Air Transport and the Network of Metropolitan Areas in Brazil: an Update of the Latest IBGE REGIC Study Considering Connectivity and Route's Density

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Resumo:

The Brazilian Institute of Geography and Statistics (IBGE) published systematic studies of the network of cities in Brazil since 1972. With increasing methodological sophistication, the latest version of 2008 used air transport data from 2004 as one of the factors defining network relationships between cities. Brazilian air transport grew quite dramatically since then, and the network relationship between the country's largest cities may have changed as well. This article proposes an evaluation of the networking of Brazilian metropolises by air transport, examining connectivity and route's densities between the country's largest cities. It develops a baseline for 2004 and updates the rationale for 2014 (after ten years of intense growth) and 2017 (after three years of economic recession), to highlight the changes that air transport may have caused in the networking relationships of Brazilian metropolises, increasing route's densities, but reducing connectivity.

AIR TRANSPORT AND THE NETWORK OF METROPOLITAN AREAS IN BRAZIL

An Update of the Latest IBGE REGIC Study Considering Connectivity and Routes' Densities

ABSTRACT

The Brazilian Institute of Geography and Statistics (IBGE) published systematic studies of the network of cities in Brazil since 1972. With increasing methodological sophistication, the latest version of 2008 used air transport data from 2004 as one of the factors defining network relationships between the cities. Brazilian air transport grew quite dramatically since then, and the network relationship between the country's largest cities may have changed as well. This article proposes an evaluation of the networking of Brazilian metropolises by air transport, examining connectivity and routes' densities between the country's largest cities. It develops a baseline for 2004 and updates the rationale for 2014 (after ten years of intense growth) and 2017 (after three years of economic recession), to highlight the changes that air transport may have caused in the networking relationships of Brazilian metropolises, increasing routes' densities, but reducing connectivity.

Key-Words: Brazil; Cities' Networks; Air Transport; Connectivity; Air Route Densities.

RESUMO

O Instituto Brasileiro de Geografia e Estatística (IBGE) publicou estudos sistemáticos das redes de cidades no Brasil desde 1972. Com sofisticação metodológica crescente, a última versão de 2008 usou dados de transporte aéreo de 2004 como um dos fatores definindo as relações de influência entre as cidades. O transporte aéreo brasileiro cresceu substancialmente desde então, e as redes de cidades também podem ter se alterado. Este artigo propõe uma avaliação das redes de metrópoles brasileiras pelo transporte aéreo, examinando a conectividade e a densidade das rotas entre as maiores cidades do país. Para tanto, desenvolve uma linha de base para 2004, atualiza o raciocínio para 2014 (após dez anos de crescimento intenso) e para 2017 (após três anos de recessão econômica), para destacar as mudanças que o transporte aéreo pode ter causado nas redes de relacionamentos das metrópoles brasileiras, aumentando as densidades das rotas, mas diminuindo a conectividade.

Palavras-Chave: Brasil; Redes de Cidades; Transporte Aéreo; Conectividade; Densidade de Rotas Aéreas.

INTRODUCTION

The objective of this paper is to verify, through a simplified analysis, how the evolution of air transport connectivity and air routes densities in Brazil happened since 2004, when this factor was included in the latest study of influence of cities in the urban network in the country (IBGE, 2008).

The analyses start by contextualizing Brazilian geography (its organization in states, regions and the distances associated with its large size), which render air transport as an important means of mobility. The paper also focuses on the urban and metropolis issues, including the four studies developed by the Brazilian Institute of Geography and Statistics (IBGE) on the network of influence between the cities (literally the Region of Influence of the Cities – REGIC), in versions published over the past decades. It then addresses the increase of aviation since the last REGIC study was published (2008, with 2004 data for air transport), justifying checking how the connectivity of the most important metropolises shifted since then, and how the density of the main air transport routes have evolved. The paper then discusses briefly changes of air transport and how this may affect both connectivity and route densities, to trigger the experimental analysis itself.

The twelve largest cities centering *de facto* metropolitan areas in Brazil were selected; Campinas, bearing the 5th busiest airport in the country, was added to the sample. The methodology involved MS Excel® dynamic tables tools allowing the identification, for each airport and/or city of origin, all airports and/or cities of destination, thus enabling viewing connectivity of these thirteen major Brazilian cities. The next step was to use the same tool to identify, by pairs of origin-destination, the busiest two-way air travel routes in terms of total passengers. Of the 156 possible routes, some exercises of selecting the busiest routes were attempted to reproduce a route-density map such as map 2 for air transport of REGIC 2007 (IBGE, 2008, with 2004 data), to then compare with the same rationale for 2014 and 2017, developing a comparative map of busiest routes in 2004 and 2014.

The results found show that connectivity – in terms of destinations available to passengers in regular flights originating on the 16 airports of the 13 selected Brazilian metropolises has diminished substantially from 2004 to 2014, and slightly more in 2017. Selecting routes which accumulated 80% of the total passengers transported within the 156 routes of the sample, the number of dense routes, though increased dramatically: from only two routes with over 1.5 million passengers both ways in 2004, there were twelve such routes in 2014 (which dropped to ten in 2017, due to the country's economic downturn). These are mostly concentrated in São Paulo as origin or destination: only three of the twelve very high-density routes did not involve this city. The number of other high and medium density routes also increased substantially, but they still involve cities close to the sea shore, and do not reach far into the country's hinterland: except for seven routes to Brasilia and one to Goiânia. None of the busiest routes within the 80% threshold criteria employed reach either Belém or Manaus, in the North of the country (within the Amazon area), either in 2004, 2014 and 2017. The emergence of Campinas as origin of one very dense route and two medium density routes may shed some light on how the influence of the cities may have changed since 2004, considering air travel as a sole factor.

BRAZIL'S GEOGRAPHY, ITS METROPOLISES AND THE EVOLUTION OF REGIC STUDIES BY IBGE

Brazil is divided in 26 States plus a Federal District which hosts the national Capital (Brasília). The states are organized in regions: North (comprising the states of Amazonas, Pará, Roraima, Amapá, Rondônia and Acre), Northeast (comprising Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia), Center-West (states of Mato Grosso, Mato Grosso do Sul, Tocantins, Goiás and the Federal District), Southeast (states of Minas Gerais, Espírito Santo, Rio de Janeiro and São Paulo), and South (comprising the states of Paraná, Santa Catarina and Rio Grande do Sul).

With quasi-continental dimensions (8.5 million square kilometers of area), Brazil is the fifth largest country in the world (after the Russian Federation, United States, China and Canada). The distances between the southern-most capital (Porto Alegre) and Fortaleza, on the Northeast is 4,032 kilometers by road or 3,215 km by air, with a travel time ranging from 4.5 hours in direct flight to 6 hours with minimal connections. The distance between Recife, one of the eastern-most points, and Manaus, in the Amazon, is 4,611 kilometers by road, or 2,835 km by air, with a direct flight taking 3.5 hours, and minimal connections also requiring 6 hours of travel time (DISTANCIASCIDADES.COM, 2018).

These nearly continental distances plus the diversity of ecosystems and natural geographical obstacles make land-based connections challenging (as roads and railways do not cross the entire Amazon forest), thus transport modes such as navigation and air transport gain importance. Waterways are competitive for solid bulks or low value added products (ores, grain, fertilizers etc.), but for the transportation of people, travel time renders it less competitive than aviation. Air transport require both airports and air navigation aids which are currently well-established, forming a national grid that covers physically nearly the entire country: Brazil's 2,472 airports included 711 public ones in 2012 (PACHECO *et al.*, 2015), but commercial aviation is limited to slightly over a hundred airports spread throughout the country's 5,570 municipalities.

Brazil has many small cities: in a previous (unpublished) survey conducted by the author, most municipalities (4,915 out of a total 5,570) have less than 50,000 inhabitants (including their urban and rural areas), 508 municipalities are in the range from 50,001 to 200,000 inhabitants, 106 are in the range from 200,001 to 500.000 inhabitants, 24 municipalities are in the range from 500.001 to 1,000,000 inhabitants, while 17 municipalities have more than 1,000,001 inhabitants.

Brazilian Metropolises have been first incepted formally during the military ruling in 1973, when 8 official urban agglomerations were legally transformed into metropolises, with due responsibilities for integrated planning and action. As the capital had been transferred from Rio de Janeiro to Brasília in 1960, the former Federal District had been renamed Guanabara State, which became defunct in 1974, with Rio de Janeiro becoming the 9th metropolitan area of the country. After reinstatement of democratic ruling, a new constitution was approved in 1988, allowing states to create new metropolises out of their urban agglomerations, following specific criteria set by the Brazilian Institute of Geography

and Statistics (IBGE). These criteria included: (i) the importance at national level; (ii) the demographic density (inhabitants per square kilometers); (iii) the actual leadership and polarization to neighboring cities; (iv) the continuous urbanization with neighboring cities; and (v) the presence of public functions of common interest with these neighboring cities (FPICs, in Portuguese). A new legislation for cities was passed in 2001 (BRAZIL, 2001), while the so-called "Statute of the Metropolises" (the by-laws for metropolitan areas) was approved in 2015 and severely modified in 2018, hollowing out many of the collective planning obligations (and governance opportunities) set forth by the original By-Law of the Metropolises of 2015 (BRAZIL, 2015; 2018).

Along the process, many of the 26 Brazilian states officially passed laws forming metropolitan areas often disregarding actual metropolitan facts and IBGE criteria, such as a population density, polarization leadership and existence of FPICs like integrated water or transport systems. Hence, a previous (unpublished) survey by the author found that there are currently 74 (seventy-four) formal metropolitan areas, 4 (four) urban agglomerations, 7 (seven) Integrated Development Regions (RIDE) and 2 (two) Metropolitan Collars. Only a few of these are metropolises *de facto*. This diversion from technical criteria to political ones allowed states like Santa Catarina and Paraíba, for instance, to "transform" practically their whole territories into metropolitan areas – some of which centered by 20,000-people cities without any FPICs with their surrounding even smaller cities. It is not the objective of this article to discuss if these metropolitan areas should be formally recognized, but it is part of its objectives to focus on air transport contribution to leverage the influence between cities (the fulcrum of actual metropolises and the polarizing influence between cities), thus forming eventual real, factual networks between cities – and real metropolises. This has been the object of specific studies – the so-called "Regional Influence of the Cities" (REGIC) – carried out by IBGE since the 1960s, herein further detailed.

The first REGIC study addressed the "Division of Brazil in Functional Urban Regions" (IBGE, 1972). It considered matrices and areas of influence of the Brazilian cities with data from 1966. It accounted relationships between the cities and their areas of influence. At that time, Manaus, Brasília and Campinas were not included among the centers of major importance because they did not show as many relationships as the other metropolises. This included the lack of agricultural flows, loose bonds between the distribution of goods and services to the economy, and relatively little services and distribution of goods for their population. There was no weighing of the importance between such flows and relationships, so this earlier study was more quantitative than qualitative.

The first update of the original study used data from 1983 and was entitled "Regions of Influence of the Cities" – REGIC in the jargon of planners (IBGE, 1987). The sample of this study was increased substantially to comprise 1,416 Brazilian cities which were either poles of attraction or attracted by the central poles. Factors considered included retail and wholesale commerce and trade, representations and services. The theoretical basis extrapolated the classic formulation of the Theory of Central Locations, developing findings from considering network of cities.

The second update, published in 2000 with 1993 data (IBGE, 2000) kept the same title of the previous edition. The flows of consumption were determined by 14 items of

goods and services of lower complexity and 30 items of higher complexity, including the presence of small aircrafts (general aviation, private airplanes), associated with the existence of aerodromes serving these cities, but not explicitly considering them as commercial airports. The results were expressed as types of centralities, and not by types of metropolises.

The third and latest edition was published in 2008, going back to the nomenclature of hierarchy between urban centers (metropolises, not centralities), in a more adequate manner to describe Brazil's more complex network of cities, resulting in both a quantitative and qualitative analysis (IBGE, 2008). It was based on 2007 data for most of the information, but one of the major exceptions is precisely the data on air transport, which used the database from National Civil Aviation Agency (ANAC) for 2004. The aspect of the networks considering air transport was defined by multiple parameters, including the air connections. It applied a gravitational model with 1,077 pairs of Origins and Destinations with at least one monthly connection on the year of 2004. These flows characterized dominating cities (origin in the largest cities and destinies on the smaller ones) and subordinated cities (otherwise: destinies on the largest cities and origin on the smaller ones). The number of air connections for the year of 2004 was thereby mapped and related to population estimates for 2007 (IBGE, 2008, map 63). On the same token, displacements of air transport users were mapped from their originating cities to the airports they used in 2007 (IBGE, 2008, map 71).

On this latest version, however, after defining the twelve major metropolises of the country, a session on the relation of networks of highest level urban centers (coinciding with the twelve leading major metropolises) includes a map of the connections between them (IBGE, 2008, map 2) for federal management (2006 data), business management (2004 data), road transport (2005 data) and air travel connections (2004 data). The connections depicted for business management and air travel are very much alike. All connections are ranked into four categories (first, second, third and fourth order), with straight lines often superposing each other, making it difficult to understand the actual matrices of connections. The text justifies, though, as a feedback to the selection of the twelve major metropolises, the choice of São Paulo, Rio de Janeiro (capitals of the states with the same respective names), Brasília (national capital, in the Federal District), Belo Horizonte (Minas Gerais state), Porto Alegre (Rio Grande do Sul), Recife (Pernambuco), Salvador (Bahia state), Fortaleza (Ceará), Curitiba (Paraná state), Belém (Pará state), Manaus (Amazonas state) and Goiânia (Goiás state) as the top tier of metropolitan areas in the country. They are followed by a second tier of "regional capitals" which includes the other fifteen state capitals and the city of Campinas, 90 km northwest of São Paulo (IBGE, 2008).

The REGIC publications by IBGE indicate that in the past four decades there has been a consolidation of São Paulo as a Large National Metropolis, the ascension of Brasilia as a National Metropolis (to the same level of Rio de Janeiro), and an alternating consideration of Brasília, Manaus and Belém as metropolises, as well as a growing importance of Campinas, – the only city in the top two tiers which is not a state capital – therein considered as a regional capital on this 2007 update (IBGE, 2008). The list of Brazilian metropolises present in all REGIC editions also includes Belo Horizonte, Porto Alegre, Salvador, Fortaleza, Curitiba and Goiânia.

Over a decade has passed since the latest REGIC Study by IBGE, and this last version used air transport data from 2004, justifying a possible update. The work of IBGE, though, is apparently very sophisticated and difficult to be reproduced in an isolated manner without full access to the full database and the specific methodology. There are, however, alternatives of simplified paths that can reproduce approximately the results found for air travel considering the major metropolises with their connectivity (emulating map 63) and the densities of routes between them, emulating map 2 (IBGE, 2008).

Hence, air transport-wise, one should consider the new magnitudes and paradigms of air transport which are more visible in Brazil nowadays. For instance, air transport's output in terms of passengers practically tripled from 2000 to 2015, from 38.96 million total passengers in 2000 (domestic and international, in regular and non-regular flights) to a peak of 119.84 million passengers in 2015 – a number which decreased to 114.39 million passengers in 2017, due to the recession that hit the country in the past few years. Air freight increased by 50% in the same period, augmenting from 725.85 thousand metric tons in 2000 to 1,168.97 thousand metric tons in 2017, after a peak of 1,220.55 thousand metric tons in 2013 (ANAC, 2018).

Figure 1 shows the evolution of passengers for the period from 2000 to 2017, showing the best fit of a polynomial of third degree as a tendency curve. After a flat basin of little or no growth at all from 2000 to 2004 (when air transport world-wide growth languished following the attacks of September 11, 2001, the outbreak of the Gulf War and the epidemic of SARS in Asia-Pacific countries). This was followed by a period of exponential growth from 2004 to 2014 (in spite of the financial Subprime crisis in 2008-2009, which affected air transport growth world-wide, but had relatively little effect in Brazilian economy and its national air transport market). Finally, there was a relative drop from 2015 onwards, due to the economic recession that hit Brazil in this part of the analytical period.

Figure 1: Evolution of Passengers in Brazilian Air Transport, 2000-2017

$$y = -0,0702x^3 + 423,09x^2 - 849863x + 6E+08$$
$$R^2 = 0,9854$$
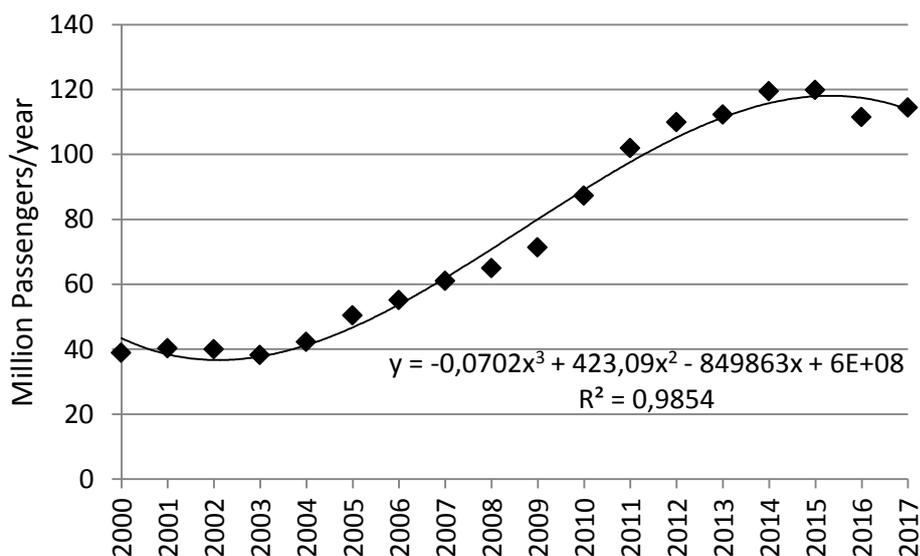
Source: Developed by the author, based on ANAC data (ANAC, 2018).

AIR TRANSPORT AS A FACTOR OF NETWORKING CITIES

Along mankind's history, as population grew and domestication of plants and animals became feasible, mobility evolved from walking (as hunters-gatherers) to technology-aided displacements, first with animal traction and then with steam and oil-derived motors (PONTING, 2007). The expansion of European-centered empires was very dependent on the ability of open sea navigation, thus establishing naval powers (MELLO, 1999) with ships first based on wind sail and human oars, then also replaced by steam and oil-derived motors. Such naval powers depended on the capacity of sustaining both technological and geopolitical enterprises of dominance (ACEMOGLU and ROBINSON 2012). The networks of maritime navigations established a new, upcoming geopolitical order which was hence followed by a system of networked cities (DUCRUET *et al*., 2018), being partially replaced and dully complemented, within time, by railroads and trains in the 19th century, by roads and automobiles in the 20th century, and by a growing network of airports, aircrafts and air routes emerging in this 21st century. Although these transport networks can be associated with the movement of people, goods, industrial products and commodities, they basically connect cities, from smaller ones to large metropolitan centers.

The world cities currently gather more than half of the world population, and they will grow more than rural areas in the coming decades (UNITED NATIONS, 2015). The vast majority of this urban growth, though, will be concentrated in emerging cities of the Global South (DAVIES, 2006), where tendencies of importing urban planning theories from the Global North to tap problems such as real-estate speculation, social exclusion, housing deficits, sanitation and mobility problems are likely to fail meeting any reasonable goals (WATSON, 2009; HEALEY, 2011).

Urban issues have changed dramatically along 20th century. In the 1970's, the crisis of spatial-Keynesianism triggered a process in which cities would be bound to compete with each other as well as cooperate in networks of reproduction of neo-liberal capitalism (FERNANDES, 2001). The scales of power were soon transferred from Nation-states to corporative cities – the world cities, as Friedmann and Wolff (1982, 309) put it: "these vast, highly urbanized – and urbanizing – regions play a vital part in the great capitalist undertaking to organize the world for the efficient extraction of surplus". This re-scaled the structures of power as the Nation-states lost their status as sole controllers of production, triggering the hegemonic domination of city-centered globalizing capitalism, demanding new types of regulation and creating new kinds of conflicts (JESSOP, 2000), including the potential erosion of citizenship presenting increasing challenges to democracy within neoliberal globalization (PURCELL, 2007).

Regardless of its potential economic "success", this neoliberal economic order posts challenges of all types, but rely strongly on technological means of production, control and dissemination of information and knowledge (CASTELLS, 1996), as well as demands rapid travelling in global scale, which can be achieved "for a hand-shake" only by aviation as a new mode of mass transport. It allows fast and quite economic "physical movement of people, good and ideas", as observed by Cwerner (2009). The air connectivity between cities gained importance, creating a new spatial-fix and leveraging the importance of "aeromobility".

Land connections (allowing the use of roads and railways – including high-speed rail) demand continuous territory or very long bridges and tunnels to beat large water bodies, such as straits. Perhaps the most well-known example is the Eurotunnel, connecting England to France (HUNT, 1994). The Øresund bridge-tunnel connection between Copenhagen, in Denmark, to Malmö, in Sweden, is also a good example of ingenuity to enhance land connections (THE ORESUND BRIDGE, 2018). More recently, the new bridge connecting Hong Kong to Zhuhai and Macau (in China's mainland) adds yet another example (HZMB, 2018).

But tunnels and bridges are still quite far to allow abandoning maritime transport, which is consistently the mode of transport responsible for the biggest quantitative share of moving key commodities such as oil and petroleum products, solid bulks (like grain and ores), and increasingly growing traffic of industrialized products in containers, which is completely changing the paradigms of long-haul shipping logistics (UNCTAD, 2017). On the other hand, for the quick mobility of people and very high value-added goods, air transport is competitive when there is the need of reaching far destinations in a short period of time. Aviation (or air transport) involve regulatory agents, air traffic control, aircraft and navigation aids manufacturers, air companies, and airports. The latter establish Origin-Destination pairs between the cities or metropolises they serve, becoming important elements on the annihilation of space by time, gathering the local and global scales. As Fuller and Harley (2004, p. 103) put it:

> "Airports reconfigure geography [per] the spatio-temporal rhythms and cross modal standards of global capital, by flattening all difference into manageable, measurable, and commodifiable contours. Airports are geo-mechanical-digital forms that are changing the contours of land, sea and sky. To consider the relationship between an airport and its environs is to consider the entwining of movement, money, land, sky, matter and information".

Aviation is, thereby, a "growth industry": it depends on constant growth to economically sustain itself. And it grows faster than the rest of the economy, as can be seen in Figure 2. Aviation experimented exponential growth over the past decades: the total air transport production (revenue-passenger times kilometers flown) was multiplied by 3.5 from 1990 to 2015 (with its overall growth trend diminished only in the 2002-2004 period, after the September 11, 2001 attacks and the SARS epidemics, and in the 2008-2009 period, due to the recession following the Subprime Crisis in the United States). Along the same period, the world's Gross Domestic Product (GDP) has grown by a factor of 1.9 times that of 1990, and the industrial production of the countries of the Organisation for Economic Co-operation and Development (OECD) of 2015 was 1.44 times that of 1990. Thus, while challenges such as housing and sanitation for emerging metropolises will not be negligible in the future, on the other hand some of their metropolitan or urban infrastructure elements are likely to thrive (not necessarily without harming their neighbors). This could be precisely the case airports – the ground-based and more visible element of the production chain of aviation.

Figure 2: Comparative Evolution of World Aviation production, World GDP and OECD Countries Industrial Production (1990 = 100)
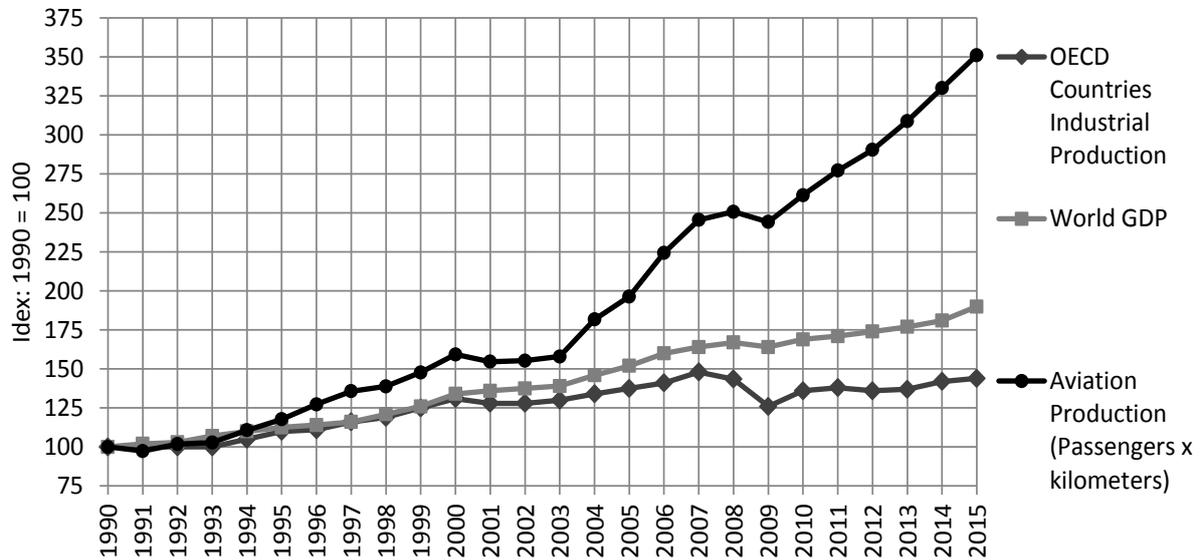
Source: Elaborated by the author, based on UNCTAD, 2017, and AIRBUS, 2016.

As of Brazilian airports, the country's aviation experimented, from 2004 to 2015, a period of exponential growth in terms of passengers travelling within the country (See Figure 1). Simply put, aviation became an inter-urban, medium to long-distance mass transport. Twenty-nine airports in Brazil process more than one million passengers per year (diminished from a peak of thirty-one airports in 2015) against fifteen airports in 2004 (ANAC, 2018). The twelve more influential cities in the country are served by 15 (fifteen) of the main Brazilian airports, and the 5th busier airport in terms of passengers' throughput is in Campinas, the only city that is not a state capital and is still considered a *de facto* regional capital (IBGE, 2008). These 13 (thirteen) cities and 16 (sixteen) airports are the most influential and important in Brazil, as they represent the most well-connected cities, the busiest airports and involve the busiest domestic flight routes (IBGE, 2008; ANAC, 2018).

The number of airports is larger than that of cities because the country's three largest cities – São Paulo, Rio de Janeiro and Belo Horizonte – had earlier smaller airports unfit for long-haul and larger aircraft flights thus they have developed a newer, larger, and more remote airport each. This created airport systems, originally due to runway restrictions (DE NEUFVILLE and ODONI, 2003), but in the case of São Paulo and Rio de Janeiro, the need of more than one airport in each city is currently patronage-driven rather than a single runway restriction, as these cities have duets of quite busy airports (ANAC, 2018).

At many times downtown, city-encroached airports kept busy while newer and better airports remained idle for years (DE NEUFVILLE, 1995). In São Paulo, from 2000 to 2007, downtown Congonhas Airport was busier than much larger Guarulhos International Airport. In Rio de Janeiro, although the Galeão (Antonio Carlos Jobim) International Airport is busier than downtown's quite limited Santos Dumont Airport, the latter remains quite important

part of the city's airport system. In Belo Horizonte, however, while the very restricted, overcrowded and urban-surrounded Pampulha Airport was the busiest in the Metropolitan Area, for many years the larger Confins (Presidente Tancredo Neves) International Airport was often virtually deserted. This changed dramatically in 2005 with the enforcement of using Confins for commercial traffic, leaving Pampulha only for regional flights. With the 2015 crisis, regional aviation declined and Pampulha virtually became a ghost airport, while Confins (now under private concession) handles practically all commercial air traffic to and from Belo Horizonte.

Airports have evolved from part of State bureaucracy in the 1960's to profitable business-wise assets from the 1980's onwards (DOGANIS, 1992), associating non-aviation revenue streams to help financing capacity expansion (ASHFORD and MOORE, 1999). Some airports also became architectural landmarks of intangible value (GORDON, 2004). At the same time, their network of influences changed from original country's or regions' gateways to hub-and-spoke systems, first including least-cost single-hub air networks and then more sophisticated, geographically distributed systems with stopovers and feeder airports with more than one single-hub (KUBY and GRAY, 1993; BOWEN Jr., 2012).

After the de-regulation of the Air Transport industry in the United States in 1978, the rest of the world followed in Europe and elsewhere, with less regulation of routes, privatization of formerly state-owned airlines (the so-called "flag-carriers"), liberalizing air travel (DOGANIS, 1992). This allowed the emergence of the so-called "Low Cost Carriers" (LCC), with competitive advantage over the former "flag-carriers" (CALDER, 2003), and at times operating either from older terminals within large airports, or from remotely located small satellite airports around large and important city-capitals (GILLEN and LALL, 2004), like Brussels-South airport at Charleroi (BARBOT, 2006), Bergamo-Orio Al Serio as an option to Milan's Linate and Malpensa airports, Skavsta airport as an option to Stockholm's Arlanda and Bromma airports, Oslo's Sandfjord airport (and the now defunct Rygge airport) as options to Gardermoen Airport, apart from growing number of passengers using LCCs at Beauvais-Tillé Airport (now renamed Paris-Beauvais) instead of Paris' traditional Charles De Gaulle and Orly airports. This is more demand-driven than primarily dependent on airport charges (WARNOCK-SMITH and POTTER, 2005).

Although "airports are widely-recognized as important engines of economic growth" (ROBERTSON, 1995), their benefits are spread (BUTTON and TAYLOR, 2000) and they tend to co-produce effects on urban and air space, thus increasing the potential relationship between city-regions (ADDIE, 2014). But they also cause externalities which are often felt in their neighborhoods (SCHIPPER *et al.*, 2001), where the conflict is perceived in terms of excessive aeronautic noise, urban segmentation, traffic congestion, air, water and soil pollution, loss of natural habitats, loss of property values in their surroundings etc. Graham and Marvin (2001, p. 11) highlight that "one person's infrastructure is another's difficulty: urban infrastructure networks [are] 'congealed social interests'". But these authors also highlight that unbundled infrastructures such as hub-and-spoke airport systems may evolve to more sophisticated systems where "tunnels" can provide direct connections between two smaller, spoke or feeder cities without necessarily passing through the hub, increasing heterogeneity and traversing the original hub-and-spoke organized airport system, thus re-

scaling and re-defining the networks of importance between the cities (GRAHAM and MARVIN, 2001, p. 200-202).

The changes in connectivity and the advent of new routes with increasing transport densities is precisely what is verified in this paper, simplifying the network of air transport indicated by REGIC with 2004 data (IBGE, 2008), and updating the same rationale for 2014 (after a decade of unchallenged exponential growth) and 2017 (verifying the effect of air market travel retraction due to the recession affecting Brazil's economy in the past years).

METHODOLOGY

Since the original National Civil Aviation Agency (ANAC) database with 1,007 pairs of origin-destination was unavailable, to verify how air travel connectivity and air routes' densities evolved since the maps of the latest REGIC study was published (IBGE, 2008) involved a new, probably simplified but reproductible approach.

As a first step, the origin-destination ANAC yearly database was downloaded ("consulta6" of their standard options, for 2000 to 2017; ANAC, 2018). These are MS Excel® spreadsheets with 37 columns and data for each month of each year for all air carriers operating flights in Brazil in that period, totaling from 38 to 45 thousand lines of data for each year, including domestic and international flights, regular (commercial carrier flights with pre-assigned, constant hour and day of start), non-regular (charter flights, air taxi, air-ambulance and customized flights) and unproductive flights (ferry flights, cancelled take-offs, aircraft transfer and delivery flights).

The years 2004, 2014 and 2017 were selected for their representativeness to allow viewing a position of the same year of the latest REGIC data (2004, while the majority of the latest REGIC data are from 2007; IBGE, 2008), covering a decade of unchecked exponential growth and a more recent position, after three years of economic downturn affecting air travel in Brazil. For these years, a dynamic spreadsheet resource tool of MS Excel® was prepared, identifying both origin and destination airports, revenue and non-revenue passengers and cargo (allowing the calculation of respective totals), and number of take-offs (indicating direct flights only, as many origin-destination pairs for passengers involved connecting flights taking off from intermediate airports).

To identify the evolution of connectivity, for each originating airport (or pair of airports in the cases of São Paulo, Rio de Janeiro and Belo Horizonte), the total number of cities and airports with regular flights as destination was computed. Non-regular and international connections were not included (even if the route is international with domestic stopovers). The number of total connections of total passengers (revenue and non-revenue passengers) flying (directly or with stopovers) to any other airports in Brazil was computed, considering the connections to airports located in the other twelve metropolises, and the connections to all other airports of non-metropolitan cities (also split into other-region, within the same region, and within the same state). This allowed viewing the evolution of connectivity from 2004 to 2014 and 2017.

To identify the density of the routes, the total passengers (revenue plus non-revenue passengers) for each origin and destination was computed. The first attempt to classify denser routes involved organizing total passengers' values from the largest figure to the lowest and splitting the universe of 156 possible routes into quartiles (39 routes each). This yielded too many lines, rendering too crisscrossed route maps (impractical to read), with much more information than map 2 of the latest REGIC (IBGE, 2008). The inclusion very little density routes (*e.g.* pairs of cities on which there were no passengers in that year, like from Goiânia do Manaus in 2014) did not add to the result (IBGE had a threshold that was applicable to another format of database), requiring a different approach.

Being that, the origin and destinations were treated as pairs (*e.g.* passengers originating in São Paulo flying to Rio de Janeiro summed with those flying in the opposite direction, on both airports of both cities), reducing the total number of routes. The total of all metropolitan passengers was computed and used as a reference for a ABC-curve (Pareto) treatment, ordering the densities (from denser to less dense) and computing the accumulated percentage of total passengers processed in this cut of the country's network in each of the years of the sample.

Then, three alternative thresholds were tested: (i) the first, including only routes with more than one million passengers both ways on each year; (ii) a second one, including all routes with more than half a million passengers both ways each year; and (iii) a threshold of routes accounting for 80% (eighty percent) of the total passengers in all 156 routes between the 16 airports of these 13 metropolises. The latter showed more promising results (both as per balance of the sample and ability to produce more informative maps as that of 2008's REGIC). Hence, the procedure applied summed both ways of origin and destination and selecting the routes that concentrate 80% of the total passengers moved between each and all 13 metropolises, thus rendering maps with similar number of lines, comparable to the original reference (IBGE, 2008, map 2). In the maps, the tiers of density on the routes were split into more than 1.5 million passengers both ways, from 1.125 to 1.5 million passengers, from 0.8 to 1.125 million passengers, from 650 thousand to 800 thousand passengers, and less than 650 thousand passengers per year, provided within the 80% densest routes.

RESULTS

The results found are shown first in terms of connectivity and then in terms of the routes' densities. Table 1 shows a summary of the results for connectivity considering domestic and regular connections for total passengers originating at the thirteen metropolitan cities' 16 airports for the years 2004, 2014 and 2017. These are organized by largest to lowest population of the fulcrum cities (IBGE, 2018), showing the grand total of connections form each origin at these years. The grand total is the sum of the metropolitan and non-metropolitan destinations. The former is broken down as inter-regional and within region metropolitan destinations, while the latter is broken down as inter-region, within region, and within state as well. The lower part of the table includes a key of the columns and the rationale of how the values of each column were summed.

Table 1: Summary of Connectivity Results for 2004, 2014 and 2017

City / Metropolis Population Data			Number of Connections with Passengers in Orign and Destination																	
			Metropolitan Destinations												Non-Metropolitan					
City / Metropolis	Population (Million Inhabitants)		Grand Total			Subtotal Metropolitan			Inter-Regional			Within Region			Subtotal Non-Metropolitan			Inter-Regional		
	City	Metro	2004	2014	2017	2004	2014	2017	2004	2014	2017	2004	2014	2017	2004	2014	2017	2004	2014	2017
São Paulo	11.97	21.09	72	65	60	12	12	12	9	9	9	3	3	3	60	53	48	42	42	3
Rio de Janeiro	6.48	12.28	42	41	48	12	12	12	9	9	9	3	3	3	30	29	36	23	21	2
Salvador	2.92	3.95	39	40	31	12	12	12	10	10	10	2	2	2	27	28	19	7	9	
Brasília	2.91	4.21	51	47	44	12	12	12	11	11	11	1	1	1	39	35	32	34	31	2
Fortaleza	2.59	3.98	29	29	24	12	12	12	10	10	10	2	2	2	17	17	12	8	8	
Belo Horizonte	2.50	5.24	32	47	48	12	12	12	9	9	9	3	3	3	20	35	36	12	21	2
Manaus	2.06	2.52	45	39	29	12	12	9	11	11	8	1	1	1	33	27	20	8	10	
Curitiba	1.88	3.50	33	29	24	12	12	9	11	11	8	1	1	1	21	17	15	12	10	
Recife	1.62	3.91	29	30	39	12	10	12	10	10	10	2	2	2	17	18	27	7	7	1
Porto Alegre	1.47	4.26	35	29	32	11	12	12	10	11	11	1	1	1	24	17	20	13	7	1
Belém	1.44	2.40	38	32	23	11	12	9	10	11	8	1	1	1	27	20	14	9	6	
Goiânia	1.43	2.42	30	28	21	11	11	11	10	10	10	1	1	1	19	17	10	15	12	
Campinas	1.16	3.09	23	68	65	9	12	12	6	9	9	3	3	3	14	56	53	11	37	4
Key:			A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3	F1	F2	F3

Rationale: Ai = Bi + Ei Bi = Ci + Di Ei = Fi + Gi + Hi

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Regarding the routes' densities, for 2004, the criterium of considering only routes with more than one million passengers each year yielded only six routes in 2004, fifteen routes in 2014 and fourteen in 2017. Changing the criterium to half a million passengers, the number of 2004 routes would increase to ten, while in 2014 that would include thirty-two routes, and in 2017, twenty-nine. In either case, the number of connections would remain lower than the number of densest connections shown in the latest REGIC's map 2 for 2004, and higher for 2014 and 2017 (IBGE, 2008).

The threshold of accumulated 80% of the total sample (a so-called ABC approach based on Pareto's approach of a part of the sample being sufficiently representative of most of the results or the most significant ones; PACHECO *et al.*, 2015) resulted nineteen routes in 2004, still less than that of the original REGIC's map 2. This number was increased similarly to that of REGIC's map 2 for the years 2014 and 2017, with twenty-five and twenty-three routes, respectively, about the order of magnitude of routes of the original REGIC's map 2. Overall, this was the closest approach to that of the latest REGIC's map 2 (IBGE, 2008).

This allows an illustrative comparison, as shown on the maps of Figure 3. In 2004, 80% of the total densest routes imply only two very high-density routes, two other high-density ones, two medium density routes and several low-density routes. The same threshold of number of total passengers (revenue plus non-revenue) in regular domestic flights shows a much larger number of very-high-density routes and high-density ones, with scarcer numbers of medium- and lower-density routes. This means that nearly the same number of routes are included, but their densities are significantly increased. Even though, they concentrate in cities at or near the sea-shore, with seven routes heading to Brasilia and one to Goiânia (in the Center-west of the country) as the few exceptions, and none heading either to Belém or Manaus (at the North of the Country, in the Amazon), which involve routes of less densities, all in the remaining 20% of the ordered sample.

Number-wise (not shown on Figure 3), it is worth mentioning that the busiest route in Brazil is systematically that with origin and destination either in São Paulo and Rio de Janeiro, with always twice as many passengers as the second busiest route in any given year of the survey: it accounted 4.13 million passengers in 2004, 7.42 million in 2014 and 7.03 million in 2017. The second busiest route, however, changed from São Paulo-Brasília in 2004 (with 1.52 million passengers) to São Paulo-Porto Alegre already in 2014 (3.66 million passengers) and again in 2017 (3.69 million passengers). In 2017, the route between São Paulo and Brasília has lost density to 3.17 million passengers (compared to 3.62 million in 2014) and rank position to the route São Paulo to and from Belo Horizonte, which increased from 1.37 million passengers in 2004 to 3.11 million in 2014 and 3.20 million in 2017.

DISCUSSION

The adjustment of yearly total throughput of passengers from 2000 to 2017 (Shown in Figure 1) as a third-degree polynomic curve shows a rather good adjustment ($R^2 = 0.9854$). The adjustment of an exponential growth curve for the same data from 2003 to 2014 yields an $R^2 = 0.9841$, also very high. The use of trend lines tool at MS Excel® proved very helpful upon simple dispersion graphs in all cases.

Figure 3: Air Transport Densest Routes Connecting Brazilian Metropolises, 2004 and 2014.
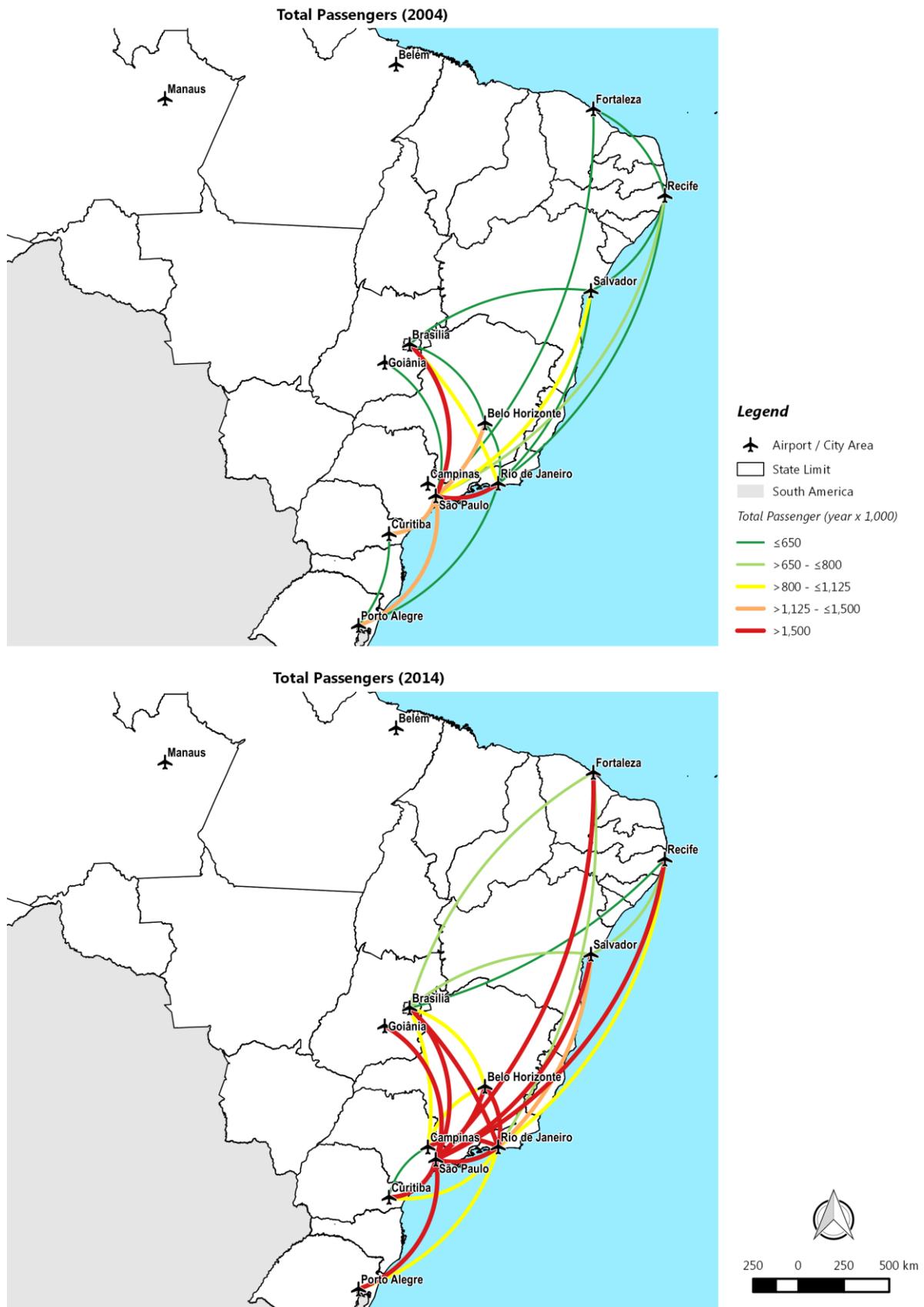
The studies of connectivity in air transport have a choice of methodological procedures that yield different – but all rather interesting – results. This was solely a quantitative study for connectivity, considering domestic, regular connections, regardless of the routes' densities: some connections accounted for exceptional diversion flights, while others include very dense origin-destination pairs. The use of dynamic tables tool of MS Excel® was fundamental for a quick identification of the number of connections between all the thirteen metropolises and other non-metropolitan destinations. In general, data shown in Table 1 indicate that the overall number of cities connected to and from the major metropolises has diminished from 2004 to 2014 (and further in 2017).

The number of total destinations per metropolises has decreased more from 2004 to 2014 than from 2014 to 2017. This has been apparently a result of maximizing efficiency aiming profitable results by aviation industry rather than any non-market, regulatory restriction. In terms of metropolitan destinations (both origin and destination in one of the sixteen metropolitan airports considered on the survey), the market downturn has affected the total number of connections from 2014 to 2017 except for Campinas, which was poorly connected in 2004 and leads the pack from 2014 onwards, with more destinations than the two airports of São Paulo (which led connectivity in 2004). The number of inter-region destinations is affected by the number of metropolises, more numerous in the Southeast (four cities and seven airports) than elsewhere (three cities and airports in the Northeast, and two cities and airports in the North, Center-West and South of the country).

Considering non-metropolitan destinations, São Paulo remains important, but lost its leadership to Campinas from 2014 to 2017 within this subtotal, mostly when considering the inter-regional destinations. The number of connections to and from Brasília has decreased, while the number of connections to and from Rio de Janeiro and Belo Horizonte increased, apart from the effect of Campinas' growth eroding the number of connections to and from São Paulo – still significant, though. When considering within-region destinations (not in the same state), there is a leadership of cities and airports in the Northeast, where numerous connections to cities in neighboring states are available (but not to other regions, as can be seen form the airports in the Southeast).

When considering connections within the same state, better-connected cities within larger states kept their number of destinations, except for the metropolises in the North: while Manaus and Belém were the most within-state connected in 2004, this characteristic was lost in 2014 and 2017, as the number of regular connections to cities within their respective states (very large in size, deprived of roads and railway) of the Amazon and Pará diminished dramatically (the number of cities connected by air travel was halved). The number of within state connections also dropped for Bahia state (from Salvador), while in the state of São Paulo the number of connections from the state capital (São Paulo airports) diminished, but the number of connections from Campinas airport increased (some of the destinations herein accounted solely as numbers coincide from both cities' airports).

In terms of route's densities, as previously stated, the latest REGIC study (IBGE, 2008) used a gravimetric model with 1,077 pairs of origin and destination, which require having full access to the database (not the case of this study). Another alternative is to use the Lorenz curve: a comparison of concentration curve against a straight 45-degree line correlating

cumulative seat offer or total passengers versus cumulative share of airports, and the Herfindahl-Hirschman Index (HHI), which proved to be very good for showing concentration effects on international flights where competition can be measured between national and international carriers (PACHECO *et al.*, 2015). In this paper an approximation using accumulated percentages of the sample (for domestic flights only) instead of the traditional quadratic function of Lorenz equation emulated the ABC-curve procedure to acknowledge Pareto's Law, finding the point from which an increase of the sample does not produce any further qualitative result or, in other words, "the study of a small proportion of the sample studied is responsible for a large proportion of the results" (PACHECO *et al.*, 2015).

Although this is different from the threshold used by IBGE on its latest REGIC study (which selected origin-destination pairs with more than one monthly connection within the full database), the choice of regular, direct flights plus passengers connecting through stopovers to reach their destination yielded good results to allow understanding the increase of density of the routes between the major metropolises (see Figure 3). With the threshold values herein adopted, the densest routes do not include the two Northern metropolises (Belém and Manaus) in 2004, 2014 or 2017. In 2004 there were relatively few very dense routes, which has changed a lot in 2014, when the routes to and from São Paulo's airports severely increased their densities. Campinas had none of the densest routes in 2004, but gained one very dense route in 2014, along with two medium density routes and one less dense route in the same year. Brasília kept its hub position due to its political status (as the country's capital) and due to its geographical situation (amid the natural routes path from South and Southeast to the North and Northeast of the country), although a more important increase of routes' densities can be seen to and from cities closer to the coast, like the cases of São Paulo and Rio de Janeiro, eroding Brasília's relative importance.

CONCLUSIONS

From 2004 to 2014 and 2017, despite intense growth of Brazilian aviation, the number of cities connected from metropolitan airports has diminished. The loss of air travel destinations was more severe in the North (to and from Manaus and Belém), while number of destinations remained important in the Northeastern states to and from their three metropolises. The rise of Campinas as a hub for Azul airlines (somewhere in between a regional and a LCC airline) increased both the cities' connectivity and routes densities, which may affect its influence towards other Brazilian cities through the effects of air travel. The advent of LCC airlines (or "quasi-LLC" in Brazil) did not affect geographical results so significantly, but triggered competition between airlines offering lower fares, which may have contributed to the overall increase of air transport in Brazil in this period.

Contrarily to the diminishing number of total destinations (lesser overall connectivity from air travel, country-wise, derived from market-optimization mechanism rather than political will of promoting regional air transport), the increase of routes' densities, though, was substantial – like the general increase of air transport, mostly concentrated in the 2003-2014 period. The effects of the 2015-2017 crisis were substantial, but some origin-destination pairs involving São Paulo have increased their densities from 2014 to 2017. This may lead to the conclusion that the increase of routes density from 2004 to 2014 was also

market-driven rather than a result of any political or regulatory incentive or enforcement. Although the overall numbers of air transport in Brazil retracted with the economic downturn of the country from 2015 onwards, some of the routes increased their densities, such as São Paulo to and from Porto Alegre, Belo Horizonte and Curitiba.

The REGIC publications by IBGE indicate that since the 1960's there has been a consolidation of São Paulo as a Large National Metropolis, the ascension of Brasilia as a National Metropolis (to the same level of Rio de Janeiro), and an alternating consideration of Brasília, Manaus and Belém as metropolises, as well as a growing importance of Campinas – the only city in the top two tiers which is not a state capital – therein considered as a regional capital on this 2007 update (IBGE, 2008).

The increase of air travel in Brazil from 2000 to 2017 was important, and quite concentrated from 2003 to 2014, where an exponential, unchecked growth was experienced. This was led by the densest routes, as the overall connectivity of the metropolises with smaller cities diminished: the number of destinations served by commercial aviation is smaller in 2014 than that of 2004, with a substantial decrease of number of destinations within the Northern states of Amazon and Pará from their respective capitals, Manaus and Belem. The list of Brazilian metropolises present in all REGIC editions also includes Belo Horizonte, Porto Alegre, Salvador, Fortaleza, Curitiba and Goiânia, which lost number of connections, but increased their remaining routes' densities, mostly due to increases of air transport based on larger metropolises such as São Paulo and Rio de Janeiro.

The flows identified by the four versions of the IBGE's REGIC studies indicate dominating cities (with origin on the largest cities and destinies on the smaller ones) and subordinated cities (vice-versa). This is apparently consistent with air travel evolution in Brazil from 2004 to 2014 (and somewhat to 2017, despite the economic downturn of the country). In this period, the upcoming of Campinas in terms of increasing air travel connectivity and its inclusion within the densest routes may change the cities' relation of influence along the country, as routes originated from or destined to the city became far denser than those of some of the more traditional Brazilian metropolises. It is important to highlight that some non-(purely)-metropolitan routes are denser than many of the routes herein analyzed due to origin and destination solely on the selected metropolises (*e.g*. São Paulo-Florianópolis – a non-metropolitan destination, with 2.03 million passengers in 2017, would rank ahead of Rio de Janeiro-Brasília as the 8th busiest route in Brazil).

Although the REGIC studies consider several other types of flows between the cities, the choice of Campinas as a hub by Azul airlines (which entered the market with the purpose of exploring a larger number of medium-density connections rather than simply competing with the current existing quasi-duopoly of airlines on denser routes) may change the overall balance results of a new REGIC study, should IBGE update the latest version of 2008, now somewhat outdated, despite with significant improvements and substantial methodological sophistication as related to the previous versions.

Finally, air transport may indeed affect the network of cities and metropolitan areas in Brazil, as shown by evidence gathered from 2004 to 2014, when air travel increased exponentially, despite some reduction of overall connectivity.

REFERENCES

ACEMOGLU, D. and ROBINSON, J.A. (2012). *Why nations fail: the origins of power, prosperity, and poverty*. New York: Crown Business.

ADDIE, J.P.D. (2014). Flying high (in the competitive sky): conceptualizing the role of airports in global city-regions through "aero-regionalism". *Geoforum*, 55: 87-99.

AIRBUS (2016). *Global Market forecast: mapping demand 2016-2035.* Blagnac-Cedex: Airbus S.A.S.

ANAC – AGÊNCIA NACIONAL DE AVIAÇÃO CIVIL (BRAZIL). (2018). Available at: http://www.anac.gov.br/assuntos/dados-e-estatisticas/mercado-de-transporte-aereo/consulta-interativa; viewed at March 2018.

ASHFORD, N.J. and MOORE, C.A. (1999). *Airport finance*. 2ª ed. Woodhouse Eaves (Leicestershire): The Loughborough Airport Consultancy.

BARBOT, C. (2006). Low-cost airlines, secondary airports, and state aid: An economic assessment of the Ryanair–Charleroi Airport agreement. *Journal of Air Transport Management*, 12: 197-203

BOWEN Jr., J.T. (2012). A spatial analysis of FedEx and UPS: hubs, spokes, and network structure. *Journal of Air Transport Geography*, 24: 419-431.

BRAZIL (FEDERAL GOVERNMENT) (2001). Lei nº 10.257/2001 – (Cities By-Law).

BRAZIL (FEDERAL GOVERNMENT) (2015). Lei nº 13.089/2015 – (Metropolises By-Law).

BRAZIL (FEDERAL GOVERNMENT) (2018). Lei nº 13.683/2018 – (Modifies the Metropolises By-Law).

BUTTON, K. and TAYLOR, S. (2000). International air transportation and economic development. *Journal of Air Transport Management*, 6: 209-222.

CALDER, S. (2003). *No frills: The Truth Behind the Low-cost Revolution in the Skies*. London: Virgin Books.

CASTELLS, M. (1996). *The rise of the network society*. Oxford: Blackwell.

CWERNER, S. (2009). "Introducuing aeromobilities". In: CWERNER, S., KESSELRING, S., and URRY, J. (Eds.). *Aeromobilities*. London: Routledge, p. 1-21.

DAVIES, M. (2006). *Planet of slums*. London: Verso.

DE NEUFVILLE, R. and ODONI, A. (2003). *Airport systems: planning, design, and management*. New York: McGraw-Hill.

DE NEUFVILLE, R. (1995). Management of multi-airport systems: a development strategy. *Journal of Air Transport Management*, 2(2): 99-110.

DISTANCIASCIDADES.COM (2018) Available at: http://www.distanciasentrecidades.com/, viewed in November 2018.

DOGANIS, R. (1992). *The airport business*. London: Routledge.

DUCRUET, C., CUYALA, S. and HOSNI, A.E. (2018). Maritime networks as systems of cities: the long term interdependencies between global shipping flows and urban development (1890-2010). *Journal of Transport Geography*, v. 66, p. 340-355.

FERNANDES, A.C. (2001). Da reestruturação corporativa à competição entre cidades: lições urbanas sobre os ajustes de interesses globais e locais no capitalismo contemporâneo. *Espaço e Debates*, 41, 26-45.

FRIEDMANN, J. and WOLFF, G. (1982). World city formation: an agenda for research and action. *International Journal of Urban and Regional Research*, 6 (9): 309-344.

FULLER, G. and HARLEY, R. (2004). *Aviopolis: a book about airports*. London: Black Dog.

GILLEN, D. and LALL, A. (2004). Competitive advantage for low-cost carriers: some implications for airports. *Journal of Air Transport Management*, 10: 41-50.

GORDON, A. (2004). *Naked airport: the cultural history of the world's most revolutionary structure*. Chicago: University of Chicago Press.

GRAHAM, S. and MARVIN, S. (2001). *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition*. London: Routledge.

HEALEY, P. (2011). The universal and the contingent: some reflections on the transnational flow of planning ideas and practices. *Planning Theory*, 11(2), 188-207.

HUNT, D. (1994). *The Tunnel: the story of the Channel Tunnel 1802-1994*. Upton upon Severn (Worcestershire, UK): Images.

HZMB – HONG KONG – ZUHAI – MACAO BRIDGE (2018). Available at: http://www.hzmb.hk/eng/about_overview_01.html, viewed in October 2018.

IBGE – BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (1972). *Divisão do Brasil em regiões funcionais urbanas*. Rio de Janeiro: IBGE.

IBGE – BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (1987). *Regiões de Influência das cidades.* Rio de Janeiro: IBGE.

IBGE – BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (2000). *Regiões de Influência das cidades 1993*. Rio de Janeiro: IBGE.

IBGE – BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (2008). *Regiões de Influência das cidades 2007.* Rio de Janeiro: IBGE.

IBGE – BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (2018). *Population estimates for Brazilian cities.* Available at www.ibge.gov.br, viewed in October 2018.

JESSOP. B. (2000). The crisis of the national spatio-temporal fix and the tendential ecological dominance of globalizing capitalism. *International Journal of Urban and Regional Research*, 24(2): 323-360.

KUBY, M.J, and GRAY, R.G. (1993). The hub network design problem with stopovers and feeders: the case of Federal Express. *Transp. Research-A*, 27A(1): 1-12.

MELLO, L.I.A. (1999). *Quem tem medo de geopolítica?* São Paulo: Edusp; Hucitec.

PACHECO, R.R., BRAGA, M.E. and FERNANDES, E. (2015). Spatial concentration and connectivity of international passenger traffic at Brazilian airports. *Journal of Air Transport Management*, 46: 49-55.

PONTING, C. (2007). *A New Green history of the world: the environment and the collapse of great civilizations*. London: Penguin Books.

PURCELL, M. (2007). City-regions, neoliberal globalization and democracy: a research agenda. *International Journal of Urban and Regional Research*, 31(1): 197-206.

ROBERTSON, J.A. (1995). Airports and economic regeneration. *Journal of Air Transport Management*, 2(2): 81-88.

SCHIPPER, Y., RIETVELD, P. e NIJKAMP, P. (2001). Environmental externalities in air transport markets. *Journal of Air Transport Management*, 7:169-179.

THE ORESUND BRIDGE. (2018). Available at: https://www.oresundsbron.com/en/node/6738, viewed in October 2018.

UNCTAD – UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (2017). *Review of Maritime Transport – 2016.* Geneva: UNCTAD.

UNITED NATIONS, Department of Economic and Social Affairs, Population Division (2015). *World Urbanization Prospects: The 2014 Revision*. (Tables de MS Excel® tables downloaded from https://esa.un.org/unpd/wup/CD-ROM/, in January, 2018).

WARNOCK-SMITH, D. and POTTER, A. (2005). An exploratory study into airport choice factors for European low-cost carriers. *Journal of Air Transport Management*, 11: 388-392.

WATSON, V. (2009). 'The planned city sweeps the poor away…': Urban planning and 21st century urbanization. *Progress in Planning*, 72, 151-193.