

An evaluation of logistics sprawl in Chicago and Phoenix

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ABSTRACT

This paper evaluates whether or not there is a sprawling tendency to the spatial patterns of warehouse establishments in the Chicago and Phoenix metropolitan areas. The trend of warehouses to move away from the urban centers to more suburban and exurban areas is referred to as “Logistics Sprawl”. To measure sprawl, the barycenter of warehousing establishments was compared to the barycenter of all other industry establishments in the region between the years of 1998 and 2013 for Chicago; 1998 and 2015 for Phoenix. This shows that logistics sprawl is a behavior experienced by warehouses in the Chicago area, but not in the Phoenix area. This paper discusses if logistics sprawl is a national trend or a regional behavior by comparing these results to the previous case studies of the Atlanta, Los Angeles, and Seattle metropolitan areas.

1. Introduction

The United States warehousing industry has experienced incredible growth in the last twenty years both in terms of employment, and number of establishments. In 1998, United States warehousing employment was 119,493 workers. By 2015, the number of employees grew to 809,359 employees, increasing by 577% and reflecting a compound annual growth rate of 11.91%. The number of warehouse establishments also experienced rapid growth between 1998 and 2015, growing by 114% compared to the average growth of all industry establishments of 10.40%. Although the recession slowed the growth of all employment in 2009 and 2010, by 2012 the warehouse industry returned to a positive employment rate of 5%, higher than the average 2% employment rate of all industries (U.S. Census Bureau, 2017a).

This growth means tremendous change for cities, both in terms of land use and transportation. Warehouses are key nodes on supply chains, generating significant truck traffic. Their single-floor design conducive to quick goods movements makes them particularly land intensive users; modifying the physical and economic landscape for cities. As shown in Fig. 1, the average size of warehouses built in the U.S. between 2012 and 2017 increased by 143% to 17,158.54 sq. meters since the last development peak between 2002 and 2007 (CBRE, 2017). Using the ITE trip generation manual to estimate potential traffic impact (Fig. 2), an average size new warehouse will generate an average of 655 vehicle trip ends per weekday; trip generation estimates

during the morning and afternoon peak hours are 77 and 83 trips, respectively (ITE, 2012).

Because of this importance, several recent studies have explored warehouse location over time and demonstrated a shift in the locations of warehousing and distribution centers to more suburban and exurban areas (Giuliano et al., 2016, Bowen (2008), Cidell (2010)). This behavior reflects the industry response to transportation cost, operating models, and real-estate cost (Giuliano et al., 2016). This location shift was called first “logistics sprawl” by Dablanc (Dablanc and Rakotonarivo, 2010).

This paper examines the question of whether or not logistics sprawl occurred in the Chicago metropolitan area between 1998 and 2013; and the Phoenix metropolitan area between 1998 and 2015. Previous studies of logistics sprawl have evaluated, among others, the metropolitan regions of Atlanta, Paris, Los Angeles, Seattle, and Toronto (Dablanc and Ross (2012), Dablanc et al. (2014), Heitz and Dablanc (2015), Woudsma et al. (2016)). This paper compares Phoenix and Chicago to Atlanta, Los Angeles, and Seattle, which have been studied with the same spatial analysis method (described below).

Identifying logistics sprawl allows us to understand the aggregate trends in freight transportation and anticipate impacts on regional transport. This research can serve as an input into conversations about regional freight transportation management and land use.

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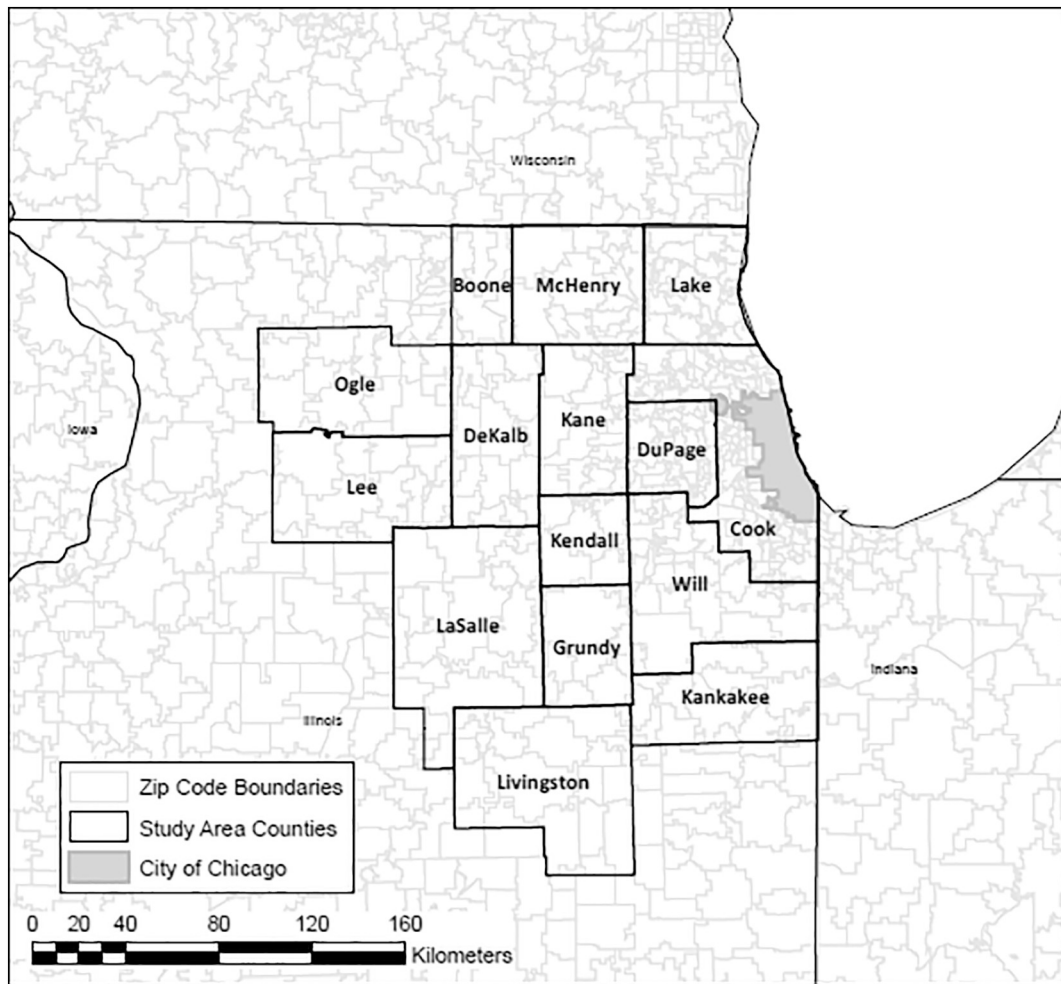


Fig. 1. Chicago study area (Source: U.S. Census Bureau.)

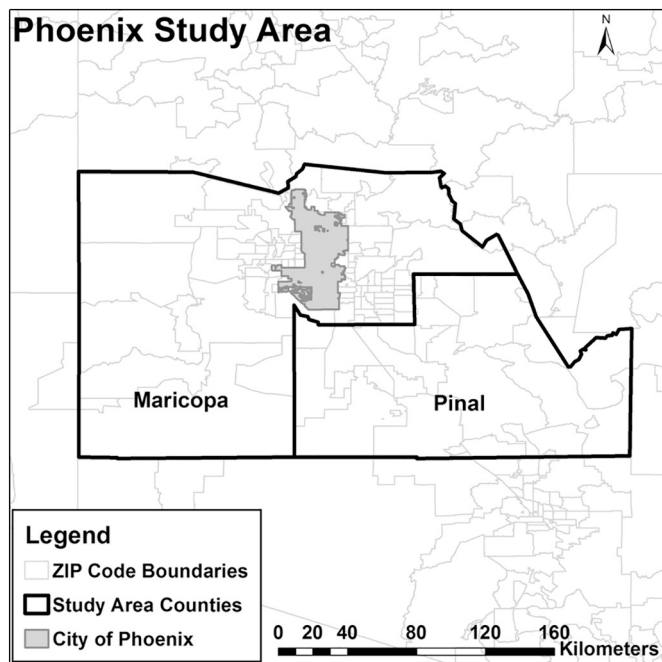


Fig. 2. Phoenix study area (Source: U.S. Census Bureau.)

2. Literature review

Warehousing employment and development patterns reflect long-term economic and development policy choices. Christopherson and Belzer (2009) explain that “before the era of containerization and the rationalization of the surface freight transportation system to favor expedited, low-cost freight transportation, seaports largely served their surrounding regions”. The transition to the modern freight system was a result of deregulation of the industry and new policies that influenced an open global market of goods movement.

In the modern freight system, national policies, as well as regional specifics, affect the tendency of warehousing and logistics facilities to move away from urban areas toward the more suburban and exurban areas (Dablanc et al., 2014; Heitz and Dablanc, 2015). Warehouse location choice (or site selection as it is referred to in the industry) reflects several supply chain costs, including transportation, inventory, facility operations, and real-estate (Dablanc and Ross, 2012). Warehouse site selection is a well-studied problem with robust available analytical support tools (Korpela and Tuominen, 1996). While this explains individual warehouse location decisions, this is separate from the analysis of aggregate trends in warehouse location that are observed at a metropolitan scale. The latter is the problem addressed in this literature review and this paper.

The Dablanc and Ross (2012) study of the Atlanta region focused on the spatial patterns of freight and logistics activities more broadly than only evaluating logistics sprawl. As stated by this study, “historically, warehouses and freight terminals tended to be close to city centers and

rail stations. They relocated in search of more, and more affordable space, as well as proximity to highway networks and airports". The access to highway and airports have become important when selecting the location of warehousing. This access allows the distribution activity to connect to a "more complex economy of regional and national flows from suburban areas." (Dablanc and Ross, 2012) (Woudsma et al., 2008).

Andreoli et al. (2013) also look more broadly at the spatial patterns of freight and logistics activities. They explain the rapid growth of the warehouse industry and the development of mega distribution centers (DC's) in multi-regional markets. "Processes of globalization have manifested in new geographies of production which have transformed the logistics landscape. The volume of goods flows increased exponentially, and as a consequence so too has supply chain complexity". Bowen (2008) also highlights the growth of the warehousing industry between 1998 and 2005 and shows that warehousing location preference is increasingly correlated with accessibility to roads and airports, but less so to rail terminals. He concludes that the changes in warehousing geography are about the spaces connecting metropolitan, regional and national economies; rather than just the restructuring of the metropolitan areas. He also acknowledges that the thickening of long-distance linkages among distant economies has driven the changes in location and the growth of the warehouse industry (Bowen, 2008).

Cidell (2010) examined the suburbanization of warehousing and truck activity for fifty of the largest metropolitan areas in the U.S. between 1985 and 2005. This research used the U.S. Census Core Base Statistical Area as the base geography and Gini coefficients as a measure of concentration. This index has been used by transportation geographers to compare concentrations of maritime and air traffic over time and across space. The spatial distribution changes within the period are examined considering additional variables like population density, median household income, miles of interstate per capita and miles of railroad track per capita. Taking all these variables into account, multiple regression models were developed to explain the relationship between the number of facilities, Gini coefficients and the change over time.

Sakai et al. (2016) used large-scale freight survey data to examine historical information of the logistics facilities in Tokyo Metropolitan Area and investigate possible causal factors for the changes. Only facilities with a floor area of at least 400 square meters were considered, and the ones located less than 1.5 km from the coastal area of Tokyo Bay were excluded. Information about demography and land price were included in the analysis too. The Kernel Density Estimation (KDE) method was used to create a visualization of the concentration of logistics facilities that are spatially spread. The paper recognized public policies related to these facilities, such as land use regulation and development permissions as key factors for the distribution. However, a calculation of logistics sprawl was not undertaken.

Previous analyses of logistics sprawl have used the distance from the barycenter (i.e., the weighted geometric center of a geographic distribution) as the key measure. The barycenter of warehousing establishments is determined and compared to the barycenter of all facilities. In Dablanc et al.'s (2014) study of Los Angeles and Seattle, the spatial pattern of logistics was measured by averaging the total distance from warehousing establishments under NAICS Code 493 to the spatial mean of warehousing establishments. The same method was used in case studies of Atlanta, Paris, and Toronto (Dablanc and Ross, 2012), (Heitz & Dablanc, 2015), (Woudsma et al., 2016). In these three studies, researchers found that all the study areas experienced logistics sprawl. The results of the Chicago and Phoenix analysis are compared to these previous studies in Section 6 of this paper. The contribution of this paper is to add to the body of metropolitan areas that have been analyzed for the presence of logistics sprawl. Only after a sufficient number of cities have been analyzed can more systematic patterns emerge regarding the relationship between logistics sprawl, regional and national policies, and other significant factors.

3. Study area

For this logistics sprawl analysis, the Chicago and Phoenix metropolitan areas were selected.

3.1. Chicago

Chicago is the third largest metropolitan area in the United States with a population of over 7.3 million (U.S. Census Bureau, 2016b) and is a key national freight hub. The Midwest city on the shore of Lake Michigan has historically been the nation's rail hub due to its critical location at the nexus of the North American railroad network. Six of the seven largest rail carriers access the region. Chicago today remains the busiest rail hub in the United States. Each day, nearly 1300 trains pass through the region. Chicago handles one-fourth of the nation's freight rail traffic, each day handling 37,500 railcars (Chicago Region Environmental and Transportation Efficiency Program (CREATE) Website, 2016). The city was selected due to its importance as a national freight hub.

The region of study included zip codes of the Chicago-Joliet-Naperville area within the State of Illinois. The city of Chicago is located on the east side of the region, shown in Fig. 1. Many rail corridors converge into the inner metropolitan area of Chicago, and the warehouse establishments located were distributed along these lines.

3.2. Phoenix

Phoenix metropolitan area has a population of 4.2 million people (U.S. Census Bureau, 2017d) and is located in a desert area in the southwest of the United States. It consists of Maricopa County and Pinal County (Fig. 2). This area comprises approximately 37,813 km², more than three times the Seattle MSA and about one and a half times the Atlanta MSA (U.S. Census Bureau, 2017d). The Phoenix MSA (Metropolitan Statistical Area) has a very low population density when compared to other MSAs in the United States. The population highly concentrated in the west of Maricopa County and Northeast of Pinal County.

The Phoenix MSA's topography is primarily flat, with the major streets and highways laid-out on a grid network. Truck transportation dominates freight movements in the state (Center for Transportation Analysis, 2017a). In contrast to the Chicago area, Phoenix is not a major national freight hub, instead, it primarily serves the freight needs of the region. There is no major port or intermodal terminal in the region, with an approximate distance of 612 km to the nearest major ports in Los Angeles and Long Beach. Phoenix was selected for analysis as a contrast to Chicago because it plays such a different role in the national freight system.

4. Data and methodology

In this analysis, warehousing is defined as those industries classified in 493XXX ("Warehousing and Storage") of the North American Industry Classification System (NAICS). This classification includes industries classified as general, refrigerated, and farm product warehousing and storage. This industry comprises establishments primarily engaged in operating merchandise warehousing and storage facilities. These facilities generally handle goods in containers, such as boxes, barrels, and/or drums, using equipment, such as forklifts, pallets, and racks (Andreoli et al., 2010). This definition is consistent with the analyses of logistics sprawl in Seattle, Los Angeles, and Atlanta presented in Section 6.

Data for all establishments were obtained from the Census County Business Patterns website for the years 1998 through 2013 for Chicago; and 1998 through 2015 for Phoenix, using the longest time period available at the time of analysis. The site provides economic data by industry, which includes the number of establishments by economic data-

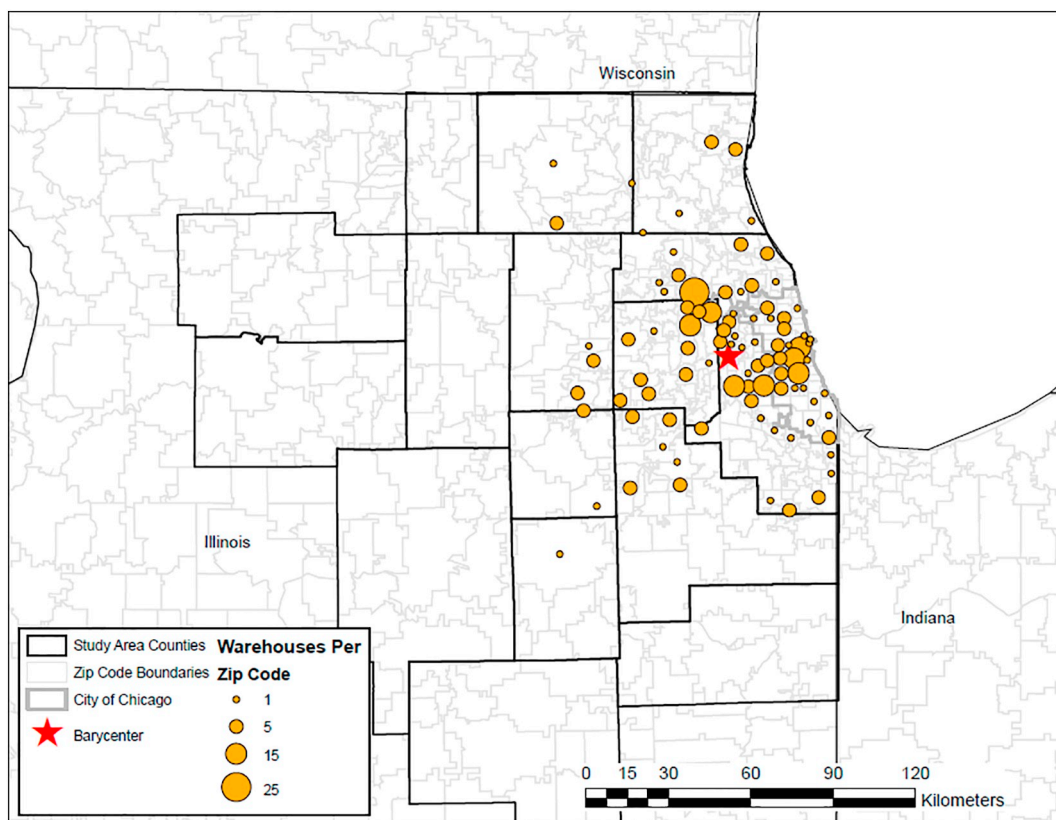


Fig. 3. Chicago area warehousing, 1998. The weighted geographic center is indicated by a star (Data Source: U.S. Census Bureau, 2016a)

size classes at the zip code level. R - a language used for statistical computing- and SQL, - a standard language for storing, manipulating and retrieving data - was used to compile and aggregate the data. ArcGIS software was used to map the warehouse establishments and provide the spatial analysis of the data. The Barycenter, or geographic mean (distance weighted), was calculated and plotted using the GIS Toolset features. This methodology allows for computing the level of dispersion of the warehousing facilities by a georeferenced spatial analysis that describes the average area over which the studied facilities are spread (Dablan and Ross, 2012). Using this approach will allow us to compare our results with the previous case studies of Atlanta, Los Angeles, and Seattle metropolitan areas.

5. Results

5.1. Chicago

In 1998, most warehouse establishments in the Chicago area were located in Cook, DuPage, and northern Will Counties. The rest of the warehouse establishments were further west in Kane County or north near the Wisconsin border in Lake County. Fig. 3 shows the locations of the warehouses (per zip code) in the Chicago study area in 1998.

The warehouse establishments increased in the three highly concentrated Counties in 2013. Fig. 4 shows the increase and expansion of establishments in almost every direction away from Chicago. Increased numbers of establishments appeared in southern Cook, central Will, and eastern Kane and McHenry Counties. The four large concentrations of establishments were in central Cook, southern Cook, northeast DuPage, and northern Will Counties.

There was growth in the number of zip codes with warehousing establishments as well as the number of establishments. Many of the 66 zip codes that experienced the development of new warehouse establishments were located in outer edges of the region. The overall number

of establishments increased 115% from 217 in 1998 to 466 in 2013. The zip codes that experienced the largest increase in establishments were located near the cities of Naperville and Joliet which border DuPage and Will Counties. It is interesting to note that both of these zip codes had zero establishments in 1998. In general, the growth pattern of the establishments was outward away from the city of Chicago.

To measure the shift of the locations of warehouse establishments, the barycenter (weighted geographic mean) was calculated for all establishments, as well as for warehousing establishments for both years. Using analysis tools from ArcGIS, the barycenter was used to measure the average distance to warehousing establishments within the region. From this analysis, we conclude that:

- The average distance from the barycenter for warehousing establishments increased from 71.0 to 79.8 km.
- The average distance from the barycenter for all establishments increased from 22.500 km to 24.200 km.

The distance for warehouse establishments increased by 11.5% compared to 7.3% of all establishments. The barycenter has moved 13 km in the southwestern direction. These metrics along with the visual observation of the maps give an indication that warehouse establishments are experiencing faster sprawl relative to all establishments.

5.2. Phoenix

In 1998, warehousing establishments in the Phoenix MSA were located in Maricopa County except for one establishment in the northwest of Pinal County. Fig. 5 shows that a total of 41.6% of the warehousing establishments are within 19.3 km of downtown Phoenix. The other cities with more than one establishment are Mesa, Temp, and Chandler.

Between 1998 and 2015, the total number of warehousing establishments grew from 41 to 183, an increase of 346% (Fig. 6). Zip codes

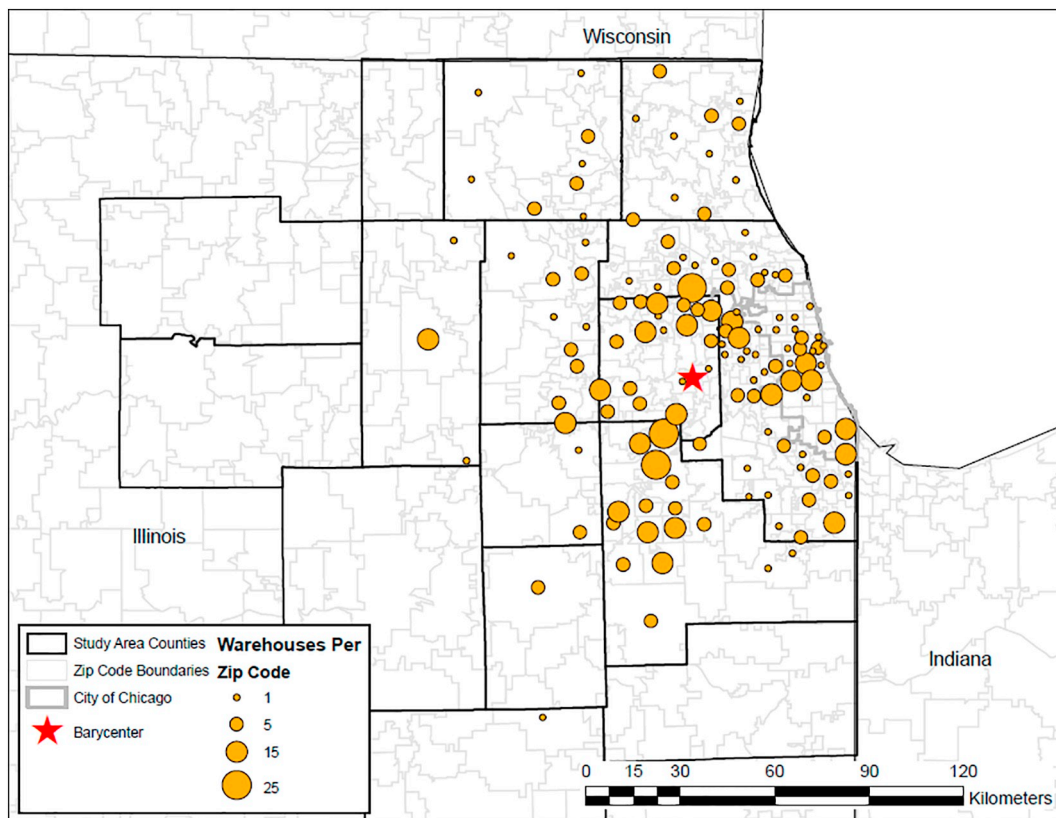


Fig. 4. Chicago area warehousing, 2013. The weighted geographic center is indicated by a star (Data Source: U.S. Census Bureau, 2016c)

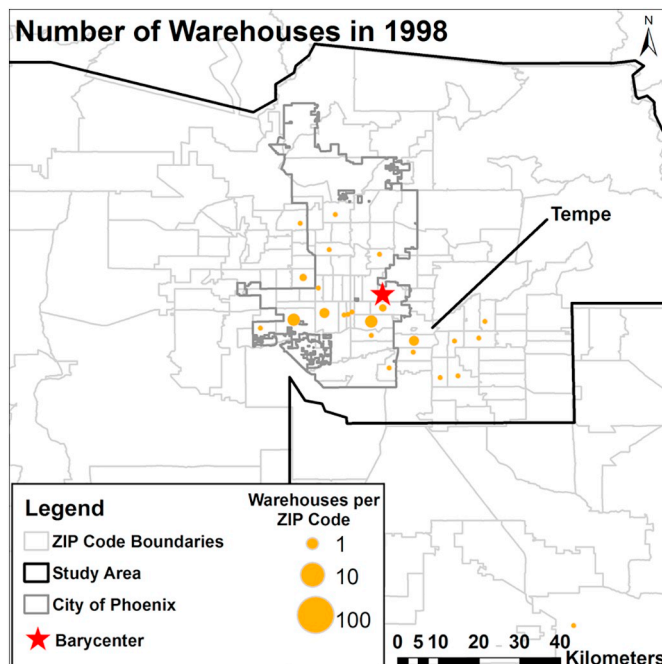


Fig. 5. Phoenix area warehousing, 1998. (Data Source: U.S. Census Bureau, 2017b)

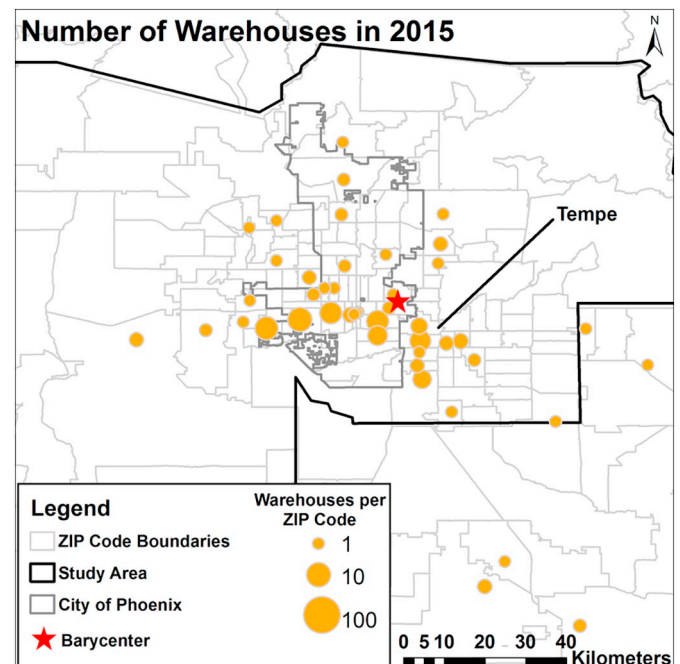


Fig. 6. Phoenix area warehousing, 2015. (Data Source: U.S. Census Bureau, 2017c)

with existing warehousing establishments contributed 91 of the 142 new establishments. Warehousing establishments within the City of Phoenix lowered to 56% of the total number located in this city. ZIP Code 85043, on the west side of downtown, remained the ZIP Code with the largest number of warehousing establishments. The second city with more warehousing establishments was Tolleson, increasing

from one to 20 establishments. Tolleson, 19.3 km west of downtown Phoenix, includes zip code 85353, which ranked second in warehouses per zip code. In Pinal County, the number of warehousing establishments increased to 9 in 2015, scattered along the northwest side of the county.

Doing the same previously described analysis, we found that:

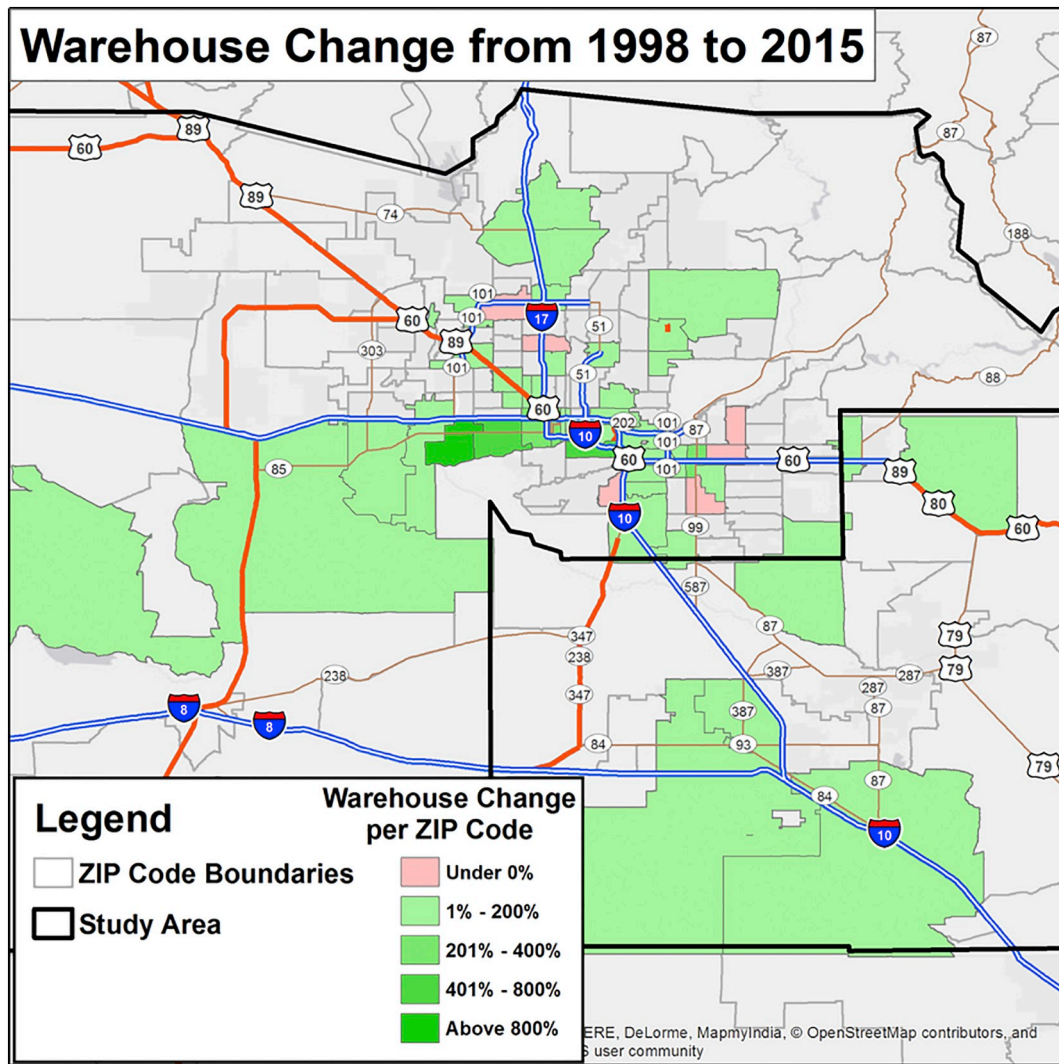


Fig. 7. Phoenix area warehousing change, 1998–2015.

Table 1
Logistics sprawl studied.

Author	Area	Time Period	Average Sprawl of all Establishments	Average Sprawl of Warehousing Establishments	'Relative Logistics Sprawl in Warehousing Establishments
Dablanc and Ross (2012)	Atlanta, GA	1998–2008	2.09 km	4.5 km	Yes
Dablanc et al. (2014)	Los Angeles, CA	1998–2009	–0.2 km	9.8 km	Yes
Dablanc et al. (2014)	Seattle, WA	1998–2009	0.3 km	–1.29 km	No
XX	Chicago, IL	1998–2013	1.7 km	8.8 km	Yes
XX	Phoenix, AZ	1998–2015	5.5 km	2.7 km	Yes

- The average distance of all establishments to their barycenter increased from 18.86 km to 24.38 km, an increase of 29%,
- The average distance from warehousing establishments to their barycenter increased from 17.86 km to 20.60 km or 15%.

2.62 km southeast. In contrast, the barycenter of the industry moved 5.05 km southwest.

6. Discussion of results

The results show that there was a change in the distribution of warehousing establishments. However, sprawl for all establishments was more significant. The data suggests that in the Phoenix MSA, warehousing establishments have not sprawled more than all establishments. In fact, they have sprawled but considerably less than all establishments, with an average distance of 2.7 km comparing to 5.5 km of all establishments. Warehousing establishments also show a different pattern of sprawl than all establishments, whose barycenter moved

The number of warehouse establishments in the Chicago area grew rapidly between 1998 and 2013 (from 217 to 466). Spatially, the growth has occurred in all directions away from the city. Will and Cook counties experienced the most growth. Chicago is within Cook County, and much of the new growth happened directly south of the city. Will County is adjacent to Cook and southwest of Chicago, and most of the new growth occurred in northern and central parts of the county. Chicago remains one of the busiest rail hubs in the region and along

with its many intermodal facilities, it is often considered an inland port. Chicago's "dry port" consists of 6 Class I Railroads operating 18 intermodal rail terminals (Lanigan Sr et al., 2007). However, many of the new warehouse establishments did not converge around the intermodal terminals. Looking at the fast-growing zip codes for establishments, it shows that these zip codes are located in proximity to large road networks. Zip codes 60,115, 60,502, 60,517, 60,440, 60,446, and 60,421 experienced the most significant growth in the number of establishments and were all adjacent to Interstates 80, 55, 57, 94, and 294. Zip code 60007 which contained the largest number of zip codes was next to Interstate 90.

Between 1998 and 2015 warehousing in the Phoenix area experienced periods of tremendous growth in many zip codes (from 41 to 183 warehouses). Fig. 7 shows the change in warehouses from 1998 to 2015. More than half of new warehouses are located in zip codes which previously had warehouses, and warehousing establishments have not sprawled as considerably as all establishments.

The results show that five of the six zip codes are adjacent to Interstate 10. According to Freight Analysis Framework Version 4 (FAF4) (Center for Transportation Analysis. Freight Analysis Framework Version 4 (FAF4) – TOP Five Trade Partners by Weight/Value for trade leaving state, n.d), 54.3% of domestic shipments carried inbound to Arizona and 46.5% of domestic shipment carried outbound from Arizona in 2015 were by truck. The proximity to the highway system allows for lower travel time as well as other cost reductions such as drivers' wages, and fuel. California, the biggest trading partner with Arizona, accounts for 35% of total trade value with other states (Center for Transportation Analysis. Freight Analysis Framework Version 4 (FAF4) – Weight/Value for shipments Within, From, and To State by Mode, n.d). The barycenter of warehousing establishments sprawled approximately 5.05 km to the west, closer to California, compared to the barycenter of all establishments which moved 2.62 km to the east. Given that primary trade flows are to the west of Phoenix, this may be influential with warehousing and transportation establishments.

7. Conclusions

As a Midwestern hub, Chicago experiences high volumes of freight shipments. The number of warehouse establishments in the region has grown dramatically in recent years. The logistics sprawl analysis shows that between 1998 and 2013 there was a shift of the barycenter of these establishments of about 13 km in the southwest direction. The study also determined that the average distance between the barycenter and the warehouse establishments had increased nearly 9 km. As a percentage, this was a significant increase compared to all establishments. Logistic sprawl is occurring in the Chicago area, and it is doing so at a faster rate than establishments in general.

In the Phoenix MSA between 1998 and 2015, the number of warehouse establishments grew by 346%. Spatially, the average growth has occurred to the west side of the MSA, in contrast to the average of all industry establishments, which occurred to the east. The results of a logistics sprawl analysis show evidence of sprawl. However, when compared to the spatial distribution of all establishments, logistics sprawl occurred at a lower rate.

This research adds additional cities to those having been analyzed for the presence of logistics sprawl. With an increasing list of cities analyzed, the results can be compiled and compared with the goal of drawing more systematic conclusions about the relationship between policy and environmental characteristics and the presence of logistics sprawl. Summarized study results for the existing cities analyzed are shown in Table 1. These studies show that logistics sprawl has occurred in four of the metropolitan areas, and has not occurred in one of the areas studied. Recall that logistics sprawl is the tendency of warehouses to move away from urban regions toward more suburban and exurban areas (Dablanc and Ross (2012)).

With the list of cities compiled to date, it is Seattle and Phoenix that

provide outstanding examples. As discussed in Dablanc et al. (2014), Seattle's home state of Washington enacted a Growth Management Act which influences sprawl in the state. In addition, the Seattle region has geographic features which constrain development within and along existing corridors. It is for these reasons that it is suggested in Dablanc et al. (2014) that logistics sprawl is not present in the Seattle metropolitan area.

In the Phoenix MSA, both warehousing and all commercial activities are sprawling. Unlike the Seattle area, Phoenix has not implemented growth management strategies. Property values are more homogenous between urban and ex-urban areas than in other metropolitan areas, so there are not the same economic forces driving warehousing out of the city. Population density in the Phoenix area is low with land still available for development within the city limits. Within Maricopa County, the median house price per square foot increased from \$70 in 1998 to \$125 in 2015, an increase of 78%. A similar median house price per square foot increase occurred within the Phoenix metro area (78%), from \$69 in 1998 to \$123 in 2015. In comparison, between 1998 and 2015, Los Angeles metro area median house prices per square foot increased 179% (from \$128 to \$357) and within Seattle metro area (93%) from \$108 to \$201.

The contribution of this paper to the existing literature is a documentation of the presence, or lack thereof, or logistics sprawl in the Chicago and Phoenix metropolitan areas. An evidence-based explanation for these outcomes has not been undertaken. However, a discussion of some relevant factors has been presented. When comparing these results to previous study results, it is apparent that both national economic and policy trends, as well as regional characteristics, influence the tempo-spatial distribution of warehousing facilities in a region. As additional cities are added to the list of those analyzed, these influences can be more systematically unpacked.

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