paper provides a useful data analysis (along with insights on trends of logistics sprawl) and visualization; however, it will be great if the authors can come forward with some policy implications (both in public and private sectors (for other e-commerce players)) of the identified facility location trends.*
- 3)- *Adding some details on the methodology of finding/identifying the standard deviational ellipses (in section 5.3) would make it easier for reader.*

A note was added to give some details on the standard deviational ellipses (section 5.3).