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A multiscalar and comparative analysis of warehousing development patterns and logistics sprawl in four metropolitan areas: Dallas, Houston (Texas Triangle) New York and Philadelphia (Northeast corridor)

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Abstract

This paper evaluates whether or not there is a sprawling phenomenon in the spatial patterns of warehouse establishments in the four metropolitan areas (Dallas, Houston, New York and Philadelphia). The trend of warehouses to move away from the urban centers to more suburban and exurban areas is referred to “logistics sprawl”. To understand and analyze this logistics sprawl, the logistics establishments data (from the County Business Pattern survey conducted by the U.S. Census Bureau) were collected and mapped for two years (2012 and 2019). The standard deviational ellipse area from the barycenter for all warehousing establishments was calculated and compared between the years of 2012 and 2019. This shows that logistics sprawl is experienced by warehouses strongly in the Dallas and the Houston areas, quite strongly in the Philadelphia area, but not in the New York area. This paper discusses if logistics sprawl is a global trend by comparing these results to previous works on logistics sprawl. This paper contributes to the existing literature because it provides a comparative and multiscalar analysis of these four metropolitan areas and two megaregions (Texas Triangle and Northeast Corridor).

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Keywords: Freight transportation; logistics sprawl; United States; urban logistics; warehousing

1. Introduction and research objective

The warehousing industry is one of the fastest growing sectors of the United States. Indeed, warehousing employment increased by 577% from 1998 to 2015, representing an average annual growth rate of 11,9% and the number of warehouse establishments grew by 114% at the same period (Dubie et al., 2020). The warehousing industry is very unevenly distributed spatially, with strong concentrations where the main economic clusters are located and where the territories are multimodal transport hubs on a national and even international scale. In 2019, only nine states exceed 500 logistics facilities listed under the County Business Pattern survey code 493: New York (589), Pennsylvania (706), New Jersey (736), Georgia (752), Ohio (781), Illinois (791), Florida (795), Texas (1616) and California (2238). Moreover, if we add up the establishments for the entire New York economic area (New York, New Jersey, Pennsylvania), we reach 2031 logistics establishments. Three regions stand out very clearly, confirming their role as a major gateway for the American economy and for the global supply chain (the Northeast coast around New York, California and Texas) (U.S. Census Bureau, 2019). This process of spatial concentration of the warehousing sector is also found at the finer scale of metropolitan areas (MSAs). Only 8 metropolitan areas have more than 300 logistics establishments in 2019. In addition, there is a phenomenon of strengthening of the main logistics hubs, which could be likened to a process of logistics metropolization (Table 1).

Table 1. Number of logistics establishments by major metropolitan areas listed as category 493 in the County Business Pattern database (2012, 2015, 2018, 2019) and the change from 2012 to 2019.

Metropolitan Statistical Area	2012	2015	2018	2019	Evolution 2012-2019 (%)
Atlanta, Sandy Springs, Roswell	371	376	419	434	16,9
Chicago, Naperville, Elgin	496	544	580	602	21,3
Dallas, Fort Worth, Arlington	371	432	505	526	41,7
Houston, The Woodlands, Sugar Land	281	308	362	360	28,1
Los Angeles, Long Beach, Anaheim	573	639	707	713	24,4
New York, Newark, New Jersey	757	795	861	890	17,5
Philadelphia, Camden, Wilmington	275	304	339	345	25,4
Riverside, San Bernardino, Ontario	360	428	496	523	45,2

Produced by the authors, 2022. Source : U.S. Census Bureau, 2012, 2015, 2018, 2019

With such high levels of growth, it is crucial to understand the factors that drive the location of logistics facilities in metropolitan areas and the inherent changes over time, particularly the phenomenon of logistics sprawl or the gradual return of small logistics facilities to the core areas of MSAs.

Logistics sprawl corresponds to the growth in the number of warehouses on the outskirts of large cities, particularly in peri-urban areas where densities are low, land is available and cheap and plot sizes are high (Giuliano et al., 2013; Dablanc et al., 2018). Urban renewal, land pressure, competition with other activities, have created a context that is less and less favorable to the development of logistics activities in dense areas (Heitz, 2017) while peri-urban areas offered logistics activities large plots of land and proximity to large consumer markets thanks to good road and highway connections. The availability of transport infrastructure in fact offers good accessibility on two scales: firstly, local (to delivery areas) and secondly, regional or inter-regional (to other cities, to other countries for logistics facilities that have an extended hub role). Local public policies in favor of the development of logistics policies also influence the location of warehouses, with, for example, the creation of logistics zones on the outskirts to attract warehouses. The lack of regulation of metropolitan margins has favored the development of warehouses in peri-urban areas, fueling a process of logistics sprawl (Dablanc et al., 2014), which shows that the geography of warehouses is concentrated in

sparsely populated peri-urban areas (Bowen, 2008; Cidell, 2010). The intensity of logistical sprawl varies with the type of warehouse (higher for distribution centers, lower for courier terminals) and according to the type of strategy implemented by the actor considered. This logistics sprawl can also be explained by the evolution of the supply chain and the demand for logistical real estate (Hesse, 2008).

The lack of regional and metropolitan regulation of logistics has given way to logistics development on the margins of cities, contributing to logistics sprawl, the result of a negotiation between isolated peri-urban municipalities and real estate development actors integrated into international financial markets (Raimbault, 2014). The main negative impacts of logistics sprawl (congestion, pollution, land artificialization) contradict the objectives of the "sustainable city" which includes densification, functional mix, reduction of congestion and CO₂ emissions, fight against land artificialization. These new sustainability objectives have led to a refocusing of the debate on the "last mile", rather than the development of logistics in the peripheries, as a compensatory measure to this 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 new urban warehouses. This new demand for real estate also corresponds to the public authorities' objectives of redeveloping logistics activities in city centers in order to limit logistics sprawl. Thus, on the one hand, we are seeing the development of peri-urban logistics characterized by the rise of large, standardized logistics buildings, mainly intended for logistics service providers, mass distribution or industry (Heitz et al., 2017). On the other hand, we are witnessing the rise of urban logistics made up of buildings that are still largely "tailor-made" and which are subject to particular attention in terms of urban integration. This dualization of the real estate market reveals two patterns of logistics real estate development: a peri-urban logistics that is in the majority and an emerging urban logistics that is in the minority. However, these two types of logistics can now function as a network covering the entire metropolitan area.

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) (Ramcharran, 2013; Hagberg et al, 2016) 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 (Bowen, 2012; Rodrigue, 2020). Jean-Paul Rodrigue (2020) 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 (decrease in retail real estate and land footprint and increase in warehouse footprint), effect on logistics facilities (development of new types of warehouses - e-fulfillment centers, sortation centers, urban logistics centers), effect on business strategies (vertical integration, development of 3PL and 4PL services or own transport services by e-commerce pure players). E-commerce players are seeking to maximize access to urban markets and minimize delivery times by relying on 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 this vertical integration, of which Amazon is a pioneer company (Lieb and Leib, 2016).

The changes in the location of logistics establishments reflect the overall transformation of the warehouse and logistics economic sector (Hesse and Rodrigue, 2004; Christopherson and Belzer, 2009; Movahedi et al., 2009; Dablanc and Ross, 2012). The geographical impact of e-commerce is reflected in two distinct developments in logistics real estate (Dablanc, 2018). On the one hand, the creation of so-called "XXL" distribution centers or mega-fulfillment centers (over 50,000 square meters), which follow the historical trend of logistics zones moving away from urban centers and, on the other hand, the search for space in dense areas to meet the demand related to e-commerce. In order to meet consumer expectations, which are generally shown in surveys to appreciate ever faster deliveries, goods must be located close to the consumer. Urban warehouses have been introduced by large e-commerce players such as Amazon, which has, for example, set up in several central locations in Los Angeles (several dozen urban warehouses, from 5 to 20,000 m²), New York or Chicago (Schorung, 2021). Historically, Asian cities have pioneered urban warehouses, such as in Tokyo, Hong Kong, and Seoul (Dablanc et al., 2017). Because there is a potential for optimizing urban goods mobility (distributing as much with less), pooled urban distribution centers have been envisioned to more collaboratively manage the operations of all carriers needing to deliver in a given urban area (a city center, for example). E-commerce has accelerated the development of what are known as urban logistics spaces and logistics micro-hubs. New models are being organized based on small logistics bases in dense urban areas to organize load breaks and enable last-mile or last-mile deliveries with electric or non-motorized vehicles (Buldeo Rai, 2019).

This paper examines the question of logistics sprawl and the overall evolution of warehousing location patterns in four main logistics hubs in the United States (Dallas MSA, Houston MSA, New York MSA, Philadelphia MSA) during the last decade, between 2012 and 2019, including the latest survey of the County Business Pattern of the U.S. Census Bureau released in May and June 2021. This paper completes and compares to the results of previous studies on Atlanta, Los Angeles, Seattle, Phoenix and Chicago, using a similar spatial and cartographic analysis method (described below). We contribute to two of the major aspects of the geography of the logistics sector. The first is logistics sprawl, i.e. the spatial deconcentration of logistics facilities and distribution centers in metropolitan areas (Dablanc and Rakotonarivo, 2010). The second aspect we examine is the polarization of logistics activities, i.e. the concentration of logistics facilities in large metropolitan areas. Going a step further than the existing literature, we examine the sprawl patterns of freight facilities at a local level (zip-code) in four metropolitan areas not treated before in the literature. Then we conduct this analysis at the “megaregional” level, only a few scientific papers have examined it (such as Piedmont Atlantic megaregion (Dablanc and Ross, 2012)).

2. Literature review

Several recent studies have analyzed the location of warehouses in metropolitan areas and the evolution over time of this location. These studies have demonstrated a shift in the location of warehouses and logistics facilities to peri-urban areas (Bowen, 2008; Allen and Browne, 2010; Cidell, 2010; Heitz and Dablanc, 2015; Giuliano et al., 2016; Heitz, Dablanc, and Tavasszy, 2017; Kang, 2020a). Logistics warehouse location dynamics are based on several criteria and a complex supply chain cost structure (transportation, accessibility, distribution activities, structure of the regional economy, warehouse equipment, land and real estate, organization of logistics flows and the last mile, etc.) (Dablanc and Rakotonarivo, 2010). This evolution has been characterized as a "logistics sprawl" phenomenon that can be defined as "the tendency for warehouses to move from urban to suburban and exurban areas" (Dablanc and Ross, 2012, p. 434) that has been identified by research in all the case studies considered (Cidell, 2010; Dablanc and Ross, 2012; Dablanc et al., 2014; Heitz and Dablanc, 2015). In the case of North America, several works have analyzed case studies, Atlanta, Los Angeles, Seattle, Toronto (Dablanc and Ross, 2012; Dablanc et al., 2014; Woudsma et al., 2016) and recently comparative analysis on Chicago and Phoenix (Dubic, Kuo, Giron-Valderrama, Goodchild, 2020) and on 45 US metropolitan areas and 8 megaregions (Schorung and Lecourt, 2022).

Several works seek to identify the determinants of the location of logistics facilities:

- The opportunity to access larger and cheaper vacant parcels in peripheral areas and proximity to highway networks and airports (Allen and Browne, 2010; Dablanc and Ross, 2012) ;
- The growth of the logistics industry fueled by globalization and new production and distribution dynamics (Andreoli et al., 2010; Sakai, Beziat, and Heitz, 2020; Kang, 2020b);
- The correlation of the dynamics of the location of logistics establishments with economic dynamics at the national and regional levels (Bowen, 2008);
- The presence of public regulatory tools in terms of development permits and land use (Sakai et al., 2016) ;
- Transportation costs although they have become less of a determinant over the past 30 years or so. The spatial distribution of logistics warehouses depends only marginally on transportation costs (Glaeser and Kohlhase, 2004; Dablanc and Ross, 2012) offering them "increased locational flexibility" (Rodrigue, 2004) ;
- The transformation of the logistics real estate sector, increasingly dominated by global firms whose activities are organized around multi-scalar distribution networks (Hesse, 2004);
- Land and real estate costs, which mostly favor the location of warehouses in the outskirts of major cities (Oliveira, Dablanc and Schorung, 2021);
- Social and wage conditions can also play a role in the location of warehouses such as the availability of a large and cheap labor force and the differential in terms of labor costs, as in the case of the Inland Empire in Southern California (De Lara, 2013).

3. Data and methodology

This research aims to analyze logistics sprawl and warehousing development patterns in four U.S. metropolitan areas, based on the County Business Pattern database (U.S. Census Bureau) for 2012 and 2019 data at the Zip Codes granularity. For the four metropolitan areas, the same data period was defined (2012–2019) to ensure consistency in the analysis. Warehousing is defined in this study as establishments classified in 493 (“Warehousing and Storage”) of the North American Industry Classification System (NAICS). This classification comprises establishments engaged in operating merchandise warehousing and storage facilities.

Centroids, or barycenters, are the most central point of a polygon (in this case, the Zip Codes), here without any particular weighting. This technique limits the size effect by relating each polygon to a point, independently of its surface. These maps show, by proportional circles, the number of logistics establishments in 2018. The color of the circles indicates the evolution of this number compared to 2012. Only the centroids strictly within the study areas are represented. This method of representation facilitates comparison with other previous cartographic productions, and offers an initial look at the distribution of establishments in each metropolitan area.

These maps also propose a representation of the standard deviation ellipse, and its barycenter, of the MSA / CSA of interest, for the years 2012 and 2019. To calculate it, we chose not to rely directly on the Zips Codes territories, as these often straddle MSA/CSA boundaries, and it would not be relevant to include or exclude them for the calculation. Instead, weighted barycenters were calculated from cells containing more than 0 logistics establishments, and selecting only those that are strictly and entirely within the MSAs/CSAs studied. This method can be used to observe a phenomenon of extension in one geographical direction, in cases where this extension is not compensated for by another extension in the opposite direction (two equivalent extensions in opposite directions will not displace the barycenter), nor by a concentration dynamic around the barycenter. This indicator should therefore be used with caution. As the scale of the maps differs according to the MSA/CSA in the report, the displacement of the barycenter of the ellipse in kilometers has been specified in the legend, in order to allow comparisons.

To further refine the analysis, an indicator on logistics sprawl was calculated, expressed in km², for 2012 and 2019. This does not measure the total area of Zip Codes with at least one establishment, as this indicator would be too influenced by large Zip Codes with few establishments, which do not necessarily mean sprawl as discussed above. We chose to rely on both the random points and the grid: we selected all the cells of the grid containing at least one generated point (i.e. an establishment). This indicator gives a fairly reliable idea, particularly for comparing the sprawl of two cities and for measuring its diachronic evolution. This research used R, a language for statistical computing, to compile, aggregate the data and the QGIS software was used to map the warehouse establishments and to provide the spatial analysis, especially the barycenters. This approach by the barycenter is used in many logistics sprawl studies (Dablanc and Ross, 2012; Dablanc et al., 2014; Heitz and Dablanc, 2015; Dubie et al., 2020) which allows us to compare the results.

4. Study areas

4.1. Dallas-Fort Worth-Arlington MSA

Dallas is part of the Dallas-Fort Worth-Arlington metropolitan area, also known as the Dallas-Fort Worth metroplex, is a 22,500 square kilometer (8674 square miles) conurbation that encompasses two major Texas cities and spans eleven counties. This MSA has a population of 7.6 million according to the 2020 US Census Bureau: the most populous area in Texas and the fourth largest metropolitan area in the US. This MSA has very strong population growth: +18.5% from 2010 to 2019 (compared to a national average of 6.3%). Dallas-Fort Worth is the northernmost metropolis in the Texas Triangle. This urban area has thus grown as fast as the other Sun Belt cities. With its remarkable location as a railroad hub, Dallas was very early on the great inland city of Texas, at the heart of the great cattle and cotton production areas, and benefited from the oil boom and the development of high-tech industries, particularly semiconductors and microcomputers. This major high-tech hub is nicknamed Silicon Prairie or Telecom Corridor. Dallas is now a major business center, especially in the banking and insurance sectors. The city has a huge airport (Dallas/Fort Worth International Airport) and is the hub of American Airlines. This international airport is the

largest in Texas and the second largest in the country. In addition, the metropolitan area is a major highway (second highest highway mileage per capita in the country) and rail hub (with the Dallas Intermodal Terminal of Union Pacific).

4.2. Houston-The Woodlands-Sugar Lands MSA

The Houston-The Woodlands-Sugar Lands metropolitan area, also known as Greater Houston, is the fifth most populous MSA in the United States, and the second most populous MSA in Texas behind Dallas-Fort Worth, with a 2020 population of 7.1 million (2.3 million for the City of Houston alone). The metropolitan area is the maritime frontage of the Texas Triangle in the Gulf of Mexico and is a major center of the oil economy, the maritime economy and international trade. Five of the six major oil companies have offices in Houston. Hundreds of oil-related companies - oilfield equipment, oil rig and offshore research companies, consultants, banks and financial institutions - support the economic fabric of the metropolis. Houston is also a rival to Dallas in terms of high technology (Hewlett-Packard) and aerospace (Lyndon B. Johnson Space Center, United Space Alliance, the partner of the United States). Johnson Space Center; United Space Alliance, NASA's industrial partner). The city has also developed biotechnologies in connection with the Texas Medical Center, south of the city (a campus of more than 400 hectares, which brings together some fifty health care, medical and paramedical training and research institutions). Finally, the metropolitan area is a major multimodal hub with a very powerful seaport (Port of Houston) which is the leading American port for all activities combined (international and domestic) and the fifth largest American port for container traffic in 2019. The MSA is also a major highway and rail hub. *General guidelines for the preparation of your text*

4.3. South of the BosWash Megalopolis : New York-Newark-New Jersey MSA and Philadelphia-Camden-Wilmington MSA

Located on the Atlantic seafloor of the northeastern United States, the Megalopolis stretches from Boston to Washington, D.C., and includes New York, Philadelphia and Baltimore for more than 700 kilometers. This urban area is distinguished by its demographic weight (52 million inhabitants), its dense urban fabric and above all by the concentration of economic and financial power, political power and cultural symbols. It is a major hub that polarizes all the flows of globalization (migratory, commercial, financial and information).

The New York-Newark-New Jersey metropolitan area, also commonly referred to as the Tri-State area, is the largest metropolitan area in the world by urban landmass (12,093 km² or 4,669 square miles), and one of the most populous urban agglomerations in the world. This MSA is the most populous in the United States, 20.1 million residents in 2020. The metropolitan area is home to approximately 6% of the United States' population. This MSA is a major center of many industries, including finance, fintech, international trade, real estate, education, entertainment, biotechnology, etc. The New York metropolitan region is one of the most important economic regions in the country. As of 2019, the New York metropolitan area is estimated to produce a gross metropolitan product (GMP) of \$1.7 trillion. It is also a major multimodal gateway of the country with three international airports (JFK International Airport, Newark Liberty International Airport, LaGuardia Airport), very dense motorway and rail networks and a major harbor gateway (third container port and third port for all traffic (international and domestic) of the United States) managed by the Port Authority of New York and New Jersey.

The Philadelphia-Camden-Wilmington MSA is located within the Delaware Valley and is commonly named Greater Philadelphia or the Philadelphia metropolitan area ("the [Lower] Delaware Valley Metropolitan Area"). The Delaware Valley is coterminous with a Metropolitan Statistical Area (MSA) and a larger Combined Statistical Area (CSA), and consists of counties in southeastern Pennsylvania, southern Jersey, Delaware, and the northern Maryland Eastern Shore. According to the 2020 census, the MSA has over 6 million residents, being the seventh-most populated MSA of the country. The Philadelphia-Camden-Wilmington metropolitan area is located in the northeastern United States and is part of a larger urbanized area known as the Northeast Megalopolis or BosWash Megalopolis. Philadelphia is by far the most populous city in the region (nearly 1.6 million in 2020), which has returned to modest population growth after several decades of population decline while the region continued to grow. This metropolitan area is a historic economic hub of the Northeast Coast and a major hub with a highly developed highway system and a nationwide port (19th largest container port in the United States).

5. Results

5.1. Dallas-Fort Worth-Arlington MSA

When we look at the change in the number of logistics establishments between 2012 and 2019 in the Dallas-Fort Worth CSA, we see a strong increase in the number of warehouses and relatively evenly across the metro area. In 2012, the CSA had 376 warehouses compared to 533 in 2019, a 41.7 percent growth. As a result, the number of warehouses per 10,000 residents has also increased, from 0.56 establishments per 10,000 residents in 2012 to 0.69 in 2019. Logistics warehouses have increased significantly in the northeast part of the metropolitan area, the southeast, and the southwest near Arlington. These areas are affected by the largest changes from 2012 to 2019. In addition, a dual movement is unfolding: on the one hand, a strengthening of already established logistics clusters (which have between 25 and 100 logistics warehouses); on the other hand, the rapid constitution over the period studied (2012-2019) of new logistics concentrations that have the highest rates of evolution. Figure 1 (a) shows a double pattern of warehousing development: the strengthening of logistics establishments in the first peri-urban ring of Dallas and at the same time a rapid development of a second ring in the metropolitan fringes of the Dallas area. In addition, logistics facilities are being established near highway networks and airports.

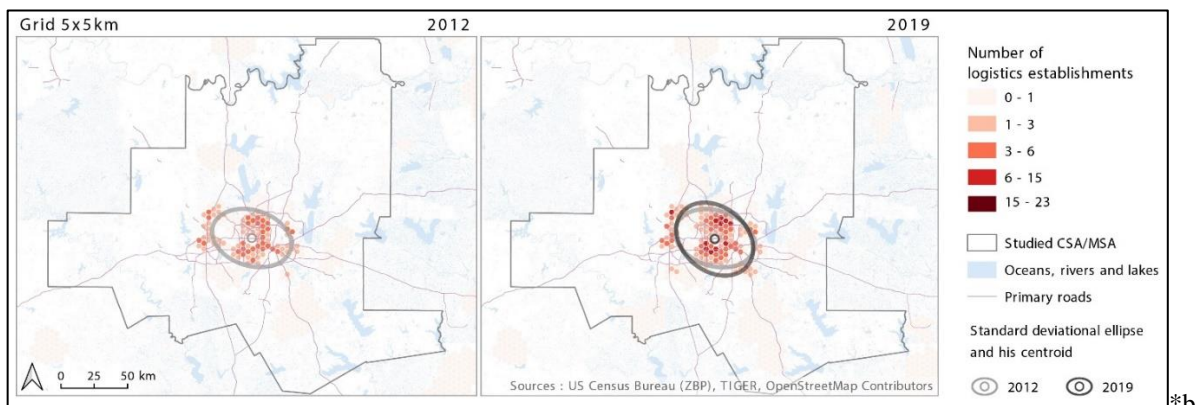
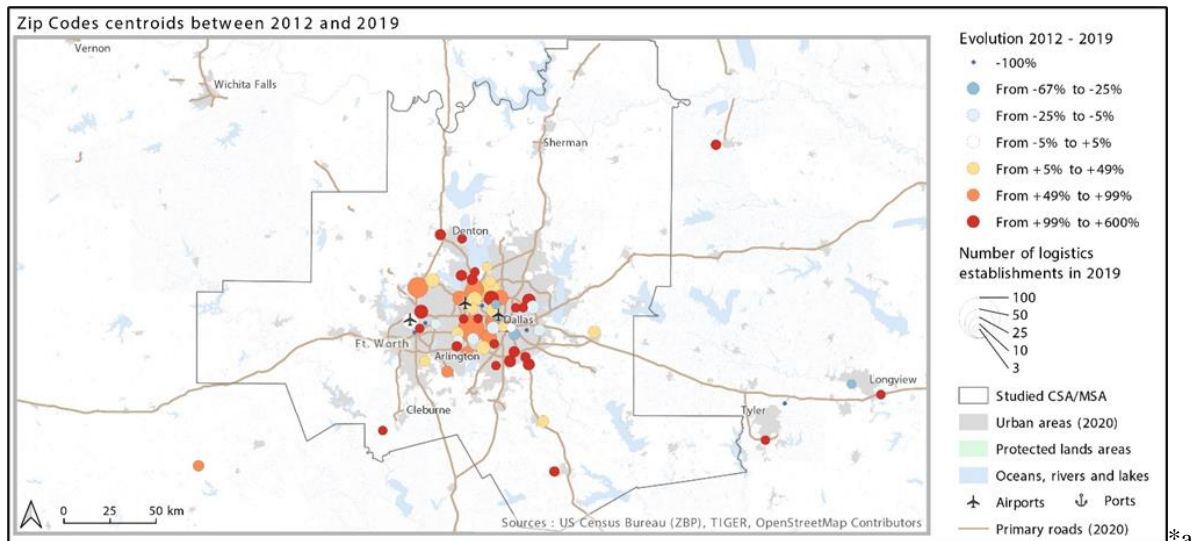


Fig. 1. *(a) Evolution (2012-2019) of the spatial distribution of logistics warehouses in the Dallas-Fort Worth CSA ; *(b) Evolution (2012-2019) of the ellipse area in the Dallas-Fort Worth CSA. Produced by the authors, 2022.

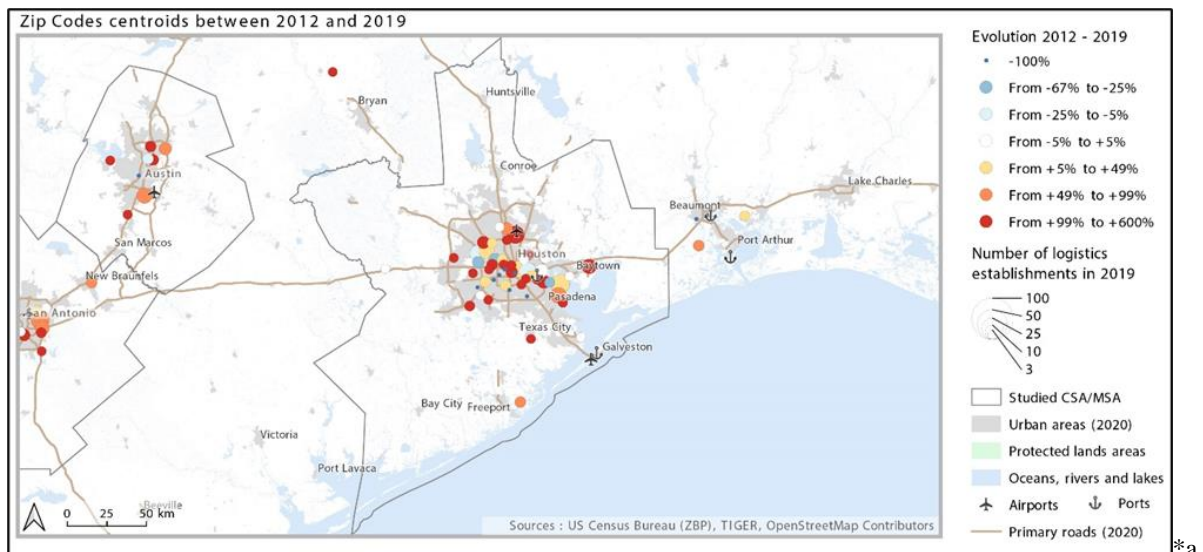
To measure the evolution of the locations of warehouse establishments, the standard deviational ellipse area (from the barycenter) was calculated for all warehousing establishments for both year:

- the standard deviational ellipse area from the barycenter was in 2012 1942.65 km²;
- this area from the barycenter increased by 19,6%.

The ellipse area (Fig. 1 (b)) has moved in the southeastern direction mainly and in the northwestern direction.

5.2. Houston-The Woodlands-Sugar Lands MSA

The Houston-The Woodlands-Sugar Lands metropolitan area is a fast-growing logistics hub: 281 logistics facilities in 2012, 363 in 2019. The number of warehouses increased by 29.1% confirming the rapid growth of logistics activities in Texas metro areas. The number of warehouses per 10,000 inhabitants has consequently increased from 0.45 per 10,000 inhabitants in 2012 to 0.51 in 2019 (a 13% increase). The Houston metropolitan area is typical of large Sunbelt cities that have experienced strong population and economic growth and have been transformed by very significant urban sprawl. Houston's urban landscape is characteristic of the American suburban city and highly sprawling single-function areas connected by a dense highway network. The CSA's logistics facilities are concentrated in three main clusters: a cluster around the Port of Houston to the southeast; a cluster around the international airport to the north; and a west/northwest axis from downtown (Interstate 10, Washington Avenue, Interstate 610, Hempstead Road). The largest number of warehouses and the highest growth rates are concentrated in these clusters, particularly around Interstates 10 and 610. There is a scattering of a small number of logistics warehouses in the south-central and southern portion of the metropolitan area. Finally, the location of logistics establishments seems to respond to the classic patterns of logistics sprawl: a privileged location near major transport infrastructures; the development of a double logistics ring (pericentral and peripheral) (Fig. 2 (a)).



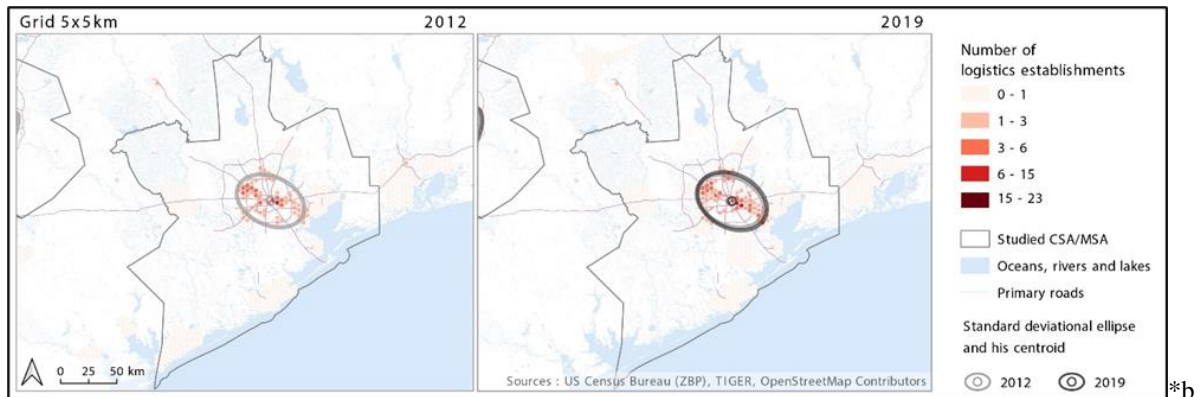


Fig. 2. *(a) Evolution (2012-2019) of the spatial distribution of logistics warehouses in the Houston-The Woodlands-Sugar Lands MSA ; *(b) Evolution (2012-2019) of the ellipse area in the Houston-The Woodlands-Sugar Lands MSA. Produced by the authors, 2022.

The standard deviational ellipse area (from the barycenter) was calculated for both years for this CSA:

- the standard deviational ellipse area from the barycenter was in 2012 2047.51 km²;
- this area was in 2019 2328.13 km².

The standard deviational ellipse area has increased by 13,7% between 2012 and 2019. This ellipse area (Fig. 4) has moved in the southeastern and northeastern directions.

5.3. South of the BosWash Megalopolis : New York-Newark-New Jersey MSA and Philadelphia-Camden-Wilmington MSA

The New York-Newark-New Jersey CSA is the largest metropolitan area in the United States for the number of logistics facilities. There were 844 warehouses in 2012 and 993 in 2019, a 17.6% growth between 2012 and 2019. New York's major logistics hub continues to grow, confirming the metropolitan area's role as an international and domestic gateway. As a result, the number of logistics establishments per 10,000 inhabitants has increased, moderately, from 0.38/10000 inhabitants in 2012 to 0.44/10000 inhabitants in 2019 (a 17.2% growth between 2012 and 2019). The map (Fig. 3 (a)) shows a high concentration of logistics establishments that makes the map more difficult to read than for the other study cases. A few areas are affected by a decrease in the number of logistics establishments, in the extreme south of the metropolitan area north of Trenton, in northwestern New York, and on Long Island.

Four areas of concentration of logistics warehouses are identifiable:

- a southwestern axis from Newark to New Brunswick along Interstate 95 that brings together a large number of warehouses with several Zip Codes that have between 50 and 100 warehouses. The area west of Staten Island (Elizabeth) is experiencing very high growth rates.
- an axis in the center of Long Island around Interstate 495 that concentrates several industrial and logistics zones.
- a pericentral ring around Manhattan which is based primarily on the facilities of the Port of New York-New Jersey. In addition, warehouses are concentrated in western Brooklyn (Brooklyn Heights around Interstate 278, East Williamsburg); northwestern Queens around La Guardia Airport; the southern Bronx near Interstate 278; western and southwestern Manhattan in Jersey City and Bayonne near Interstate 78.
- An area northwest of the urban core, from northern Newark, west to Union City, around the Teterboro Regional Airport and near Interstate 95.

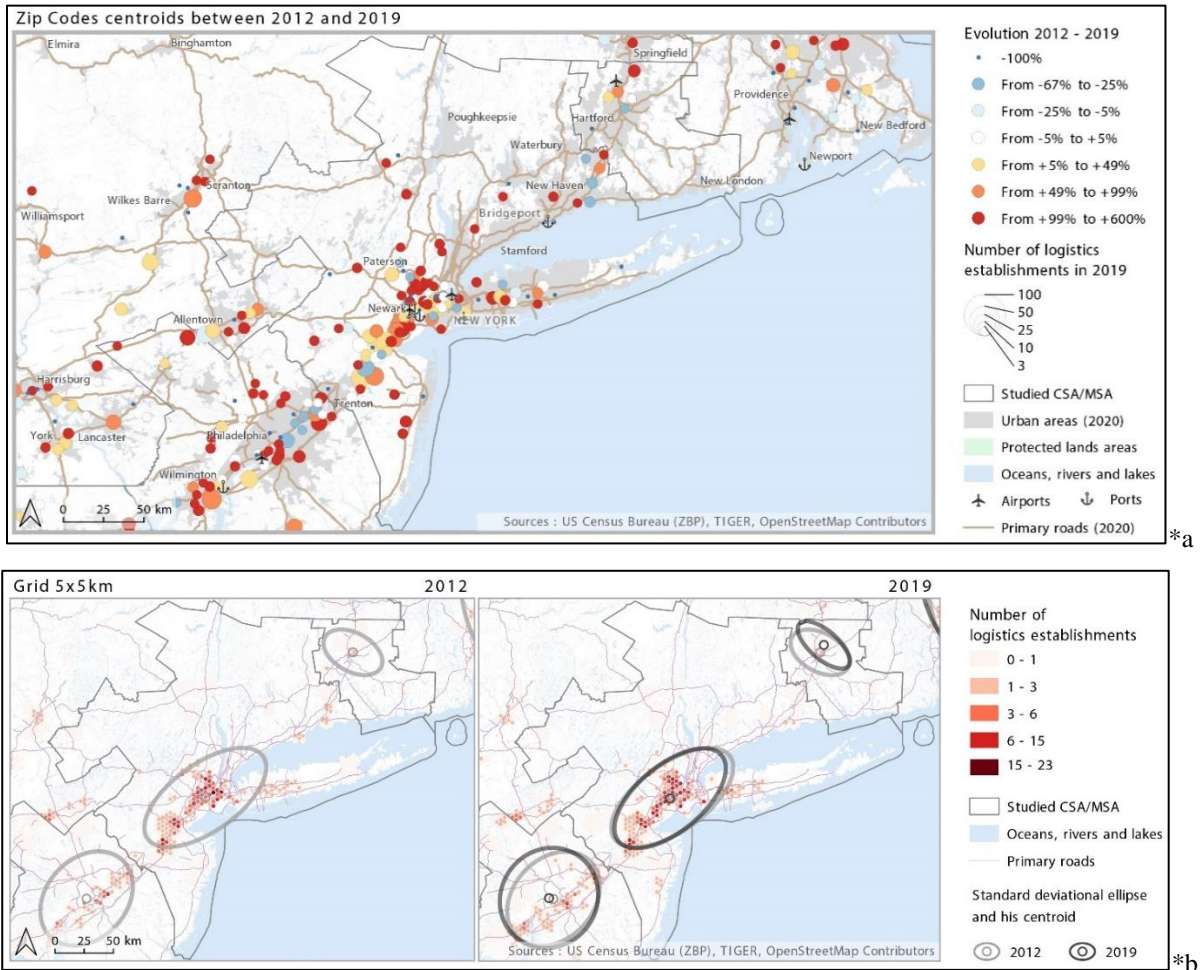


Fig. 3. *(a) Evolution (2012-2019) of the spatial distribution of logistics warehouses in the New York-Newark-New Jersey CSA; *(b) Evolution (2012-2019) of the ellipse area in the New York-Newark-New Jersey CSA. Produced by the authors, 2022.

The case of the New York-Newark-New Jersey CSA confirms a logistical dispersion effect to the northwest and south of the agglomeration. This logistical sprawl nevertheless takes an original form, essentially within the urban corridor of the Megalopolis. Several factors must be taken into account: the importance of major transportation infrastructures (Port of New York-New Jersey, Interstates, Newark and La Guardia airports), the limited number of available plots of land in a highly urbanized region, and New York's role as a global gateway that serves as trade nodes to the entire region and the whole country as well as dynamic and enormous consumer markets. The standard deviational ellipse area (from the barycenter) was calculated for both year for this CSA:

- the standard deviational ellipse area from the barycenter was in 2012 5290.22 km²;
- this area was in 2019 4906.91 km².

The standard deviational ellipse area decreased by 7,25% between 2012 and 2019. The ellipse area (Fig. 3 (b)) was contracted from the northeastern direction. This case study presents a case for reducing logistical sprawl. This evolution could be explained by three explanations that need to be confirmed: 1) a reinforced metropolization effect in this highly developed and mature logistics market; 2) a reduction in the number of logistics establishments in locations far from the CSA's economic hubs; 3) a turnaround in the logistics real estate market with more logistics establishments in central areas.

The number of warehouses in the Philadelphia-Camden-Wilmington CSA has grown significantly from 2012 to 2019, from 324 logistics facilities in 2012 to 395 in 2019. This represents a growth of 21.9 percent. As a result, the number of warehouses per 10,000 residents increased by 20.4% from 2012 (0.45/10000 residents) to 2019 (0.55/10000 residents). Logistics warehouses have significantly different location patterns (Fig. 4 (a)) to those in the Dallas-Fort Worth CSA. Most warehouses follow the Megalopolis urban corridor along a northeast/southeast longitudinal axis. It is within this urban corridor that major highway and rail transportation infrastructure as well as major ports and airports are concentrated. From 2012 to 2019, profound changes are nevertheless taking place:

- the development of warehouses in the pericentral area of Philadelphia, in Camden, i.e., closest to the heart of the agglomeration (with very high warehouse growth rates).
- a significant increase in the number of logistics warehouses in Wilmington, in the southwest of the CSA.
- a rapid growth of warehouses in the peripheral bangs of the metropolitan area, particularly in the north and northwest.
- the emergence of a zone of decline in logistics facilities between Philadelphia and Trenton along Interstate 95.

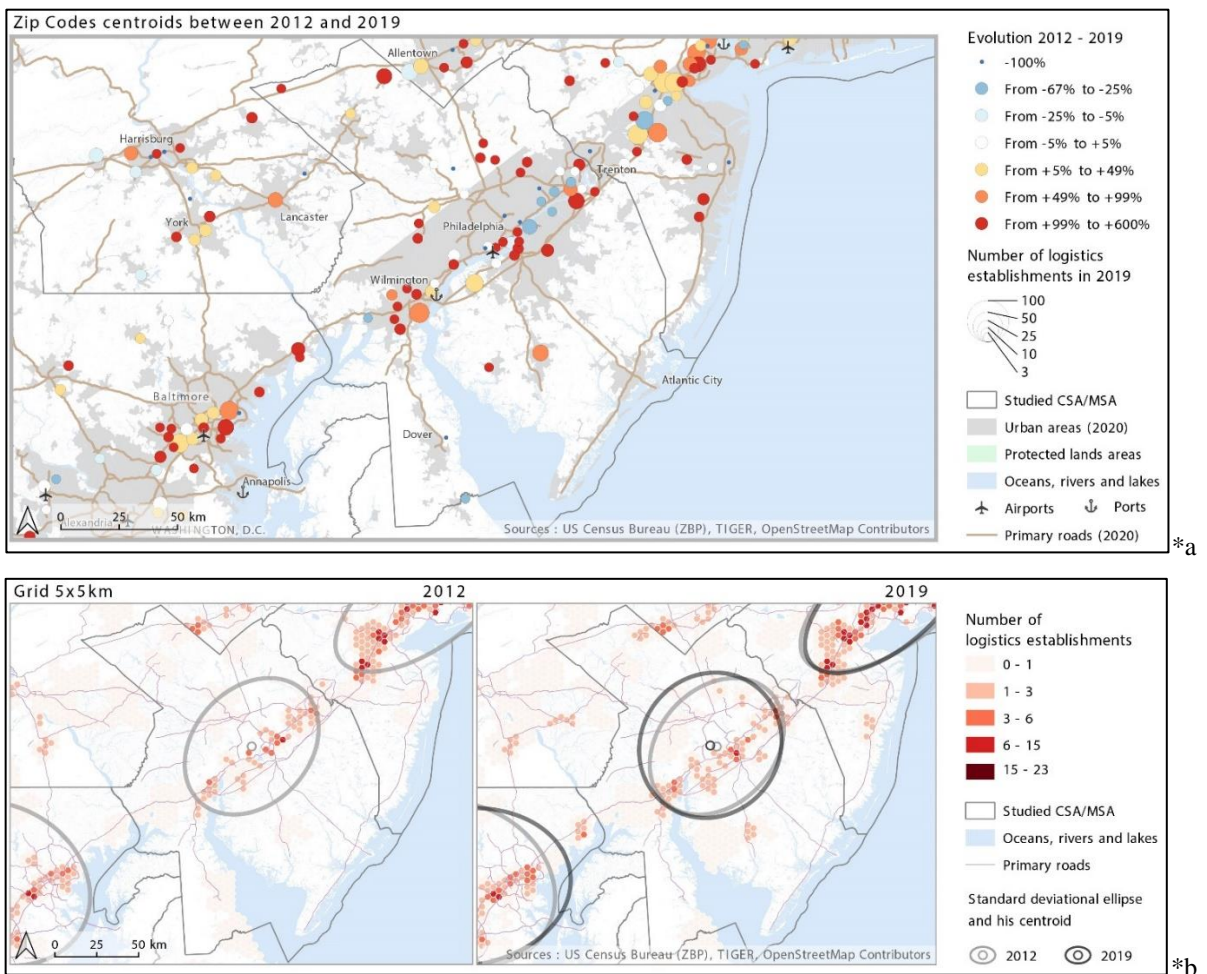


Fig. 4. *(a) Evolution (2012-2019) of the spatial distribution of logistics warehouses in the Philadelphia-Camden-Wilmington CSA; *(b) Evolution (2012-2019) of the ellipse area in the Philadelphia-Camden-Wilmington CSA. Produced by the authors, 2022.

The case of the Philadelphia-Camden-Wilmington CSA seems to confirm the major trends in the logistics real estate market, in particular a dualization of this market between peripheral warehouses (where owners are looking for large and inexpensive parcels) and warehouses near the center of the metropolitan area to meet the needs of urban logistics and e-commerce. To measure the evolution of the locations of warehouse establishments, the standard deviational ellipse area (from the barycenter) was calculated for both year:

- the standard deviational ellipse area from the barycenter was in 2012 4763.58 km²;
- this area was in 2019 5567.76 km².

The standard deviational ellipse area increased by 16,8% between 2012 and 2019. The ellipse area (Fig. 4 (b)) has moved in the northeastern direction and modestly in the southern direction.

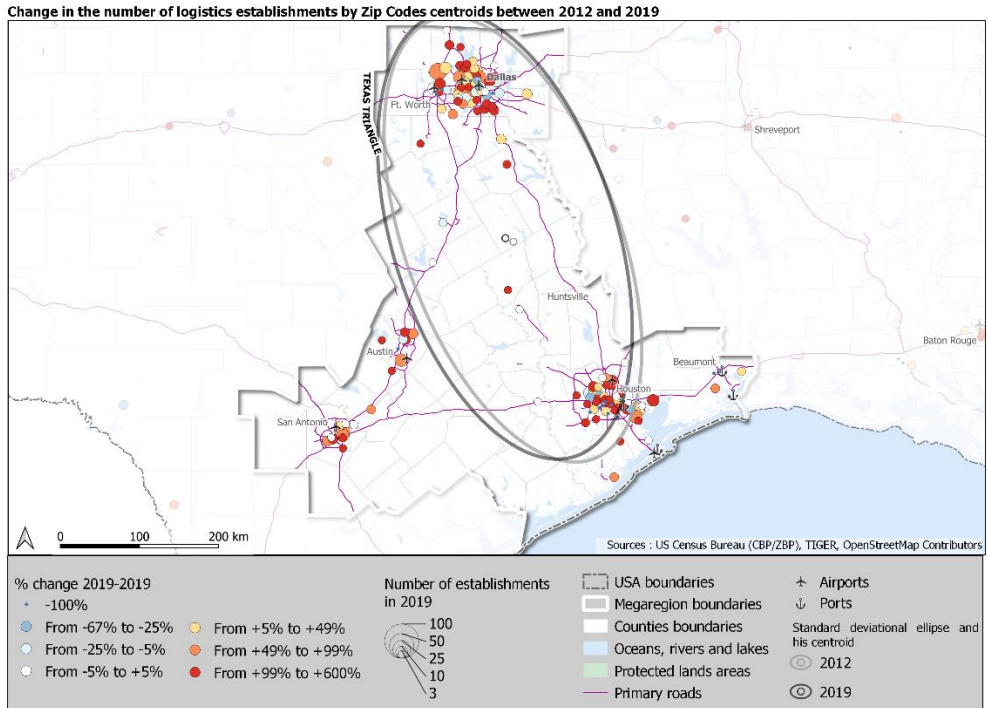
5.4. A complementary look at the megaregional level: the emergence of metropolitan clusters

Some research focuses on the megaregional scale, due to the complexity of freight flows at multiple scales and the complementarity of logistics facilities networks (Schoring, Dablanc, Buldeo Rai, 2023). Ross and Woo (2009, 2010), Ross et al. (2009) identify a very strong relationship between road freight transport and megaregions. Gifford et al., (2011) explore the relationships between freight movements and the megaregion scale using the Commodity Flow Survey (CFS). Dablanc and Ross (2012) confirms the existence of logistics polarization at a megaregional scale, in the case of the Piedmont Atlantic Megaregion, confirming the polarization pattern of freight facilities (Gilli, 2009).

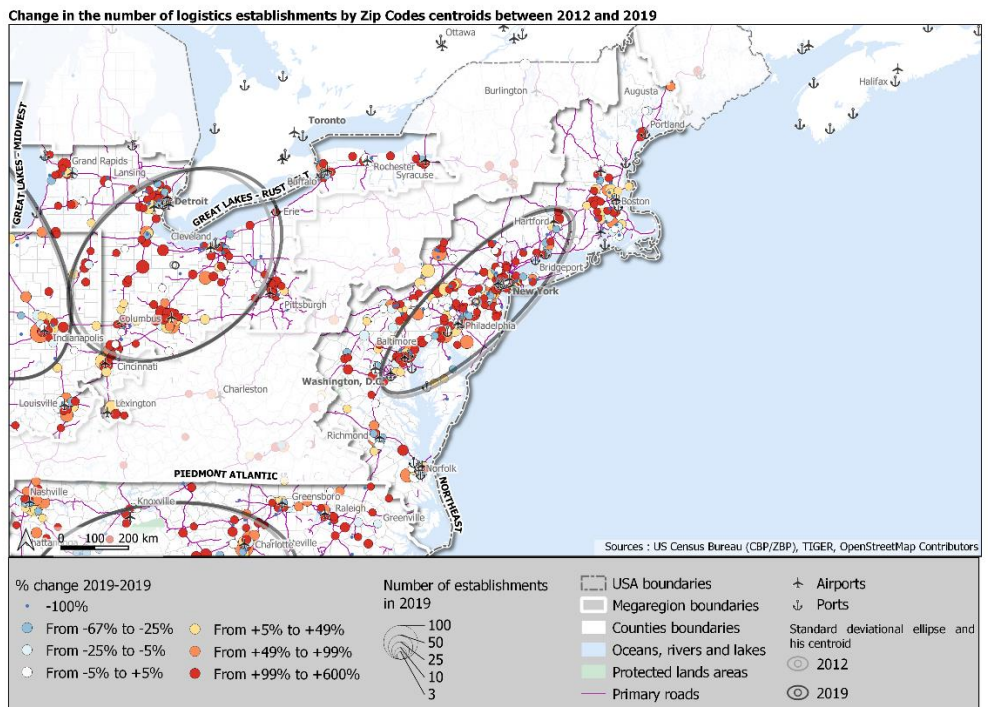
The megaregion is a new scale of analysis clearly identified by political actors and transport authorities. Ross (2009) define megaregions as « *networks of metropolitan centers and their areas of influence that have existing social, environmental, economic, and infrastructure relationships, are geographic areas that will contain two thirds of the nation's population by the mid-twenty-first century* ». The megaregion is the result of a continuous process of polarization and accumulation of population, wealth and activities, which goes beyond the existing administrative units as well as the traditional scales of analysis – inner city, urban area, metropolitan area. Each megaregion forms a large but coherent territory, marked by environmental, economic, and infrastructural interactions, creating a new transactional and traffic space. An important part of a megaregion's competitiveness both nationally and in the global marketplace depends on the transportation infrastructure that ensures the fluidity of its internal and external exchanges of goods and people.

Three processes underlie the development of megaregions:

- the growth, intensification, and diffusion of economic activities that require more and more space to develop;
- the improvement of communications between urban centers resulting from the development of transportation corridors
- the economic and functional specialization of urban centers and their increased interdependence, which is accompanied by very intense passenger and freight flows (Dablanc and Frémont, 2015).



*a



*b

Fig. 5. *(a) Evolution (2012-2019) of the spatial distribution of logistics facilities in the Texas Triangle megaregion; *(b) Evolution (2012-2019) of the spatial distribution of logistics facilities in the Northeast megaregion. Produced by the authors, 2022.

The megaregional scale is very complementary for the study of freight and logistics. Our analysis has focused on the polarization patterns of freight facilities at the megaregional scale. The polarization of logistics activities (Gilli, 2009) is the concentration of logistics activities in the major metropolitan areas and the most prominent transport hubs. This analysis confirms the existence of logistics polarization at a megaregional scale, in the case of the Texas Triangle megaregion and the Northeast megaregion. Figure 5 shows the evolution of the location of warehouses (NAICS 493) in all zip codes of the two megaregions between 2012 and 2019. The data are from the County Business Patterns Survey with an aggregation of data for all zip codes comprised within a specific area. We chose to use the same geographic delimitation for the two megaregions as the delimitation defined by the Regional Plan Association in their report *America 2050. Defining U.S. Megaregions*[†]. Figure 5 shows that the number of warehousing establishments has increased in many zip codes in or close to the core metropolitan areas. In relative as well as absolute terms, these zip codes have attracted more logistics facilities than most other urban, semi-urban, or rural counties in the region.

6. Discussions and conclusions

The number of warehouse establishments in the four metropolitan areas analyzed in this study grew rapidly between 2012 and 2019. Conclusions can be drawn based on the similarities between the two Texas CSAs (Dallas and Houston) and between the two CSAs from the Northeast region (New York and Philadelphia). Warehousing in the Houston and the Dallas areas has increased and has experienced a steady logistics sprawl. The Dallas-Fort Worth CSA is being more and more a warehousing hub (surpassing Atlanta in number of logistics establishments) because of its booming demographics and economy. This CSA is now a major inland gateway for national freight flows. The very strong growth of the warehousing sector has led to a major dispersion in terms of warehouses location, especially in peripheral Zip Codes (northwest, southwest and more recently southeast of the Dallas area). Suburban and exurban areas is where the land is available for development and less expensive. These areas can offer access to a more complex system of regional and national infrastructures and flows. The Dallas area is a typical case of a booming warehousing hub (+41,7% between 2012 and 2019) and of a sprawling metropolitan area. The Houston-The Woodlands-Sugar Lands CSA appears to follow the same path. This area has experienced a strong growth of its logistics establishments as well (+29,1% between 2012 and 2019) but has sprawled less than the Dallas area. The location of warehouses is less dispersed and polarized in more distinctive areas (west, north and southeast of the Houston area). The significant clustering of warehouses in these areas, near the weighted geographic center, is caused mainly by the close presence of major infrastructures (Port of Houston, Houston International Airport) and next to Interstates.

The two other case studies (Philadelphia-Camden-Wilmington CSA and New York-Newark-New Jersey CSA) offer quite different trajectories. The Philadelphia-Camden-Wilmington CSA has experienced a growth of warehousing establishments (+21,9% between 2012 and 2019) but a more limited logistics sprawl than the two Texas case studies. The analysis of logistics establishments between 2012 and 2019 shows an evolution of location patterns: less dispersed within the core corridor between Philadelphia and Trenton with some Zip Codes that have seen a decreased in the number of warehouses; a reinforced logistics hub in the south of Wilmington; new warehousing implantations outward away from the City of Philadelphia (north and west of the CSA). The development patterns of the warehousing sector in the Philadelphia area appear mainly organized by the urban and transportation corridor of the Megalopolis (following a northeast/southwest axis). The New York-Newark-New Jersey metropolitan area has experienced a limited growth of logistics establishments (+17,6% between 2012 and 2019) but this growth has occurred in an already mature and well-developed logistics market (993 warehouses in 2019). This case is the only of the four case studies that has experienced a decrease of its standard deviational ellipse area and a less sprawled warehousing sector.

This study extends works which analyzed the tendency of warehousing and logistics facilities to move away from central areas toward suburban and exurban areas. In four studies, researchers found that all case studies experienced

[†] <https://rpa.org/work/reports/defining-u-s-megaregions>

logistics sprawl. This present research adds new metropolitan areas to these having been analyzed for the phenomenon of logistics sprawl. Logistics sprawl has been confirmed for six metropolitan areas in North America and Europe (Atlanta, Los Angeles, Phoenix, Chicago, Toronto and Paris) (Dablanc et al., 2014; Heitz and Dablanc, 2015; Woudsma et al., 2016; Dubie et al., 2020) and has not been confirmed in one metropolitan area (Seattle) (Dablanc et al., 2014). Our present paper examined the spatial patterns of freight and logistics activities, using a comparative approach (New York, Philadelphia, Dallas, Houston) and a multiscale approach (Texas Triangle and Northeast megaregions). The contribution of this paper to the existing literature is a documentation of the presence, or lack thereof, of logistics sprawl in the New York, Philadelphia, Dallas and Houston metropolitan areas, offering a comparative view of two city pairs (two in the Northeast region, two in the Texas Triangle). When comparing these results and this cartographic analysis to previous study results, it is apparent that national and regional economic trends, distribution of freight and flows, the function of global gateway and accessibility to transportation influence the distribution of warehousing facilities. This paper confirms the crucial role of accessibility, connection to regional and national flows and proximity to highway networks, ports and airports on the location and development patterns of the warehousing sector (Bowen, 2008; Dablanc and Ross, 2012). Two important aspects of the geography of the logistics industry are mostly confirmed: “logistics sprawl” - the spatial deconcentration of logistics facilities and distribution centers in the Houston, Dallas and Philadelphia metropolitan areas; and the polarization of logistics activities - the concentration of logistics activities in the urban areas of Texas Triangle and Northeast Corridor. research can be completed with an analysis of the planning efforts and policies associated to logistics, land use and transport decarbonization.

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RESPONSES TO THE REVIEWERS

Reviewer 1

I am a supervisor of Mr Schorung so I have a conflict of interest. Nonetheless, I have read the paper and I think it is a robust piece and serious work. My only comment is that it lacks originality.

Response of the authors

The originality of the paper lies in the comparative analysis of four case studies, not yet studied in the scientific literature. The methods used are similar to the standards of studies on this research theme (cartographic analysis, calculation of the barycentre, diachronic and comparative approach). Nevertheless, to ensure an even more robust originality of the paper, the authors decided to add a multiscale dimension by integrating two megaregions. This scale is still very little used in the literature. In this, the introduction and the objectives of the research have been modified. A subsection on the two megaregions has been added.

Reviewer 2

This paper evaluates the location of warehouses in four U.S. cities. It is an interesting study that compiles data on the suburbanization of logistics hubs, but it has not yet reached the level of academically generalized findings.

Response of the authors

The introduction has been modified and enriched, in particular concerning the megaregions and the objectives of the research. The results section has also been modified.