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A INFLUÊNCIA DA MOVIMENTAÇÃO DE PASSAGEIROS NOS AEROPORTOS BRASILEIROS QUANTO AO AUMENTO DO CONTÁGIO DA COVID-19

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RESUMO

Este artigo tem como objetivo evidenciar o impacto da movimentação de passageiros nos aeroportos dos principais destinos turísticos brasileiros e sua relação com a disseminação da pandemia da COVID-19. Para tanto, o estudo realizou uma análise qualitativa com fulcro em dados secundários obtidos em sítios eletrônicos de órgãos de controle e utilizou-se de ferramentas quantitativas, tais como: regressão múltipla, análise de cluster e discriminante a fim de mensurar uma relação de causa e efeito entre as variáveis observadas. Os destinos turísticos abordados são as capitais dos estados brasileiros, a capital federal, e as cidades de Campinas, Foz do Iguaçu e Balneário Camboriú, a escolha se deu por serem estas as cidades que representam um maior fluxo de passageiros nos aeroportos. Os resultados apontam para uma forte correlação entre a movimentação de passageiros nas capitais brasileiras e a disseminação dos casos da COVID-19.

PALAVRAS-CHAVE: movimentação de passageiros, COVID-19, regressão múltipla, análise de cluster.

THE INFLUENCE OF PASSENGER TRAFFIC IN BRAZILIAN AIRPORTS ON INCREASED CASES OF COVID-19

ABSTRACT

The paper aims to evidence the impact of passenger traffic in the airports of major Brazilian tourist destinations and its relation to the spread of COVID-19 pandemic. To achieve this, the study performed a qualitative analysis based on secondary data obtained from official websites of regulatory authorities and a quantitative analysis through the use of multiple regression, cluster and discriminant analysis in order to measure a cause-and-effect relation between the variables observed. The tourist destinations addressed are the capitals of Brazilian federal states, the national capital (Brasília), and the cities of Campinas, Foz do Iguaçu, and Balneário Camboriú - the choice was made based on the cities with the highest number of airport passenger traffic. The results indicate a strong correlation between passenger traffic in Brazilian capitals and the spread of COVID-19 cases.

KEYWORDS: passenger traffic, COVID-19, multiple regression, cluster analysis.

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1 INTRODUCTION

In December 2019, a new acute respiratory disease has been detected in China and named Coronavirus Disease 2019 (COVID-19), caused by a new coronavirus, the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The virus was transported by air to all continents and, by mid-March 2020, had reached 146 countries (Gössling, Scott & Hall, 2020), when the World Health Organization announced COVID-19 as a pandemic. Since then, transmission rates have been increasing, covering more than 200 countries and territories, and, according to data informed by the WHO, confirmed cases by January 4th 2021 reached 83.7 million with a 1.8 million deaths.

Air transportation plays an important role in supporting the development of tourism and international global trade, both being strongly connected, and providing a positive feedback on each other development. As tourism is one of the main global employers and contributors to the GDP for several countries, the impacts caused by COVID-19 are at the epicenter of all international discussions (Sigala, 2020). For long-distance travels, trips to island destinations with economies dependent on tourism, and visits to remote areas within a country, air travel is the main mode of transportation.

Air travel stimulated growth in tourist trips and the discovery of new long-distance tourist destinations. The commercial effect resulting from travels, the trade opportunities created, and the exports they generate resulted in a series of structural changes and in the nature of the tourism industry. Some of the structural changes include the continuous importance of air transportation in the globalization of tourism; the increasing flexibility of inclusive tourism to sustain tourist demand and facilitate long-distance travel; and the emergence of specialized travel services.

International tourists traveling by air are estimated to have spent about USD 850 billion in 2018, an increase of more than 10% compared to 2017 (IATA, 2020). However, tourist travel can also be observed as a cycle in which travelers can transport pathogens to their destination or bring them back to their country, becoming a carrier through interaction with multiple people and environments (Wilson, 2003).

Among the countries with the highest percentage of revenue per passenger-kilometers (RPK) are China, the United States, Russia, Brazil, and Japan (IATA, 2020). These countries represented 28% of the total global RPK and approximately 78% of the total domestic RPK in 2019 (IATA, 2020).

Brazil received more than 6.3 million tourists in 2019. Air transportation is the most prominent mean of transportation in tourism, which generated 3.33 billion dollars in 2019, followed by land transportation, with 2.44 billion dollars, and water transportation, with 0.15 billion dollars in the same year (Ministry of Tourism, 2020).

The tourism industry has presented, in recent years, satisfactory results for the economy and job creation in Brazil. According to the research carried out by British consultancy firm Oxford Economics, the industry’s total contribution to the country’s GDP was USD 152.5 billion (equivalent to 8.1%), in addition to being responsible for the generation of 6.9 million jobs in 2018 (Tourism, 2020).

Among the main tourists seeking Brazil as a destination, in addition to neighboring countries, such as Argentina, Paraguay, Chile, and Uruguay, the Brazilian Ministry of Tourism also points to the United States, France, Germany, Italy, and Portugal, countries that have become epicenters of the pandemic of the new coronavirus between March and April 2020.

Therefore, this paper aims to evidence the impact of passenger traffic in the airports of major Brazilian tourist destinations and its relationship to the spread of COVID-19 pandemic. Hence, the study will analyze the impact of passenger flow in Brazilian tourist destinations, verifying the following hypothesis: the higher the passenger flow, the higher the number of new coronavirus cases.

As it will be discussed in our literature review, this paper follows other studies that investigate the impact of tourism activities and travelling to the dissemination of epidemic diseases. In this sense, we aim to contribute to the debate with additional evidence from the Brazilian experience amid the COVID-19 pandemic, helping to inform health policies and measures when facing new waves of the disease or similar situations in the future.

2 LITERATURE REVIEW

2.1 Tourism, air travel, and epidemics

Health-based crises, particularly Epidemics (local) or Pandemics (global), have direct impacts on the tourism industry, either by encouraging travelers to think about health risks and change their plans (Lee *et al.*, 2012; Novelli *et al.*, 2018), or because international travelling creates a risk of disease spreading (Richter, 2003; Bogoch & Findlater, 2018), which encourages the creation of sanitary barriers and restrictions directly affecting the flow of travelers (Gossling, Scott & Hall, 2020). Although these impacts have an economic weight in regions and countries with economies that depend on tourism, they have a relationship between international tourism and the consequent increase in international travel and the spread of diseases on a global scale.

Gössling, Scott, and Hall (2020) note that the Spanish Flu (1918-1920) can be considered the first modern Pandemic, characterized by a rapid spread through long distance transportation – mainly steamships and railways. The spread of the disease benefited from the context of a large global movement of people during the First World War (Richter, 2003), which was fought by 60 million soldiers and directly or indirectly involved more than 100 countries and territories. International travel, however, remained an exception throughout most of the 20th century, becoming popular in its last decades with technological development and popularization of aviation, and the reduction of travel costs and political barriers to international travel (Richter, 2003).

Thus, the number of international tourism trips, which, in 1950, was 25.3 million (Baker, 2015), reached 600 million in 1996 (Richter, 2003), 1.13 billion in 2014 (Baker, 2015), and 1.4 billion in 2018 – a milestone that was reached two years ahead of industry predictions (UNWTO, 2019). Tourism in the 21st century has become an activity of great economic importance and is encouraged through public policies to attract visitors. However, the context increases the possibility of spreading microorganisms and disease vectors harmful to human health, increasing the risk of Epidemics and Pandemics (Richter, 2003; Baker, 2015; Gossling, Scott & Hall, 2020).

Travelers enable dynamic interactions between microorganisms and places and can act as victims, sentinels, carriers, processors, and transmitters of microbial pathogens (Wilson, 2003; Baker, 2015). Travel is associated with behaviors that can lead to the transmission of pathogens through blood and exposure to body fluids, such as sexual activity, the practice of extreme/unusual sports and exposure to the nature, in addition to other activities that expose them to risks they would not do in their place of origin (Baker, 2015). Even interactions in hotels have potential for transmission. During the SARS epidemic in 2002, an infected guest, while spending a night in a hotel in Hong Kong, infected 7 other people staying on the same floor (Baker, 2015).

Bogoch & Findlater (2018) state that, although most travel-related illnesses are mild and self-limited, the list of infections brought by travelers returning home has grown (Table 1). These are diseases with epidemic potential and which spread, on an international scale, has been facilitated by air transportation.

Table 1: Infectious diseases significant to global health that have recently emerged or resurfaced, facilitated by air travel (Adapted from Bogoch & Findlater, 2018, page 774).

Disease	Origin (year)	Destination
Influenza H1N1 (Flu A)	Mexico (2009)	Global (Pandemic)
Vibrio Cholerae (Cholera)	South Asia (2002, 2008)	Epidemics in Haiti (2010)
NDM-1 resistant to carbapenems in Gram-negative Bacteria (superbug)	India (2009)	Australia, Austria, Belgium, Canada, China, Croatia, Czech Republic, Denmark, France, Germany, Ireland, Italy, Japan, Kuwait, Lebanon, Netherlands, New Zealand, Norway, Oman, Singapore, South Africa, Spain, Sweden, Switzerland, Taiwan, Turkey, United Kingdom, and USA.
Mcr-1 resistant to Gram-negative Bacteria colistin (superbug)	China (2014)	Algeria, Argentina, Belgium, Brazil, Cambodia, Canada, Denmark, Egypt, France, Germany, United Kingdom, Italy, Japan, Laos, Lithuania, Malaysia, Netherlands, Nigeria, Poland, Portugal, South Africa, Spain, Switzerland, Taiwan, Thailand, Tunisia, USA, and Vietnam.
Dengue fever	Southeast Asia (1950)	Global emergence in the last 5 decades.
MERS-CoV	Saudi Arabia (2012)	Epidemics in South Korea and Saudi Arabia, cases in Algeria, Austria, China, Egypt, France, Germany,

		Greece, Iran, Italy, Jordan, Kuwait, Lebanon, Netherlands, Oman, Philippines, Qatar, Thailand, Tunisia, Turkey, Arab Emirates, United Kingdom, USA, and Yemen.
Zika virus	Africa and Asia	First detected in Latin America and the Caribbean in 2015, transmissions occurring in these regions and in the South Pacific.
Chikungunya virus	Asia and Africa	Latin America and the Caribbean in December 2013, conveyances occurring in these regions and cases brought from Europe.
SARS-CoV	South China (2002)	Epidemics in Hong Kong, Canada, USA, Vietnam, Singapore, Philippines, and Mongolia.
Schistosomiasis	Africa	Epidemics in Corsica (2013), with local transmission.

Although the entire global structure of multimodal transport enables the spread of diseases, air travel specifically makes possible the rapid international transport of infected people, whether symptomatic or in an incubation period (Bogoch & Findlater, 2018). Baker (2015) exemplifies that with a singular episode during the SARS crisis. In the reported case, a traveler left Hong Kong on March 30, 2003 bound for Frankfurt, Germany. Subsequently, he took 7 flights in 5 days, including stops in major urban centers like Barcelona, London, and Munich before returning to his home city. On April 8, the traveler was admitted with suspected SARS – confirmed two days later.

Bogoch and Findlater (2018) point out that the incubation period, which enable infected people to travel asymptomatic, or even the transfer of vectors (such as mosquitoes), make air travel ideal for spreading pathogens. What Bogoch and Findlater (2018) describe as “airport malaria” occurs when people who have not traveled to regions where it the disease is endemic, are infected at airports through mosquitoes carried by airplanes. Diseases with long incubation periods, such as Ebola (which can be incubated for 3 weeks), have caused cases to be discovered in the UK and Italy and local infections have been reported in the United States and Spain (Bogoch & Findlater, 2018).

Airborne diseases (through aerosols) or direct contact found in the confined space of airplanes are an ideal place for dissemination (Baker, 2015). Flu (such as H1N1) has strong potential for mutation (making previous immunization difficult) and easy contamination. Respiratory syndromes caused by coronaviruses, such as MERS (MERS-CoV), SARS (SARS-CoV), and COVID-19 (SARS-CoV-2) have emerged in the last two decades imposing serious health risks on an international scale, including the Pandemic scenario installed in 2020.

Although the study by Mangili and Gendreau (2005) asserts that the perceived risk of transmission during transportation is larger than the actual risk, thanks to modern aircraft air filtration systems, cases of SARS transmission during international flights in 2003 confirm that this can contribute to the global spread of airborne diseases. The relative security pointed out by Mangili and Gendreu (2005), however, does not eliminate the risk of travelers in incubation period or asymptomatic transmitting the disease on the return to their origin or in their destination (Bogoch & Findlater, 2018; Baker, 2015).

Further evidence can be found in the study by Bowen and Laroe (2006) on the effects of air transportation in the spread of SARS in 2003. The analysis evidence not only that the accessibility of the route network was a particularly influent variable, but also that the importance of this variable decreased during the last weeks of the outbreak. The latter is partially attributed to public health measures, especially health checks at airports. In the same context, but considering the Sars-Cov-2 pandemic, also in China, Zhao, Liu, and Li (2020) found a relation between passenger movement and the speed at which the disease spreads, with a significant decrease, however.

Cai *et al*. (2019) also analyzed the roles of modes of transportation with evidence from the 2009 influenza A (H1N1) pandemic spread through China. As a sample, 127,797 influenza A (H1N1) laboratory-confirmed cases from May 2009 to April 2010 were used, as well as quantile regressions. The results showed that the early arrival of the virus had no relation to early peak incidence. Airports and train stations in Chinese prefectures anticipated the arrival days but had no significant impact on peak days. Air and road travels played an important role to speed up the spread during phases I and II, but train travels were only significant during Phase II.

In the similar context of the COVID-19 pandemic, Zhang, Zhang, and Wang (2020) analyzed the factors that influence the number of cases imported from Wuhan (China) and the speed and pattern of the spread of the pandemic. A quantile regression was used therefor, and its results evidenced that the frequencies of air flights and high-speed train (HST) services from Wuhan are directly corelated to the number of COVID-19 cases in the destination cities.

Furthermore, Zhang, Zhang, and Wang (2020) assert that the presence of an airport or HST station in a city is significantly related to the speed of spread of the pandemic, but its connection with the total number of confirmed cases is weak. The bigger the distance from Wuhan, the lower was the number of cases in a city and slower was the spread of the pandemic. The pandemic may arise sooner in big cities than in small ones, as the GDP is a factor positively associated with the speed of spread.

2.2 Impacts of COVID-19 in the travel and tourism industry

Despite the continuous growth over the last decades, global tourism is recurrently affected by crises of different natures that lead the industry to periods of stagnation (Novelli *et al*, 2018; Page, Song, and Wu, 2012; Gossling, Scott, and Hall, 2020). Events that trigger crises in the industry may involve natural disasters, terrorist attacks, economic crises, and health emergencies, such as Epidemics and Pandemics (Novelli *et al*, 2018; Gossling, Scott, and Hall, 2020; Page, Song, and Wu, 2011). As a result, such crises, whether on a global or local scale, have their effects in the tourism industry. This is perceived in the decrease in the number of flights, hotel occupation rates, and expenditures (Pine and McKercher, 2004; Novelli *et al*, 2018).

Times of depression in the industry are not uniform due to the different nature of such crises: after the September 11 attacks in 2001, the number of arrivals in tourist destinations suffered 5 consecutive months of decline before a positive month; the 2008 global economic crisis led to a continuous 9-month decrease; and the SARS epidemic in 2003, to 4 consecutive months of decrease (UNWTO, 2020c).

The COVID-19 Pandemic has been having a significant impact on the global economic, political, and sociocultural systems (Sigala, 2020). Among the economic sectors mostly affected by the health crisis, the travel and tourism industry stand out for having its activities directly affected by the restrictive measures against disease contagion implemented by countries (Assunção *et al*., 2020).

It is a consensus that the increase in international transportation, especially by air, has been having a significant impact on the spread of infectious diseases, either by the speed of spread of the virus to different regions through tourists (Sancho, 1998; Sanchez, 2020) or the experience of travelers in exotic destinations, culminating in the emergence of unknown virus (Rodríguez-García, 2001). Based on this, the first measures implemented against the spread of COVID-19 included, in addition to health guidelines, restrictions to travelers from the affected countries and inactivation of visas, which affected especially the international touristic flows (Sanchez, 2020).

According to data published by the World Tourism Organization (UNWTO), by the end of April, 100% of global destinations had put restrictions on international travelling, leading to a decrease during the first four months of the year of 2020 (compared to the same period of the previous year) of 44% in the arrival of international tourists and a loss of about $195 billion in international tourism revenues (UNWTO, 2020a). According to experts from the WTO, these numbers may decrease in up to 78%, which would cause a loss of USD1.2 trillion in tourism export revenues and 120 million of direct job cuts in the industry (UNWTO, 2020b).

Among the sectors related to tourism, passenger air transportation has shown quite significant impacts. In the last report published by the International Air Transport Association (IATA), the industry had a global decrease of 91.3% in RPK[1] in May 2020, in comparison with the same period of the previous year. According to IATA, the industry's recovery will be slow, with an estimated global passenger transportation decrease of up to 34% in 2021, with a slower recovery in the international flights industry, compared to domestic flights, and an average increase of 50% in travel costs (Bouças, 2020).

However, it is worth mentioning that the tourism industry has historically shown resilience in the sense that impacts, to a greater or lesser extent, do not affect its historical growth trend (Kuo *et al.*, 2008; Gössling, Scott, and Hall, 2020).

[1] Revenue Passenger Kilometers

3 METHODOLOGY

The research used a quantitative-qualitative approach, as it first proposes to organize an analysis of secondary data available on the websites of control bodies, such as the Brazilian Institute of Geography and Statistics (IBGE), the Ministry of Tourism and the National Civil Aviation Agency (ANAC), with data extracted from January/2020 to May/2020. This is followed by a quantitative analysis of the impact of passenger flow in the main Brazilian tourist destinations and its relationship to COVID-19, carried out using the methods indicated by Hair *et al.* (2010) for studies seeking to measure a cause-and-effect relation, such as Pearson's correlation and multiple regression. Cluster analysis and discriminant analysis were also used to form groups of cities considering the affinities observed by the study variables. The methods were run with the support of the software Statistical Package for the Social Sciences (SPSS), version 24.0.

The sample is made up of the capital city of all Brazilian federal states, the national capital (Brasília), plus the cities of Campinas, SP, Foz do Iguaçu, PR, and Balneário Camboriú, SC, as they represent a higher passenger flow from air arrivals and departures.

To verify the effect of the passenger flow coming from flights (national and international departures and arrivals) and the cases of COVID-19 in the cities used as a sample, the multiple linear regression model presented in Equation (1) was developed.

$$CASES\_COVID = \beta_0 + \beta_1 TRAF\_PASS\_QUAR + \beta_2 HDI + \beta_3 PD \qquad (1)$$

Where:

CASES_COVID = Dependent variable that represents the number of accumulated cases of COVID-19 in the Brazilian states capital cities, Brasília and the cities of Campinas, SP, Foz do Iguaçu, PR, and Balneário Camboriú, SC, until May 31, 2020.

β_0 = Regression intercept

TRAF_PASS_QUAR = The independent variable of interest that represents the passenger flow coming from flights (national and international departures and arrivals) in the cities of the sample, from March to May 2020, which corresponds to the beginning of the spread of COVID-19 on a global scale and the closure of Brazilian air borders.

HDI = Control variable that represents the human development index of each city and can influence the increased number of cases of COVID-19.

PD = Control variable that represents the population density of each city and may have influence on the increased number of cases of COVID-19.

The control variables that were added to the equations were tested in this research experimentally, since, in addition to passenger traffic across the country, the relevant social and health conditions inequality among Brazilian regions must be considered. Therefore, the variables HDI and PD were included – this has already been identified by Cai *et al.* (2019) as a determining factor for the spread of the H1N1 virus – but not tested in its model. The INCOME variable was tested based on a research carried out by Zhang, Zhang and Wang (2020). Although no study has directly measured the passenger flow arriving at airports, the study by Zhang, Zhang and Wang (2020) analyzed the effect of the number of departures considering the increase in COVID-19 cases and pointed this effect as positive and meaningful.

3.1 Case characterization: Overview of the Air Tourism Sector in Brazil and COVID-19 crisis.

The tourism sector has an important participation in the Brazilian economy, with a total contribution (direct and indirect) of 8.5% of the national GDP in 2016 (USD 152.2 billion), in addition to 7% (6.9 million) of jobs (Tourism, 2018). With continental dimensions, the country is environmentally diverse and cultural, historical, and architectural attractions, in addition to having one of the ten largest economies in the world, motivating domestic and international tourism for leisure or business. A summary of the different focuses of interest in the major regions of the country is shown in Table 2.

Table 2: Main Tourist Attractions and Destination Cities in the Great Regions of Brazil. (Data: ANAC, 2020; Ministry of Tourism, 2020)

Great Regions of the Country	Main Destination Cities (Air Passengers)	Main Attractions of the Region
North	Manaus, AM; Belém, PA; Porto Velho, RO	Free Economic Zone of Manaus, Amazon Rainforest, Agribusiness; Mineral and Vegetable Extraction; Fishing; Culture;
Northeast	Recife, PE; Salvador, BA; Fortaleza, CE; Natal, RN; Maceió, AL; Porto Seguro, BA; São Luiz, MA;	Coastal beaches; Plateaus; Carnival; History; Culture; Agribusiness; Mineral Extraction; Industry; Events;
Midwest	Brasília, DF; Goiânia, GO; Cuiabá, MT; Campo Grande, MS	Public Administration; Architecture; Agribusiness; Mineral Extraction; Pantanal; Plateaus; Events; Fishing
Southeast	São Paulo, SP; Rio de Janeiro, RJ; Belo Horizonte, MG; Campinas, SP; Vitória, ES	Industry; Costal beaches; Carnival; History; Culture; Agribusiness; Mineral Extraction; Events
South	Porto Alegre, RS Curitiba, PR; Florianópolis, SC; Foz do Iguaçu, PR; Navegantes, SC	Industry; Costal Beaches; History; Culture; Agribusiness; Events; Iguazu Falls;

Regarding international tourism, data from 2016 point to 56.8% of visitors motivated by leisure, 18.7% by business and events, and 24.5% for various reasons (such as studies, personal visits, religion) (Ministry of Tourism, 2018). Most international visitors come from South America (57%), followed by Europe (25%) and North America (12%) (Ministry of Tourism, 2020b). Tourists from Asia comprise only 4% of visitors, and Africa, Oceania, and Central America, only 3%.

In 2019, the top 10 countries sending tourists (Table 3) were responsible for 73% of visitors, with emphasis on Argentina, which was responsible for 30% only. Air travel is the predominant form of arrival among 8 of the main visiting countries, except for Uruguay and Paraguay, where road access is possible and predominant. These two countries, as well as Argentina, have a direct border with Brazil, in addition to participation in Mercosur, facilitating the traffic of people in passenger cars.

Table 3: Main countries sending tourists, through the access way to the country. Data: Ministry of Tourism, 2020

Countries of permanent residence	Total	Arrival of Tourists			
		Access Way			
		Air	Land	Sea	River
	2019	2019	2019	2019	2019
Total Visitors	6,353,141	4,288,528	1,839,451	123,127	102,035
Argentina	1,954,725	1,006,018	802,184	69,012	77,511
United States	590,520	543,075	32,216	11,432	3,797
Chile	391,689	372,907	16,438	2,295	49
Paraguay	406,526	60,686	340,811	251	4,778
Uruguay	364,830	139,632	219,935	5,120	143
France	257,504	193,936	51,020	2,880	9,668
Germany	206,882	172,658	28,104	5,589	531
Italy	182,587	162,334	16,992	3,176	85
United Kingdom	163,425	130,552	25,072	5,190	2,611
Portugal	176,229	173,079	2,522	575	53

The main international ports of entry and exit by air in the country are found in the Expanded Metropolitan Complex of São Paulo (Guarulhos and Campinas airports) and in the Metropolitan Region of Rio de Janeiro (Galeão airport). Together, these three airports make up 82.98% of all international passenger air traffic in the country, with the airport in Brasilia in third place, with 2.75%. In addition to being megalopolises and centers for leisure and business tourism, São Paulo and Rio de Janeiro, in addition to Brasília, are also hubs for flight connections between the North, Northeast, Midwest, and South of the country. Together, the 5 main airports that serve these metropolitan regions (Guarulhos, Congonhas, and Campinas, in São Paulo; Santos Dumont and Galeão, in Rio de Janeiro, and Brasília airport) are responsible for 49.12% of the volume of passengers in domestic flights.

Table 4: Main Cities and Metropolitan Regions by number of national and international passengers, data from 2019 (Data: Ministry of Tourism, 2020)

International			Domestic		
City/Metropolitan Area	**Number of Passengers**	**Participation**	**City/Metropolitan Area**	**Number of Passengers**	**Participation**
São Paulo Expanded Metropolitan Complex (Guarulhos and Campinas)	15,362,578	64.79%	São Paulo Expanded Metropolitan Complex (Guarulhos, Congonhas, and Campinas)	59,364,142	31.17%
Rio de Janeiro (Galeão)	4,294,335	18.19%	Rio de Janeiro (Santos Dumont and Galeão)	18,273,906	9.59%
Brasília	649,289	2.75%	Brasília	15,920,782	8.36%
Fortaleza	547,576	2.32%	Belo Horizonte (Confins)	10,307,498	5.41%
Recife	534,472	2.26%	Recife	8,095,991	4.25%
Porto Alegre	502,256	2.13%	Porto Alegre	7,601,988	3.99%
Salvador	430,062	1.82%	Salvador	6,915,953	3.63%
Belo Horizonte (Confins)	422,764	1.79%	Fortaleza	6,316,532	3.32%
Florianópolis	259,701	1.1%	Curitiba	6,316,532	3.32%
Belém	164,845	0.7%	Florianópolis	3,468,805	1.82%

Considering the arrival of foreign tourists only, the states of Rio de Janeiro and São Paulo are hubs for 27.95% and 54.16% of them, respectively (the Ministry of Tourism does not specifically provide details on the airport of arrival). Other less prominent states that are hubs for foreign tourists are located in the Northeastern (Bahia, Ceará, and Pernambuco) and Southern (Santa Catarina, Rio Grande do Sul, Paraná) regions of the country.

Table 5: Tourist Arrivals by Air by Federative Unit, data from 2019 (Data: Ministry of Tourism, 2020).

Federative Units	Tourist Arrivals by Air	% Total	Main Airports of the Federative Unit (% passengers of the Federative Unit)
São Paulo	2,322,772	54.16%	São Paulo (Guarulhos) (54.85%) São Paulo (Congonhas) (28.92%) Campinas (13.23%)
Rio de Janeiro	1,198,522	27.95%	Rio de Janeiro (Galeão) (60.24%); Rio de Janeiro (Santos Dumont) (39.47%);
Bahia	141,552	3.30%	Salvador (71.98%); Porto Seguro (18.34%)

Santa Catarina	110,051	2.57%	Florianópolis (54.93%) Navegantes (27.8%)
Ceará	108,315	2.53%	Fortaleza (91.86%);
Pernambuco	100,969	2.35%	Recife (92.55%)
Distrito Federal	73,860	1.72%	Brasília (100%);
Rio Grande do Sul	58,937	1.37%	Porto Alegre (94.51%)
Minas Gerais	54,424	1.27%	Belo Horizonte (Confins) (85.94%) Uberlândia (9.02%);
Paraná	41,156	0.96%	Curitiba (59.95%) Foz do Iguaçu (21.46%)
Other Federative Units	78,060	1.82%	
Total	**4,288,528**		

At the beginning of 2020, the market for air travel had been having good growth prospects; however, mitigation measures implemented by the Brazilian government, beginning in March, to fight against the pandemic were responsible for the virtually complete interruption of its operations, for example: restrictions on the arrival of foreigners by the country's land and air borders; reduction in business activities and closing of environments prone to crowing in several states and cities, with many of these establishments providing only essential services.

With the air travels suspended and the country's borders closed, international touristic activity has become unsustainable. Additionally, the rest of the chain related to the industry was affected as well, as even locals are not allowed to visit tourist destinations due to the risk of contamination. This caused the interruption of activities in hotels, restaurants, and bars; blocking of roads, cancellation of events of any kind; drastic decrease in the number of flights, and impossibility for tour operators to sell their packages (FVG, 2020).

Among the main activities[2] of the Brazilian tourism industry, it is important to note that the air travel industry, as in the rest of the world, has been one of the most affected by the crisis. According to data published by the Ministry of Infrastructure (Infrastructure, 2020), a 94.6% decrease in paying passengers on domestic flights (PAX) and 97.9% in the international market were registered in April, resulting in a 16.4% decrease in the aircraft utilization rate, reflecting the cancellation and/or rescheduling of pre-booked flights during this period.

These data are also evidenced by the decrease of more than 90% in the ten biggest Brazilian airports in terms of traffic of passengers, responsible for many of the main Brazilian tourist

[2] Classification based on the study published by IBGE in 2012, which lists the main activities related to the industry, namely: hotels and lodgings; bars and restaurants; road transportation; air transportation; other transports and auxiliary transport services; travel agency and organizer activities; rental of personal properties; recreational, cultural, and sports activities.

destinations, namely: Guarulhos – São Paulo, Viracopos – São Paulo, Brasília – Federal District, Recife – Pernambuco, Confins – Minas Gerais, Santos Dumont – Rio de Janeiro, Porto Alegre – Rio Grande do Sul, Salvador – Bahia, Afonso Pena – Paraná (Infrastructure, 2020).

As such, the three major airlines (Azul, Gol, Latam) had PAX decreases of 91.8%, 94.2%, and 96.1%, respectively (Infrastructure, 2020). This situation led to the creation of an essential route network started in April, in a partnership with these companies, in order to prevent the service from being completely interrupted (ANAC, 2020a).

According to a study published by Fundação Getúlio Vargas (FVG, 2020a), all activities related to the tourism industry have shown a significant reduction trend in its output volume during the first semester of the year, and may have different recovery levels over 2020-2021, such as: food services, since they may work with delivery services, tend to be less affected than recreational, cultural, and sports activities. The FGV study also presents an analysis based on three main types of tourism, which ranges according to the destination of the tourist and their main interests, namely: domestic tourism, international tourism, and business and events tourism. In this scenario, it is expected that domestic travels will recover more quickly, to the prejudice of international travels, which will need more time to show the first recovery numbers, confirming the estimates presented by IATA (2020). Still according to the study, the estimated economic losses for this industry in comparison with the 2019 GDP will be of -46.9% in 2020 and -12.6% in 2021.

4 RESULTS

During the two first months of 2020, the airports of the main Brazilian capitals and touristic cities had a monthly average of a little more than 125,700 domestic flights and 12,351 international flights, of which 46% of domestic flights and 71% of international flights are in the three major Brazilian hubs (São Paulo, Rio de Janeiro, e Brasília). After the Pandemic reached Brazil, by the end of February 2020, several measures were taken to restrain the entering of foreigners in the country, among which is worth mentioning the decreased number of domestic and international flights, as shown in Appendix A – columns 11 and 12, pursuant to the studies by Assunção *et al*. (2020); Sanchez (2020).

The cities with the highest decreases in the number of domestic flights were, respectively, Natal (76.84%), Balneário Camboriú (75.93%), and Maceió (75.61%), three of the main Brazilian tourist destinations. The cities with the lowest decreases, however, were Porto Velho (58.20%), Manaus (60.75%), and Campinas (61.03%). Considering international operations, the impacts were even more severe, and the decreases in the number of flights reached 87.88% in João Pessoa, 86.60% in Florianópolis, and 83.26% in Belém. On the other hand, it is worth mentioning that Campinas (31,80%) and Curitiba (47,36%) had way below-average decreases, by virtue of the former having a high flow of cargo operations and the latter being a hub for the Brazilian Postal Services (Correios).

Data regarding the accrued number of COVID-19 cases (CASES_COVID), as well as the Human Development Index (HDI), population density (PD), per capita income (INCOME), passenger traffic from January/2020 to February/2020 (before quarantine in Brazil), and passenger traffic from March/2020 to May/2020 (TRAF_PAS_QUAR) can be observed, respectively, in columns 1, 2, 3, 4, and 5 of Appendix A.

The average number of COVID-19 cases observed in the cities studied was 7,795; however, these data are highly variable, given two outliers clearly identified in the research. The city of Palmas, with only 6 cases reported until May 31, 2020, and São Paulo, with 60,131 cases. The average population density in the cities studied was 2,684 inhabitants/Km^2, and the highest densities observed in the country's biggest capitals (São Paulo, Rio de Janeiro, Belo Horizonte, and Fortaleza), among which three were the leaders in the ranking COVID-19 cases on May 31, 2020 (São Paulo, Rio de Janeiro, and Fortaleza), which converges with the studies carried out by Cai *et al*. (2019) on how metropolitan areas had the highest number of cases. The lowest population densities were observed in the capitals of the northern region, which has the largest territories and are less populated.

Regarding passenger traffic in airports, the average was 1,199,111 arrivals and departures before the pandemic, with highlights to the Guarulhos Airport, with a traffic of 11,423,156 passengers, while Boa Vista had the lowest number with 60,454 passengers during the same period. After the restrictive measures imposed on the Brazilian airports, there was a decrease in the average passenger traffic in the cities studied. 420,968 arrivals and departures were recorded from March to May 2020, which represented an average decrease of 64.9% between the periods studied. These restrictive measures were taken based on the fact that the air travel has proved to be a determinant factor in the transmission of viral diseases, as already seen in the studies of Richter (2003); Baker (2015); Gossling, Scott, and Hall (2020).

Considering the multiple regression proposed in this research, after the first iteration between the independent variables and the dependent variable (CASES_COVID), it was verified that the variable INCOME was not significant (p = 0.58), which determined its exclusion from the multiple regression model, in accordance with the results presented by Zhang, Zhang, and Wang (2020). The correlations between the variables of the model, with a maximum correlation of 0.51 (*P-value* <0.05) between independent variables and strong correlation (0.86) between the dependent variable (CASES_COVID) and variable TRAF_PAS_QUAR. The correlation also indicates that there is no multicollinearity between variables. The normality tests determined that the independent variables are normal (prob>chi2 = 0.000).

Adjusted R_2, present in Table 6, corresponds to 0.833, which shows an explanation factor of approximately 83.3% for the independent variables in comparison with the dependent one. This is a high value and, in addition to being sufficient to demonstrate the causal relationship between the variables investigated, it still has a good predictive power (Hair *et al*., 2010). When the F Test was analyzed, we confirmed that, as the *P-value* (p = 0.000) is less than 0.05, the hypothesis that R_2 equals zero is rejected, that is, the independent variables have an influence on the dependent and the model proves to be significant, demonstrating that there is statistical evidence that the model is adequate to measure the effect of passenger flow on the increase in the number of cases of COVID-19.

Table 6: Multiple Regression Outputs

	Coefficients	***Standard error***	***Stat t***	***P-value***
β_0	83767.82	21188.98	3.953	0.000*
HDI	-108048	27470.19	-3.933	0.000*
PD	0.872504	0.416	2.097	**0.042
TRAF_PASS_QUAR	0.013938	0.001	9.236	0.000*

Note 1: *Significance level 99% (*P-value* <0.01) **Significance level 95% (*P-value* <0.05) Source: Research data extracted from SPSS

Resuming Equation (1) and according to the signs and coefficients resulting from the regression model, observed in Table 6, Equation (2) was estimated:

$$CASES_{COVID} = 83767.82 - 108048 * HDI + 0.872504 * PD + 0.01393 * TRAF\_PASS\_QUAR \quad (2)$$

According to Equation (2), the passenger flow in the airports of the main Brazilian capitals (TRAF_PASS_QUAR) from March to May 2020 showed a positive causality in relation to the increase of about 0.01393 (p = 0.000) in the cases of COVID-19. This shows that, for every 100 people who arrived and/or departed from the airports of the cities studied, an average of approximately 1.4 people could have been infected and, consequently, contributed to the increase in the rate of transmission of the disease, which converges with the study by Zhang, Zhang, and Wang (2020), whose causality was positive (p = 0.002).

The variable PD proved to be adherent to the proposed model, given the fact that the transmissibility is higher in more densely populated areas. This variable had a positive causality in relation to the dependent variable, with a coefficient of 0.872504 (p = 0.042). It is possible to attest that at every increment of 1 inhabitant per Km_2 in the main Brazilian capitals, there is an average increase of approximately 0.87 cases of COVID-19. Therefore, the higher the population density of the cities studied, the higher the number of cases of COVID-19, which converges with the results found by Cai *et al*. (2019) regarding the confirmation that the highest amount of cases in China occurred, during the H1N1 pandemic, in more densely populated cities that had international airports.

Regarding the HDI, a negative effect was observed (-108,048; p = 0.000) on the number of cases of COVID-19, which makes sense, as the cities with the highest HDI (Florianópolis, Camboriú, and Vitória) have the best health, education and per capita income conditions. Equation (2) evidences that at every hundredth more in the HDI of a city, there is a decrease of 1,080 cases of COVID-19 in that city.

In the predictive analysis, the variable TRAF_PASS_QUAR was replaced in Equation 2 by the variable TRAF_PASS_NORM (Appendix A – column 5), which refers to the passenger traffic from flights in the period from January/2020 to February/2020, whose flights operated under normal conditions. The purpose of the replacement was to predict the growth in the number of Cases of COVID-19 in the cities analyzed, if the number of flights had not been reduced. Taking the City of São Paulo as an example, the predictive model indicates a 171% increase in the number of cases of COVID-19, in a situation in which flights had not been suspended. Which would be more significant, given the flow of persons in the capital city of the State of São Paulo and its connection with the main cities in the country and the world. The results of the prediction for each city can be seen in columns 13 and 14 of Appendix A.

In order to identify the similarity between groups of cities, a Cluster analysis based on the normalized data was performed, including the variable INCOME (Appendix A – column 4), which, despite not being significant in the regression, is important to the cluster analysis due to a better adjustment. Initially, the analysis was performed using Ward's method and Euclidean distance. Based on the dendrogram and helped by the data, we defined three clusters. A new cluster analysis was performed using the K-means method to identify the cities belonging to each cluster. Based on the clusters formed, a discriminant analysis was performed to identify whether there was an error in the distribution of observations in each cluster and to verify which variables contributed the most to their formation. The discriminant has proved to be 100% correct in the classification of cities in each cluster (Table 7).

Table 7: Classification of Clusters and Discriminatory Variables in the Formation of Clusters

Clusters/Cities		Discriminant				
		CASES_COVID	HDI	PD	INCOME	TRAF_PAS_QUAR
1	São Paulo, Recife, Fortaleza, Rio de Janeiro, and Belo Horizonte.	0,590	0,945	0,376	0,506	0,910
2	Porto Alegre, Curitiba, Vitória, Natal, João Pessoa, Aracajú, Salvador, Goiânia, Campinas, Brasília, and Camboriú.	0,433	0,930	0,873	0,497	0,348
3	Campo Grande, Florianópolis, Cuiabá, Palmas, Foz do Iguaçu, Teresina, Boa Vista, Porto Velho, Rio Branco, Macapá, Maceió, São Luiz, Belém, and Manaus.	0,077	0,896	0,661	0,370	0,029

Source: Extracted from SPSS 24.

Cluster 1 is composed of cities that concurrently present high numbers of accumulated cases of COVID-19 and a high passenger flow from national and international flights. Cluster 2 is composed of the group of tourist capitals with the highest Human Development Index, high population concentration and, for the most part, for having airports with intermediate to high passenger traffic, while cluster 3 is composed of cities which airports have the lowest flow of arrivals and departures, in addition to concentrating the capitals with the lowest populational densities in Brazil. The discriminant analysis enabled the identification of the variables that were important to discriminate each cluster (Table 7). The important variables to discriminate cluster 1 were CASES_COVID and TRAF_PASS_QUAR. The variable PB was important in discrimination of cluster 2.

5 CONCLUSION

This research aimed at evidencing the impact of passenger traffic in the airports of Brazil major tourist destinations and its relationship to the spread of COVID-19 pandemic. Based on the multiple regression modeled for this research, it was possible to add a high influence of the variable TRAF_PASS_QUAR, with a positive effect, in relation to the increase in cases of COVID-19 in the main capitals and tourist cities of Brazil

This effect was even more evident in cities with a high population density (São Paulo, Rio de Janeiro, and Fortaleza) associated with the fact that these cities are the main ports of entry in Brazil for flights from Europe (Italy, France, Germany, Spain, and Portugal) and the United States – all countries that had high number of COVID-19 cases between March and June. In this perspective, initially, there was a strong concentration of cases in Brazil in the country's coastal region, mainly because it contains the largest metropolitan areas and where the busiest international airports in Brazil are located. Capitals located in the central region and with less busy airports (Campo Grande, Palmas, Cuiabá, and Teresina) had a lower number of cases of the disease, as well as capitals and tourist cities in the southern region of Brazil (Curitiba, Florianópolis, Porto Alegre, Balneário Camboriú, and Foz do Iguaçu), which still have the highest human development indexes, which demonstrated a negative effect regarding the dissemination of COVID-19 cases.

Therefore, equation (2), which is the result of the multiple regression, obtained a high predictive factor (adjusted R2 = 0.833), allowing the construction of a scenario capable of assessing how the development of the pandemic would have been had the airports maintained their regular activities. The results pointed out in this study affirm that the measures that determined the reduction of around 65% in the route network in the country, after the beginning of the pandemic, prevented a significant increase in the number of cases of the disease in important cities of different regions of Brazil, considering the observation deadline established (March 31, 2020), as: Porto Alegre (2,438%), Curitiba (1,283%), Campinas (1,212%), Brasília (307%), São Paulo (171%), and Rio de Janeiro (101%).

The results help to understand the current crisis faced by the tourism industry. The continuous growth shown in the last decades was accompanied by the development of the air industry. With the correlation found between passenger flow and the number of cases of COVID-19, it becomes clear that public policies on travel restrictions are effective to control the Pandemic; however, they also act directly to discourage tourism. Thus, a challenge for the entire industry is imposed: without proper control, at global or national level, of the Pandemic (either by reducing the number of cases or vaccine) air travel will continue to suffer some type of restriction and tourism, as a whole, will operate below its normal capacity. Although countries or even blocks (such as Europe) may have stronger control over COVID-19, the global status of the crisis will continue to condition air travel to various types of restrictions.

Thus, it is expected, throughout the crisis, a continued negative impact on jobs, revenues, and tax collection linked to the industry, affecting workers, companies, and governments. The development of health strategies to increase safety in tourism will involve extra care for passengers during flights and at airports, in addition to hotels and tourist sites, also involving monitoring travelers after their return. While increasing security, these actions act as restrictions so that the number of trips is likely to remain well below the pre-Pandemic expectation.

A reading of this scenario points to a favoring of local tourism and faster recovery of domestic (national) tourism, considering shorter distances, making it possible to travel by private car and less time traveling by plane; fewer transitions between sanitary and legal barriers; better assessment of travel risks; and faster recovery in low-cost tourism, something valid in response to the economic crisis and compatible with less desire to invest in tourist experiences limited by Pandemic.

It is suggested, for the development of future research, the application of the methodology proposed in this research for the rail, waterway, and road modes of transportation, in order to measure the weight of each mode in the transmissibility of pandemics. The application of this methodology in other international regions, such as continental areas or those related to trading blocks, is also important.

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APPENDIX

Appendix A – Data used in the analyses.

Cities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Aracajú	4,061	0,770	3,607	25,186	213,215	76,680	861	0	223	0	74.12%	*	11142.96	174.39%
Belém	11,591	0,746	1,409	20,821	610,872	237,899	2232	120	786	20	64.78%	83.26%	25666.95	121.44%
Belo Horizonte	1,852	0,810	7,581	35,245	1,912,732	636,798	8161	225	2307	48	71.73%	78.77%	69474.48	3651.32%
Boa Vista	2,761	0,752	70	26,924	60,454	25,870	201	0	76	0	62.19%	*	4682.282	69.59%
Brasília	8,807	0,824	523	80,502	2,920,933	944,791	10036	456	2795	99	72.15%	78.19%	96914.44	1000.43%
Camboriú	390	0,845	3,147	38,062	345,411	112,255	1375	0	331	0	75.93%	*	7242.094	1756.95%
Campinas	1,753	0,805	1,515	49,243	1,786,484	947,298	7984	935	3111	638	61.03%	31.80%	60325.66	3341.28%
Campo Grande	312	0,784	111	30,925	242,879	89,132	1008	0	332	0	67.10%	*	7613.165	2340.12%
Cuiabá	747	0,785	188	39,486	463,854	179,692	2094	1	682	0,67	67.42%	33.33%	15267.47	1943.84%
Curitiba	984	0,823	4,445	44,385	1,068,921	378,862	4895	136	1392	71	71.55%	47.36%	35947.79	3553.23%
Florianópolis	679	0,847	742	40,163	764,875	258,512	2460	500	696	67	71.69%	86.60%	19535.64	2777.12%
Fortaleza	23,613	0,754	8,546	23,437	1,262,584	403,139	3849	265	1057	55	72.55%	79.12%	53725.46	127.52%
Foz do Iguaçu	126	0,751	418	50,991	458,986	130,532	1508	102	346	19	77.07%	81.05%	18972.93	14957.88%
Goiânia	1,661	0,799	2,080	33,438	500,918	168,197	2254	0	627	0	72.19%	*	16696.89	905.23%

João Pessoa	3,959	0,763	3,852	24,320	264,461	101,818	955	6	257	1	73.09%	87.88%	13897.63	251.04%
Macapá	5,035	0,733	77	21,055	113,018	43,503	390	0	147	0	62.17%	*	8571.393	70.24%
Maceió	5,891	0,721	2,001	21,210	451,013	138,629	1549	6	378	1	75.61%	75.76%	23317.28	295.81%
Manaus	18,293	0,737	191	34,363	563,478	216,946	2343	230	919	117	60.75%	48.87%	23926.61	30.80%
Natal	3,120	0,763	5,281	26,497	482,611	145,937	1592	89	369	30	76.84%	66.10%	22742.22	628.92%
Palmas	6	0,788	134	28,754	84,466	32,174	384	0	120	0	68.71%	*	1684.694	27978.24%
Porto Alegre	743	0,805	2,995	49,741	1,396,448	480,829	5476	458	1524	93	72.17%	79.74%	48033.77	6364.84%
Porto Velho	3,495	0,736	16	31,793	122,916	51,556	441	0	184	0	58.20%	*	8538.595	144.31%
Recife	15,474	0,772	7,520	31,744	1,647,969	616,316	6229	254	1808	68	70.97%	73.23%	64306.62	315.58%
Rio Branco	4,104	0,727	46	21,259	66,520	26,382	303	0	92	0	69.70%	*	7573.708	84.54%
Rio de Janeiro	29,157	0,799	5,598	51,776	4,212,082	1,322,624	14233	2387	3571	554	74.91%	76.79%	149007.1	411.05%
Salvador	11,087	0,759	4,142	21,231	1,501,168	478,554	5314	272	1376	49	74.11%	81.86%	57651.56	419.99%
São Luís	9,255	0,768	1,890	27,226	278,641	102,880	995	0	324	1	67.40%	*	12139.76	31.17%
São Paulo	60,131	0,805	8,055	57,759	11,423,156	4,021,767	33653	5914	9611	1865	71.44%	68.46%	401628.3	567.92%
Teresina	2,304	0,751	622	22,482	207,854	76,207	748	0	219	0	70.66%	*	10404.74	351.59%
Vitória	2,453	0,845	3,728	55,779	556,407	183,251	2232	0	680	0	69.55%	*	15097.03	515.45%