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Logistics Sprawl in São Paulo Metro Area

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The location of logistics facilities close to consumers and well-planned transport infrastructure is important for the flow of goods and sustainability in the region. The main purpose of this research is to verify the logistics sprawl in São Paulo Metropolitan Area and to discuss its reasons. To verify the existence of the phenomenon, a sample of logistics companies' addresses has been selected and the geographic centers of this sample were calculated, using the barycentre of a set of points and then calculating the average distance of these points to the center. The analysis reveals the intensity of the phenomenon between the year 2000 and the beginning of 2017 and explores the attraction factors for logistic companies, including geographic, economic and tax aspects. The results reveal a small sprawl in the studied period for companies with a capital stock equal to or greater than 250 thousand reais, of 1.8 km in the northwest direction of São Paulo Metro Area.

Keywords: Logistics Sprawl; Urban Sprawl; Relocation of logistics facilities; Geography of freight

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1 Introduction

During the last decades of the 20th century and at the beginning of this century, large cities have grown intensely, sprawling their structures and population beyond their usual boundaries. This phenomenon is known by the name of Urban Sprawl and always occurs in the suburban regions, around the access roads to the main city, being a development in hills and in low density (Burchell and Mukherji, 2003). The reasons for such sprawl were several. Burchfield et al. (2006) pointed to the following causes for urban sprawl in various regions of the USA: dispersion of employment, automobile dependence over public transportation, rapid population growth, real estate speculation on undeveloped land, ease of drilling a well for water supply, temperate climate, rugged terrain and no high mountains, amount of land available in areas not subject to municipal planning rules, low impact of public service financing by local taxpayers (Burchfield et al., 2006). In Peking, the causes for the urban sprawl were different. With land reform, the tax values charged differed, and many factories and warehouses left the central region in search of lower taxes. Another reason is the permission of public-private partnerships that have made incorporators invest in more central regions, besides the Government encourage the population to migrate to the suburbs. Local governments also made investments in the suburbs to improve the quality of life of the population (Wang and Yixing, 1999).

Although most studies on urban sprawl and expansion are more concentrated in countries of Europe or North America, it is possible to empirically confirm that the phenomenon exists in some Brazilian cities. São Paulo also suffers urban sprawl, with loss of population in central areas of the city due to the increase in investment by developers, increasing the population in peripheral areas (Torres, Alves and de Oliveira, 2007). Just as there is an urban sprawl phenomenon as in the case of São Paulo, is related to the price increase of central properties, there is a specific case of warehouses and logistics operators sprawl outside the boundaries of the metropolis (Cidell, 2010), known as logistics sprawl (Dablanç and Rakotonarivo, 2010).

Therefore, in order to propose public policies to make a better use of urban space, reduce the environmental and social impact, and increase the productivity of these companies, it is necessary to study the causes that push away these logistical structures from urban centers. Given the importance of this theme to megacities, this work aims to study the movement in space and time of ware-

houses and logistics operators within São Paulo Metro Area (SPMA), verifying if there were systematic changes in these dimensions.

The probable moves of these logistic companies may be to peripheral regions or municipalities and their appearance may be sparse or concentrated in a given microregion. In this research, the reasons why this movement occurs over time and its determinant factors to cause this phenomenon will also be discussed later. The second contribution of this work is to understand the dynamics of sprawl in developing countries cities such as Brazil, since most of the work on this subject refers to more developed economies.

This paper is divided into four sections. Section 2 refers to the literature review on "logistics sprawl". Section 3 is a brief presentation of the SPMA. Section 4 refers to data gathering of the companies used, as well as the cut made to get a sample of companies for the analysis. Section 5 presents and discusses the results. The conclusion presents a closure of the research and provides some recommendations for future research.

2 Literature Review

The subject of logistics sprawl is relatively recent in the academic literature. One of the first works was published by Dablanc and Rakotonarivo (2010), where the problem is defined. On the other hand, it is observed in the literature that this phenomenon appears indirectly in previous studies (Cidell, 2010; McKinnon, 2009; Bowen, 2008; Woudsma et al., 2008; Hesse, 2004b). This section approaches this phenomenon and tries to summarize the main factors that define the researches presented at the moment.

2.1 Definitions of Logistics Sprawl

Logistics sprawl is the dispersion of warehouses and distribution centers in the metropolitan region of a city (Dablanc and Rakotonarivo, 2010). Although there are other similar expressions to define the same problem, the term "logistics sprawl" has become better known in the literature (Aljohani and Thompson, 2016).

Table 1: Works about Logistics Sprawl

Author	Region/Sprawl Extension	Period
Dablanc and Rakotonarivo, (2010)	Paris Île de France: 10km	1974 – 2008
Dablanc, Ross, (2012)	Atlanta (Piedmont Atlantic Megaregion): 4,5km	1998 – 2008
Dablanc, Ogilvie, Goodchild, (2014)	Los Angeles Metro Area: 9.7 km; and Seattle Metro Area: -1.3 km	1998 – 2009
Sakai, Kawamura, Hyodo, (2015)	Tokyo Metro Area: 2,4km	1980 -2003
Woudsma, Jakubicek, Dablanc, (2016)	Greater Toronto Area:1,3km and Greater Golden Horseshoe: 9,5km	2002 – 2012
Heitz, Dablanc, Tavasszy, (2017)	Paris Île de France: 5km and Randstad Metropolitan Areas (Netherlands): Noord Holland: -2km; Zuid Holland: -1km; Flevoland: 3.3km; Utrecht:0.5km)	Paris (2004 – 2012); Randstad (2007 – 2013)
Oliveira, Santos, Nobrega et al., (2017)	Belo Horizonte Metro Area: 1,2km	1995 – 2015

Some studies have been carried out in recent years aiming to understand the extent of the phenomenon in the metropolitan areas. Table 1 is a summary of the main published works about the subject.

According to Table 1, although the subject is fairly recent, the periods surveyed vary widely, from 34 years (Paris Île-de-France) to only 6 years (Randstad). A second aspect is the scope of research, most of them focused on the metropolitan region of cities, following the hypothesis that this phenomenon is characteristic of large metropolises that serve as nodes of a large region, as well as being the center

of a consumer market (Dablanc, Ogilvie and Goodchild, 2014). The exceptions were the researches of Woudsma et al. (2016) which covered an area beyond the immediate metro area (Greater Golden Horseshoe), and Heitz et al. (2017) regarding Randstad (Netherlands), which was about a polycentric sprawl, in other words, with different metropolises of attraction in a single continuous region.

Most of the researches have proved the logistics sprawl of the cities, but there were two exceptions: Seattle had land available near the airport and the port, and this area is served by highways, causing companies to continue to settle in the region (Dablanc, Ogilvie and Goodchild, 2014) and Randstad, where the logistics companies were concentrated in the urban regions, probably due to a local planning policy and greater control of land use (Heitz, Dablanc and Tavasszy, 2017). Although most of the researches have been carried out for metro areas of developed countries, there are new researches in different regions, with two recent surveys, one carried out in Brazil, on the Belo Horizonte region (Oliveira et al., 2017) and a specific research about timber industry in New Delhi (Gupta and Garima, 2017).

The centrophagic method was used in the majority of the researches and consists of calculating the barycentre of a set of points and then dispersing the points around this center. The choice of the barycentre is due to the fact that it is more sensitive to address changes over time (Dablanc and Rakotonarivo, 2010). The exception is the research of Sakai, Kawamura, Hyodo (2015) that was carried out using as a parameter the average distance between the logistics company and its points of origin (inbound) and destination (outbound). This calculation was carried out for all the companies, using the average of the Euclidean distance (Sakai, Kawamura and Hyodo, 2015).

2.2 Motivational Factors of Logistics Sprawl

There are many factors that contribute to logistics companies migrating from a central region to a more peripheral one. In 2005, it was found that storage in the United States was still concentrated in urban areas, but on the other hand, its growth was higher in suburban and exo-urban areas. In this case, the main reasons for this phenomenon were related to the access to different means of transportation, being the highway and the access to the airport the most relevant and with the greatest correlation with the growth of the number of warehouses, corroborating with the factor "speed of delivery" (Bowen, 2008). It is important to

notice that nowadays the speed of delivery is one of the most important factors for logistics companies (Lasserre, 2004) and that the truck and air transportation have more advantages compared to natural competitors - truck versus train in domestic transportation and air versus sea in international transportation (Bowen, 2008).

Distribution centers tend to move to more inland regions of the country and carriers to the suburban regions of major cities. The explanation for this change to the interior of the country is due to the increase of the volume transported and that the companies become more globalized. In this way, the warehouses near the ports became overloaded, forcing the companies to go inland. Moreover, the need to increase the profitability of enterprises leads them to occupy larger spaces, forcing them to move from urban centers to suburban regions, which are cheaper (Cidell, 2010).

Moreover, retailers and factories are delegating their logistics activities to specialized companies in this type of activity that, due to the gain in scale, seek more space to increase operations and stored stock, and in parallel, peripheral cities use tax subsidies to attract these companies (Hesse, 2004a). Another factor to be considered is the growth of e-commerce, which has led to an increase in demand for warehousing, order consolidation and shipment facilities, which implies five types of logistics structures: mega e-fulfillment centers, parcel sorting centers, local parcel delivery centers, local urban logistics depots and return processing centers (Morganti et al., 2014).

The increase in consumption of goods and merchandise also pressure logistics operators for more physical space and wider roads, allowing a growing flow of trucks to deliver goods. In this way, many activities related to the distribution of goods, moving from their traditional location in central areas, close to ports and railways, have changed to peripheral areas where road and airport connections are more predominant (Rodrigue, 2004; Woudsma et al., 2008).

Finally, we must also consider the increase in global trade, imposing on companies the need for more physical space (Cidell, 2011; Rodrigue, 2006). Lower costs are also a factor of attraction, where companies seek cheaper land costs in the suburbs (Dablanc and Rakotonarivo, 2010).

The price of central regions was also seen as a determining factor for the logistics sprawl, as well as the regulatory policies of the prefectures neighboring Tokyo (Sakai, Kawamura and Hyodo, 2016). A similar survey was conducted for Los Angeles and the main factors of sprawl were the lower price of land outside the city,

the policy of some municipalities in attracting warehouses, logistics infrastructure such as ports and roads already located far from the center (Dablanc, Ogilvie and Goodchild, 2014).

A survey about Toronto Metro area, despite some difficulties with the definitions of data, logistics companies are not distancing themselves significantly from the Toronto center as expected when considering only the Greater Toronto Area, because it was expected that there would be no land for this. On the other hand, when the study considers the Greater Golden Horseshoe region, which encompasses Greater Toronto, there is a strong evidence of logistical sprawling and, specifically, of warehouses. (Woudsma, Jakubicek and Dablanc, 2016).

2.3 Impacts of Logistics Sprawl

The impacts resulting from logistics sprawl have not yet been fully studied (Aljohani and Thompson, 2016). However, it can be assumed that all regions that have proven the increase of the logistics sprawl has the increase of distance traveled by the trucks in their deliveries as a consequence (Dablanc and Rakotonarivo, 2010; Dablanc and Ross, 2012; Dablanc, Ogilvie and Goodchild, 2014; Sakai, Kawamura and Hyodo, 2015; Woudsma, Jakubicek and Dablanc, 2016; Oliveira et al., 2017). As a result of this increased distance, there is an increase of CO₂ emissions from vehicles, increasing the environmental impact, as demonstrated in the study for the Paris region, over 34 years of sprawl. On the other hand, as a suggestion to minimize logistics sprawl, the creation of a regional authority to examine permits for logistical developments and more consideration for new architectural solutions integrating logistics buildings within the urban center would be good solutions (Dablanc and Rakotonarivo, 2010).

In addition to the increased distance, the fact that there are warehouses and transshipment places in the peripheral region of cities attracts more heavy vehicles to this region (Allen, Browne and Cherrett, 2012). Gupta & Garima (2017) studied a specific economic sector - timber industry in New Delhi (India). The authors concluded a huge logistical expansion, being the expansion rate twice the increase of tonne transported, impacting directly on the distances and emissions traveled. The study concluded that a planned decentralization of timber logistics facilities could help reduce emissions by 59% and save 25% on energy.

3 São Paulo Metro Area

The studied region is São Paulo Metro Area (SPMA), located in the State of São Paulo, with more than 21 million inhabitants (Brazilian Institute of Geography and Statistics - IBGE, 2017). The 39 municipalities belonging to SPMA are: Arujá, Barueri, Biritiba-Mirim, Caieiras, Cajamar, Carapicuíba, Cotia, Diadema, Embu das Artes, Embu-Guaçu, Ferraz de Vasconcellos, Francisco Morato, Franco da Rocha, Guararema, Guarulhos, Itapeçerica da Serra, Itapeví, Itaquaquetuba, Jandira, Jujutiba, Mairiporã, Mauá, Mogi das Cruzes, Osasco, Pirapora do Bom Jesus, Poá, Ribeirão Pires, Rio Grande da Serra, Salesópolis, Santa Isabel, Santana de Parnaíba, Santo André, São Bernardo do Campo, São Caetano do Sul, São Lourenço da Serra, São Paulo, Suzano, Taboão da Serra, and Vargem Grande Paulista.

The logistics structure of the region has ten highways that connect the city of São Paulo to all regions of the state, as well as a ring road linking most of them. The SPMA is surrounded by three airports. Airport of Guarulhos is the international airport of the region and there are two more airports located in the city of São Paulo itself, being an exclusive for executive aviation (Campo de Marte) and a civil aviation with domestic flights to the main Brazilian capitals (Congonhas Airport). The main connections of this network are the Port of Santos, the ports of the State of Rio de Janeiro, Minas Gerais and the central and southern regions of the country. The connection with the port of Santos, located 80km from São Paulo, is made through two highways.

4 Data and Sampling

The research is divided into two parts: the data collection of companies; sampling and georeferencing of the addresses where the companies are located.

4.1 Data Gathering and Sampling

The companies' data of the 39 SPMA municipalities were collected on the Internet, from the website of State of São Paulo Commercial Board (JUCESP, 2017), which provides files in pdf format. Active and inactive companies were considered at the time of extraction. The following economic activity codes registered in

JUCESP (2017) and related to logistics and storage considered in this research are: 5250-8/05 Multimodal Transportation Operator; 5211-7/01 General Warehouses - Warrant Issue; 5211-7/99 Goods Warehouse for Third Parties, Except General Warehouses and Furniture Storage.

The data collection of these three economic activities was realized by the description of the activity and municipality, which consist of 4638 companies, occurred between January and February 2017. Eleven companies were cut out because they had the wrong city in the registry, and 66 companies due to inconsistencies in the activity description, leaving 4561 in total. Each business address was checked according to their current location in Google Maps®. However, this comparison revealed a real challenge, because as there was an incompatibility between some addresses reported by JUCESP and Google Maps. It was not possible to find the address for 495 companies, for the most part of them, the number was not found, even using the Street View® functionality (Google Maps). In addition, 1881 companies were not identified visually as logistics installation, that is, they were located in residences, shops, apartments or commercial rooms. One of the biggest challenges was identifying the right places, some of which are difficult to identify, and Google Street View® photos were taken at different times (e.g. the company was created in 2016 and the picture of the address was taken in 2011).

For this research, only companies with stock capital above US\$ 71,700.00 (R\$250,000.00) were considered in the analysis. Larger companies usually have a greater impact on traffic and the environment than smaller companies, and certainly must work with a larger volume of supplies and deliveries than smaller companies. Inside the set of 519 companies in the sample, some of them did not exist on these cut dates (2000 and 2017), that is, they started their operations after the analysis cut-off date and were closed before the next date, not appearing in the calculations. This phenomenon occurred with 59 companies and one company was discarded due to lack of reliable information in the register, remaining 459 companies in the final sample.

4.2 Geocoding

The company address' geocoding was performed using QGIS® software through the Google Maps API. However, although most of the geographic coordinates were found automatically, some were not found by the API and were manually referenced directly on the Google Maps® site. In addition, it was noted the addresses

on small roads or highways were geocoded far from the correct location. In this case, these types of addresses have been checked and corrected manually. The shape of the municipalities of SPMA was gotten from the Center of Studies of the Metropolis (CEM/Cepid, 2018).

4.3 Data Limitations

Although the data source is abundant, there are limitations of three natures relating to the data source. The first one is the database itself, because the addresses are only of the corporate headquarter, although there is a description of the subsidiaries inside the complete documents. It is noted that some companies had branches in SPMA, which may be part of a more comprehensive research in the future. The fact is only companies based on SPMA were considered in this research. There may be companies based in cities outside SPMA or even in other states, but with branches in the SPMA. These subsidiaries are also out of this research. The post offices warehouses were left out because they are not registered on JUCESP's database.. Finally, it was used key excerpts from each description of economic activity were used to find the companies in the Jucesp database. Due to this and limitations of the site some companies may have been left out of the sample. The second limitation is due to the anachronism of the data. It was considered that the active and inactive companies collected, whose last economic activity of them had one of the CNAEs previously described, had the same activity codes in the past. In addition, companies that were warehouses in the past, but nowadays have other activities remained out of this research. This limitation is due to JUCESP website, which does not allow to search for the past activities of companies. Furthermore, it was not investigated whether the companies' past addresses were also located in warehouses. The third limitation refers to the compatibility of the reported addresses and their real location on Google Maps. Despite the fact that the verification work was exhausting, there is a risk that some of these addresses have not been mapped correctly.

4.4 Analysis Tools and Method

For the calculation of logistics sprawl, the barycentre of all addresses in each year of analysis was calculated, and then the euclidian average distance of all points to this barycentre (Dabanc and Rakotonarivo, 2010). The calculation of

the barycentre and the elaboration of the distance matrix between each company and the barycentre were performed by QGIS v2.18. Population and economic data were analyzed as aspects that cause logistics sprawl. Population growth was calculated using data between the 2000 census and an IBGE estimate of 2017. GDP per municipality varies from 2000 to 2015. Both data are from IBGE. The 2000 GDP data were updated by the official inflation index (IPCA), also provided by IBGE (2017). The roads and municipalities shapes were collected from Centro de Estudos da Metrópole (CEM, 2018).

5 Preliminary Results

5.1 Sample and Analysis Representation

Initially, two specific points in time were used to analyze the companies' sprawl: the year 2000 in which the Brazilian demographic census was conducted, and 2017 that was the date of collection. Figure 1a and 1b show the geographic location of companies per year and highlight how close companies are to major access routes.

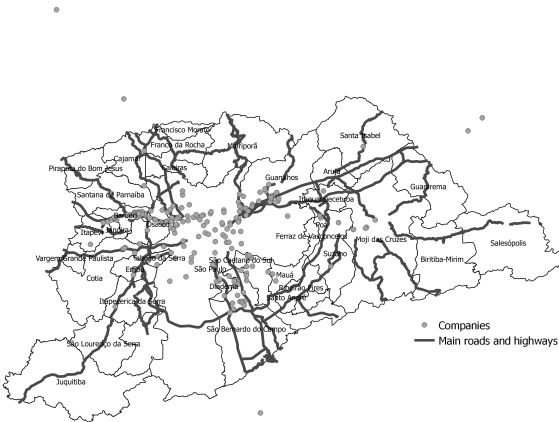


Figure 1: Sample of Companies in 2000

**Source: NREL (2018)*

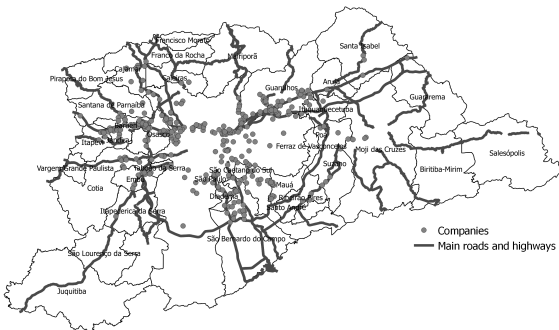


Figure 2: Sample of Companies in 2017

**Sources: Shapes from Centro de Estudos da Metrópole (2018) and addresses from Jucesp (2017)*

Table 2: Shows the growth of companies' number per city, based on the most representative cities in 2017.

City	2000		2017		Growth(%)
	Number	Percent-age	Number	Percent-age	
São Paulo	75	36	132	32	76
Guarulhos	28	13	62	15	121
Barueri	23	11	49	12	113
São Bernardo do Campo	18	9	25	6	39
Osasco	10	5	18	4	80
Embu das Artes	5	2	16	4	220
Mauá	3	1	14	3	367
Others	47	22	101	24	115
TOTAL	209	100	417	100	100

Table 2 highlights the seven main municipalities, whose sum of companies is very close to 80% (column representativeness (%) 2017) of the total. It is possible to notice the representativeness of the municipalities had little change over the years, but it can be observed that São Paulo had a slight decrease from 36% of the companies in 2000 to 32% in 2017. On the other hand, the growth of companies stands out in municipalities such as Guarulhos, Barueri, Embu das Artes and Mauá, far superior to the growth of São Paulo, confirming the sprawl.

Regarding the barycentre, when considering its spatial variation, from 2000 to 2017, the displacement is 1.8km to the northwest direction. Moreover, the average distance of the companies to the barycentre has also increased over years. In 2000, the average distance was 17.7km, with a standard deviation of 11.9km. In 2017, the number jumped to 19.3km, with a standard deviation of 15.6km. There was a 1.6km increase in the average distance between the companies and the barycentres, resulting in an 8.8% increase. Although this increase is not expressive, it is possible to demonstrate the occurrence of logistics sprawl phenomenon. Some results presented in the literature had similar values (Oliveira et al., 2017; Sakai, Kawamura and Hyodo, 2015; Woudsma, Jakubicek and Dabanc, 2016). The

standard deviation had an increase of 30%, showing the addresses have become more widespread.

Among the cities in Table 2, there was a proportional increase in the number of companies, superior to São Paulo in five cities: Guarulhos, Barueri, Osasco, Embu das Artes and Mauá. All of them concentrate a good logistics infrastructure, being served by highways. In the specific case of Barueri and Osasco, both have the Castello Branco Highway, which connects São Paulo to the west of the state, and the Rodoanel passing through its territories, besides being connected directly to the expressways Marginal do Rio Tietê and Marginal of the Rio Pinheiros. Guarulhos is served by three major highways: the Presidente Dutra Highway and Ayrton Senna Highway, which link São Paulo to the Paraíba Valley and Rio de Janeiro and Fernão Dias Highway, linking São Paulo to Belo Horizonte, in Minas Gerais State. It is important to mention that Guarulhos is served by Guarulhos International Airport, which is an important air cargo terminal. Embu das Artes is very close to São Paulo and is cut by Regis Bittencourt Highway, which is the main cargo route to southern Brazil. Mauá has a strong industrial park, close to the Rodoanel and close to the access to the highways of the coast, mainly Anchieta Highway, which leads to the port of Santos.

However, an aspect to be highlighted is the taxation of municipalities on services provided by storage companies. The main tax levied on companies is the Service Tax (ISS) and can influence warehouse and storage companies to migrate from one municipality to another, seeking more attractive tax rates. Although an exhaustive study on the evolution of tax values over the years has not been realized, table 3 shows the ISS rates for warehousing and storage activities by municipality in 2017 and it is possible to notice a correlation between the growth of the number of companies in some locations and lower service taxes related to warehousing and storage activities. The only exception to this list is the municipality of São Bernardo do Campo, which has a lower tax rate but has had a small growth in the number of companies. It should be emphasized that a historical study of the evolution of taxes was not carried out, which would be fundamental to certify and quantify the influence in logistics sprawl.

Table 3: Comparison between number of companies' growth to services tax rates, population and GDP

City	Company growth(%)	Service tax rate(%)	Pop. growth (%)	GDP growth(%)
São Paulo	76	5	16	-3
Guarulhos	121	4	26	136
Barueri	113	2	28	333
São Bernardo do Campo	39	3	18	112
Osasco	80	5	7	563
Embu das Artes	220	2%	29	415
Mauá	367	3 to 4	27	109

*Sources: Prefeitura de São Paulo, 2018; Prefeitura de Barueri, 2018; Prefeitura de Osasco, 2018; Prefeitura de São Bernardo do Campo, 2018; Prefeitura de Guarulhos, 2018, Leis Municipais, 2018.

When comparing population and economic data with the logistics sprawl, it is possible to notice that there is a data correlation between the municipalities that had a bigger growth of logistics companies and population and economic growth.

Figure 2 and 3 show the companies in 2017, in the municipalities with the highest population growth and GDP respectively. It is possible to notice that the biggest economic and demographic growths are also, in the majority, in the cities of the western zone of the SPMA.

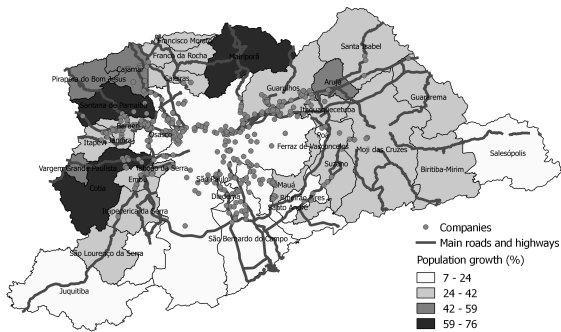


Figure 3: Population Growth per Municipality.

**Sources: Shapes from Centro de Estudos da Metrópole (2018), addresses from Jucesp (2017) and data from IBGE (2018).*

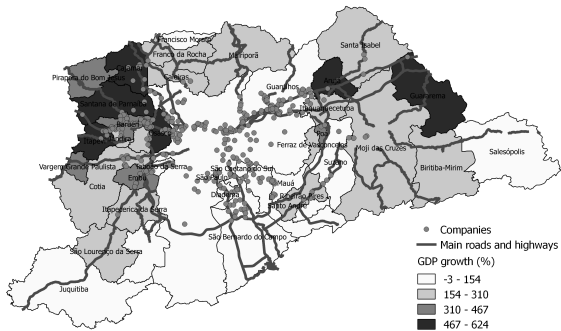


Figure 4: GDP Growth per Municipality

**Sources: Shapes from Centro de Estudos da Metrópole (2018), addresses from Jucesp (2017) and data from IBGE (2018).*

6 Conclusion

The conclusion is that SPMA has suffered the phenomenon known as logistic sprawl during the last years. The distance between the barycentre and the companies, on average, was not so expressive, only 1.6km. There was an increase in the concentration of companies in cities neighboring the city of São Paulo, such as Osasco, Barueri, and Guarulhos.

Certainly, some of the reasons for this phenomenon still need to be better investigated, but all the factors presented have some correlation with logistic sprawl: good transportation infrastructure, lower service tax rates, economic growth and demography. It is possible to notice that the biggest economic and demographic growths are also, in the majority, in the cities of the western zone of the SPMA.

Although the sample offered interesting results, the issue of SPMA logistic sprawl is still open and cannot be considered exhausted, since the preliminary results contemplated only a small number of storage and logistics companies to realize the analyzes. As a suggestion for future researches, deepening of the tax question and the more detailed study of the socioeconomic correlations may provide more information about the dynamics of the SPMA.

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