Analysis of urban health and mobility indicators and their relationship with Covid-19: The Case of Passo Fundo -RS

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ABSTRACT

Urban areas are expanding rapidly, and the lack of appropriate urban planning has resulted in environmental impacts, compromising the health of cities and their inhabitants. In this context, the concept of Smart Cities, through the use of Information and Communication Technologies (ICTs), can help public managers to outline more assertive strategies for city problems through the measurement of urban indicators. Therefore, the objective of this research is to analyze the health and mobility indicators of Passo Fundo/RS and their relationship with the epidemiological data of COVID-19. The methodology used in this research was a comparison between Passo Fundo's health and mobility indicators and the same indicators from medium-sized cities in the South of the country best classified in the Connected Smart Cities Ranking of 2021, 2022 and 2023. Soon after, the survey was carried out of the rates of infections and deaths resulting from COVID-19 in these same cities. From the results it was possible to verify that some of the main weaknesses in relation to mobility are public transport and low incentive for active mobility. In the health area, the city presented some satisfactory results, but lacks investment in family health programs and updates to the online medical consultation process. In relation to epidemiological data, it was noticed that the cities best classified in the Ranking had a better fight against the pandemic by implementing ICTs in the consultation management process.

KEYWORDS: Urban Health. Smart Cities. Urban Indicators.

1 INTRODUCTION

Disorderly urban growth without proper planning can affect the distribution of urban form, its efficiency, equity and sustainability, as well as economic aspects (Marques et al., 2021). According to Almeida, Cota and Rodrigues (2020), the lack of planning and adequate infrastructure leads to the proliferation of infectious diseases. Thus, the urban environment can become a major generator of diseases, and such aspects are also related to social factors.

In this sense, in addition to environmental problems, urbanization can influence inequality, causing problems of violence and economic imbalance in income distribution, demonstrating the notorious reality of large cities (Shan; Ann; Wu, 2017; Furtado et al., 2020). As an example of this, the new Coronavirus (COVID-19) pandemic highlighted such social problems as hunger, lack of sanitation and support for needy families. The first cases appeared in China in 2019 and spread rapidly worldwide (Thombre; Agarwal, 2021). Thus, COVID-19 reinforced the chaos created in society, demonstrating the crisis of public management in different government spheres (Paixão et al., 2020).

Thus, the complexity and dynamism of cities requires that the methods of planning and managing public infrastructure and services be constantly changing to face the consequences and challenges of the urban environment, as well as to formulate strategies and plans for the future (Castells, 2009). Thinking about the future, smart cities are concerned with the development of the population, the environment and the city as a whole (Guimarães; Júnior; Lima, 2021). Smart cities become a support structure for municipal governments, aiming at better urban planning, greater assertiveness in decision-making and improving the quality of urban life.

With the use of information and communication technologies (ICTs), it becomes possible to collect and store data, making possible to monitor the evolution of cities and contribute to changes for the adaptation and improvement of urban infrastructure. As with the epidemiological situation of COVID-19 itself, data is the fuel for fighting the crisis, increasing

resilience, as it equips governments with the necessary tools to manage their cities effectively (Facchina, 2020). In this sense, governments can use urban data collected from ICTs as a benefit to seek the development of smarter cities and more sustainable, efficient and resilient practices (BIBRI, 2019).

Therefore, this research aims to analyze the urban health and mobility indicators of Passo Fundo, using as reference the data from the Connected Smart Cities Ranking of 2021, 2022 and 2023, as well as to compare these indicators with the indexes of the medium-sized cities in the South of Brazil best ranked in the ranking. In addition, the study aims to analyze a possible relationship between the COVID-19 pandemic indexes and the urban infrastructure of these municipalities, considering the urban mobility and health indicators collected. In addition, some mobility guidelines developed from the results found in this analysis are presented.

2 METHODOLOGY

This work was carried out through qualitative, exploratory research, based on a case study of the analysis of Health and Mobility indicators in Passo Fundo city. Thus, this research has an applied nature, which aims to seek knowledge that can be used to mitigate real problems, according to the following steps presented in Figure 2.

Figure 1 – Methodological processes
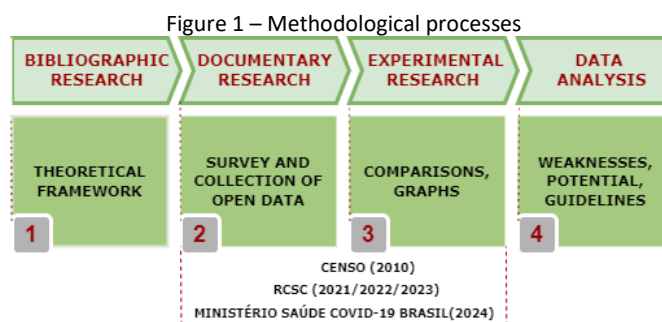
Source: Prepared by the authors (2024).

2.1 Study Object

Located in the northern part of Rio Grande do Sul state, the city of Passo Fundo (Figure 2) is characterized by being an educational, medical and economic hub. It has an estimated population of 206,215 people (IBGE, 2023). In addition, it has an urban network of small municipalities, becoming a reference in the socioeconomic and population dynamics of nearby cities (Ferreto, 2012; Muller, 2021).

Figure 2 - Location Map of Passo Fundo/RS.
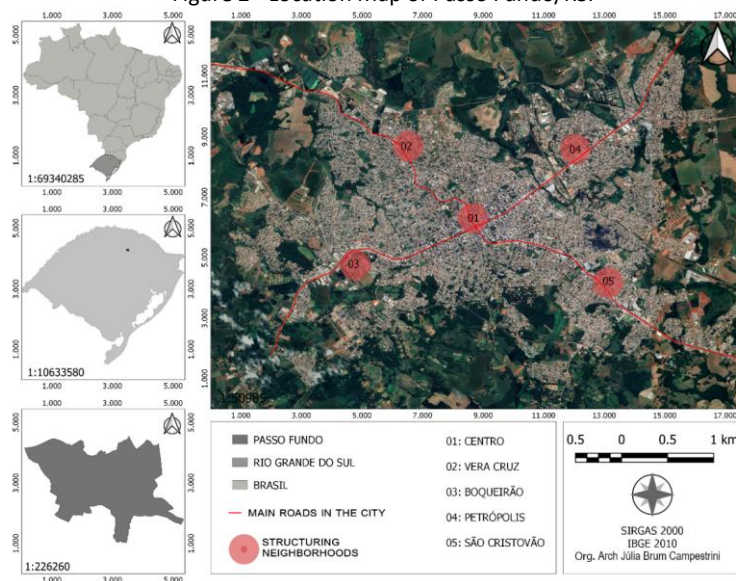
Source: Prepared by the authors (2024).

As shown in Figure 2, Passo Fundo developed along two main axes: Avenida Brasil and Avenida Presidente Vargas, where the railway was built and brought great development to the area (Prefeitura Municipal de Passo Fundo, 2014). Thus, the two responsible avenues for the city's structure are shown in red, which currently has 22 sectors, divided between neighborhoods, subdivisions and villages.

Thus, Passo Fundo city becomes the object of study, with the objective of investigating the city's development in the health area, in comparison with the medium-sized cities in the South region of the country best classified in the RCSC of 2021, 2022 and 2023, as presented in Table 1, with the aim of understanding the needs and potential of the cities analyzed in relation to public health services.

Table 1 - Classification of medium-sized cities in the South region (RCSC, 2021).

CITIES	RANKING 2021 POSITION	RANKING 2022 POSITION	RANKING 2023 POSITION
Balneário Camboriú (SC)	12º	15º	11º
Blumenau (SC)	16º	21º	16º
Jaraguá do Sul (SC)	17º	28º	31º
Maringá (PR)	25º	20º	43º
Passo Fundo (RS)	-	-	-

Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

As shown in Table 1, the four best-ranked cities in the south of the country were selected for comparison with the municipality of Passo Fundo, three of which are located in the state of Santa Catarina and one in Paraná. The comparison was then made based on the investigation of the RCSC urban indicator data presented in the next section.

2.2 Ranking Connected Smart Cities (RCSC)

The method proposed for the evaluation of this study consists of collecting data from sources referenced in Tables 2 and 3, which present the indicators of the Health and Mobility

axes of the Connected Smart Cities Ranking (RCSC, 2023), measured during the years 2021, 2022 and 2023, as well as the units of measurement provided for each indicator.

In summary, as shown in Table 2, the RCSC indicators for the health axis are related to the supply of beds, qualified professionals, coverage of care, public investments, infant mortality and remote medical care. This last indicator was listed only in 2021, shortly after the COVID-19 pandemic scenario, where isolation made it necessary to use new strategies for medical care for the population, using the internet as a means of communication.

Table 2 - Urban indicators of the Health Axis of the Connected Smart Cities Ranking (RCSC).

AXLE	INDICATOR	UNIT	SOURCE
HEALTH	Beds per thousand inhabitants	# / thousand habits	Datasus
	Doctors per 100 thousand inhabitants	# / 100 thousand bahts	CNES
	Population Coverage of the Family Health Team	%	Datasus
	Per Capita Expenditure Paid for Health	R$ / habits	Siconfi
	Deaths/thousand live births (place of residence)	# / thousand live births	Datasus
	Online Appointment Scheduling in the Public Health Network	-	IBGE - P. M.

Source: Prepared by the authors based on the 2023 RCSC.

In addition to collecting data on health indicators, an in-depth study of the health of the municipalities was carried out by collecting epidemiological data on COVID-19. The number of people infected and who died due to the Coronavirus was investigated, specifically in the cities analyzed. This data was collected from the page dedicated to monitoring COVID-19 of the Ministry of Health (Ministério da Saúde, 2024).

Table 3 presents the Mobility indicators of the Connected Smart Cities Ranking (RCSC, 2023). Data were collected from the ten indicators presented in the table. These indicators analyze public and individual transportation, cycle paths, vehicle emissions, other modes of transportation, average age of the vehicle fleet, interstate connections, air destinations, electronic public transportation tickets, and smart traffic lights.

Table 3 - Urban indicators of the Mobility Axis of the Connected Smart Cities Ranking (RCSC).

AXLE	INDICATOR	UNIT	SOURCE
MOBILITY	Cars per Inhabitant	# / 1000 inhabitants	Denatran / IBGE
	Average Age of Vehicle Fleet	years	Denatran
	Buses / cars	#	Denatran
	Other modes of public transport	KM / 100 THOUSAND INHABITANTS	Survey
	Cycle paths	KM / 100 THOUSAND INHABITANTS	Survey
	Interstate connections	Destinations	ANTT
	Number of airports with regular flights within a 100 km radius	Airports	Horans
	% of low-emission vehicles	%	Denatran
	Electronic public transport ticket	-	IBGE
	Smart traffic lights	-	IBGE

Source: Prepared by the authors based on the 2023 RCSC.

Based on these data collection, we sought to understand whether the urban indicators analyzed are interrelated with COVID-19 data, and whether the cities classified as smart by the RCSC had a better response to the pandemic, in relation to Passo Fundo city.

3 RESULTS AND DISCUSSIONS

In this section, the obtained results from the data collection regarding Health indicators and their relationship with COVID-19 data will be presented, as well as the analysis of Mobility indicators for Passo Fundo and the other cities analyzed.

3.1 Analysis of urban health indicators

The first health indicator measured was "Beds per 1,000 inhabitants", shown in Graph 1. Based on Graph 1, it can be seen that Passo Fundo had a higher rate of beds per inhabitant in 2021, one of the most vulnerable moments in the fight against COVID-19. As COVID-19 cases decreased, the number of beds in the cities analyzed also decreased.
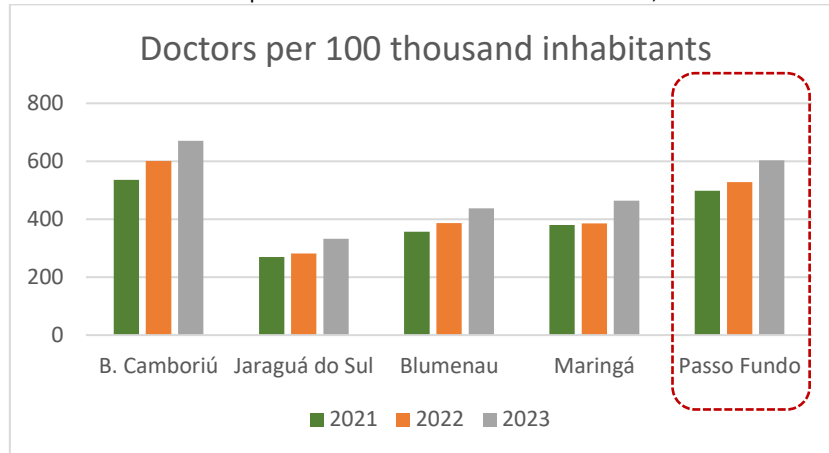
Graph 1 - Beds/1000 inhabitants' indicators in the 2021, 2022 and 2023 Rankings.
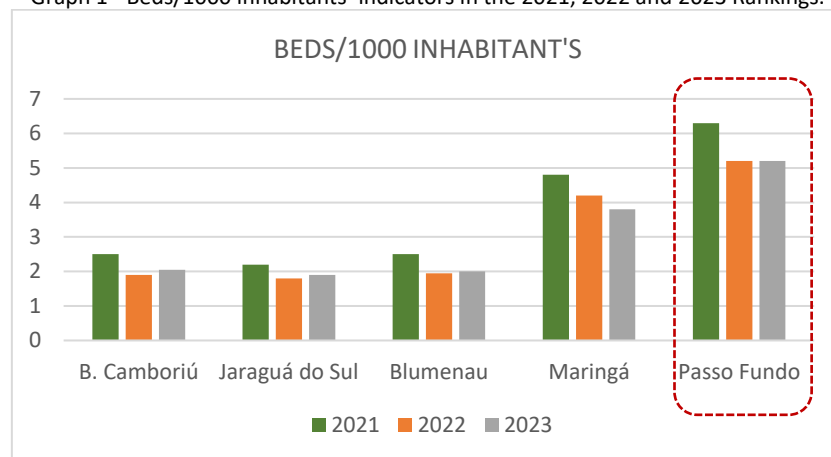
Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

In Graph 2, when comparing "Doctors per 100,000 inhabitants", the obtained results showed that there was a significant increase in this rate each year. This increase was possibly due to the need for medical care due to the COVID-19 pandemic. With the pandemic scenario, many newly graduated doctors went to work in emergency rooms, assisting in the care of patients with Coronavirus (Destefani, 2021).

Graph 2 - Indicators of Doctors per 100 thousand inhabitants in the 2021, 2022 and 2023 Rankings.

Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

Regarding the indicator "Population coverage of the Family Health Team" (Graph 3), Passo Fundo presented rates below 30% in the last three years, lacking more planning in this area. According to Graph 3, the best classified cities in relation to this indicator were Blumenau and Maringá, demonstrating concern about the service.

Graph 3 - Population Coverage Indicators of the Family Health Team in the 2021, 2022 and 2023 Rankings.
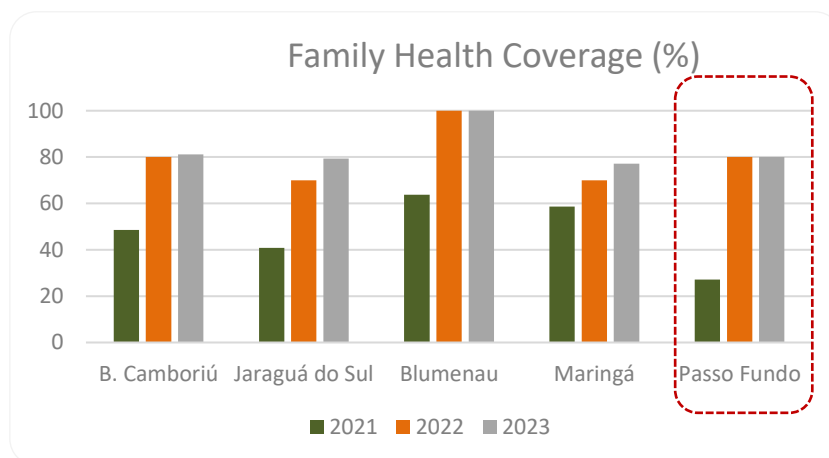
Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The fourth analysis assessed "per capita expenditure paid for health care". According to Graph 4, during the three years of the Ranking analysis, Passo Fundo presented low rates of investment in health care expenses in relation to the other cities analyzed, presenting greater investment during the year 2023, a factor that may be related to the Family Health Coverage Indicator, presented in Graph 3, since the greater the monitoring, follow-up and direction, the more resources and professionals the municipal government is allocating to such demand.

Graph 4 - Indicators of paid health expenditure in the 2021, 2022 and 2023 Rankings.
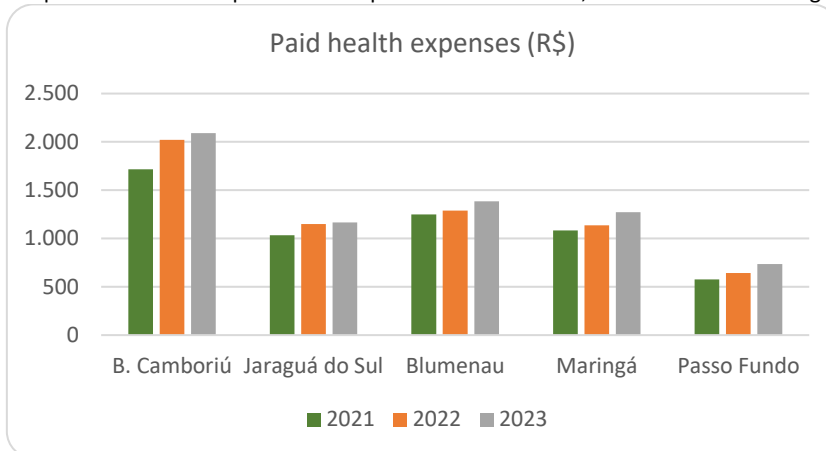
Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The fifth analysis measures the indicator of the "number of deaths per live birth" per occurrence in the municipality. As shown in Table 4, the 2021 indices showed a low number compared to the years 2022 and 2023.

Table 4 – Deaths/thousand live births (place of residence).

CITY	2021	2022	2023
Balneário Camboriú (SC)	0,7	2,5	2,1
Blumenau (SC)	2	5,3	8,1
Jaraguá do Sul (SC)	0,8	7	4,4
Maringá (PR)	1,2	4,1	4,4
Passo Fundo (RS)	1,5	5,7	7,1

Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The last indicator was added to the Health axis in the 2021 Ranking, and analyzes the cities that presented online appointment scheduling in the public health network. According to the study, Passo Fundo does not have online scheduling, Maringá only had it in 2022, and the other cities do, making it possible to observe different methods used by cities to avoid crowds and contamination during the pandemic period. This indicator is important to verify the possible methods that cities adopted, especially during the COVID-19 pandemic, to avoid crowds and the spread of the virus.

Furthermore, in order to investigate whether there is any relationship between this information and the health indicators of the cities analyzed, epidemiological data on COVID-19 were collected, as shown in Table 5. A cut-off date was used for collection, which was from March 20, 2020 to December 31, 2023. The data were collected from the Ministry of Health – COVID-19 Data (Ministério da Saúde, 2024).

Table 5 - List of COVID-19 data up to December 31, 2023.

CITY	NUMBER OF INHABITANTS	NUMBER OF CUMULATIVE CASES	NUMBER OF CONTAMINATED PEOPLE (100 THOUSAND INHAB.)	NUMBER OF DEATHS	MORTALITY (100 THOUSAND INHAB.)
Balneário Camboriú (SC)	142.295	39.099	27.477	516	362,63
Blumenau (SC)	357.199	121.969	34.146	847	237,12
Jaraguá do Sul (SC)	177.697	65.369	36.787	478	269,00
Maringá (PR)	423.666	150.964	35.633	1875	442,57
Passo Fundo (RS)	203.275	77.645	38.197	836	411,27

Source: Prepared by the authors based on the Ministry of Health (2024).

Based on the data in Table 5, we can see the city's population in the first column. This data will help us understand the context of the pandemic in each city, since despite being classified as being of the same size, there are often significant population differences. The second column shows the number of confirmed cases in the established time frame. Next, we present the number of infected people per 100,000 inhabitants, a figure that equates the populations. Regarding the number of deaths, Maringá and Passo Fundo are the cities that have had the highest number of deaths from COVID-19. However, Blumenau and Jaraguá do Sul have lower mortality rates compared to the other cities analyzed, which may be related to the search for improvements in the services offered, such as greater monitoring in basic health and through care programs, as well as greater investment per inhabitant in the health area.

Therefore, by relating the epidemiological data to the cities' health indicators, it is possible that there is a relationship between the city's infrastructure and the recovery and care of the population. However, it is worth noting that the population's attitudes towards the spread of the virus and its precautions, as well as prevention actions and campaigns in the cities analyzed, were not explored in depth in this study, but they can also influence these rates.

3.2 Analysis of urban mobility indicators

The first mobility indicator analyzed was "Cars per Inhabitant", presented in Graph 5. From Graph 5, it is possible to see that the cities analyzed have seen a slight increase in cars per inhabitant in recent years, with a greater increase in 2023 for Blumenau and Maringá. The demand for private vehicles increased after the 2020 pandemic, due to the search for safety, as public transport becomes a means of crowding (NZN, 2021).

Graph 5 - Indicators of Cars per Inhabitant in the 2021, 2022 and 2023 Rankings.
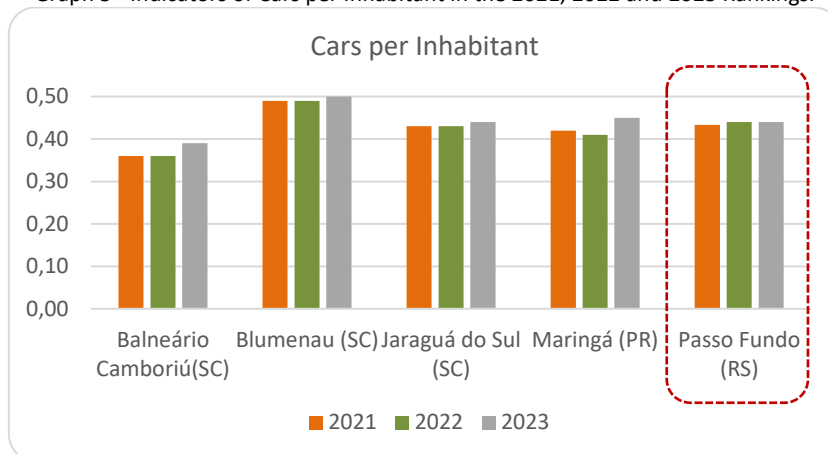
Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The seventh analysis presented the indicator of "Middle Ages of the Vehicle Fleet" (Graph 6), this indicator seeks to present better quality and speed in the public transportation, also causing health, as the oldest vehicles bring greater consequences for air quality, increasing the pollution rates. According to this research, Balneário Camboriú presented the newest vehicles in the last three years.

Graph 6 - Average Age Indicators of the Vehicle Fleet according to the RCSC of 2021, 2022 and 2023.
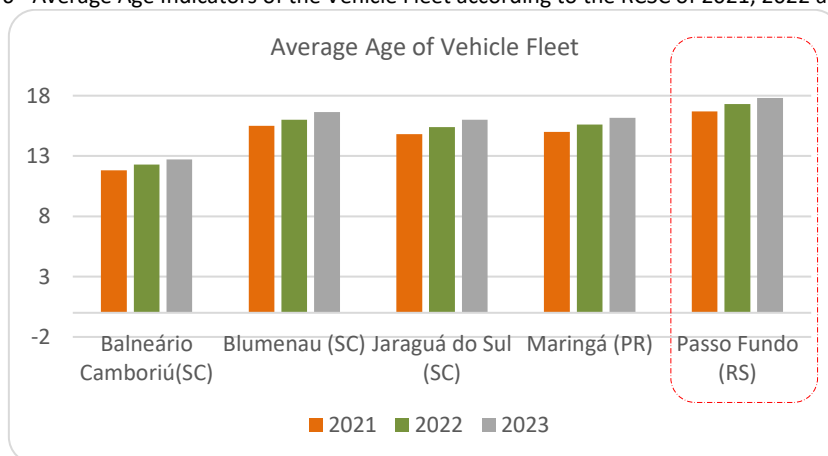
Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The next check considers the proportion of buses in relation to the number of cars. According to the analysis, the five cities analyzed had a ratio of 0.01 buses per car in the years analyzed, which indicates a large number of private vehicles in relation to public transport.

Regarding the indicator "Other Public Transport Modes", which is related to public transport other than the traditional one (buses), the five cities analyzed did not have enough public transport modes in relation to kilometers per thousand inhabitants until 2022, a factor that began to be counted in the year 2023. However, the rates are still low, making it necessary for the cities analyzed to take measures and initiatives to improve and readjust the public transport offered, seeking to encourage the use of these means.

According to the results in Graph 7, Passo Fundo and Maringá have lower rates of bike lane kilometers per 100,000 inhabitants, while the other cities demonstrate greater investments in this means of transportation, especially the city of Jaraguá do Sul, which recorded approximately 50 km of bike lanes per 100,000 inhabitants in the three years of analysis. This analysis provides greater visibility regarding the cities' concern with active mobility in the municipality, guaranteeing the right to transportation in an accessible and safe manner.

Graph 7 - Indicators of km of cycle paths according to the RCSC of 2021, 2022 and 2023.
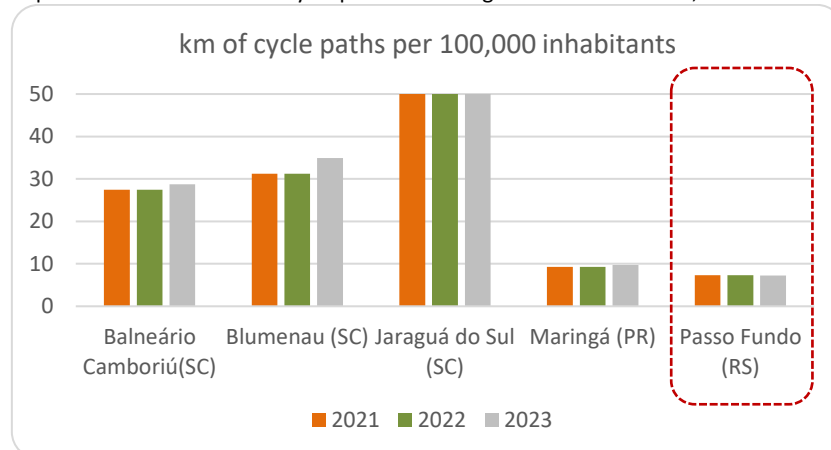
Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

Graph 8 aims to inform the number of road destinations outside the state. In Passo Fundo, interstate destinations decreased from 2021 to 2023, which may be related to the increase in private vehicles and the reduction in highway bus schedules during and after the pandemic period. In this regard, Balneário Camboriú and Maringá had the highest number of interstate connections among the cities compared in 2021, however, their destinations also decreased after 2022.

Graph 8 - Indicators of interstate connections according to the RCSC of 2021, 2022 and 2023.
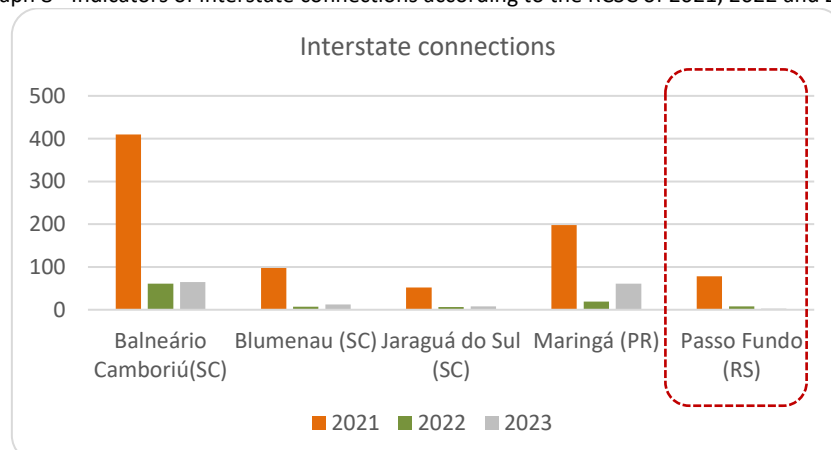

Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The next analysis concerns the indicator of "number of airports within a 100 km radius" of the city under analysis. For this indicator, the numbers remained constant in the three

measurements (2021, 2022 and 2023), being respectively: 3 airports for Balneário Camboriú/SC; 2 for Blumenau/SC; 2 for Jaraguá do Sul/SC; 2 for Maringá/PR and none for Passo Fundo/RS. However, the Passo Fundo airport, which had been closed since 2021 for expansion works on the runway and passenger terminal, resumed operations in April 2024.

Table 6 presents the Low Emission Vehicle indicators, where Balneário Camboriú appears in first place during the three years of analysis, while Passo Fundo shows rates below the other cities, signaling the need for alternatives that aim at the adoption of newer and more efficient alternative vehicles, as seen in the analysis of Graph 6.

Table 6 - Indicators of Percentage of low emission vehicles according to the RCSC of 2021, 2022 and 2023.

| Percentage of low emission vehicles	2021	2022	2023
Balneário Camboriú (SC)	0,26%	0,74%	1,09%
Blumenau (SC)	0,07%	0,16%	0,26%
Jaraguá do Sul (SC)	0,06%	0,14%	0,23%
Maringá (PR)	0,07%	0,17%	0,25%
Passo Fundo (RS)	0,03%	0,09%	0,15%

Source: Prepared by the authors based on the RCSC of 2021, 2022 and 2023.

The research includes an analysis of the "Electronic Public Transport Ticket Indicator", in which Passo Fundo has not yet adopted this technology. Thus, it is suggested that in the future the city can improve public transport, and increase its quantity as seen in the Buses per Car Indicator, and seek to introduce automation systems, in search of safety and a better quality of life for its citizens.

Finally, the Connected Smart Cities Ranking also analyzes the Smart Traffic Lights Indicator. In this survey, all cities analyzed presented the use of this technology. The collection of information through the use of Smart Traffic Lights can be used for safety alerts, assistance to drivers and traffic control (Aquino, et al. 2015).

3.3 Relationship between mobility and health indicators

The map presented below (Figure 3) seeks to understand the relationship between active urban mobility in Passo Fundo and the main points of health units in the municipality, in order to find easy access to transportation. Law 12.587/12 on Urban Mobility (2013, p. 9) has as one of its objectives "to promote access to basic services and social facilities; and provide improvements in the urban conditions of the population in terms of accessibility and mobility". For this survey, public transportation and cycle path maps were used to map this data together with the health points identified through the use of the Google Maps tool (2022).

Figure 3 - Mobility Study Map and Health Points of Passo Fundo/RS.
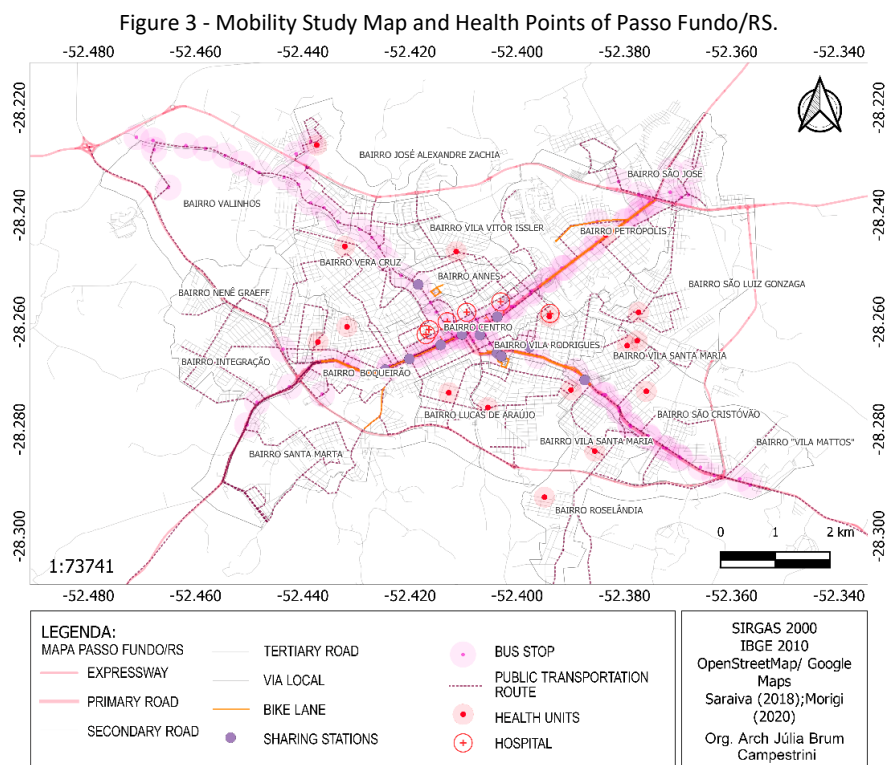
Source: Prepared by the authors (2022).

As shown in Figure 3, it is possible to see that Passo Fundo allows greater accessibility to health services through public transportation, a satisfactory result, since it helps citizens to get around more easily, as well as urban health through the relationship with the urban environment, reducing excessive traffic of private vehicles and the release of polluting gases into the air. However, in relation to active mobility (cycle paths), the municipality covers the central, eastern and southeastern regions, making it necessary to have greater coverage in the other neighborhoods of the city.

Although Passo Fundo presents positive results, it is necessary that the municipality's mobility planning continues to be reviewed, so that the development of the municipality's infrastructure and urban services can offer greater safety, accessibility, well-being and sustainability to its citizens.

Based on data from the indicators and official data from the City Hall of Passo Fundo, guidelines were developed to improve urban mobility in this city. In line with the Municipal Urban Mobility Plan (Prefeitura Municipal de Passo Fundo, 2014) and the "Passo Fundo vai de Bici" Program, a map was created showing the current situation of cycle paths and shared stations. Based on this diagnosis, the axes of mobility stimulus are presented in the map in Figure 4.

Figure 4 - Map of Proposals for Active Mobility in Passo Fundo/RS.

Source: Prepared by the authors (2022).

As shown in Fig. 4, the induction axes for the creation of the cycle path network are located along Av. Brasil, both in the direction of the Boqueirão neighborhood and in the Petrópolis neighborhood. The third induction axis is located next to the São Cristóvão neighborhood. It is worth noting that in addition to the cycle path network, the entire necessary structure of shared stations, signage and information will also be necessary.

Another important point analyzed through the indicators is the high coefficient of cars per inhabitant, combined with the old vehicle fleet and the small percentage of low-emission cars. Given these rates, a solution that could optimize and mitigate these effects is to increase the incentive to use public transportation. As a way to encourage the use of this means of transportation, there is the use of electronic ticketing, the creation of applications for real-time route tracking, monitoring equipment (GPS) and universal accessibility.

4 RESULTS AND DISCUSSIONS

The research presented a survey and analysis of urban Mobility and Health indicators for Passo Fundo city and the four medium-sized cities in the Southern region of Brazil that ranked best in the Connected Smart Cities Ranking of 2021, 2022 and 2023.

From these initial analyses, it was possible to identify Passo Fundo's weaknesses and potential. Therefore, compared to the other four municipalities, Passo Fundo has some indicators that require greater attention, especially in the indicators of "Population coverage of the Family Health Team", "Health expenses paid", "Average age of the vehicle fleet", "Km of cycle paths per 100 thousand inhabitants" and "Percentage of low-emission vehicles".

Regarding COVID-19 data, there was a significant change between the three years of analysis in the health and mobility axis. However, future research is needed to investigate other issues in the cities analyzed that may have influenced the rates of contamination and deaths

from COVID-19, such as strategies to combat dissemination and even cultural issues, to provide a better basis and understanding of these analyses.

Finally, even with regular results, it is important to encourage Passo Fundo to implement new strategies to strengthen health, in order to provide quality services to its citizens, as well as investments and initiatives in the area of mobility, especially in public transportation and automation systems, seeking to provide citizens with greater flexibility in movement and a better quality of life.

Therefore, measuring and monitoring urban indicators of smart cities becomes an interesting alternative for cities, as they can help public managers to have a greater understanding and transparency of the current situation of their cities, so that it is possible to outline new strategies for improvements and adaptations for urban planning.

ACKNOWLEDGMENTS

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