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

Université Gustave Eiffel

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Urban studies, urban planning, geography

- Macro spatial analyses to micro level studies on warehouses
- E-commerce, innovations, new trends in consumption and impacts on city logistics
- Policy analysis, environmental policy, new data collection methods

https://www.lvmt.fr/en/chaires/logistics-city/

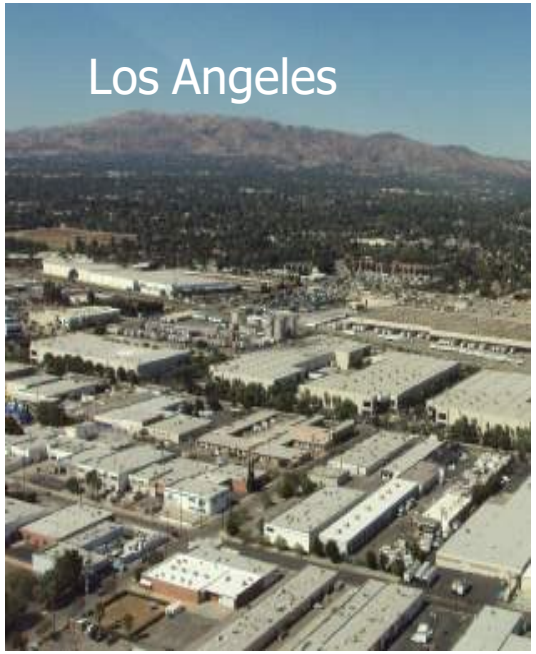
Results available online eg

- E-book on warehouse geography in the US
- Database on logistics sprawl (78 world cities)
- Observatory of ecommerce mobilities
- Relationships between logistics real estate, logistics market prices and urban forms

Context. Logistics landscape in large US cities

Changes in the location of logistics facilities reflect the broader transformation of warehousing and logistics as an economic sector

- XXL distribution centers and mega-fulfillment centers (over 50,000 sq m) → historical trend of logistics clusters moving away from urban centers
- Emerging real estate market : the search for space in dense areas to meet demand from e-commerce and parcel distribution



Amazon large suburban warehouses

- *Top left: Amazon Fulfillment Center on Staten Island near I-278, across from the Port of Elizabeth in New Jersey (in this area, four large Amazon warehouses in total)*
- *Right: Amazon Hub (Delivery & Distribution) located across from the Fulfillment Center shown above*
- *Top right: Amazon Fulfillment Center in Newark near Newark Liberty International Airport, near I-95 (across the street is a large Amazon Distribution Center)*

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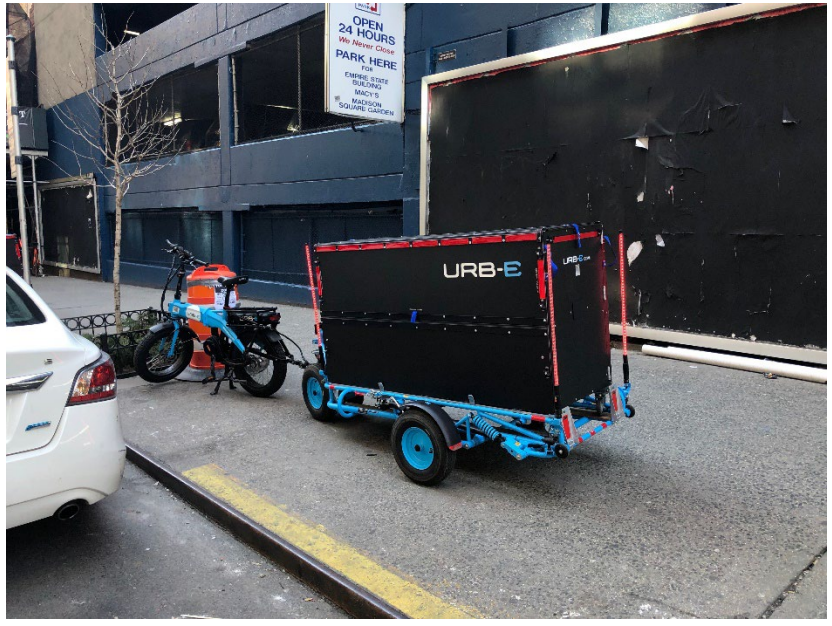
Amazon intermediate suburban distribution centers: one example in Hunts Point

- Left: the back of the distribution center where Amazon trucks are unloading goods
- Right: the front of the DC where a line of private vehicles is waiting to pick up the goods (Amazon Flex) - an employee outside is in charge of traffic management

Amazon distribution center on 35th Street (between 6th and 5th avenues) which supplies all of Manhattan



- A half block dedicated to Amazon (Amazon bookstore + distribution center, the latter very discreet in front)
- Trucks feed it and the last mile is done by carts and URB-E

Intense Amazon Flex activity in a discreet warehouse in Brooklyn/Red Hook (Dablanc, 2022)

- A delivery driver every 10 minutes or so at the time of observation (a Monday from 11am to 12pm)
- Delivery drivers park on the street
- One cart per delivery person, 60 bags per cart approximately (5 to 10 customers)
- Very bad condition of the sidewalk, difficulties to maneuver

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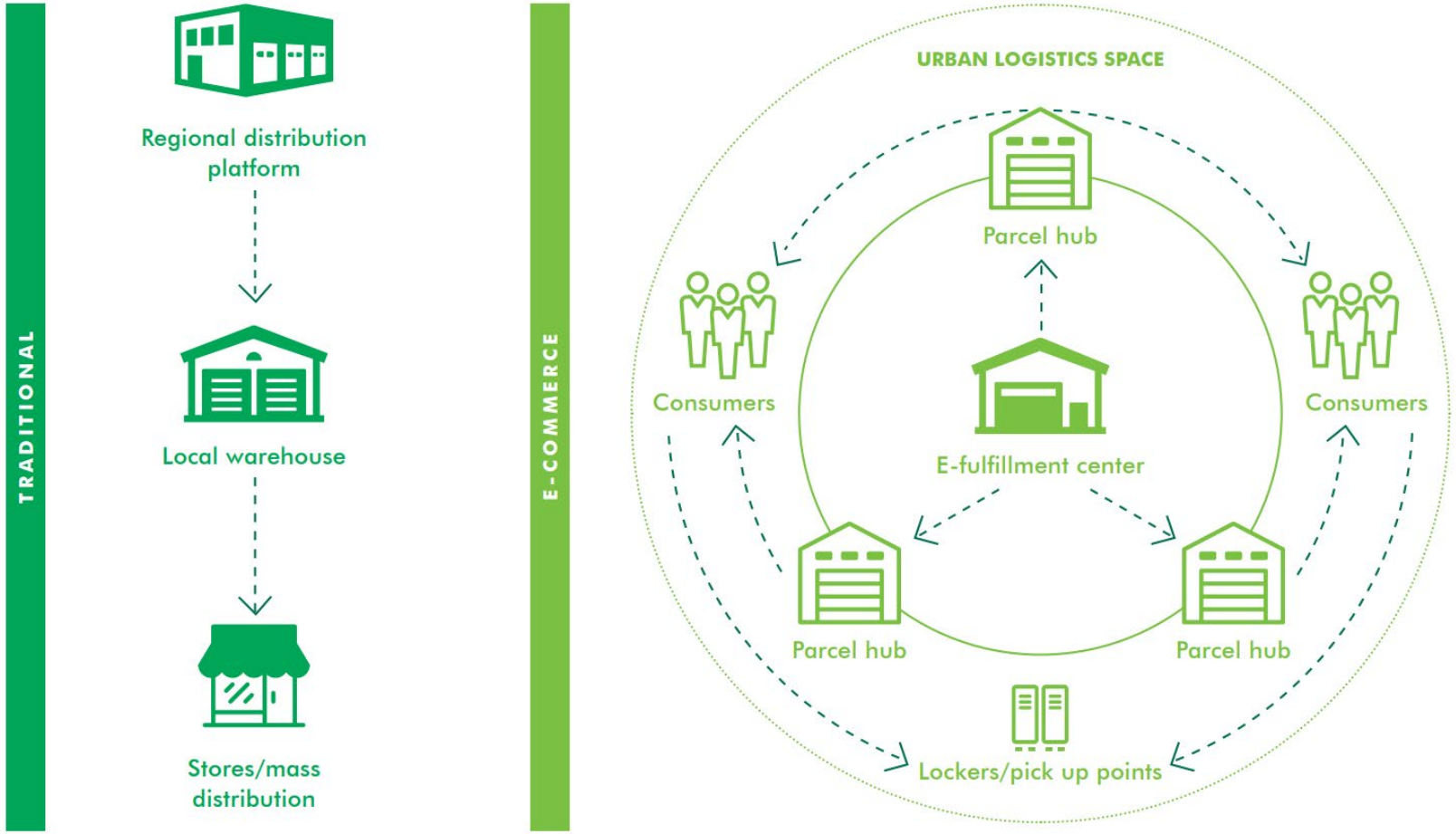
Introduction

E-commerce is creating :

- a new retail landscape through digitalization and new consumption and distribution practices (virtual access to a wide range of products, instantaneity, omnichannelity) (Ramcharran, 2013; Hagberg et al., 2016)

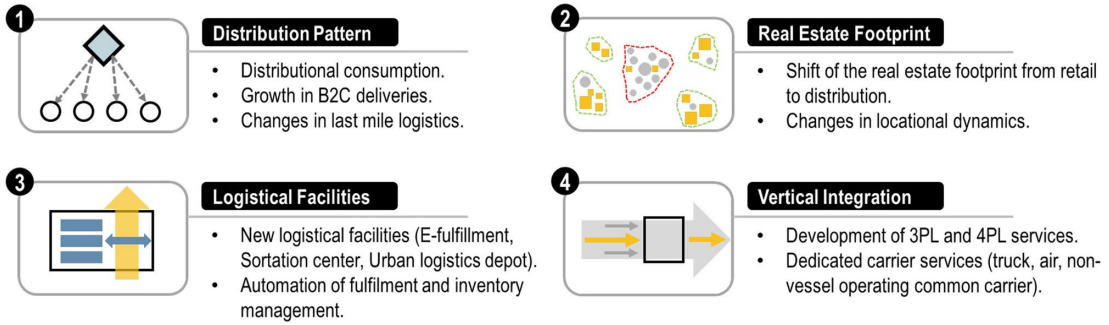
- a new freight landscape in terms of demand structuring, warehouse and distribution center location characteristics, transport strategies (modes and nodal facilities) and last-mile handling in central urbanized areas (Bowen, 2012; Rodrigue, 2020).



Traditional versus e-commerce logistics schema (CBRE, 2017)
CBRE (2017). *Last mile / City logistics. Global industries and logistics*.

Four major effects of e-commerce on the distribution of goods (Rodrigue, 2020):

- effect on distribution structures (growth in B2C deliveries)
- effect on the real estate market (decrease in retail's real estate and land footprint, and increase in the footprint of warehouses)
- effect on logistics facilities (development of new types of warehouses - E-fulfillment centers, sortation centers, urban logistics centers)
- effect on corporate strategies (vertical integration, development of 3PL and 4PL services or own transport services by e-commerce "pure players").



Rodrigue, J. P. (2020). The distribution network of Amazon and the footprint of freight digitalization. Journal of Transport Geography, 88.

E-commerce players are seeking to maximize access to urban markets and minimize delivery times by leveraging significant economies of scale and density, notably for their distribution centers (Houde et al., 2017), developing their own urban logistics strategies for last-mile deliveries (Browne et al., 2019) and promoting this vertical integration, pioneered by Amazon (Lieb and Leib, 2016).

Objectives of the research

This research examines the deployment of Amazon warehouses in the United States through an empirical spatial analysis. This research is based on a geographic 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.

Three items of interest: 1) the specialization of Amazon warehouses ; 2) the development of differentiated regional spatial patterns ; 3) the analysis of the spatial distribution of warehouses according to type and size.

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.

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).

Amazon

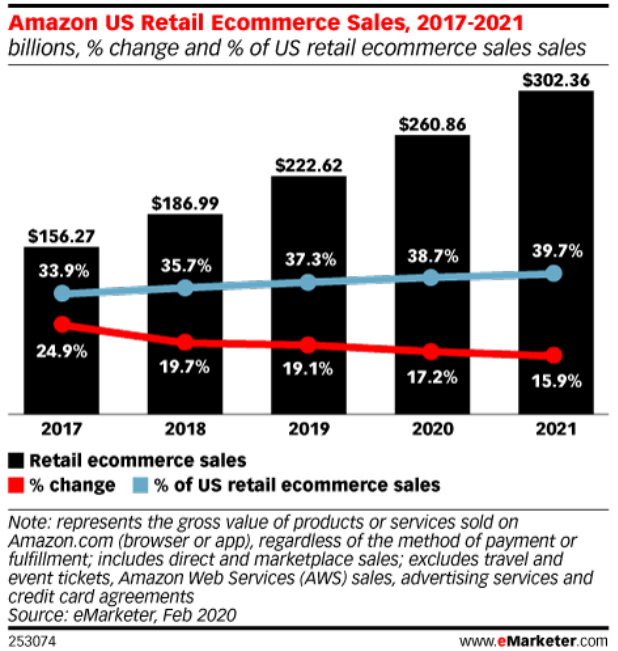
In the United States, Amazon's supremacy is clear: 39,5% of the e-commerce market in 2021, compared with 7.1% for Walmart (2nd), 4.3% for eBay (3rd), 3.7% for Apple (4th), and 2.2% for Best Buy (5th).

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 mile 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)

Some challenges:

- To control costs (more than $151b in 2021 in shipping and fulfillment costs)
- To decarbonize its transport fleet (2022 : 40 converted Boeing 767 ; Oct 2022: first order for 20 Volvo electric trucks ; Sept 2022: order for 1,500 electric LCVs for the European market ($1 billion)
- To adapt to a slowing e-commerce market
- To secure sites for new warehouses, especially in densely populated areas



Data source : an inventory of logistics facilities maintained by MWPVL International
Research conducted from April to July 2021, and based on the May 2021 inventory
The maps presented in the following study were produced using QGIS, supplemented by processing in R software for statistical representations.

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).

As of **September 2021**, to the best of our knowledge, Amazon operates the following global distribution infrastructure:

Flag	Country	Facility Type	Currently Active Facilities	Future Facilities	Active Square Feet	Future Square Feet
	United States of America	Fulfillment Centers, Supplemental Centers & Return Centers	264	106	184,832,548	71,582,958
		Pantry/Fresh Food FCs	22	1	5,537,381	240,000
		Whole Foods Retail Grocery DCs	12	0	1,457,036	-
		Prime Now Hubs	78	2	2,981,900	195,000
		Inbound Receiving Centers	22	17	12,435,707	9,996,348
		Outbound Sortation Centers	69	38	25,487,794	12,656,841
		Delivery Stations (Packages)	361	246	62,500,029	47,698,832
		Delivery Stations (Heavy/Bulky)	93	29	3,262,781	2,046,148
		Airport Hubs	17	2	4,105,193	280,750
		SubTotal USA	**938**	**441**	**302,600,369**	**144,696,877**

The importance of 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.

The Amazon warehouses listed are divided into nine categories (Schorung, 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.

• 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.

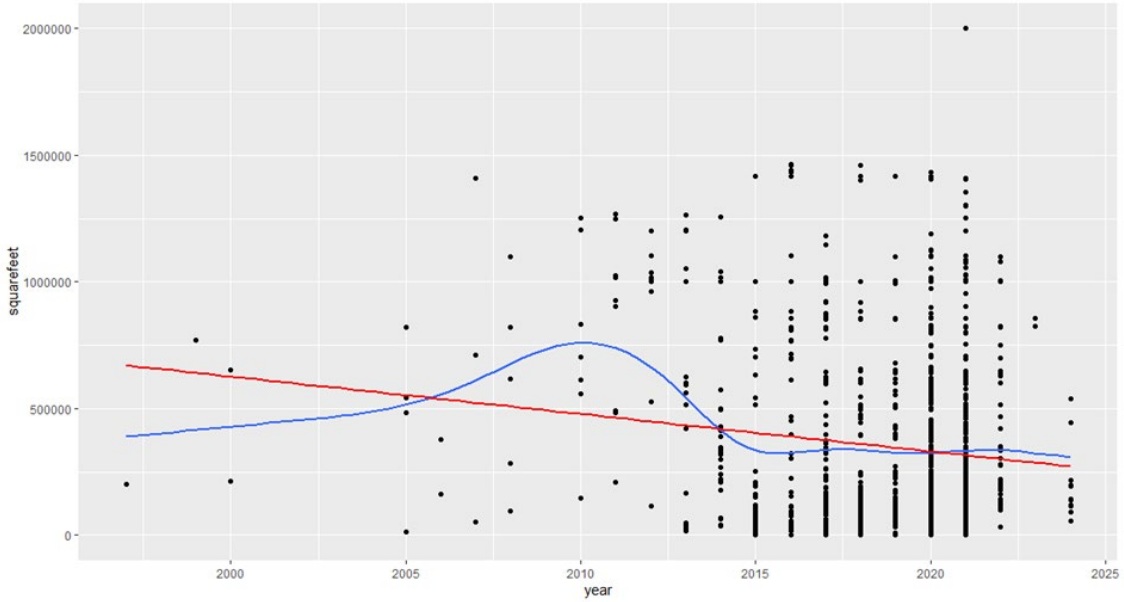
• Prime Hubs are local fulfilment and picking hubs dedicated to express deliveries and Amazon's fast delivery service. These urban hubs serve very fast deliveries, in less than 48 hours, and instant deliveries, in less than two hours.

• 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).

• 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.
• 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.

Opening of Amazon's US warehouses over time by size (sq ft) and the right and left-hand regression curve.



- Identification of the multiple phases of expansion, especially the massive business expansion and the reinforcement of the spatial coverage of the warehouses between 2015 and 2020.
- The reduction over time in the average size of the warehouses opened, especially in the years 2014-2015.

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

Data source: MWPVL©. Lecourt, Schorung, 2022.

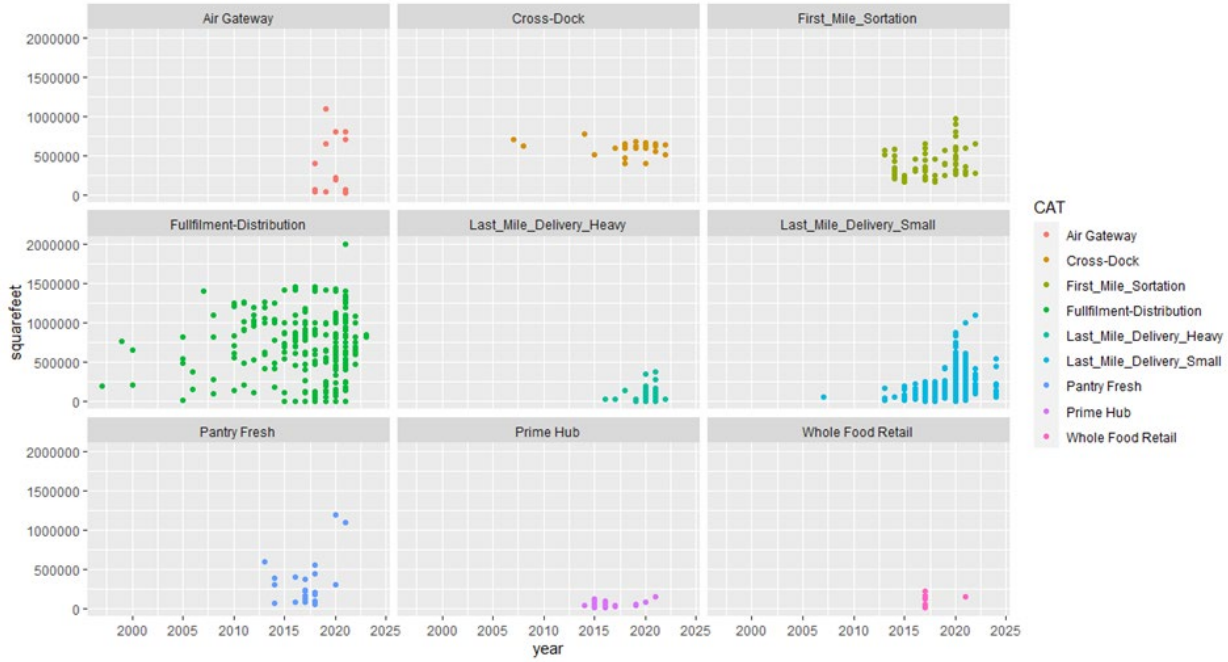
Process of functional specialization is confirmed. Several observations can be made on the basis of this graph:

• 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).

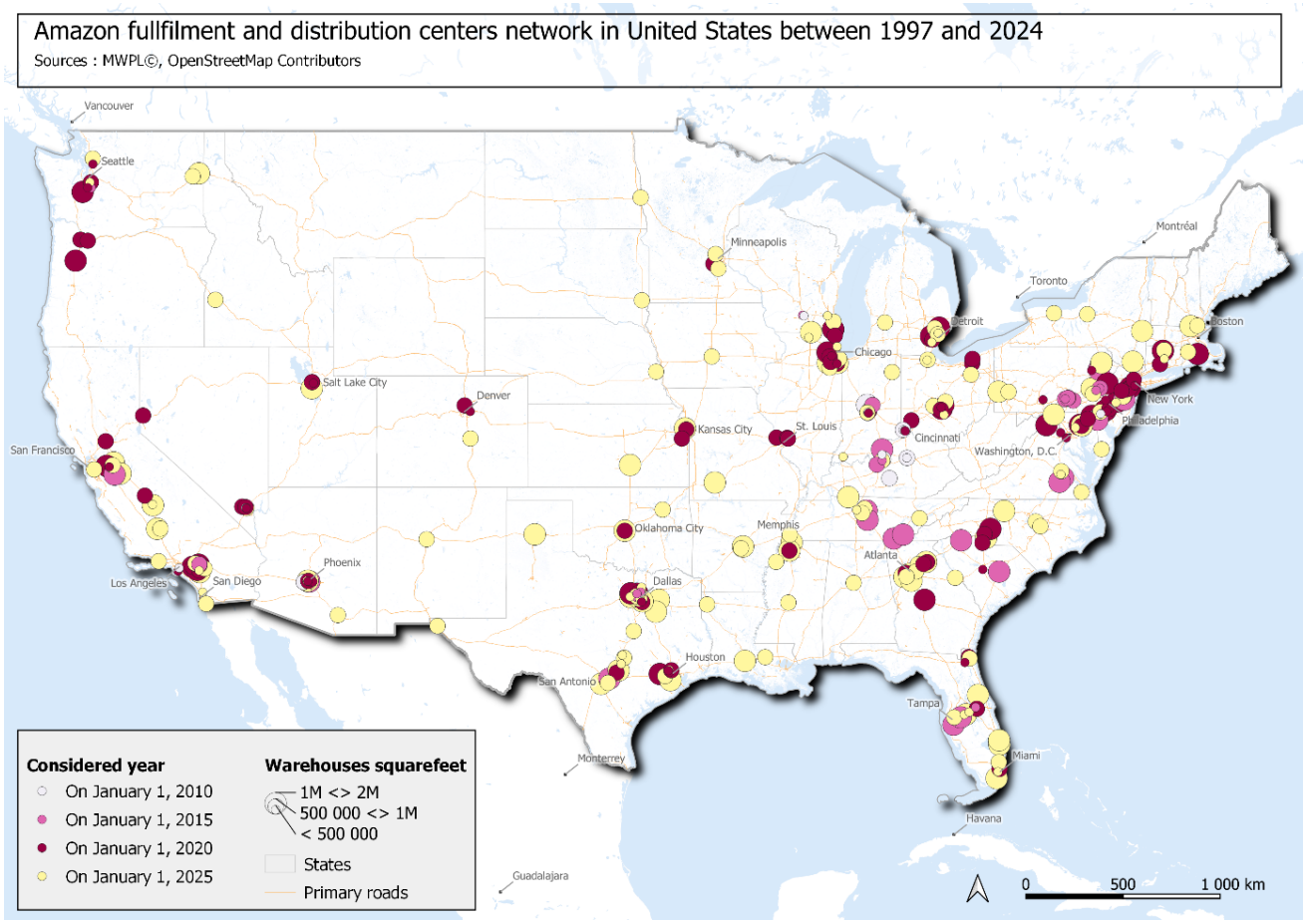
• Amazon's strategy is based on diversification and functional specialization with respect to both the size and the type of warehouse.

• 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).

Opening of Amazon's US warehouses over time according to size (sq ft) and the type of warehouse



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.



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) and favoring locations near major "gateways" (Atlanta region).
- From 2015 to 2020, all major metropolitan areas now have one or more large distribution centers, forming clusters of warehouses in the most urbanized regions (Northeast, 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.).
- Projects (2022-2024) reflect a strategy: tightening of the network in the best-served megaregions (Great Lakes, Northeast, Texas Triangle, California, Florida, Atlantic Piedmont, Northwest region); implementing of an interstitial strategy to fill the "gaps" in less densely populated territories (Idaho, North Dakota, South Dakota, New Mexico)

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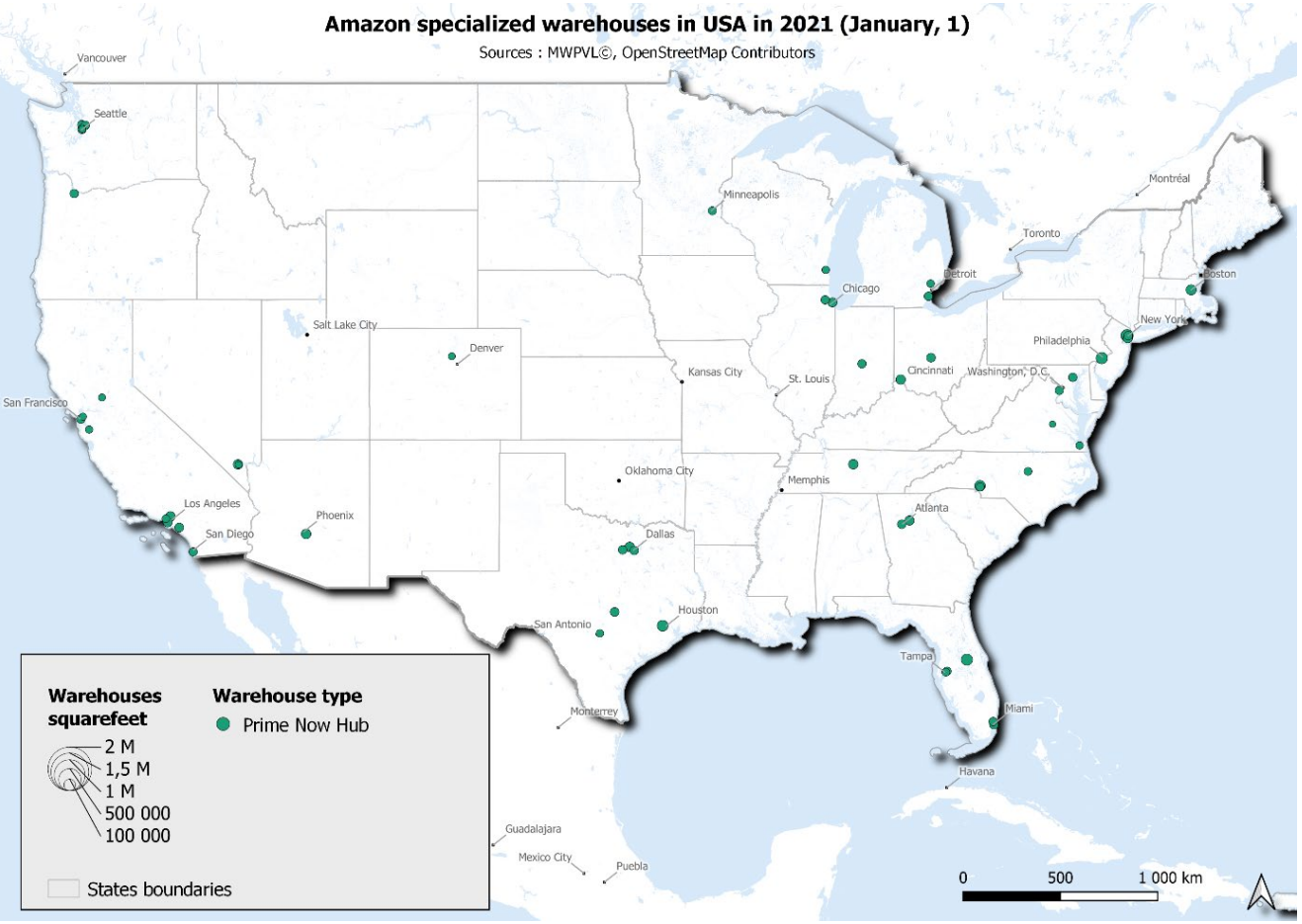
Amazon and its last-mile strategy for fast/instant deliveries

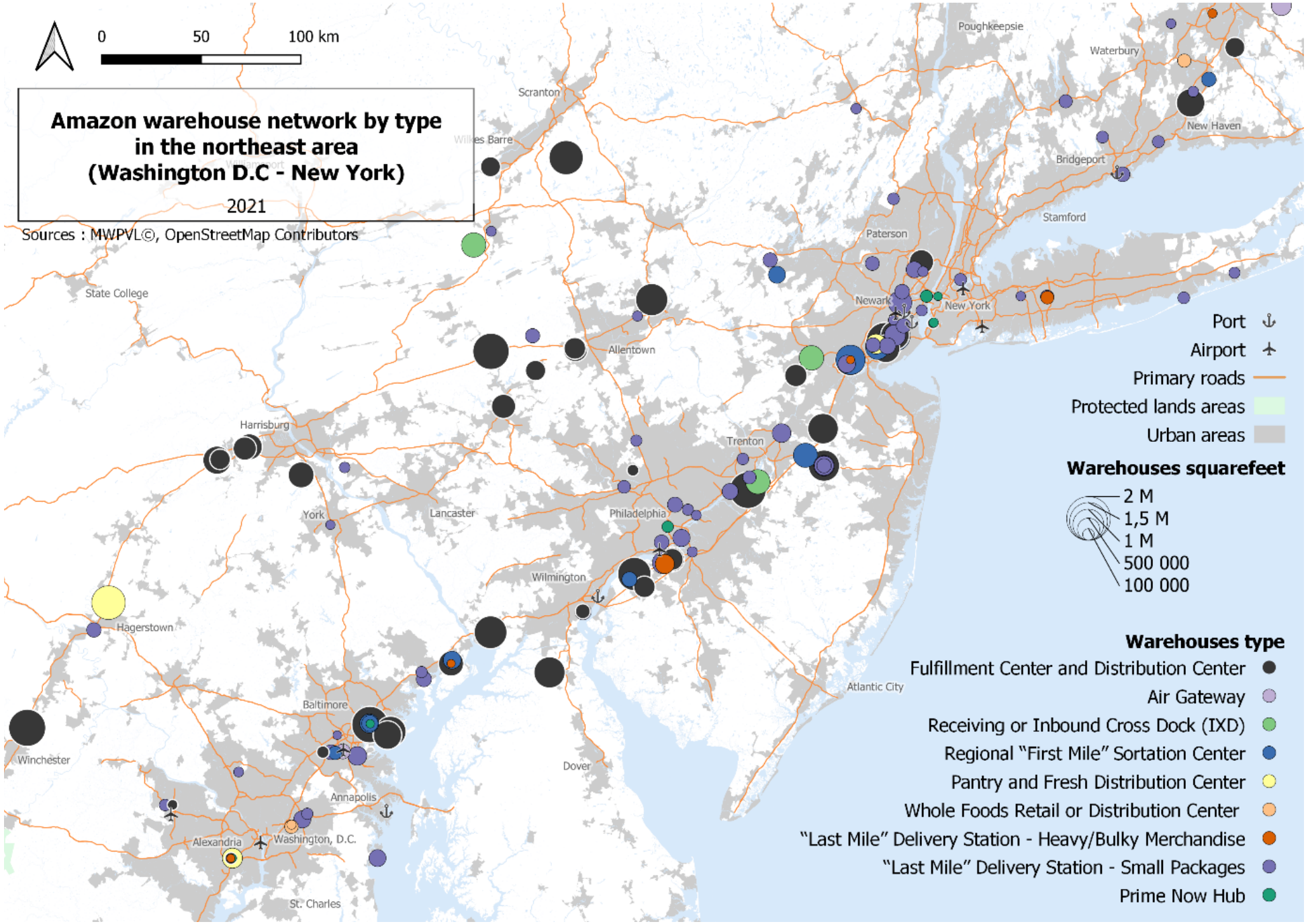


Location of small urban Amazon warehouses dedicated to Prime Now service as of January 1,, 2021. Data source: MWPVL©. Lecourt, Schorung, 2022.

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.

Providing these new services to consumers requires specially designed and dedicated logistics facilities (Prime Now Hubs).

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.



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

Here presenting the Northeast case.

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

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This analysis : 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.

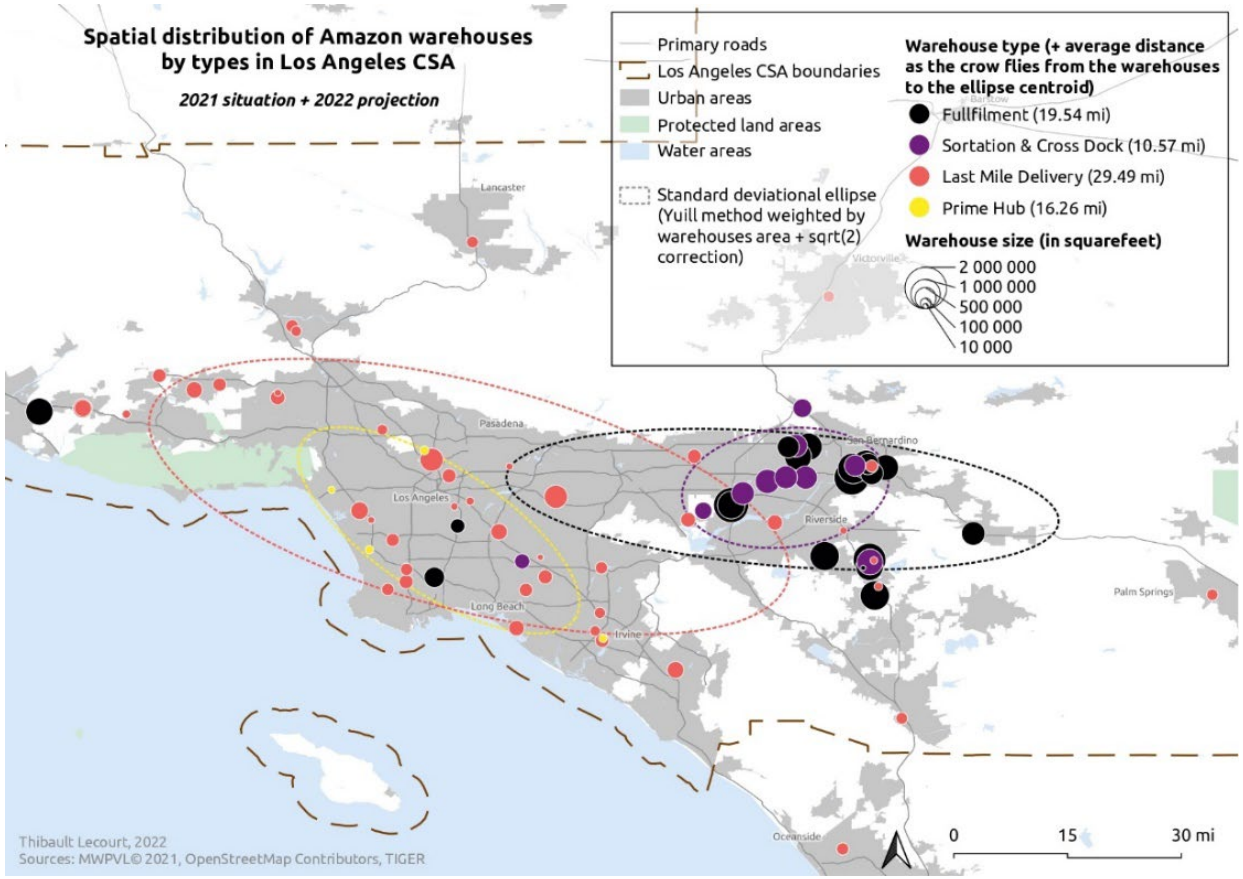
Several observations stand out:

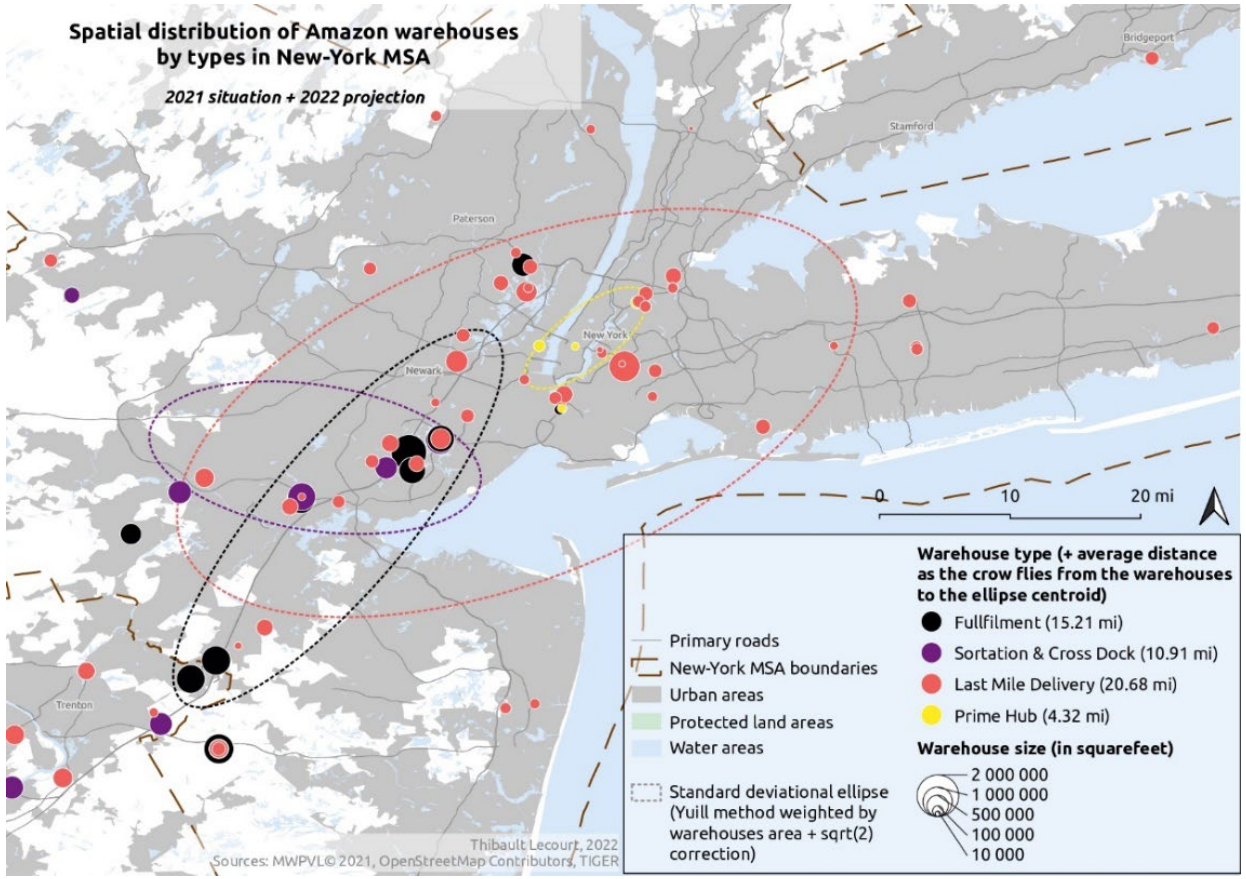
- The large distribution centers are mainly located in the outskirts of the major metropolitan areas (Baltimore, Philadelphia, New York). Moreover, several of the biggest centers are located in exurban areas, such as the three between Baltimore and Wilmington and the four between Philadelphia and New 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
- The other large logistics warehouses – Inbound Cross Dock, Regional Sortation Center, Pantry and Fresh Distribution Center – are located in the region, 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.

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.

Assess spatial patterns of logistics sprawl by size and type of warehouse (Northeast, Los Angeles)

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.





Conclusions and discussions

From this research, we can confirm some characteristics of the e-commerce sector and more broadly the retail sector:

- Increasingly specialized logistics facilities to support the company's vertical integration strategy
- Diversification in both the size and location characteristics of warehouses
- 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.

This cartographic analysis identifies several spatial patterns regarding Amazon 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.
- 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 (Buldeo Rai et al, 2022).
- Logistics sprawl (Giuliano et al., 2013; Dablanc et al., 2014) is positively correlated with the availability of large parcels in suburban 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).

- From the case studies, it appears that regionalized logistics strategies are being implemented, with several significant common characteristics but also local variations on these regionalized strategies, apparently adapted to specific territorial arrangements and socio-economic and urban dynamics.

→ These initial findings require further study 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.).

In addition, two other lines of research could be pursued:

1) 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.

2) an analysis of land and real estate costs in order to understand the impact of these costs on the location of warehouses and to understand the differential relationship between warehouse location (in urban areas and in peripheral areas) and real estate and land costs (Oliveira, Dablanc, Schorung, 2022).

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