Ride-hailing apps and equity: an accessibility study in Porto Alegre/RS

Aplicativos de transporte e equidade: um estudo de acessibilidade em Porto Alegre/RS

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Abstract

The arrival of ride-hailing apps in Brazil has raised concerns about their negative impacts on urban mobility. However, it was expected that they could serve as a complement to public transport and as a substitute for private cars, theoretically improving urban accessibility and potentially reducing inequalities in urban mobility. This study assessed this hypothesis in the city of Porto Alegre/State of Rio Grande do Sul (RS) and described the access of different socioeconomic groups to the city's main destinations using an accessibility indicator composed of time and monetary cost. Results indicate that ride-hailing apps significantly exacerbate inequality between income groups, particularly for frequent trips. However, they can be a viable option for occasional trips even for low-income communities.

Keywords: apps; accessibility; equity; inequality.

Resumo

A chegada dos aplicativos de transporte ao Brasil gerou preocupações quanto a seus impactos negativos na mobilidade urbana, porém havia a expectativa de um serviço complementar aos sistemas públicos e de substituição dos automóveis privados, aumentando, em tese, a acessibilidade das cidades e podendo reduzir as desigualdades na mobilidade urbana. Este estudo avaliou essa hipótese em Porto Alegre/RS, descrevendo o acesso de diferentes grupos socioeconômicos aos principais destinos da cidade por meio de um indicador de acessibilidade composto por tempo e custo monetário. Os resultados indicam que os aplicativos aumentam fortemente a desigualdade entre os estratos, especialmente em viagens frequentes. Porém, eles podem ser uma opção viável para deslocamentos ocasionais até para a população de baixa renda.

Palavras-chave: *aplicativos; acessibilidade; equidade; desigualdade.*

Introduction

The 2010s marked the arrival of individual motorized transport service companies in Brazil. Bringing a service known in English-speaking countries as ride-hailing, these private companies offer individualized transport by individual motorized vehicles, seeking to occupy a niche in urban transport services (Dudley, Banister and Schwanen, 2017). They present themselves as a service similar to a conventional taxi with more conveniences, such as the form of request (via mobile phone apps), generally lower prices (exempt from state regulations), and a significant supply of vehicles at all hours of the day (Rayle et al., 2016). As far as conventional taxis, there are crucial differences regarding the regulations of the vehicles and drivers that provide the service, with taxi permits, as a rule, being more stringent.

This service is now accountable for an enormous volume of trips in Brazilian cities. Uber, the company with the largest market share in the country, reports having 1 million "partner" drivers and delivery people and 30 million users in more than 500 Brazilian cities (Uber, 2023). "99", the main competitor on a national level, reports having 600,000 registered drivers and 18 million users in more than 1,600 cities (99, n.d.). Data on the number of trips is not public (probably due to market and competition issues), but both have already reported the mark of one billion trips – Uber in 2018 and 99 in 2020 (Uber, 2018; 99, 2020).

Such companies are known for being part of what was once called "sharing economy" in urban mobility, an economic model that provides access to goods and resources without necessarily having an ownership relationship. It is through sharing between different people and the popularization of the internet and social networks that these dynamics are solidified (Martin, 2016; Puschmann and Alt, 2016). Some authors refer to this model as "neoliberalism on steroids" because they expand the limits of neoliberal doctrine to aspects of life previously beyond the reach of the market. The reasons rely on the lack of government regulation in the areas they operate (lobby against contrary regulations to their commercial interests) and the precarious work relationships observed (Cockayne, 2016; Martin, 2016).

These commercial initiatives are based on a disruptive *innovation strategy* (typical of the Silicon Valley context in the United States, from where they emerged), synched with ideas of transformation and the imperative *need for* change. It is essential to highlight that this need for change, anchored in the same ideas of depletion of natural resources and the search for sustainability, aims to maintain capital's profit rates and the survival of capitalism itself. That is, entrepreneurs perceive the depletion of certain businesses, such as the massive sale of individual cars, and propose new models more suitable to current times.

Companies in this environment usually arise as "startups" (emerging technological innovation companies) because they grow through external investment. It is usual that companies behind transport apps do not generate profit, even after more than a decade of operation. Hence, they choose to continue expanding their business and retain customers, through discounts or lower fares, in an attempt

to win competing companies in the long term (Mota, 2019) as they continue to raise funds from investors or have become publicly traded companies, such as Uber (Bertão, 2019). Furthermore, there is a great expectation that, in the future, ride-hailing services will operate through driverless autonomous cars, substantially reducing companies' operating costs and enabling them to start making profits.

In 2014, the appearance of ride-hailing apps in Brazil was simultaneous to the decline in the use of public transport. According to the National Association of Urban Transport Companies (NTU, 2022), from 2013 to 2019, there was a 26% decrease in the number of equivalent passengers transported per month on the bus systems of nine of the country's main capitals, with the reductions being even greater relevant when analysing the years 2020 and 2021, strongly impacted by the covid-19 pandemic. Other factors, such as the economic recession intensified from 2015 onwards, may also have contributed to the drop in demand. However, several studies have already shown that the service attracts an expressive number of people who could be traveling by public transport (Rayle et al., 2016; Henao, 2017). This is a phenomenon seen not only in Brazil, but also in the rest of the world.

Furthermore, the rise of ride-hailing apps occurred at a historic moment of intense debate about urban mobility in Brazil. In 2013, the country had gone through a series of demonstrations at a national level that began as protests against the increase in public transport fares in the main capitals (Verlinghieri and Venturini, 2018). The demands were associated with the increase in the cost of a service that is essential for the low-income population, and which is historically unreliable and overcrowded (Vasconcellos, 2018). Low-income workers travel, on average, 20% longer than the richest, and 19% of the poorest spend more than an hour traveling daily compared to 11% of the richest in the eminent metropolitan regions of the country (Pereira and Schwanen, 2013). These shorter times experienced by the high-income population are mainly due to the financial ability to purchase their own cars, simultaneously with being able to choose a better residential location, generally close to urban centers where most destinations of interest – the "opportunities" – are concentrated (Guimarães and Lucas, 2019; Pereira et al., 2019).

After the start of the companies' operations and the establishment in most of the country's medium and large cities, there was a period of massive protests from city halls (in many cases encouraged by movements of taxi drivers and companies operating public transport), seeking to regulate or even prohibit the operation of companies. Although some of these rules came into force, there were few cases in which companies effectively stopped operating, mainly due to court decisions and lobbying by companies (Pasqual and Petzhold, 2018).

Federal law 13.640/2018, which regulates the paid private individual transport of passengers, was a milestone for the consolidation of the service in the country, as it exempted the federal government from responsibility and established that it is up to the municipalities to regulate and supervise the service (Brasil, 2018). Thus, there was a

period of consolidation in which, as a rule, services were allowed to operate in cities with some licensing requirements for companies and had minimum parameters for vehicles (Pasqual and Petzhold, 2018). Although several municipalities institute a fee for road use, usually per kilometre travelled, there are few places where taxes are paid – São Paulo is where the charge is effectively applied. In 2019, companies paid around R$215 million to the municipality (São Paulo, 2019).

On the other hand, issues linked to the employment situation of drivers remain little or not regulated at all (Pasqual and Petzhold, 2018), to the point of giving rise to a specific term to refer to this model of precarious work without social protection: “uberization” (Franco and Ferraz, 2019). In this regime, the partner driver has the flexibility to work for as many hours and hours as possible. Partner drivers are not considered employees, as the app only works as a platform between them and passengers. It functions under an idea of “freedom” that, in practice, can be seen as precarious informal work since drivers do not have access to labour rights or guarantees, regardless of how many hours or days they work.

Although apps generate an increase in the number of trips made by car and, consequently, negative impacts on traffic and environmental aspects, there was an expectation that they would be able to complement public transport and, in the long term, reduce purchases of individual vehicles, as it would reduce this need for many people, especially those in the middle class (Diao, Kong and Zhao, 2021).

One can also speculate about a possible increase in the city's general accessibility generated by the ride-hailing apps, as they offer a transport alternative to people who do not have their own vehicle or live in regions poorly served by public transport systems. Meanwhile, the service was announced for the middle and upper classes as an engrossing reinforcement to their transport options, which were already satisfactory. This panorama could increase the equity in urban mobility by potentially reducing the gap between the accessibility levels of the poor and the rich.

The two key concepts under discussion here are accessibility and equity. Accessibility is a classic concept in geography and transport, generically defined as *people's ability to reach services, activities, and goods* (Hansen, 1959; Levinson and King, 2020). In other words, accessibility is about being able to reach the "opportunities" that the city offers - the places where they will carry out activities and/or meet their needs, such as work, education, or leisure, among others (Levinson and King, 2020).

Accessibility is generally treated quantitatively, with models and metrics that assign accessibility values to spatial units through different components. In the meantime, equity is a multidimensional concept of a more abstract and subjective nature interpreted differently by separate social disciplines, including an understanding of *justice*.

Recently, studies on urban accessibility have evolved towards incorporating discussions on equity and justice, seeking to evaluate inequality between areas and social groups, under the assumption that the greater this imbalance in accessibility, the lower the equity in the city (Pereira, Schwanen and Banister, 2017; Guimarães and Lucas, 2019).

The approach that has been consolidating itself in transport studies bases itself on the principle of justice as fairness, popularized by John Rawls in his 1970s work on distributive justice and equity, which assumes that factors beyond reach, not chosen, non-discretionary – such as being born into a lower-class family or from an ethnic-racial minority – should not influence a person's life chances and opportunities. Therefore, when faced with issues such as the distribution of social goods, individuals should not be treated equally, as they are culturally, economically, and socially unequal (Rawls, 1992).

According to this approach, the potential increase in the specific levels of accessibility of the less favoured population generated by the apps should be more considerable than that of other classes, thus contributing to the reduction of differences between poor and rich in terms of access to the city and, consequently, to increase urban equity.

Nonetheless, considering reality, the high cost of the service makes this increase in accessibility for the low-income population questionable. Such aspect can be aligned with the uncertainty generated by "surge pricing" (a method to, in theory, balance supply and demand and explore peak times and times of greatest need, such as on rainy days). Likewise, the deliberate exclusion of specific regions of cities also raises questions about the inclusive nature of this service (Young and Farber, 2019; Furtado et al., 2020).

The relationship between the use of ride-hailing apps and neighbourhood characteristics is a well-established aspect in recent bibliography that includes concerns about equity, especially that published in North America, which indicates that, in general, the most drastic use of this mode occurs in regions of high density, better served by public transport and with a higher-income resident population (Baker, 2020; Barajas and Brown, 2021; Jiao and Wang, 2021).

While specifically exploring the relationship between apps and public transport, Cats et al. (2022) used data from six American and European cities and found that most trips had a viable public transport alternative, while 20% to 40% did not.

Also, the work of Oliveira Souza et al. (2021) related ride-hailing services to accessibility inequalities and compared access to formal jobs generated by them with public transport in Rio de Janeiro. The results indicate that accessibility to jobs is greater per app only in regions with a high number of jobs and in cases where two or more passengers share the trip due to the monetary cost of the trips (ibid.).

Our study contributes to the existing body of knowledge in this field of research by addressing *the effects of ride-hailing apps on accessibility and their impact on equity in urban mobility.* Through a case study in Porto Alegre, Brazil, we compared accessibility based on time and cost to different opportunities in the city

provided by apps and public transport. Porto Alegre is a pioneer in the qualification of public transport by bus and an innovator in alternative services and active mobility between the 1970s and 2000s. While using inequality indexes, we gauge their differential impact for different socioeconomic strata.

Methodology

This is a study based on secondary data and with a quantitative approach, using travel models in Geographic Information Systems (GIS) supported by programming scripts in R language of the multimodal travel routing tool r5r. r5r is a package for open source routing developed in Java for the R language based on the R5 tool, established by Conveyal (Conway, Byrd and Van Eggermond, 2018; Conway and Stewart, 2019; Pereira et al., 2021).

The unit of analysis are hexagonal cells with a diagonal of 357 meters that make up the H3 mesh originally developed by Uber (Pereira et al., 2021). The Porto Alegre network covers the entire area of the municipality and totals 6,114 unique cells.

The appraisal of inequality works through an application of an adaptation of the Palma measure, which consists of calculating the ratio between the accessibility of the richest 10% and that of the poorest 40%.

Source and destination data

Porto Alegre's population and socioeconomic data were obtained from the "Accesso a Oportunidades" Project, which produces data from the 2010 Census of 27 cities in the country available free of charge, reaggregated into their respective hexagonal grids. The average household income of the population, classified into quintiles and deciles, was the data used to characterize the population residing in the hexagon, whose centroids are the points of origin for accessibility calculations.

Destinations are urban opportunities, places where activities regarding work, education, shopping, health, and leisure happen. These are the main purposes why the majority of trips in Porto Alegre occur (Empresa Pública de Transporte e Circulação, 2004). Work and education generate utilitarian or mandatory travel, while other purposes require complementary or accessory travel.

Data regarding the location of formal job positions were obtained from the Annual List of Social Information (Rais) of the Ministry of Labor and Social Security for the year 2020 (Brasil, 2020), while the locations with educational opportunities (universities), health (hospitals), shopping (shopping centers and large supermarkets), and leisure (public parks) had their coordinates obtained from databases in the municipality of Porto Alegre[1] or from entities[2] linked to each sector.

The position in the city space of these locations was georeferenced and assigned to the hexagon within which they are.

Transport data

The research regarded travel by public transport by bus (Porto Alegre does not have an intra-urban metro system) and by ride-hailing apps – Uber[3] and 99[4] companies that dominate 95% of the Brazilian market (Carneiro, 2019).

Data relating to public transport's operation were obtained from the City Hall in the GTFS (General Transit Feed Specification) format, which contains the location of stopping points, the trajectory of the lines, and the frequency of trips. The data refers to one working day of operation in May 2019,[5] which leads to a reflexion upon a pre-covid-19 pandemic scenario (2020-2022), when the operation of public transport was largely affected and was still at levels outside of normality during the development of this study.

Accessibility measures

The concept of accessibility in urban planning dates back to the 1950s when it was defined in Hansen's pioneering work as 'the potential for opportunities for interaction', that is, 'a measure of the spatial distribution of activities from a point' (Hansen, 1959, p. 73; our translation). Hansen's definition can be expressed by Equation 1, known as the "Hansen equation" (Levinson and King, 2020):

$$A_i = \sum_j O_j f(C_{ij}) \qquad (1)$$

Where:
Ai = accessibility from location i;
Oj = number of opportunities available at destination j;
f(Cij) = impedance function / cost of the trip from i to j;

The result is "cumulative opportunities" – the number of destinations accessed within a range of time, distance, or monetary cost (Geurs and van Wee, 2004; Levinson and King, 2020).

The advantages of this measure are that it requires relatively little data and is easy to communicate for non-experts, in addition to allowing comparisons between times and locations (Levinson and King, 2020). Among the disadvantages are the arbitrary choice of the maximum travel time interval, the non-consideration of competition effects (restrictions on the internal supply of opportunities, such as job vacancies and in schools and hospital beds, for example), and the non-consideration of individual and subjective factors, such as people's preferences (Geurs and van Wee, 2004; Levinson and King, 2020).

The measure used here is an adapted version of the cumulative opportunities measurement in order to incorporate the monetary cost of travel. Also, it embodies people's ability to pay for travel from their home location. *It is called time- and cost-based accessibility.*

Towards trips by public transport, the price considered was the Porto Alegre urban bus fare in May 2019: R$4.55. For ride-hailing apps, the study used simple averages of the estimates provided by the Uber and 99 platforms, presented in Equations 2 and 3:

$$T(uber)=2{,}01+0{,}36*t(min)+1{,}12*d(km) \geq R\$5{,}60 \quad (2)$$

$$T(99)=2{,}50+0{,}15*t(min)+2{,}20*d(km) \geq R\$8{,}15 \quad (3)$$

To simplify the calculations for the sake of brevity, the "surge pricing" was not considered in this study, making meaning that the values considered may be different – in general, underestimated – on some occasions. Surge pricing is a mechanism existing in both apps as a price adaptation strategy that aims to maximize gains during peak hours or great competition for the service.

Chart 1 – Number of trips per month by purpose of trave

Motives / Opportunities	Trips/month	Percentage
Work / Work centers	22	22/53
Work and Study / Universities	16	16/53
Work, Shopping, and Leisure / Shopping Centers and grocery-stores	6	6/53
Work and Health / Hospitals	3	3/53
Leisure / Parks	3	3/53

Source: developed by the author, in 2023.

The calculation of cumulative accessibility begins by calculating the feasibility of a trip, which depends on two factors. Firstly, the average number of trips made for each travel purpose in a month, based on the mobility patterns of the local population. According to the latest Origin and Destination Survey of Porto Alegre, a mobile person makes, on average, 2.4 trips per day – approximately 53 trips per month (EPTC, 2004).

Chart 1 presents the breakdown of this total number of trips for different purposes, which was estimated based on two sources: the Porto Alegre Origin and Destination (OD) survey (EPTC, 2004) and the national survey "Urban Population Mobility" (CNT and NTU, 2017).

The second feasibility factor is the limitation of transport expenses to 20% of the average per capita monthly income of the region of origin, which is an approximate value for the average percentage of the family budget spent on travel according to the latest Family Budget Survey (IBGE, 2021). If the total monthly amount spent on monthly travel is lower than the income restriction of the hexagon/region of origin, the price is considered viable and the opportunity affordable.

Since the average income values available by hexagon/location come from the 2010 Census and there is no recent income data at such a disaggregated level, we updated the values based on Brazil's minimum wage between 2010 and 2019.

There are countless ways to allocate the personal or family budget to transport, choosing and varying the number of trips by mode and motive to reflect different mobility behaviours and profiles. For the sake of brevity, we present only two alternatives: one in which the 20% budgetary limitation is dedicated entirely to utilitarian trips (those carried out daily and which are mandatory, going to centers of employment and universities) and another in which this percentage is dedicated only to complementary trips (those that we do not carry out every day, such as going to hospitals, parks, and shopping centers).

Table 1 – Number of trips per month
and the percentage of income dedicated to “utilitarian” trips

Motives	Number of trips per month	Percentage of income
Work centers	22	11,58%
Universities	16	8,42%
Total	38	20,00%

Source: developed by the authors, in 2023.

Table 2 – Number of trips per month
and the percentage of income dedicated to “complementary” trips

Motives	Number of trips per month	Percentage of income
Hospitals	3	5%
Parks	3	5%
Shopping	6	10%
Total	12	20%

Source: developed by the authors, in 2023.

Tables 1 and 2 present the number of trips per month for the two cases examined.

Measures of inequality

Measures of Inequality seek to assess how (un) equal a set of values is, associated with people, groups of people, regions, and so on. Among the most used approaches in transport are the Gini index (the most popular) and the Palma measure, which has recently become common.

Palma's measure consists of the ratio of the value (the income itself) of the richest 10% to the value of the poorest 40% (Palma, 2011). However, it can replace income with accessibility values/degrees (Guzman and Oviedo, 2018; Pereira et al., 2019; Herszenhut et al., 2022). Therefore, the higher the ratio, the greater the disparity in accessibility between the socioeconomic strata of the population, which represents a scenario of less equity. The advantage of the Palma measure, when compared to the Gini index, is the incorporation of groups' income, not treating all values as belonging to equal individuals (Guzman and Oviedo, 2018; Herszenhut et al., 2022). In other words, it makes it possible to compare the difference in accessibility between the richest and the poorest more directly.

The measure can be calculated according to Equation 4 (Palma, 2011):

$$P = \frac{A_{10}}{A_{40}}$$

Onde:
P = Palma's ratio
A10 = Average accessibility of the 10% highest income group
A40 = Average accessibility of the 40% lowest income group

Results and discussion

Definition of the study area

Porto Alegre is a city in the southern region of Brazil, the capital of its State (Rio Grande do Sul) and has a population of close to 1.3 million inhabitants in an area of almost 500 km², making it the tenth most populous municipality in the country (IBGE, 2023). The city's growth began in the region where the so-called Historic Center is today, a peninsula on the east bank of Lake Guaíba. In general terms, the city follows a radial urban structure, with the main transport axes leaving the center to the other regions to the east, north, and south.

The highest population densities are generally around these axes and in the northeast region. On the contrary, the southern zone is mainly home to residential and low--density areas, including a considerable rural area. The regions with the highest incomes are most likely east of the Historic Center, between two and five kilometres apart, and in predominantly residential and low-density neighbourhoods in the south. The poorest regions are mostly far from the Center, on the limits of the municipality, in the Archipelago region (north of the Historic Center), and in the East Zone (greater distances from the central region).

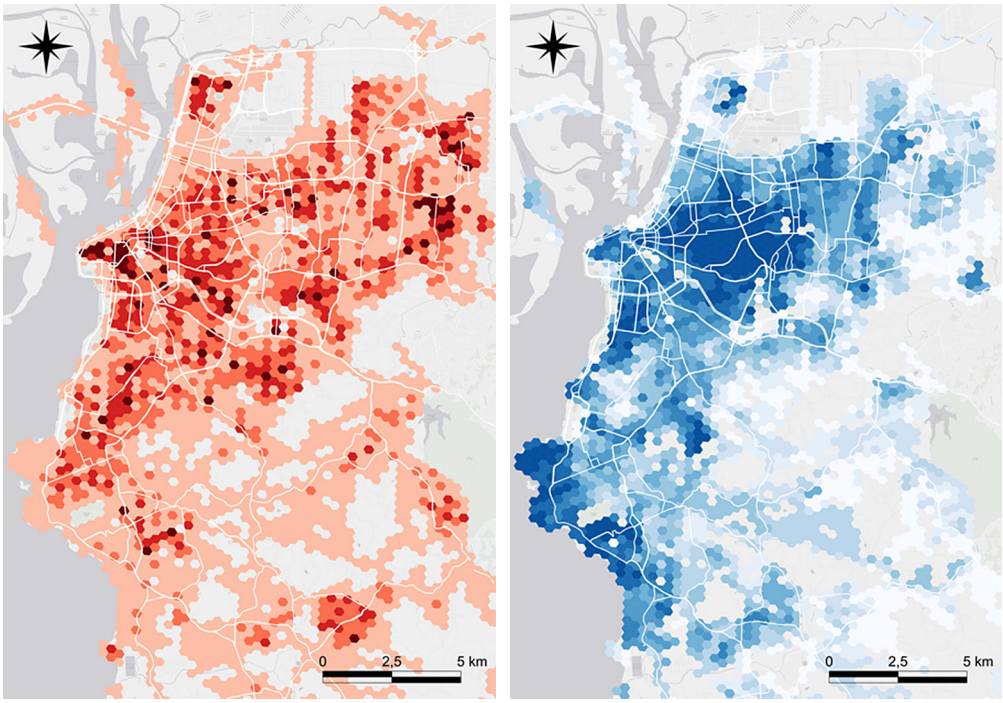
Figure 1 presents maps with population densities and average per capita income, classified into deciles with highlights of the main avenues.

One can perceive that high densities are more spread out than high incomes. They concentrate in basically two nuclei, one central and one to the south, in less central but more pleasant locations due to their proximity to the edge of the Guaíba River. The conclusion, intuitive and coherent with the reality of Brazilian cities, is that large concentrations of low-income populations on the outskirts will require trips to central opportunity zones, especially regarding jobs.

The modal split in the municipality is 21% for walking, 1% for bicycles, 40% for public transport, and 36% for individual transport and taxis (Empresa Pública de Transporte e Circulação, 2004). The fleet of vehicles per inhabitant is growing – in May 2023 it was 0.68 vehicles per inhabitant, compared to 0.55 in 2017 (Denatran, 2023). This evolution indicates that the percentage of individual trips must be even higher, given the difference between the years of data. In 2010, the average home-to--work commute time across the Metropolitan Region (MR) was 27.7 minutes – the shortest among the ten selected Brazilian MRs (Pereira and Schwanen, 2013).

Porto Alegre has historical relevance in the national scenario of urban mobility. The city's public transport system has a surface metro line that connects the Historic Center to

Figure 1 – Population density (left) and income deciles (right)
in Porto Alegre (higher = darker colour)



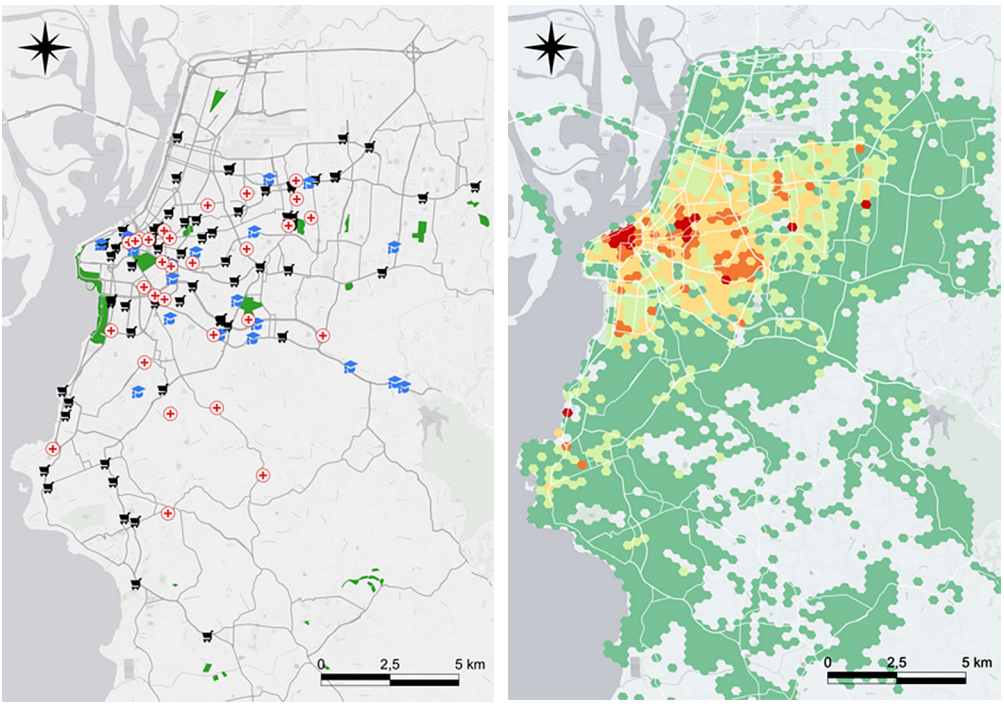
Source: developed by the authors, in 2023.

the North Zone and some of the municipalities in the Metropolitan Region, as well as a vast network of segregated corridors and exclusive bus lanes. These last infrastructures were innovations implemented in the 1970s, structuring the system based on the main radial avenues. In the 1990s, mayors affiliated to the Workers' Party ("Partido dos Trabalhadores" / PT) made the audacious move of taking control of local bus companies into public ownership, culminating in the awarding of the municipal bus company (Carris) as the best in Brazil for several consecutive years. This scenario developed until 2004 when conservative parties returned to city hall and began a period of neoliberal policies that included the prediction of privatization of Carris.

Porto Alegre was also a pioneer in cycle paths in large Brazilian cities. The city has a Cycling Master Plan from 2009, another national innovation that proposed more than 400 km of cycling infrastructure, of which 77 km had been implemented by the beginning of 2023.

Figure 2 shows the location of all urban opportunities considered in the research.

Figure 2 – Spatial distribution of opportunities in Porto Alegre. Left: georeferenced points: universities in blue, shopping in black, hospitals in red, and parks in green. Right: graduation of the number of employment relationships in the cells (red = more, green = less)



Source: developed by the authors, in 2023.

In general, the distribution of opportunities concentrates close to the central region (which has a higher average income). The opportunities far from the central region are less dispersed but almost always close to the main arterial avenues. Although it has the largest number of units and appears in different regions, shopping opportunities are the most concentrated ones, close to employment destinations. Parks are, on average, the most dispersed units because, unlike establishments implemented according to market logic, they are the product of urban planning standards that require the provision of green areas in all new urbanizations (Porto Alegre, 1999).

Accessibility analysis by time and cost

The results refer to the number of opportunities accessible from each hexagon of the city for intervals of 30 and 60 minutes by public transport (PT) and apps. There are two groups of trips: “utilitarian” (stations workplaces/universities) and “complementary” (hospitals, parks, and shopping). The results are percentages of the total number of opportunities of each type in the city.

Utilitarian trips

Figures 3 and 4 present maps with the distributions of accessibility to jobs and universities by PT and ride-hailing apps for the two travel times, highlighting the percentage of opportunities accessible from each hexagon.

For PT, there is a clear spatial pattern in which accessibility values increase eastward from the Historic Center (CH) and remain at high values, especially around arterial roads. For both destinations, the highest values are east of CH, precisely near the city's high--income regions. Such neighbourhoods are closer to most opportunities than the high--income region of the south, showing how centrality is, as expected, the "tiebreaker" factor for accessibility between areas with the same purchasing power.

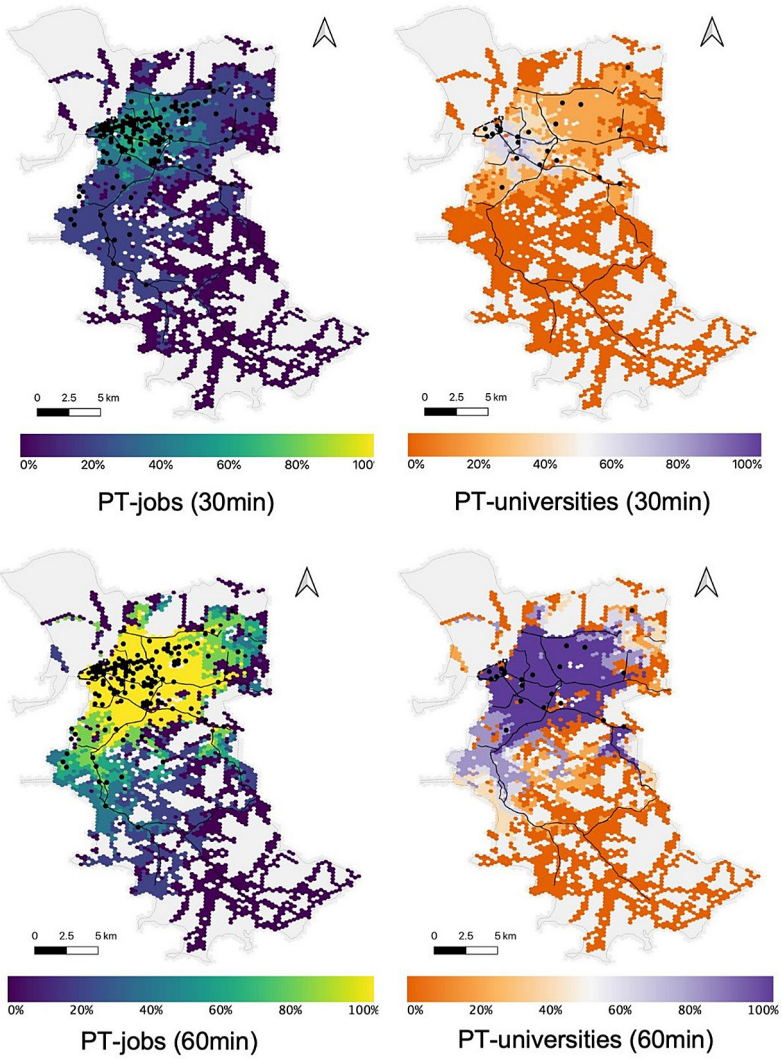
While for the PT, there is a notable increase in accessibility values in the 60-minute scenario compared to the 30-minute scenario, the results for apps present almost identical distributions for both travel times. For the first mode, the fare is always the same, regardless of the duration of the trip. Hence, with a longer travel time, more destinations are accessed by passengers. As for apps, longer trips lead to higher prices, making it not financially viable for the lower-income population. Meanwhile, the higher-income population (which, as seen, mostly lives closer to opportunities) already reaches a very high number of destinations in the 30-minute interval, with no significant difference for those in 60 minutes.

The average accessibility values were calculated for each income decile, shown in the graphs in Figure 5.

For PT, the difference between the income deciles' averages is little and has an approximately linear behaviour. On the other hand, concerning ride-hailing apps, the curve has a shape close to exponential, "accelerating" strongly from the sixth decile onwards. The ratios between the tenth decile and the first with an average greater than zero are 25.20 and 17.08 for PT and 5,540 and 1,130 for apps, for trips to jobs and universities, respectively.

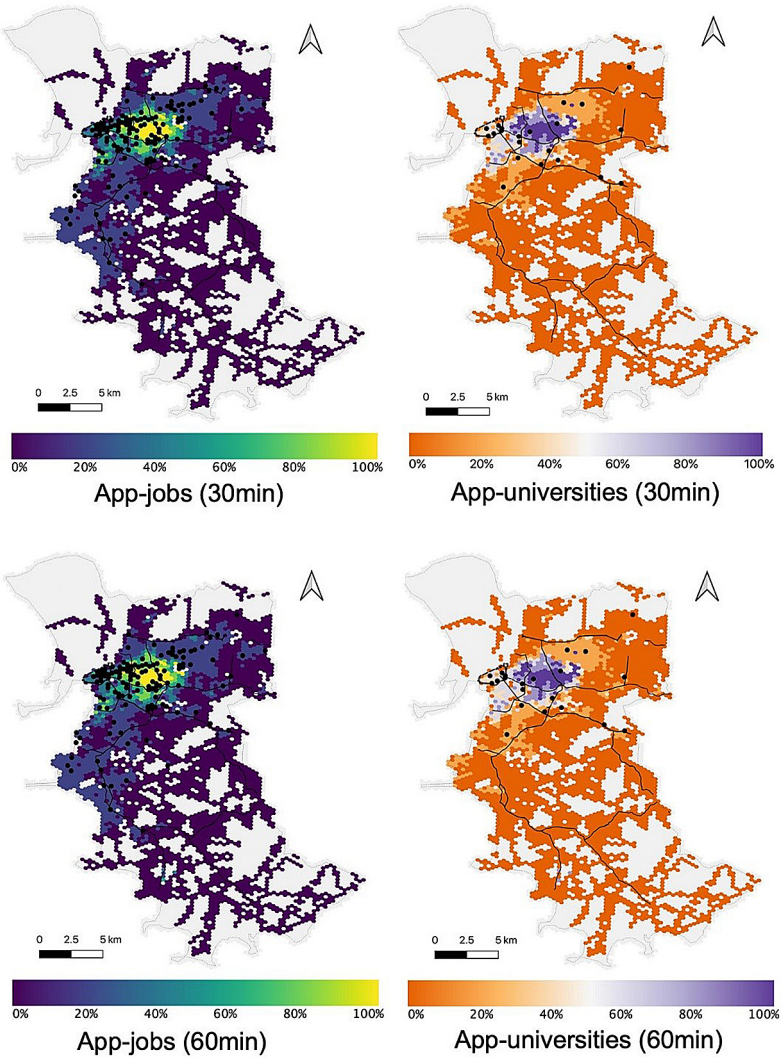
For both modes, the first income decile has practically zero average accessibility for both reasons, explaining the existence of high spatial and financial inequality and even total exclusion. The prominent inequality in this scenario is showed by calculating the Palma measures of the different accessibility distributions, presented in Figure 6.

Figure 3 – Percentage of utility opportunities accessible
by PT in 30 min (above) and 60 min (below) –
on the left, percentage for work and, on the right, universities



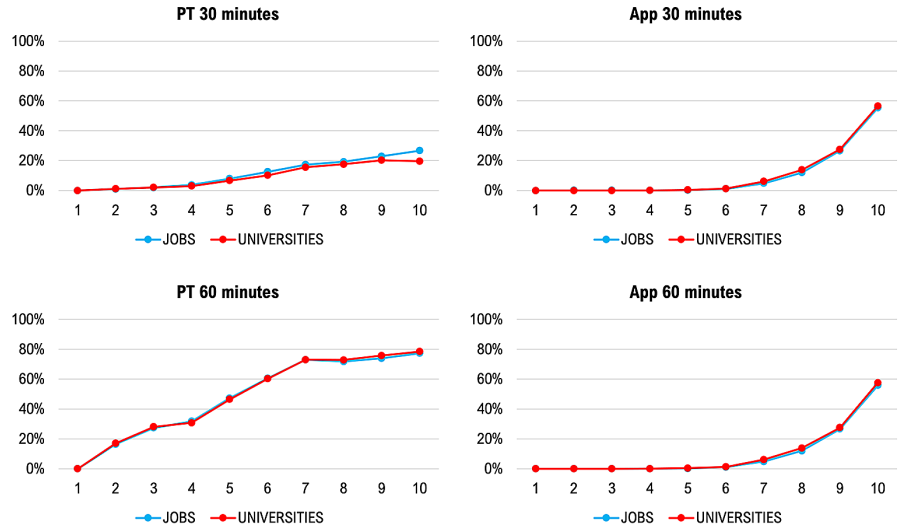
Source: developed by the authors, in 2023.

Figure 4 – Percentage of utility opportunities accessible
by app in 30 minutes (above) and 60 minutes (below) –
on the left, percentage for jobs and, on the right, for universities



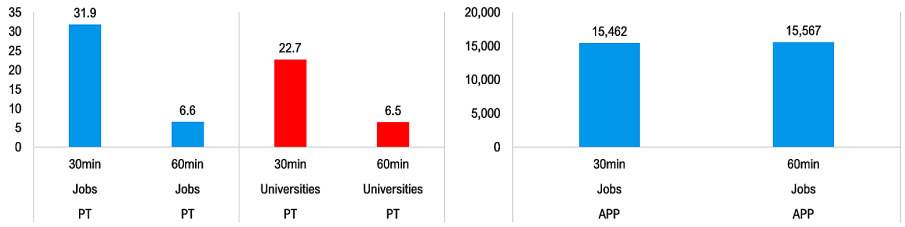
Source: developed by the authors, in 2023.

Figure 5 – Average percentage of utility opportunities accessible by PT and app by income decile



Source: developed by the authors, in 2023.

Figure 6 – Ratios of utility travel accessibility distributions



Source: developed by the authors, in 2023.

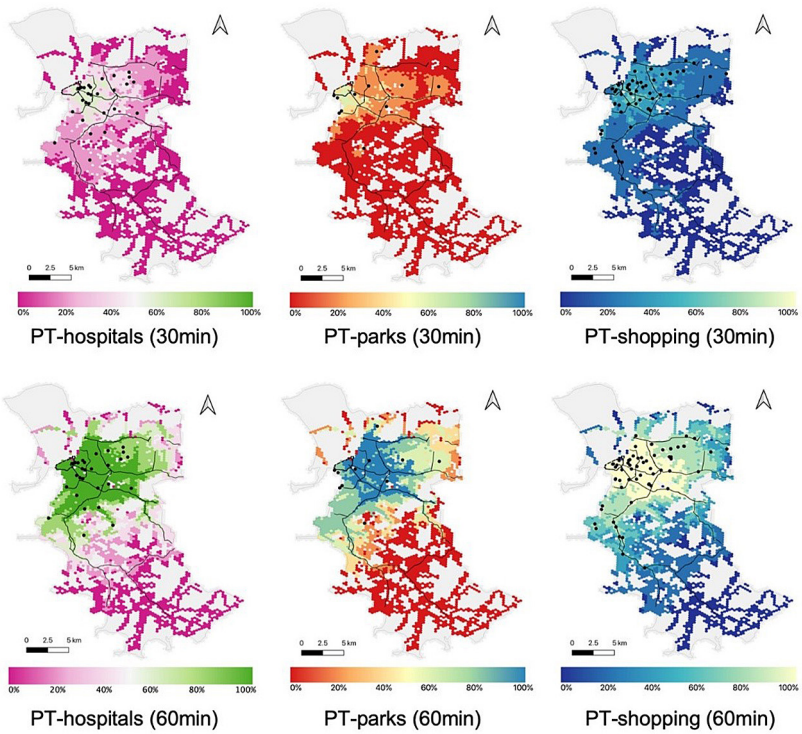
For PT, the inequality is greater in the shorter interval (30 minutes). Nonetheless, the opposite is observed for apps – and with much larger magnitudes. The inequalities determined by the ride-hailing apps are very accentuated, with Palma values exceeding 15,000 for jobs and incalculable for universities since accessibility based on time and cost for the poorest 40% is equal to zero (exclusion). Palma's measure tends to infinity (although the spatial distribution of accessibility is very similar for the two-time intervals).

Complementary trips

Figures 7 and 8 show the distributions of accessibility by PT and apps for trips to hospitals, parks, and shopping in 30 and 60 minutes.

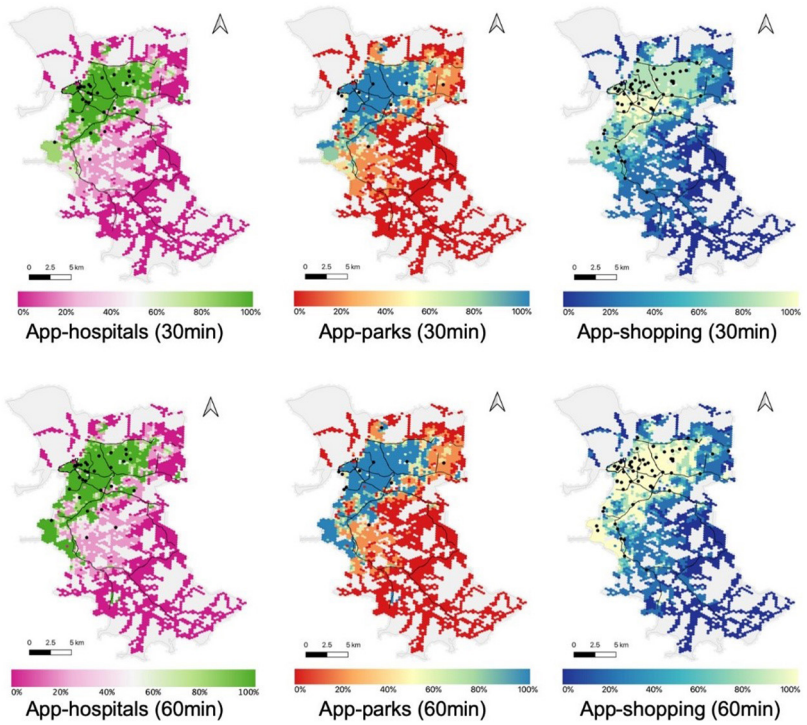
Furthermore, the contrast between the different times is more visible for the PT than for apps due to the same reasons. However, it is possible to see generalized gains in accessibility per apps in regions with different profiles, from 30 minutes to 60 minutes, due

Figure 7 – Percentage of complementary opportunities accessible by PT in 30 minutes (above) and 60 minutes (below) – from left to right, hospitals, parks, and shopping centers



Source: developed by the authors, in 2023.

Figure 8 – Percentage of complementary opportunities accessible by app in 30 minutes (above) and 60 minutes (below) – from left to right, hospitals, parks, and shopping centers

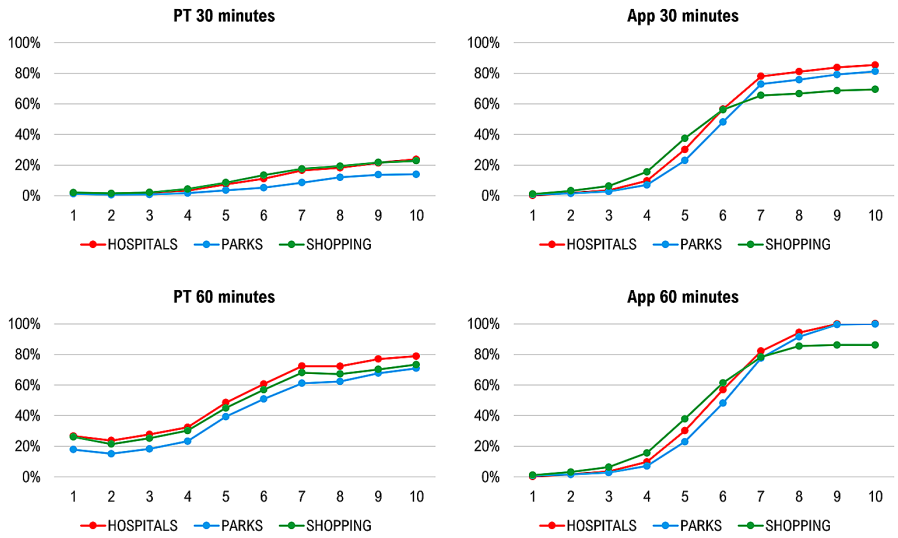


Source: developed by the authors, in 2023.

to the considerable dispersion of discretionary opportunities in the territory compared to utilitarian ones. The average accessibility values by income decile were also calculated, shown in Figure 9.

Once again, we observed higher values in trips via apps. But, in this case, the curves have an approximately sigmoid shape, with the percentage of accessible opportunities increasing solidly between the third and seventh decile and accommodating close to the maximum limit. This parameter – the upper limit – also brings relevant conclusions to the discussion: just below 25% for PT (30 minutes), around 80% for PT (60 minutes), close to 90% for apps (30 minutes), and close to 100% for apps (60 minutes), confirming the high pervasiveness of the automobile and the intrinsic limitation of the bus service.

Figure 9 – Average percentage of complementary opportunities accessible by PT and by app in 30 minutes and 60 minutes, by income decile



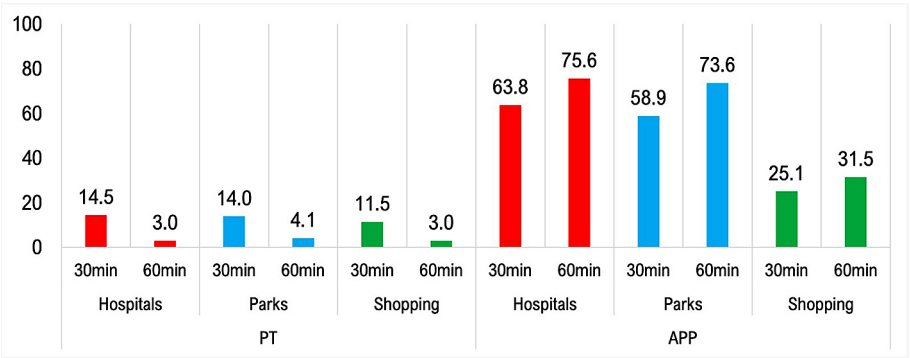
Source: developed by the authors, in 2023.

Parks are the purpose for travel with the lowest accessibility values by PT. For apps, they are shopping destinations, highlighting the low accessibility to green areas provided by public transport in Porto Alegre, especially for lower income groups.

For PT, the average accessibility ratios between the extreme deciles (tenth/eleventh) for hospitals, parks, and shopping are around 17, 20, and 14 (respectively). In other words, they are of similar magnitudes to mandatory trips: it indicates that the inequality between utilitarian and complementary trips is similar regarding public transport. As for ride-hailing apps, the average accessibility ratios between the extreme deciles, although quite accentuated (251, 101, and 60, approximately), are considerably lower than those found for apps in utilitarian trips (greater than 1,000). Given the higher frequency of utilitarian trips, such results were expected. Yet, the differences between the values are impressive and prove a scenario of great inequality in access.

The values of Palma's measurements for the complementary trips are shown in Figure 10.

Figure 10 – Palma ratios of the accessibility distributions of complementary trips



Source: developed by the authors, in 2023.

As expected, the rates show crucial decreases when compared to those for utility trips, especially for apps. In the present case, they present themselves on the same scale (y axis of the graphs) as the PT values and, unlike these, which decrease with increasing time interval, they show increasing behaviour with increasing time, in convergence with the results found by Herszenhut et al. (2022). Minor inequalities can be explained by the reduced number of trips compared to utilitarian trips.

Although the results found by de Oliveira Souza (2021) show that, in regions with many jobs and commercial activity, the accessibility to jobs generated by ride-hailing apps is higher than by PT for trips with more than two passengers, our study points out that, for work trips, this depends on the travel time. Regarding journeys of up to 30 minutes, the results are similar – the regions with greater and richer activities have greater accessibility via app than via PT. Anyhow, for 60 minutes, the scenario is reversed, and accessibility via PT is greater in all regions due to the monetary cost, fixed for bus trips and variable via apps. Consequently, it is not viable for most of the population to take on long commutes. Our research considered only trips made by one passenger, without the possibility of sharing the cost, and, on the other, incorporated trips by other purposes than work.

Conclusion

The advent of digital ridesourcing services in Brazil raised concerns about their impacts on traffic and environmental sustainability, but presented itself as an alternative that could serve peripheral regions little served by public transport. It also permitted complementing public services, potentially leading to higher accessibility for disadvantaged groups and proper equity in urban transport. Nevertheless, the monetary cost of travel – the fare – as expected, tends to act as a barrier to its frequent use for this portion of the population.

Our study quantified the accessibility provided by ride-hailing apps – measured as cumulative opportunities – and compared it with accessibility by public transport in Porto Alegre, seeking to deepen this understanding. The fare was considered as one of the components of "time and cost--based accessibility" along with travel time. The average income of each region of the municipality, the budget limit dedicated to transport, and the number of trips per month for each purpose – separated into "utility" and "complementary" – were considered to verify whether the ride-hailing system is an option of viable transport to travel to the city's main destinations. Palma's inequality measures were calculated on the resulting accessibility distributions to assess the apps' impact on Porto Alegre's social equity framework.

The results indicate that central and high--income regions have levels of accessibility on average that are much higher than those in peripheral and poor regions, which is consistent with the results of similar studies recently conducted in other Brazilian cities (Bittencourt, Giannotti and Marques, 2021; Pereira et al., 2019; Slovic et al., 2019). They also show that the difference in accessibility values between the ride-hailing apps and public transport is substantially more sumptuous for trips to the most frequent and "compulsory" destinations – employment centers and universities, especially – among the lowest income deciles, for which the value of repeated runs in a month would compromise more than the income available for transportation. For these displacements, the cumulative opportunities of the poorest population were zero or close to it, with Palma's indexes showing extremely high inequalities in relation to the highest-income population. However, for trips that are more occasional and less frequent, inequalities are less pronounced, and this service appears as a viable alternative that can be used by a larger portion of the population, including those with lower incomes.

These results are intuitive and show that, when it comes to the most noteworthy and frequent trips, the ride-hailing services do not contribute to an increase in equity in urban transport in Porto Alegre, bringing even more inequality to that already determined by the city's public transport system. However, this recent service can serve as an urban mobility alternative for journeys that do not take place daily, especially those of short duration. This can increase the low-income population's access to outdoor leisure. It can also play a role on night trips for leisure or when the driver consumes alcohol.

The differences in accessibility observed between rich and poor and the consequent increase in inequality in mobility in Porto Alegre show how the right to the city and the opportunities it offers is not guaranteed to a large part of the population of Porto Alegre and, by extension, of Brazil.

The results help to enhance our understanding on the impacts caused by app-based transport services in cities. It indicates a more thorough, cautious observation of the phenomenon by public authorities. Even if they do not contribute to greater accessibility for frequent trips by the poor and peripheral population, they can play a critical role in urban mobility.

The implications of the evidence raised here for the planning and management of urban transport in Brazilian capitals include the trivial recommendation to make the bus service more attractive, reliable, and cheap, increasing its availability and frequency, especially in lower-income regions, aligned with contemporary trends in public transport financing that could lead to the adoption of fare-free public transport (Santini, 2019; Gregori et al., 2020).

If the intention is to promote accessibility for the peripheral population via ride-hailing apps as part of a multimodality policy, subsidies for these groups for travel for work and study – a "mobility grant" – would be viable. Yet, with detailed attention to the negative impacts of the increase of car trips.

Other policies that encourage complementarity between modes of transport, such as discounts for trips to bus terminals, can contribute to increased access to the city for the segregated population. Practices of this type have already been tested in pilots in São Paulo and Rio de Janeiro (Metrô and 99 lançam..., 2017).

From a fiscal point of view, a variable tax collection policy, which covers more trips initiated in central regions and fewer in peripheral regions or which covers fewer trips with hybrid or electric vehicles, such as the one suggested in São Paulo, is an alternative that it can contribute to increasing accessibility and mitigating the negative impacts of ride-hailing apps at the same time (Pasqual and Petzhold, 2018).

The evidence allows the indication of urban policies that increase urban accessibility through changes in the pattern of land use, both on the housing side, with incentives for social housing in central regions and close to opportunities, and through the provision of more well-distributed urban activities, through tax incentives for locating businesses and services in certain underprivileged zones.

Our work certainly has some limitations: the lack of recent data on the mobility pattern and socioeconomic characteristics of the population of Porto Alegre means that the results do not accurately reflect the current reality, something that can be better understood with the results of the 2022 Census and the next Origin-Destination Survey of the municipality, being prepared at the time of writing this article (Porto Alegre, 2023).

The accessibility calculation can make the panorama of inequality significantly estranged from reality when made for only one mobility behaviour, without variations in the number of trips per purpose or in the limit of the budget

spent on transport and the non-exploitation of the possibility of sharing the cost of rides between more than one passenger (even if requires a degree of organization and rationality in travel planning on the part of users, which is uncommon in our society). The lack of "surge pricing" also may cause a biased analysis. However, considering that companies do not disclose the parameters of this calculation precisely to preserve them as a competitive differentiator, the complete treatment of this aspect would require, in addition to the definition of which and how many trips would be made at these times, the use of a technique to emulate the dynamic mechanism, possibly through the introduction of a random multiplier (increasing) term in the equations, defined by probabilistic draw at each iteration.

Another aspect to be further explored is the multiplicity of dimensions of the concept of equity. While the work only deals with socioeconomic equity, through the relationship between accessibility and income, aspects such as race/colour and gender, for example, can be incorporated into the analysis to identify how the distribution of accessibility varies between regions with different racial proportions or between women and men. Similarly, an intersectional lens would identify how accessibility changes when two or more social factors interact.

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Notes

(1) https://www.google.com/maps/d/viewer?mid=1bx99VwelBTJwSqTBM7AP8U8A3FbXryg&ll=-30.05542457741573%2C-51.14057907185402&z=10 and https://abrasce.com.br/guia-de-shoppings/?state=RS&city=Porto+Alegre&letter=.

(2) https://abrasce.com.br/guia-de-shoppings/?state=RS&city=Porto+Alegre&letter= and https://atlassocioeconomico.rs.gov.br/educacao-superior.

(3) https://www.uber.com/br/pt-br/.

(4) https://99app.com/.

(5) http://datapoa.com.br/dataset/gtfs.

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