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Critical review

The long road to achieving equity: Job accessibility restrictions and overlapping inequalities in the city of São Paulo

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ABSTRACT

Access to jobs is an important issue in cities which has not been experienced evenly. The Municipality of São Paulo, one of the world's megacities, reflects this uneven accessibility, marked by urban disparities and segregation of poverty-stricken groups. This study examines the inequalities in job accessibility and how it overlaps with socioeconomic indicators, life expectancy and infrastructure conditions, constituting multiple barriers to the most deprived populations. To capture this data, two extreme ends of the human development index have been selected: below the 10th percentile and above the 90th percentile of the Municipal Human Development Index (MHDI). The level of job accessibility was calculated considering proximity to the public transport network. The public transport network was developed in a Geographic Information System (GIS) environment based on General Transit Feed Specification (GTFS) data and Automatic Vehicle Location (AVL) from buses to measure travel times and to compute accessibility. Additionally, a spatial autocorrelation method considering job accessibility and HDI was applied to better explore the spatially overlapped pattern. Results have showed that lower rates of job accessibility are associated with areas of worse socioeconomic condition, where life expectancy is shorter and infrastructure is disproportionally precarious. In addition to facing longer travel times in public transportation, this lowest HDI percentile faces the overlapping inequalities that prevent their social ascension and inclusion. Highlighting these factors is essential in the search for equity in accessibility and the development of more inclusive transport policies.

1. Introduction

Increasing rates of world urbanization have created major mobility challenges particularly when looking at how urban residents commute, available transport opportunities and its accessibility. A growing field of research has demonstrated that accessibility has not been evenly distributed in cities (Lucas, 2012) and its association with lack of opportunities in education, work and social interactions exacerbating preexisting socioeconomic inequities (Golub and Martens, 2014; Blanco and Apaolaza, 2018). Assessing which groups and areas are most affected or excluded is essential to evaluate the role played by transports in urban equity (Lucas et al., 2016).

Measuring the discrepancy between accessibility and the socially excluded have been of particular interest in recent transport studies. El-Geneidy et al. (2016) measured job accessibility considering travel time and travel costs to reveal the equitable transit distribution on low-income groups. In Detroit, one of the most segregated American cities, Farber et al. (2015) showed that time budget constraints and race were one of the major factors contributing to segregation. In Australian cities, Dodson et al. (2011) found that low socioeconomic groups faced greater difficulties in accessing their most frequent destinations.

In Latin American (LA), cities have experienced the exacerbation of existing gaps between the wealthiest and the poorest residents, challenging mobility to an extent not seen in high-income countries (Vargas et al., 2017). In Bogotá (Colombia), Teunissen et al. (2015) compared accessibility from different socioeconomic strata and concluded that although it offered equal travel time access, there was an affordability issue that hinders low income residents to use. Guzman et al. (2017) highlighted the spatial relations between transport (infrastructure and service) and socioeconomic structure in Bogotá by exploring levels of

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equity in accessibility to jobs and education and its spatial variability among income groups and transport mode. Hernandez (2018) investigated jobs and education transit accessibility in Montevideo (Uruguay), exploring unequal access among different social classes, revealing unequal distributions for jobs and upper level public education. Martínez et al. (2018) compared access travel time from deprived settlements with the whole access in Santiago (Chile) demonstrating a lower access to opportunities in these areas. In another study in the Chilean capital, Martínez and Santibáñez (2015) looked at gender, income to accessibility dimensions. Their findings showed that the poorest portions of the female population walked more and were more vulnerable to crimes as compared to the wealthiest female populations. Rojas et al. (2016), also focused on walking access to open spaces in Chilean cities and revealed that age, gender and income, respectively, tended to have an impact on accessibility variation.

In Brazilian cities, Boisjoly et al. (2017) have explored the relationship between job informality and accessibility to employment by public transport in the Metropolitan Region of São Paulo, demonstrating that accessibility to jobs is unevenly distributed across the territory and largely concentrated in high-income areas. In Rio de Janeiro, Pereira (2018) investigated the impacts of the transport legacy of the 2014 World Cup and the 2016 Olympic Games on different income population and concluded that accessibility benefits from public transport investments generally accrued to middle- and high-income groups, reinforcing urban inequalities. Maia et al. (2016) investigated through a qualitative study the needs of low-income residents in Recife and its relationship with mobility and accessibility and revealed that focusing on transport infrastructure was not enough to reduce disparities.

No previous studies, to this date, has combined job accessibility and its overlapping socioeconomic dimensions to the study of transport equity. To this end, the city of São Paulo constitutes an important case study. This study aims to explore the multiple dimensions associated with the lack of job accessibility using Human Development Index, socioeconomic, built environment and life expectancy to characterize the multiple barriers to achieve equity and accessibility for all.

The Municipality of São Paulo (MSP), one of the world's most populated cities with 12 million inhabitants, is no exception to this uneven accessibility found in LA cities. With a current fleet of almost 8.9 million vehicles (Detran, 2017) and a scarce subway network, inhabitants of the MSP rely on public buses, bicycles, walking and private vehicles to commute. Public transportation, according to the São Paulo mobility study, has been mostly associated to low-income users, while the use of private vehicles to higher incomes (Metrô, 2007). Brazil faced an accelerated urbanization process on the second half of last century (Alves and Ojima, 2013). As a consequence, it experienced the rise of its metropolitan areas with intensive vertical growth, densification of already-urbanized areas and urban sprawl to peripheral and peri-urban areas.

In the city of São Paulo, this horizontal expansion of the city and population growth process were intensified after the 1970s also due to an intensive migration of people that came from the poorest regions of the country, in particular from the Northeast region, increasing the social vulnerability and inequalities of peripherical areas (Maricato, 2000; De Sá et al., 2019). This reinforces the importance to evaluate accessibility not only by its spatial distribution but also by the multiple barriers that prevent the reduction of disparities and better access to opportunities, objective of this study.

The following sections present the methods used to identify these multiple disparity barriers and to measure accessibility. The findings are described considering the most and least deprived inhabitants of the MSP according to the Municipal Human Development Index. The importance of incorporating socioeconomic and environmental dimensions to measure accessibility is presented in the Discussion Section. We conclude by summarizing our findings and suggestions for future research.

2. Method

This work was developed in three stages: the selection and analysis of socioeconomic variables, the calculation of job accessibility and associations of job accessibility and socioeconomic, built environment and life expectancy variables.

2.1. Constructing the multidimensional framework of MSP inequalities

To highlight intraurban disparities in the MSP, the extreme groups of socioeconomic status were studied using the Human Development Index (HDI). The HDI was developed by the United Nations Development Program (UNDP) to synthetically measure the degree of economic development and life quality across countries. HDI varies on a scale from 0 (no human development) to 1 (total human development) and comprises three dimensions: longevity, income and education grouped by a geometric mean, according to the UNDP methodology (UNDP, 2013). The choice of these two groups was based on the existing disparities of the MSP population that is marked by broad socioeconomic gaps and spatial segregation, to be presented in the Result section. For the low HDI group (Low Group), values ranked below the 10th percentile and for the High HDI group (High Group) above the 90th percentile of the HDI values for the MSP.

The Municipal Human Development Index has been developed following the same methods and dimensions suggested by the UNDP and developed by Ribeiro et al. (2019). Average mortality data from the São Paulo Municipal Health Department for the years 2009–2011 was used to compose the longevity component of the index. The choice of these years was based on the fact that the latest available demographic census data from the Brazilian Institute of Geography and Statistics (IBGE) was from 2010. Income (sum of the income of all residents/number of residents) and education (geometric average of adult population educational level and educational flow of the younger population) data were extracted from the 2010 Census.

In the MSP, the MHDI values range from 0.49 to 1.0, which are considered very low and very high, respectively. This range reflects how within the same city, living conditions can be either similar to low income countries (indices similar to Afghanistan, Haiti or Côte d'Ivoire) or to high-income countries (indices similar to Norway, Switzerland and Austria). The mean value of the MSP was 0.771 and the mean value for Brazil is 0.759,[1] considered a high MHDI, according to the UNDP (2013).

To capture the magnitude of inequalities between two extreme socioeconomic groups, life expectancy and socioeconomic variables, environmental quality and urban infrastructure indicators were selected to compare Low and High MHDI groups. The indicators selected were:

1. Socioeconomic:
   a. race (Non-WhitePop), proportion of youth < 20 years old (Young20), households with more than six inhabitants (HousMore6), households headed by women (HousHeadFemale), life expectancy (LifeExpectancy).
2. Infrastructure and environmental quality:
   a. proportion of households without electricity (HousNoLight), exclusive electric meters (HousElecMet), household environment without trees (HousNoWoodSt), proportion of households with trash collection (TrashCol), proportion of households connected to sewage networks (SewageNet) and not connected to sewage networks (OthSewageSol), proportion of households with water distribution (HousWaterDis)
   b. proportion of non-paved streets (HousNoPavSt), proportion of household with non-existence of sidewalks (HousNoSideways).

[1] http://hdr.undp.org/en/2018-update

The MSP is composed of 18,953 census tracts according to the IBGE (2010). For this research, 18,206 census tracts were selected, which contained population information. Public spaces and districts with no inhabitants or no information were removed from the sample. Descriptive analysis of the indicators for both groups and *T*-Test were used to investigate if differences between groups were statistically significant as presented in the result section.

The lack of accessibility has been associated with social exclusion (Kamruzzaman et al., 2016). In the context of accessibility, equity is defined by Carleton and Porter (2018) as "the fairness in the provision to all groups of the same level of service". It differs from the term "equality", which implies that groups should be granted similar rights and opportunities (Carleton et al., 2018). Deeper discussion on social justice and equity in transportation can be found at Pereira et al. (2017). The next section clarifies how accessibility was measured for the present study.

2.2. Measuring job accessibility in MSP

Concepts and measures of accessibility varies. To Hansen (1959), accessibility is about the desire and ability to overcome spatial distances to access spatially distributed activities. Hägerstrand (1970), was the first to mention the spatiotemporal component of accessibility through the space-time prism theory, formulating an approach based on reachable opportunities instead of number of opportunities. Davidson (1995), defines accessibility as the ease in which each person, at a given point, can have access, through the transport system, to all other places in a defined area considering attractiveness variables and cost perception. Geurs and Van Wee (2004), emphasized that accessibility can be defined and measured in different ways and for different opportunities.

Accessibility to jobs defined by Iacono and Levinson (2017) as "*the ease of reaching desired destinations*", was calculated considering job opportunities through multitemporal networks in a Geographic Information System (GIS) environment developed by Tomasiello et al. (2019).

The public transport network comprises bus, metro and train transit lines, as provided by the São Paulo Transport Department (SPTrans, 2014) in General Transit Feed Specification format (GTFS) – (Google, 2014). The GTFS data was composed of several Comma-Separated-Value (CSV) text files containing information on itineraries, stops, routes, fares, and travel times. The GTFS data originally provided relied on estimated travel times, which is not the most accurate approach since traffic is an issue in most megacities. To better represent travel times in public transit in the MSP, the GTFS data was enriched through the Automatic Vehicle Location (AVL) database provided by SPTrans, including information about bus line, bus identification, location, date and time for each record. Pedestrian mode was considered in initial, end and transfers for transit routes. The street database used to model the pedestrian mode was provided by the Center for Metropolitan Studies (CEM, 2017).

The enriched GTFS was imported to a GIS. MSP public transport is characterized by a central supply concentration, where most of metro lines are located in a radial geometry (Fig. 1). In 2014, there were 5 metro lines, 6 train lines and 1825 bus lines in the MSP.

For the purpose of this article, the 7 AM time was chosen as the departure time to simulate morning commuting travel – or morning peak hour. The algorithm used to calculate travel times considered the fastest route between the origin and destination points (zone centroids). In order to map the transport supply, the numbers of public transport vehicles in one-hour interval (from 07 AM to 08 AM) by mode and line for each stop (bus stop or metro/train station) was considered for the MSP.

Information related to the number of formal jobs have come from the social information annual report from the Brazilian Labor Department (RAIS, 2014), aggregated by neighborhood unit area with zip code spatial inference. It is important to mention that about 30% of the workforce in the metropolitan region of São Paulo were allocated to informal jobs in 2010 (Boisjoly et al., 2017). According to Boisjoly et al. (2017), the percentage of informal workers is more representative in the population earning less than a minimum wage (72%) and most of the informal jobs was located in São Paulo's downtown and in the outskirts of the metropolitan region.

For the accessibility, the cumulative measure was chosen because it considered the sum of jobs within a threshold, which facilitates its understanding and communication. Public transport accessibility to jobs was calculated considering a 60-min travel time threshold, which is closer to the average travel time by public transport in the latest MSP origin-destination survey (average 67 min travel time). The following measure was considered (Páez et al., 2010):

$$A_{ik}^{p} = \sum_{j} W_{jk} I(c_{ij} \le \gamma_i^p)$$

Where:
A_{ik}^{p} is the cumulative accessibility index.
W_{jk} is the number of jobs at the location j.
c_{ij} is the travel time by public transport network
γ_i^p is the travel time threshold
I is logical statement that receives the value 1 when true and 0 when false.

In order to investigate the multidimensionality of spatial overlapping inequalities, the measured accessibility was subsequently explored with the previous mentioned socioeconomic, built environment and life expectancy variables as follows.

2.3. Job accessibility and the multidimensions of inequalities

The accessibility metrics and the MHDI spatial patterns were explored by applying bivariate Moran and LISA cluster maps on GeoDA 1.8.16 (Anselin et al., 2005). Local Indicators of Spatial Association (LISA) was proposed by Anselin (1995) to enable the indication of spatial clustering. It gives two types of positive spatial association: the high-high, high values of each observation (above the study area mean) associated with high values on their neighbors, and the low-low, in which low values (below the mean) are associated with low neighboring values. It also identifies two types of spatial outliers, the high-low and the low-high, meaning that the observed location differs from their neighbors. Talen and Anselin (1998) explored the LISA indicator to detect significant pattern of local association of accessibility. In this study we explored an extension from the original LISA, the bivariate LISA indicator (Anselin et al., 2002) allowing the comparison between two variables. Kernel maps developed in ArcGIS (10.2) were used to illustrate bus frequency spatial pattern.

3. Results

3.1. Overlapping dimensions of inequality in the MSP

Spatial distribution of the Low and High MHDI groups considered for the analysis in the city is shown in Fig. 2. The low group (≤10th percentile) represents 1,220,805 inhabitants (10% of the total

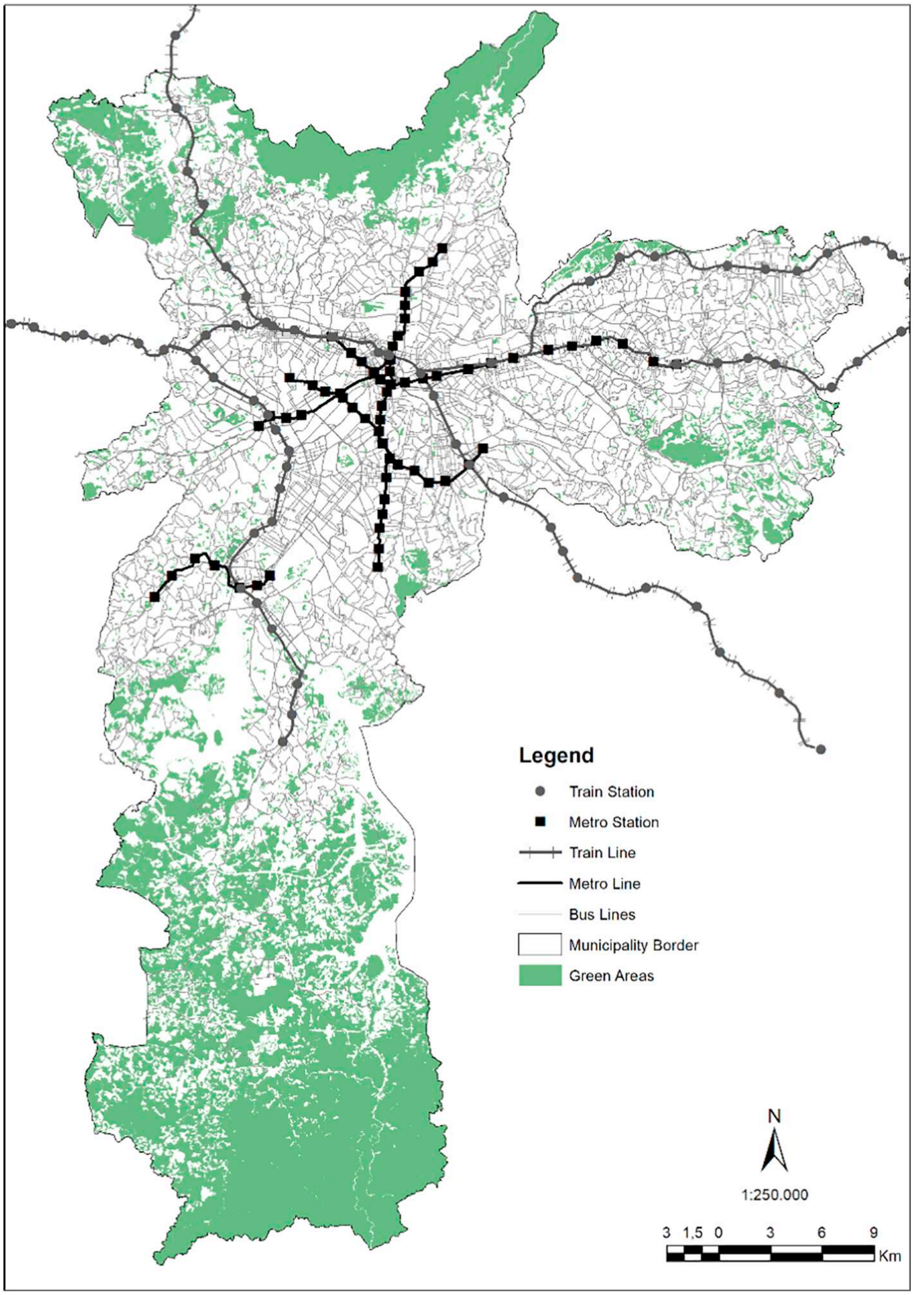


Fig. 1. MSP public transport in 2014.

population) with an average MHDI of 0.67. In comparison, the high group with a population of 871,673 inhabitants (around 8% of the population) has an average MHDI of 0.93.

Fig. 2 highlights the spatial segregation of the groups in the city, where the High Group is mostly concentrated in the center while the Low Group is mostly located in the outskirts. A few low-group sectors can also be found in precarious central regions of the city, but due to real estate speculation, they are being pushed away from the MSP center (Carlos, 2009).

Table 1 presents descriptive information about urban infrastructure and surrounding neighborhood quality for both MHDI groups. The data show that, besides living far from the central area and having long commutes, the low MHDI group lives in hazardous conditions, with low quality of life and poor health, where access to essential public services as water supply, and sewage and garbage collection are significantly deficient. The lack of sidewalks, paving and street trees are also major indicators of the environmental quality of the poorest areas and the structural difficulties to access or exit these areas.

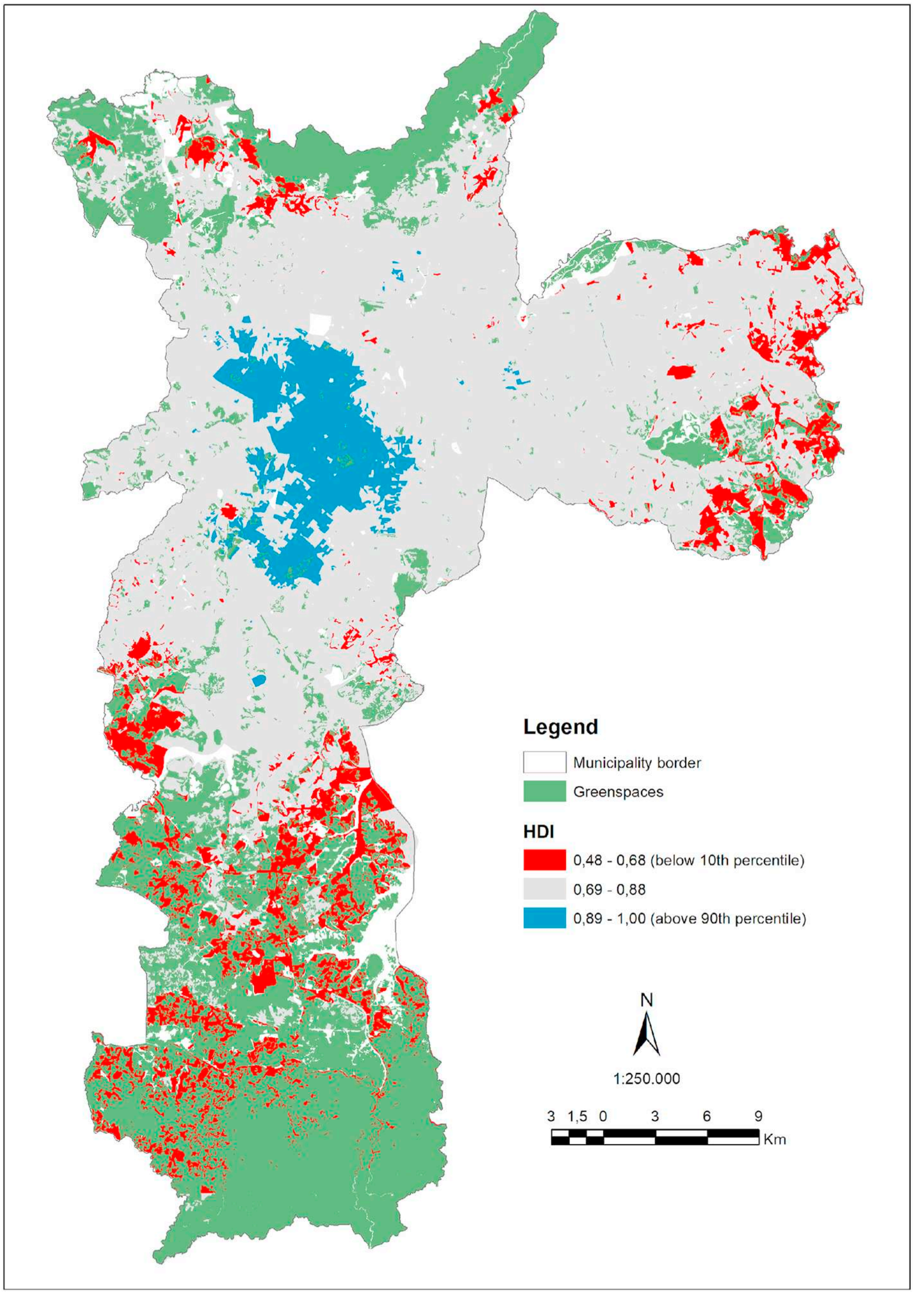


Fig. 2. Map of spatial distribution of the Low Group (< 10th percentile) and the High Group (> 90th percentile) of the MHDI values by census tract of the MSP.

Table 2 shows descriptive information about socioeconomic indicators for both MHDI groups. It emphasizes previous results showing how the low MHDI group bears a majority of non-white population with a mean of 60.38%, almost five times higher than the high MHDI group, and how the largest share of the young population (≤ 20 years old) is also in the same low-income group. In addition, the number of residents per households and the number of households headed by women as the family resource providers are higher in the very low MHDI than in the high MHDI group.

Degraded street conditions are more likely to be found in the low MHDI group, as shown in Fig. 3. Lack of pavement, sidewalks, public electricity and wooded streets is also more prevalent in the low group. Significant statistical differences are found in infrastructure variables of household structure. Households with sewage networks, trash collection and electric meter distribution means are higher among the high group, reaching almost 100%. In the low MHDI group, results show precarious conditions where households rely proportionally more on non-conventional sewage systems and electricity supply, and lack

Table 1
Descriptive data of infrastructure variables and *p* value of T Student test for the low and high MHDI group.

Variable	MHDI group	Mean	St Dev.	95% Confidence Interval	*p value*
SewageNet	Low	61.70	40.67	59.83–63.57	< 0.001
	High	99.15	3.91	98.97–99.33	
OthSewageSol	Low	38.13	40.57	36.26–39.99	< 0.001
	High	0.84	3.91	0.67–1.02	
HousWaterDis	Low	91.01	24.97	89.86–92.16	< 0.001
	High	98.53	4.36	99.42–99.83	
TrashCol	Low	81.70	30.78	80.29–83.12	< 0.001
	High	97.18	12.83	96.59–97.77	
HousElecMet	Low	64.87	32.03	63.40–66.34	< 0.001
	High	95.98	12.52	95.41–96.56	
HousNoLight	Low	7.94	19.36	7.05–8.83	< 0.001
	High	0.53	4.97	0.29–0.75	
HousNoPavSt	Low	11.98	26.61	10.75–13.20	< 0.001
	High	0.056	0.85	0.02–0.09	
HousNoSideways	Low	20.95	33.36	19.41–22.48	< 0.001
	High	0.35	4.09	0.16–0 0.53	
HousNoWoodSt	Low	32.25	36.99	30.55–33.95	< 0.001
	High	4.68	17.33	3.89–5.48	

Number of observations: Low = 1819, High = 1818. Definition of variables in appendices, table A1*

Table 2
Descriptive data of the socioeconomic variables and p value of the T Student test for the low and high MHDI group.

Variable	MHDI group	Mean	St Dev.	95% Confidence Interval	*p value*
Non-WhitePop	Low	60.38	11.40	59.86–60.91	< 0.001
	High	12.93	6.55	12.63–13.23	
Young20	Low	39.53	0.13	39.26–39.79	< 0.001
	High	19.09	0.13	18.81–19.36	
HousMore6	Low	13.32	5.58	13.07–13.58	< 0.001
	High	2.14	2.53	2.02–2.25	
HousHeadFemale	Low	46.71	15.53	45.99–47.42	< 0.001
	High	40.75	12.37	40.18–41.32	
LifeExpectancy	Low	69.22	1.48	69.15–69.29	< 0.001
	High	74.12	1.74	74.04–74.20	

Number of observations: Low = 1819, High = 1818. Definition of variables in appendices, table A1*

public services such as trash collection and proper sanitation.

Some significant differences ($p < .001$) can be seen between socioeconomic characteristics of both groups and related with other social disparities: proportion of non-white population, proportion of young population (≤ 20 years old), proportion of households with six inhabitants or more and proportion of households headed by female as shown in Fig. 4. It highlights that the surrounding infrastructure of the low MHDI group is more precarious, as seen previously, but also that the households in the low group tend to be composed of non-white younger population and households of more than six inhabitants. These indicators are representative of peripheral regions of Brazilian cities and are strongly related to high levels of violence observed in these areas (Maricato, 2000). According to the Brazilian Violence Atlas (2018), in 2016, the black homicide rate was twice as high as that of the rate of white (16.0 per 100,000 population versus 40.2). Between 2006 and 2016, the black homicide rate grew by 23.1% and most of these homicides occurred on the outskirts of large cities. In addition, violence has a severe impact on the quality of life of families already inserted in a very difficult social context: unemployment, idleness, lack of cultural and sports activities and social and environmental regulation, urban precarity and restricted mobility.

The most striking face of intra-urban social disparity in the city of São Paulo is shown by the marked difference in life expectancy between these two groups (Fig. 5). A child born in the low MHDI group has an average life expectancy of around 5 years less than one born in the high MHDI group. In some specific census tracks of the city this difference can reach up to 12 years. Disparities in the MSP start at birth and continue along life indicating a city where intra-urban disparities go far beyond access to public transport. The low MHDI has the largest young population with lower chances to ever escape poverty and segregation.

3.2. The unevenness of accessibility in MSP

When combining accessibility to jobs and MHDI (Fig. 6), high-high clusters are revealed in the inner region of the municipality. The Southern part of the city and the extremities of the Northern and Eastern zones of the MSP are the ones that show low-low results. The Northern and Southern zones also show a greater proportion of green spaces, as compared to other zones of the city. Areas with high accessibility (above the mean) are located in neighbors with high MHDI (high-high) and so on.

Public transport accessibility clearly reveals an uneven São Paulo, unveiling segregation with job accessibility concentrated among the high MHDI group (Fig. 6). The lower public transport accessibility and MHDI remain more remote from the city center while the higher public transport accessibility pinpoints the higher MHDI. These clusters demonstrate how lack of spatial interaction in the MSP are related to poverty and exclusion.

The frequency in public transport supply of bus from 7 AM to 8 AM was analyzed based on a Kernel Density Estimation (KDE) map, known as “heat maps” (Fig. 7). The KDE was originally conceived to derive a smooth estimate of a probability density, that was adapted for mapping spatial patterns of point's events (Bailey and Gatrell, 1995). It uses local information defined by a moving window, to estimate densities. Higher density zones are mapped with “hot” red color, while low density in “cold” blue in Fig. 7. Results emphasize that transport supply is concentrated in the districts with high MHDI and in some major corridors on the east side of the city. Precariousness of job accessibility of the population residing in the southern and the extreme parts of the eastern and northern zones of the city becomes evident. Considering the Southern part of the MSP, public buses supply is almost non-existent.

The poor job accessibility in low MHDI groups reflects how such residents bear the burden of long commutes on public buses while travelling far to work in the central region.

According to Metrô (2007), the poorer the household, the more dependent on public transport (Fig. 8). The 2007 Origin Destination (OD) survey microdata showed that the first decile of the population income modal split was 49% by public transport, 7% by private transport and 44% by foot. These results indicated that this group is indeed more dependent on public transport and has high rates of travels by foot, which can indicate short trips and/or financial constraints to access public and private transport. The lower income population has been found to spend a largest share of its income in transportation. In 2009, almost 22% of its income was dedicated to transport costs while the higher income population transport costs were dedicated to private transports (Carvalho and Pereira, 2012).

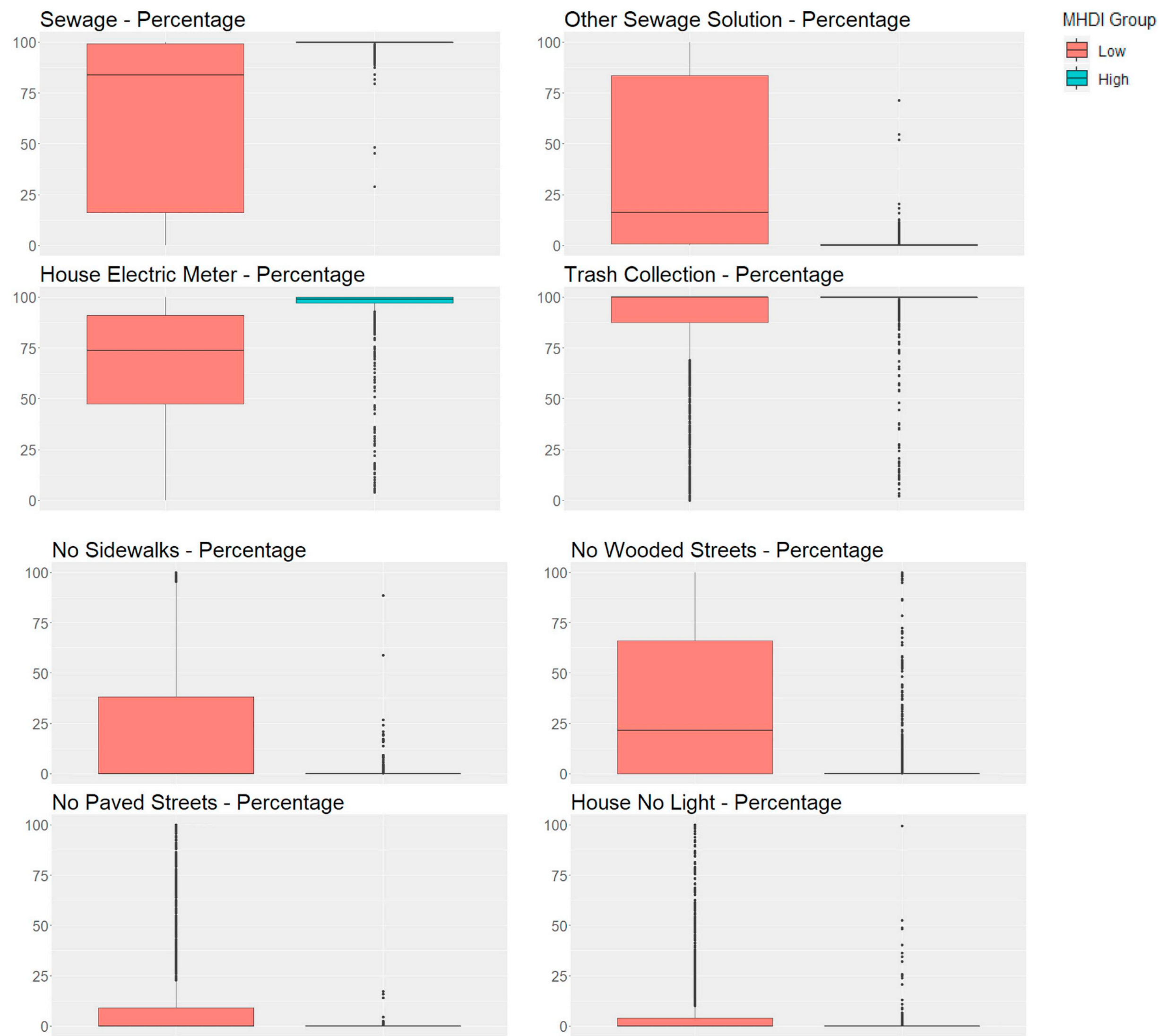
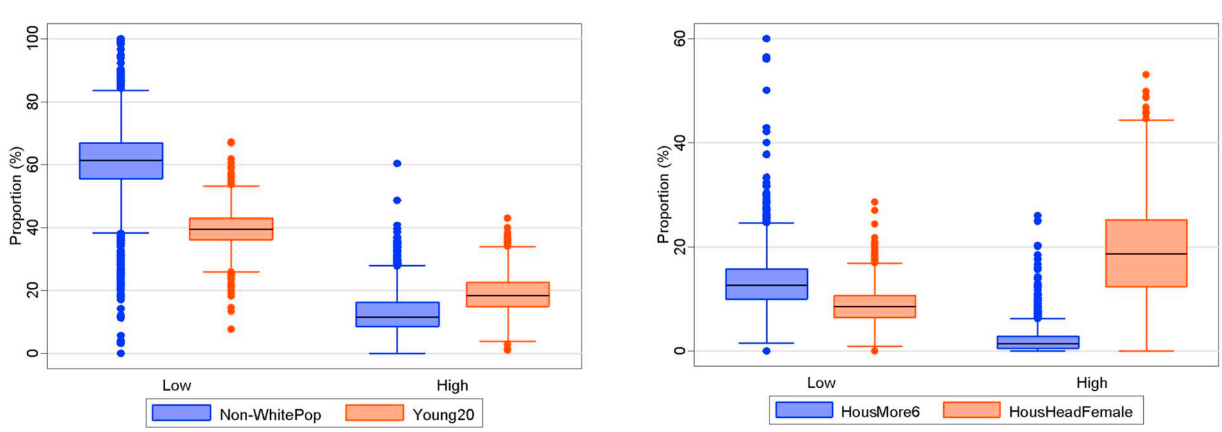


Fig. 3. Boxplot proportion of household infrastructure variables by the lowest (≤10th percentile) and highest (≥ 90th percentile) of the MHDI.



(a) Non-white population and young population (up to 20 years old).

(b) Household with more than 6 people and household headed by female.

Fig. 4. Boxplot of social economic variables by the lowest (< 10th percentile) and highest (> 90th percentile) of the MHDI of São Paulo.

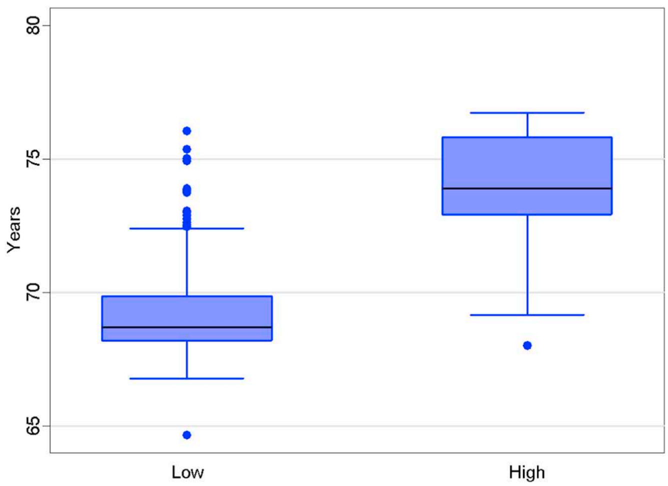


Fig. 5. Life expectancy according to the lowest and highest MHDI percentile.

4. Discussion and conclusion

This study has shown that the low MHDI group in the MSP has lower transit accessibility to jobs, is predominantly non-white, lives in the outskirts of the city with precarious urban infrastructure and has a life expectancy on average of five years lower than the high MHDI group. The low MHDI group, with twice the number of young people than the high MHDI group, relies mostly on public transport to commute.

These findings are aggravated by the MSP spatial configuration, which is directly linked to its historical construction process, around social exclusion and the intergenerational transmission of poverty. Better conditions of accessibility to jobs have become a privilege of the wealthiest population living in the center of the city. Indeed, with 55% of the state of São Paulo GDP,[2] the MSP urbanization process has been drastic with a population that went from 1.3 million in 1950 to 11.2 million in 2010 (IBGE, 2010). Developed from the center to the outskirts, the center of the MSP has concentrated job opportunities, better public services and spaces while the outskirts have gathered poorer neighborhoods composed of low-income workers banished from the center (Carlos, 2009; Alvarez, 2015). Low income residents expelled from the center live in degraded or Environmental Protection zones due to the lack of public housing policies that prevent this group from affording housing closer to opportunities (Carlos, 2009; Klink and Denaldi, 2014).

The urbanization of the MSP was intensified by a process of industrialization centered on the exploitation of the labor force through low wages and expulsion of the working masses to the urban peripheries, where the land had a low cost (Carlos, 2009). The economic crises of the 1980s and 1990s increased unemployment and deepened social inequalities (Maricato, 2000). According to Carlos (2009), since 1990, the urbanization process has focused on the realization of financial capital through the production of space, transforming São Paulo into a business financial center. In articulation with the State, the financial sector has been driving the public budget for the construction of the necessary infrastructure for businesses. The creation of real estate funds, the production of leased corporate buildings, transformed urban land into a commodity at the service of the financial capital (Carlos, 2009). As a consequence, this process has accentuated the expulsion of the low-income population living within construction area of new buildings, deepening social inequalities (De Sá et al., 2019). MSP presents an historic contradiction of the production of urban space between social production and private appropriation.

[2] Gross Domestic Product.

Studies have highlighted the presence of a significant number of empty buildings in the central region of the MSP (Nadalin and Igliori, 2017; Acolin and Green, 2017) with better accessibility and infrastructure. However, the increasing cost of real estate in the city has made these buildings unaffordable for the low-income populations, reinforcing the need for housing policies that offer subsidies to allow these populations to live in the city center. This low-income group, as highlighted by Marques and Saraiva (2017), lives in heterogeneous conditions of precarious housing, such as slums and irregular settlements and overlapping uneven socioeconomic conditions. The low HDI group carries the burden of long commutes, crowded public transport, little comfort and greater exposure to air pollution and noise while commuting, which has major impact on their health (Vasconcellos, 2005). Tajalli and Hajbabaie (2017) have looked at the relationship between commuting mode choice and public health. Walking and using the metro were the healthiest modes of transport while using public buses, cars and working from home were associated with a higher probability of mental health issues and obesity in New York City. Recent studies have looked at air pollution exposure while commuting by socioeconomic groups showing how low groups are more at risk (Pratt et al., 2015). In London however, no systematic relationship between income deprivation and exposure was identified. Rivas et al. (2017) have found that when considering the use of cars in London, low-groups (or most deprived) were the main users and most protected from exposure while the high group relied on public buses to commute, being more exposed. In the MSP, Ribeiro et al. (2019) associated increase rate of respiratory cancer incidence and mortality with increase rates of traffic density and NO_2 concentrations. Higher rates of respiratory cancer mortality were found in the lowest MHDI groups. Infrastructure and socioeconomic variables differ from one place to another. Incorporating these variables, particularly in LA cities where inequality, poor infrastructure and safety issues persist, are essential to assess and ameliorate the health benefits of transports to the population that uses it the most.

Although some progress has been made to improve public transportation service, studies show that the current distribution of public transport contributes to exacerbating education inaccessibility amid the lowest income population (Moreno-Monroy et al., 2018). In order to address these issues, land use and transport policies should consider the spatial mismatch from city opportunities, mostly focusing on the opportunity increase and social inclusion for the low-income population. Cost-benefit analysis should consider improvement of the poor urban infrastructure and of the protection of environmentally sensitive areas in poorer residential areas, rethinking social housing program regulations in order to provide better conditions for vulnerable people to overcome these disparities and to transit. Economic development and urban planning should consider creating opportunities for this extreme poor population.

Some limitations were attached to this study. The 7 AM to 8 PM time was used to calculate accessibility, but since the low MHDI group lives in the outskirts of the center, their commute time begins earlier than those living in the center, highlighting not only longer commutes but also greater potential time of exposure. In São Paulo, Vasconcellos (2005) showed how the highest income groups mostly travel by car, which increases their contribution to transport externalities and environmental impacts. For the author, the lowest income groups, which are also the group to spend a large share of their income on public transports, bear the weight of low mobility, having almost no contribution to transport externalities. For Carvalho and Pereira (2012) this represents a major issue as the higher income population does not see public transport as a mode of transport impacting policies aimed to foster the use of public transport. In addition, as mentioned in the methods section, there is a significant impact in not considering informal jobs in the accessibility analysis, especially for the lowest MHDI group, but we believe that the spatial behavior is still representative.

Conclusions drawn from this study reinforce scientific evidence that

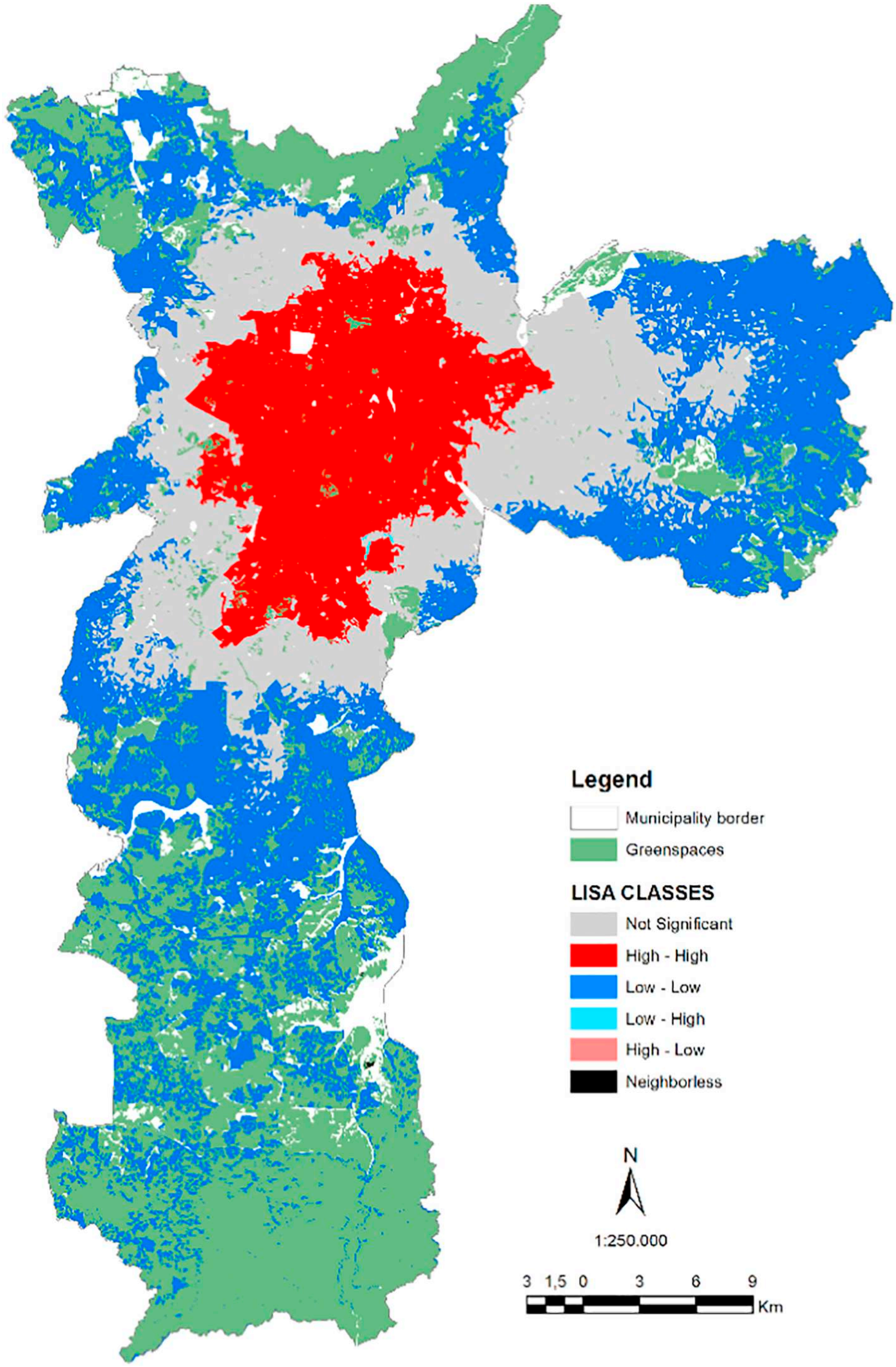


Fig. 6. LISA Moran's map of public transport accessibility and MHDI for São Paulo.

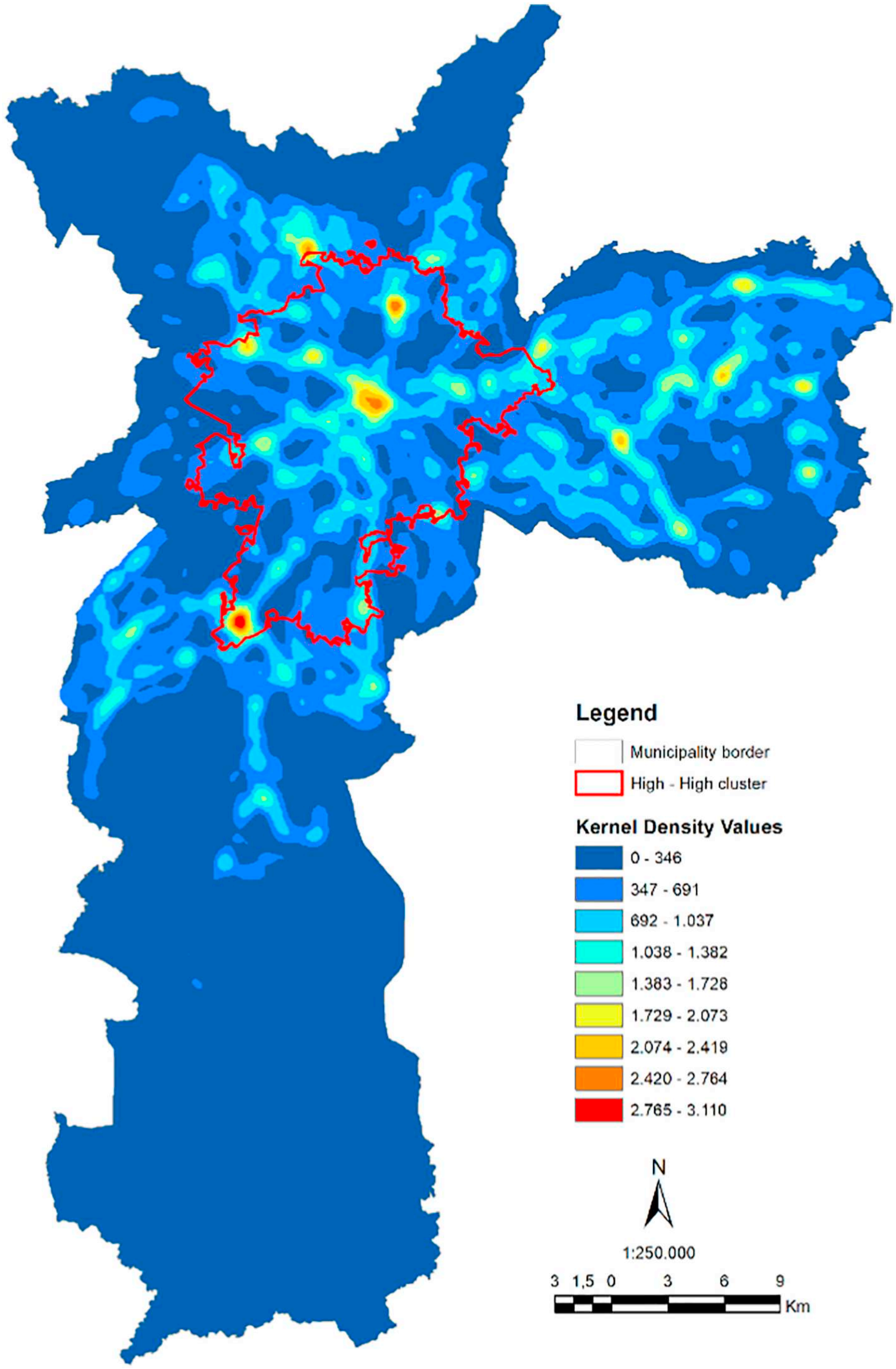


Fig. 7. Layers of bus frequency and the highest (> 90th percentile) cluster of the MHDI for São Paulo.

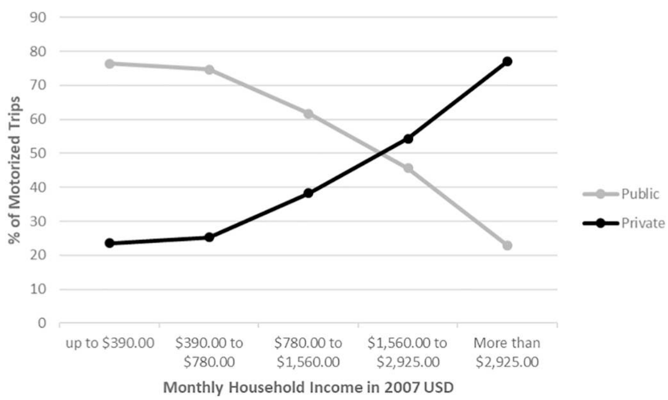


Fig. 8. Monthly household income and motorized modal split in 2007 for the MSP (Metrô, 2007)."

accessibility is not only limited to transport policies but to a set of variables that accounts for land-use choices, spatial distribution and improvements in the structural and living conditions of the population that needs it the most. Considering that low MHDI residents are the main users of public transport, it is only fair to focus on city improvements that go beyond developing the city center. Better understanding of the environmental impacts associated with these issues is also essential to capture the externalities related to transports such as air pollution exposure but also to prevent further land and water degradation in one of the most populated cities of the world. Although this study has focused on job accessibility, other dimensions of accessibility could be considered while analyzing social inclusion. Future studies could invest in extending the accessibility dimensions and its overlap with other vulnerabilities. Without effective public policies to reduce inequality, the current disparities are likely to continue to fall on future generations.

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Appendix A. Appendix

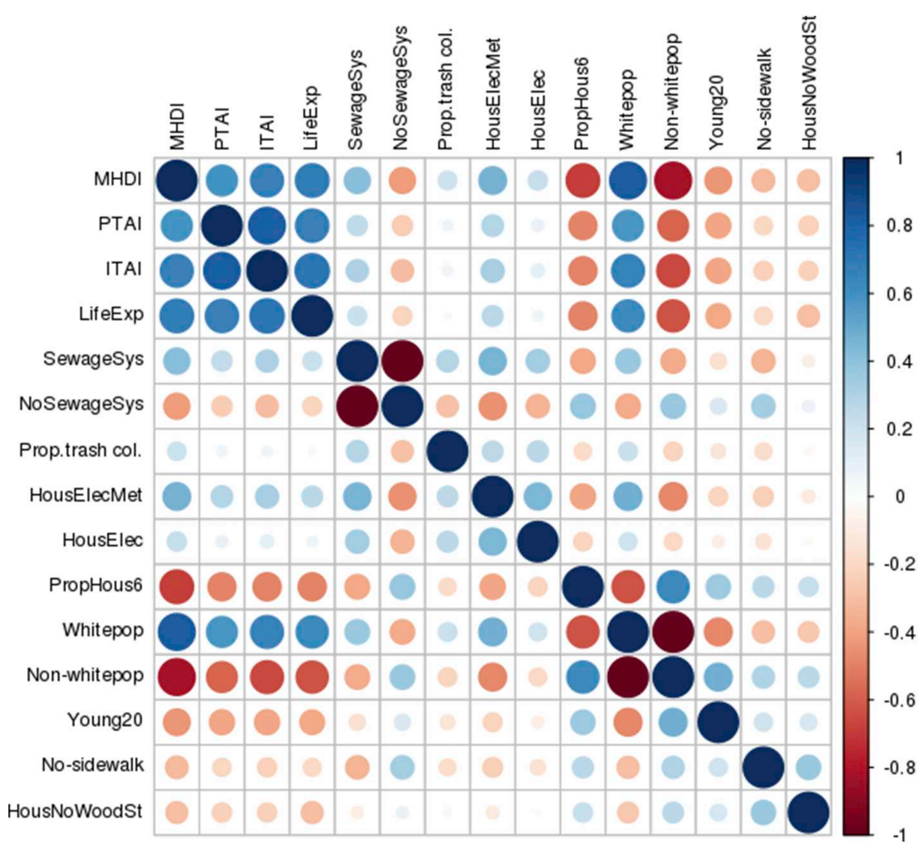

Fig. A.1. Correlation matrix of used variables.

Table A.1
List of acronyms.

Variable	Acronym
Sewage system	SewageSys
Other Sewage solution	OthSewageSol
Proportion of trash collected by service	TrashCol.
Proportion of households with exclusive electric meter	HousElecMet
Proportion of households with electricity	HousElec
Proportion of households ≥6 inhabitants	HousMore6
Proportion of households no male	HousNoMale
Proportion of households no female	HousNoFemale
Proportion households head female	HousHeadFemale
Proportion of owned or almost discharged households	OwnedHous
Proportion of non-owned households	NotOwnedHous
Proportion of households connected to water distribution system	HousWaterDis
Proportion of households with other form of water supply	HousWaterOther
Number of permanent private households	#House
Number of inhabitants	#Inhab
White population	Whitepop
Non-white population	Non-whitepop
Young population ≤ 20	Young20
Households average monthly income	Income
Households income ≤1 monthly min wage	Income≤1wage
Households income 10 min monthly wage	Income 10
Households income ≥10 min monthly wage	Income ≥10
Households no public lighting	HousLight
Households no paved street	HousPavSt
Households with no sidewalk	HousSidewalks
Municipal Human Development Index	MHDI
Public Transport Accessibility Index	PTAI
Individual Transport Accessibility Index	ITAI
Households with wooded street	HousWoodSt
Households no wooded street	HousNoWoodSt

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