Inequalities in transit accessibility: contributions from a comparative study between Global South and North metropolitan regions

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ABSTRACT

Accessibility metrics have been increasingly employed as a tool to explore the social impacts of transport systems and policies. However, few empirical studies of accessibility involve comparisons of cities from countries with different levels of development, in particular, across the Global South and North. This paper attempts to bridge this gap by focusing on two very distinct, but similarly sized, large metropolitan regions: São Paulo and London, for which we develop comparative metrics.

These metrics are used to identify patterns for different occupational groups (used as a proxy to socioeconomic groups) and discuss transit accessibility inequalities. The issues imposed by a comparative study of urban regions with distinct characteristics are discussed. The study applies the results of one metropolitan region to contrast with the other and explore how characteristics of each region's public transport system and spatial mismatch between residential and workplace locations are related to inequalities.

Groups condition were represented in the Lorenz curve, revealing a new strategy to be adopted by comparability studies on inequalities. The results from Lorenz curve and Gini coefficient reveal larger transit accessibility inequalities in São Paulo than London. The proposed groups representation enriched the comparability perspective as a tool to support transport planning.

Keywords: Inequalities, Accessibility, Comparability Studies, Lorenz Curve

1. INTRODUCTION

Identifying social inequalities related to accessibility and mobility dimensions, considering their distributions over specific areas or population groups, is a challenging problem that has been increasingly investigated (Van Wee and Geurs, 2011; Bocarejo and Oviedo, 2012; Neutens et al., 2015; Lucas et al., 2016; Pereira et al., 2017; Cui et al., 2019). Nonetheless comparative research that involves accessibility based on empirical studies in distinct urban contexts is still not so common. Some studies compare the accessibilities of cities within the same country (Levinson et al., 2017; Scheurer et al. 2017) or the same continent (Moya-Gomes and Gárcia-Palomares, 2017) but few studies have provided an intercontinental cities comparison. This study investigates inequalities in transit accessibility in areas across the Global South and North. Our two-fold goal includes a discussion of methods for comparative studies that involve inequalities in accessibility dimension and an empirical analysis of the distinct transit accessibility realities from São Paulo and London.

As inequalities are related to the distribution of opportunities (Van Wee and Geurs, 2011), areas with better access to amenities in cities are usually more expensive, which significantly affects residence opportunities for the lower income population (Boisjoly et al., 2017), with the exception of alternatives provided by specific social housing policies. São Paulo is an example of the former case, with a substantial portion of the lower income population living far from the central business district (CBD) area, while London is closer to the latter, as some social housing policies provide opportunities for the lower income groups to live closer to the CBD. Consequently, both areas are interesting case studies to explore inequalities in accessibility using a comparative lens. For that, we use the Lorenz curves and Gini coefficient, which are commonly employed to verify the income distribution across a society. These are applied to analyse the accessibility inequalities, following an increasing number of studies that encourage the discussion of transport related social exclusion (Delbosc and Currie, 2011) and the equity dimension of transport policies, considering the evaluation of inequalities of accessibility from different groups (Lucas et al., 2016;Van Wee, 2016; Pereira et al., 2017). Yet, exploring the equity distribution effect of a transport system on distinct groups is challenging (Manaugh et al., 2015). Groups of people inevitably have unequal access to opportunities, which can sometimes be considered unfair (Van Wee and Geurs, 2011).

It is not a novelty to consider accessibility measures for specific groups in a people-based approach, such as children (Talen and Anselin, 1998), gender and ethnicity (Kwan, 1998). Some studies have examined aggregate accessibility by income and socioeconomic group (Grengs, 2012; Wachs and Kumagai, 1973) and research in this area is growing but still limited. Thus, exploring aggregate accessibility dimensions from different groups in distinct countries of the Global South and North constitute a contribution pursued in this paper.

This study investigates the inequalities in transit accessibility based on occupational groups (used as a proxy to socioeconomic groups) in two metropolitan regions from countries with vastly different environments for economic development: Brazil and the United Kingdom. Results from one metropolitan region are used to contrast with the other, exploring how transit accessibility, as captured by different metrics, may be revealed by the characteristics of each region's transport system and the differences in residential and workplace spatial patterns.

The paper is organized as follow: next section presents the methods for computing the accessibility metrics considering the framework of comparison between metropolitan areas and the occupational group perspective; section three presents the results of the accessibility metrics for both metropolitan regions, followed by section four that discusses the groups represented in the Lorenz curves, revealing a new strategy to be adopted by comparability studies on inequalities. Finally, section five presents concluding remarks and suggestions for future research followed by references.

2. METHODS FOR COMPARATIVE STUDIES ON ACCESSIBILITY INEQUALITIES

In order to assure the comparability of inequalities in transit accessibility within Global South and North metropolitan regions, a comparative framework was established. This included: i) the choice of socioeconomic classification, ii) the selection of appropriate accessibility metrics and iii) the geographical definition for the metropolitan regions. These three aspects were restricted by data availability on each case study area, which imposed additional challenges for the analysis and for the decision on the spatial units to be used in the study.

In this section, these will be contextualized, detailed and justified, considering the relevant literature and context sensitive background to support the methods replication in future comparison studies. The third aspect, definition of metropolitan regions, will be addressed in the next section (3) within the discussion on the empirical study.

2.1. Socio occupational group classification

The socioeconomic classification should capture socioeconomic structure. A long tradition in sociology and urban studies has debated the use of socioeconomic variables as indicators of social structure. Income it is strongly influenced by economic cycles and conjunctures. A classification based only on income could result in comparing groups with distinct positions in each society. For instance, choosing to compare the 20% with lower income could include people that are not so vulnerable in London and, more importantly, would exclude a huge part of vulnerable population from São Paulo. Classifying based on minimum wages also would lead to even greater challenge, as a minimum wage represents distinct economic capacities in these different cities. Additionally, it is quite imprecise, since for nearly a century (at least since Max Weber's discussions on class) it is known that only income is not a predictor of social positions. Social structure, understood as the relative positions individuals and groups have in society, is much better characterized by occupation - a combination between economic activity, autonomy at work, degree of specialization and income (for a discussion, see: on social stratification - Erikson and Goldthorpe (1992) and on spatial segregation and social groups - Duncan and Duncan (1955), Pinçon-Charlot et al. (1987) and Massey and Denton (1993)).

2.2. Accessibility metrics by group

The accessibility concept has gained prominent importance in planning during the last decades (Batty, 2009). Hansen (1959), who pioneered the association of accessibility to potential opportunities for interaction, defined accessibility as "*a measure of the intensity of the possibility of interaction*". To Páez et al. (2012), accessibility is defined as the potential to attain spatially distributed opportunities and can be considered one of the main outcomes of spatial development, as the result of transport supply and the geographical distribution of opportunities. Geurs and Van Wee (2004) define accessibility as "*the extent to which land use and transportation systems allow individuals access to activities and destinations through a combination of means of transportation*,", i.e., accessibility is related to the opportunity of access, which has the activity as the end point and the transport system as the means to access it. Thus, accessibility can be understood as the ease with to achieve opportunities, taking into account the magnitude and quality of the respective activities, and as well as the potential spectrum of social and economic interactions, inherent to their relative locational advantage (Hansen, 1959; Ingram, 1971; Handy and Niemeier, 1997; Geurs and van Wee, 2004).

To measure the accessibility, this study considers the conventional cumulative and gravity-based approaches and the two-step floating catchment area (2SFCA) accessibility metrics, described in Table 1. As shown in their formulas, both cumulative and gravitational accessibilities consider supply only. An accessibility index that relates the demand-to-supply ratio and the interaction between them was proposed by Luo and Wang (2003). This is known as the two-step floating catchment area method (2SFCA), which is based on the floating catchment area method (FCA) applied by Peng (1997) and Wang (2000) adapting Radke and Mu's (2000) spatial decomposition method (Frasen et al., 2015; Luo; Wang, 2003; Luo; Whippo, 2012; Neutens, 2015).

In addition to the inclusion of demand, this method enables a better interpretation of the results than other methods (Luo and Wang, 2003). However, several studies consider the method incomplete with limitations, such as (i) the population is overestimated in the first step as the service areas of the suppliers overlap; (ii) it is a dichotomic measure, since only the facilities and population inside the service areas are counted; and (iii) no difference exists among facilities and populations with different distances or times (Dony et al., 2015; Frasen et al., 2015; Luo and Qi, 2009; Luo and Whippo, 2012; Neutens, 2015; Radke and Mu, 2000; Wan et al., 2012). Therefore, many improvements to the method, such as the Enhanced 2SFCA (Luo and Qi, 2009), a Variable 2SFCA (Luo and Whippo, 2012) and the 3SFCA (three-step floating catchment area) (Wan et al., 2012), have been proposed.

The 2SFCA method and its improvements have been highly utilized for the shortage analyses of different services, primarily in the healthcare field, such as primary care (Luo and Qi, 2009; Luo and Wang, 2003; Luo and Whippo, 2012; Wan et al., 2012) and residential care (Ni et al., 2015). However, this method is also employed for analyses of different kinds of access: to parks (Dony et al., 2015; Wei, 2017), to day care (Frasen et al., 2015), to public high school (Williams and Wang, 2014), to libraries (Guo et al., 2017) and to general services, such as pharmacies, food shops, public libraries, leisure centres, petrol stations, post offices, primary schools, and secondary schools (Page et al., 2018), or primary care physicians, grocery stores, and green space (Wang, 2018).

Table 1. Accessibility metrics.

	Metric	Definition
Cumulative	Equation 1 $$A_i = \sum_{j=1}^{n} D_j \ \ if\ t_{ij} < t_{max}$$ sum of all opportunities if the time to attain them is lower than the threshold	The cumulative metric counts the number of opportunities that can be reached within a given travel time, distance or cost or measures the required time to reach a fixed number of opportunities, such as jobs, schools or leisure (El-Geneidy and Levinson, 2006). People tend to accept a certain threshold of travel time to reach specific opportunities; this measure represents how much they would be able to access within this threshold (e.g., 30, 60 or 120 minutes) of travel time.
Gravity	Equation 2 $$A_i = \sum_{j=1}^{n} D_j \times f(c_{ij})$$ f(cij) represents the deterrence function	The gravity-based measure (Equation 2) estimates the accessibility of opportunities from zone *i* to all other zones *j* in which distant opportunities (time/cost) provide diminishing returns (El-Geneidy and Levinson, 2006; Geurs and Van Wee, 2004). The deterrence function can be interpreted as how many people would be travelling that distance/time/cost in order to reach a specific type of opportunity. The gravity metric measures how many opportunities are available within this travel distance/time/cost adjusted by the deterrence function.
2SFCA	Equation 3 $$R_j = \frac{D_j}{\sum_{k\in\{t_{kj}\le t_{max}\}} P_k}$$ Equation 4 $$A_i^F = \sum_{j\in\{t_{ij}\le t_{max}\}} R_j = \sum_{j\in\{t_{ij}\le t_{max}\}} \frac{D_j}{\sum_{k\in\{t_{kj}\le t_{max}\}} P_k}$$	The first step of 2SFCA (Equation 3) computes the ratio of suppliers-to-residents (R_j) and divides the supplier service D_j, such as the number of physicians, by the population of tract *k* (P_k), in which the centroid falls within the service area (threshold time t_{max}) centered at a supplier's location *j* (that is, $t_{kj} \le t_{max}$). The second step (Equation 4) sums up the ratios of suppliers-to-residents (R_j), where the supplier's location *j* falls within the service area centred at a resident location *i* (that is, $t_{ij} \le t_{max}$) (Luo and Wang, 2003, p. 872).

To minimise the overestimation of the population, this study proposes an additional step before the traditional first one. This step divides the population of tract k (P_k) by the number of service areas that contain the centroid of tract k ($freq_k$), which yields P'_k (Equation 5 below), where j is the number of all suppliers. Therefore, the P_k of Equation 3 is substituted by P'_k, that is

$$P'_k = \frac{P_k}{freq_k} = \frac{P_k}{\sum_{k \in \{t_{kj} \leq t_{max}\}} 1} \qquad (Equation\ 5)$$

To compare metropolitan regions to identify the accessibility inequality characteristics, instead of focussing only on a broad perspective of the entire population, metrics were adapted to capture the context from specific groups. To calculate the gravity, cumulative and 2SFCA for groups, jobs were considered only for the reference group, and the specific group population was assigned in the 2SFCA adapted method, as described in Equations 6 (gravity), 7 (cumulative), 8 and 9 (2SFCA), noted below

$$A_i^g = \sum_{j=1}^{n} D_j^g \times f(\mathrm{c}_{\mathrm{ij}}^g) \qquad (Equation\ 6)$$

where A_i^g is the gravity accessibility to the occupational group g for the origin zone i, D_j^g is the number of jobs of the occupational group g at location j and c_{ij}^g is the travel cost from origin zone i to destination zone j from group g.

$$A_i^g = \sum_j D_j^g \ if\ t_{ij} < t_{max} \qquad (Equation\ 7)$$

where A_i^g is the cumulative accessibility to the occupational group g for origin zone i, D_j^g is the number of jobs of the occupational group g at location j, t_{ij} is the travel cost from origin zone i to destination zone j and t_{max} is the threshold previously defined threshold.

$$R_j^g = \frac{D_j^g}{\sum_{k \in \{t_{kj} \leq t_{max}\}} P'^g_k} \qquad (Equation\ 8)$$

where R_j^g is the ratio of the jobs-to-residents considering the occupational group g; the number of jobs for the occupational group D_j^g is divided by the occupational population P_k^g, whose centroid falls within the service area (threshold time t_{max}) considering the travel time to the access jobs location t_{kj}.

$$A_i^{Fg} = \sum_{j \in \{t_{ij} \leq t_{max}\}} R_j^g = \sum_{j \in \{t_{ij} \leq t_{max}\}} \frac{D_j^g}{\sum_{k \in \{t_{kj} \leq t_{max}\}} P'^g_k} \qquad (Equation\ 9)$$

where the two-step floating catchment area value for origin zone i considering the occupational group g is represented by the variable A_i^{Fg}. This is composed of the sum of the jobs-to-residents ratio R_j^g, when jobs location j falls within the service area considering the residential location i and the threshold t_{max} (that is, $t_{ij} \leq t_{max}$).

3. EMPIRICAL STUDY ON GLOBAL SOUTH AND NORTH CITIES

Proper data, or lack of it, is a major challenge for comparative studies between cities and complicates the use of accessibility metrics (Boisjoly & El-Geneidy, 2017). In this study the definition of metropolitan regions and the classification of population in correspondent groups was important for comparison of the distinct political-administrative areas and social contexts. This section explored how the workplaces, population and travel time spatial patterns vary for both metropolitan regions.

3.1. Metropolitan regions comparison

The São Paulo Metropolitan Region (SPMR), which is a political-administrative area, covers an area of 7,944 km² and has a population of 19.6 million inhabitants (IBGE, 2010), with an estimate of approximately 21 million inhabitants in 2017. Unlike the SPMR, the London Metropolitan Region (LMR) is not a formally defined administrative area. By comparison of its distinct political-administrative areas, in this study, the LMR is considered an area with geographic contiguity where minimum of 10% of its population commute daily to the Greater London Authority (GLA) (Smith, 2018). The resulting LMR has a population of approximately 16 million inhabitants (2011) and an area that is 16,371 km^2, larger than São Paulo.

Figure 1 illustrates the population and jobs density, besides service areas by transit, for both metropolitan regions. Data from Census 2010 (IBGE, 2010) and Origin and Destination Survey (Companhia do Metropolitano de São Paulo, 2007) was used for São Paulo. Data from Census 2011 (Office for National Statistics, 2016) and the travel times were calculated using a multi-modal accessibility model (Smith, 2019) was used for London. Jobs from all the metropolitan areas were considered for estimating the accessibility metrics.

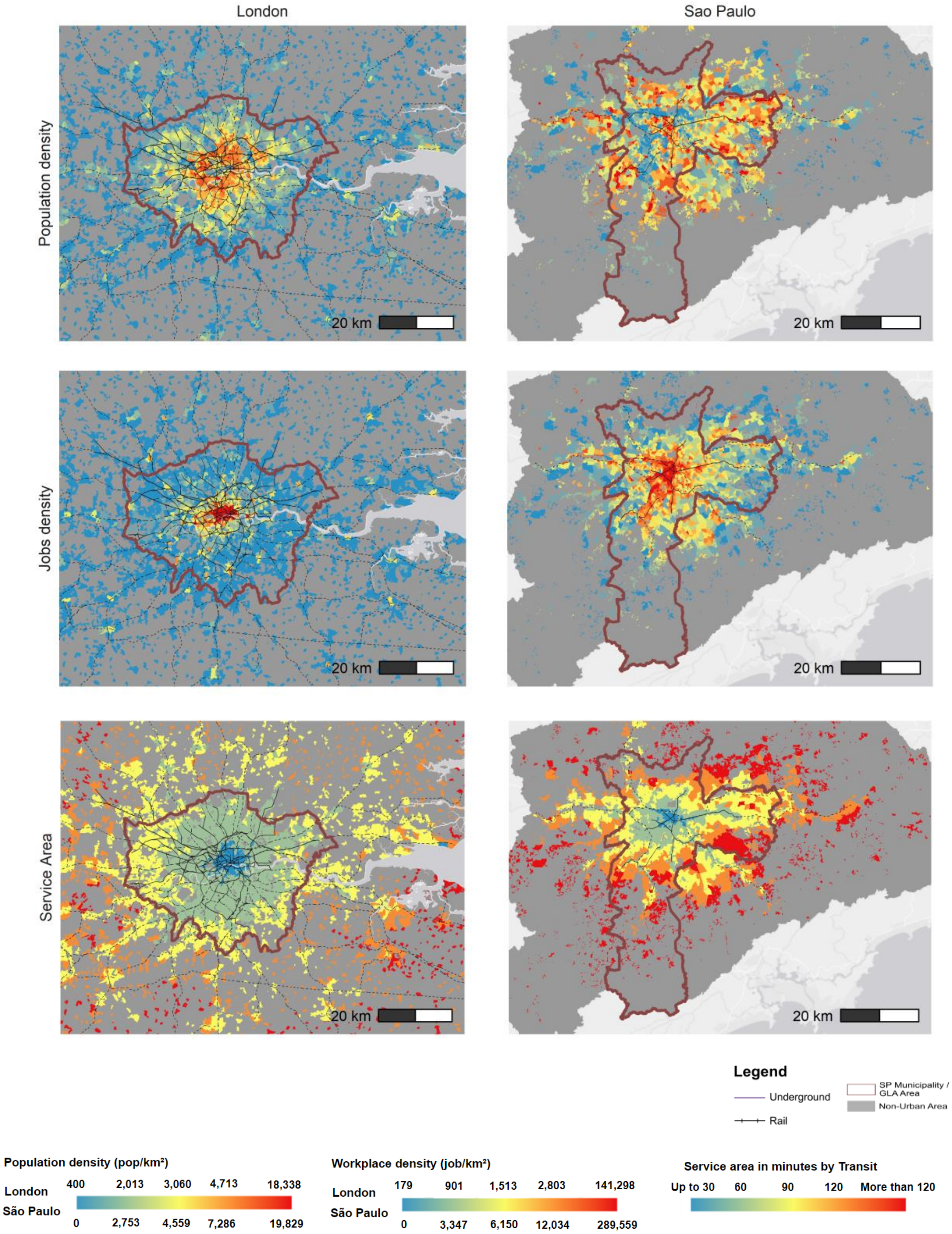

Figure 1. Comparison between workplace density, population density and service areas by transit for São Paulo and London.

Figure 1 shows that workplace density for both São Paulo and London are concentrated in the inner city, with few sub-centres over the urban area. When it comes to the population density, a different distribution pattern can be observed for both London and São Paulo. While London's inner city concentrates most of the jobs and also has a high population density, in São Paulo, there is a spatial mismatch between job and population density.

It can also be observed that most of the high-density population areas of London are located in areas up to 60 minutes of travel time from the inner city, where the jobs are. In comparison to São Paulo, a greater part of the high-density population areas is far from 90 minutes of travel time by transit from the city centre.

The occupational group classification used for this study was based on the methodology adopted by Marques et al. (2016), which was suitable for the data available for both metropolitan regions and compatible with the available transportation data. Also, as income is not available from the UK Census, the choice of occupational groups was confirmed as the most appropriate for the comparative study. For the LMR, occupational groups were based on the National Statistics Socio-economic Classification - NS-SeC (Rose et al., 2005). For the SPMR, job classification available from the OD survey (Companhia do Metropolitano de São Paulo, 2007), was regrouped using the Occupational Classification for Household Surveys (COD) from the Brazilian Institute of Geography and Statistics (IBGE) and the NS-SeC classification.

The classification consists on seven groups. This study focused only on the top and the bottom, in order to explore the inequalities between extreme opposite groups: Group 1 (managerial, administrative and professional occupations related to higher-income workers) and Group 7 (positions with a basic labour contract, in which employees are involved in routine occupations that characterize lower-income workers). While Group 1 represents 10% and Group 7, 38% of the total population in São Paulo, these values are 14% and 6%, respectively, for London. This suggests that considerable difference is expected to reflect in all the accessibility metrics, which were calculated considering the total population and the G1 and G7 groups specifically.

Figure 2 presents the modal split by occupational group for São Paulo and London. The graphs reflect inequality between groups regarding car ownership and accessibility to transit services in both metro regions. For London, it is evident the major use of the car in relation to other modes, followed by transit. Group 1 for London shows a greater use of transit (median equal to 8%) compared to G7 (median of 5%). While for São Paulo, it is clear that there is a high use of cars for the higher-income workers (G1, median equal to 58%) and a high use of public transport for the lower-income workers (G7, median of 39%).

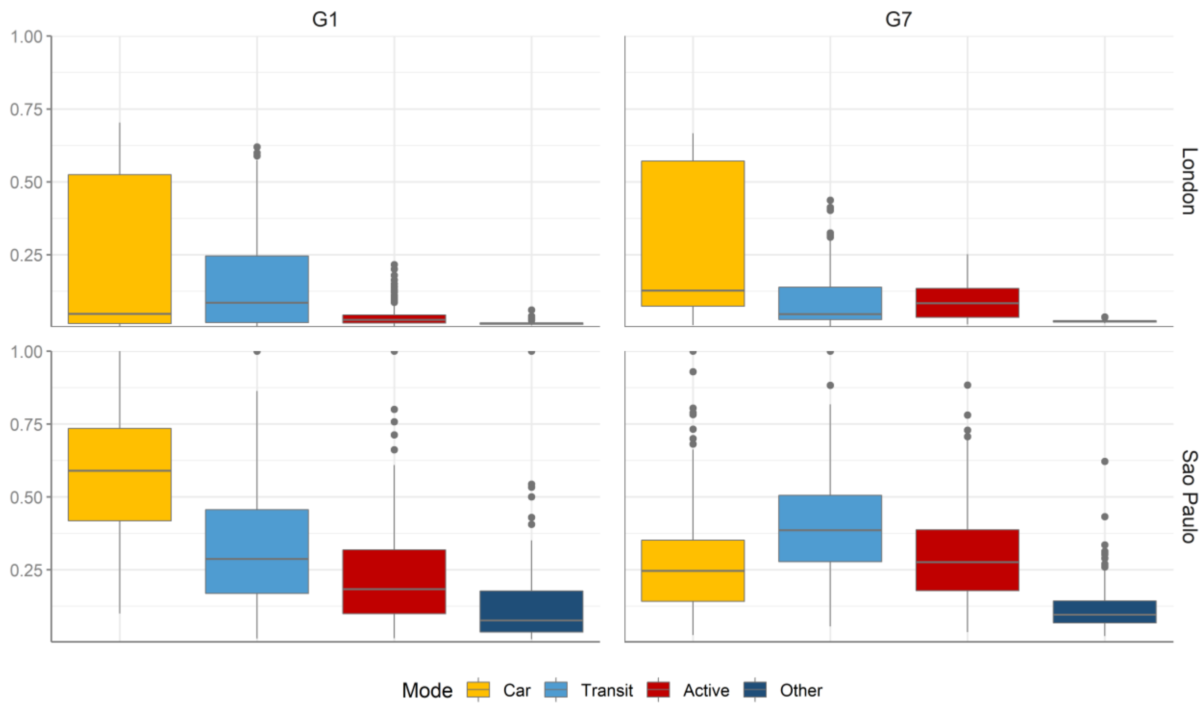

Figure 2. Modal split comparison by occupational group.

Although the comparison of transport mode by the occupational group reveals the structural diversity of transport and a large use of car, the analysis focus on the public transport mode. The transit is related to the structural infrastructure from transport systems, especially considering mode captivity for the lower social classes as car ownership is income dependent (Tilahun and Fan, 2014). Transit was also chosen because the data quality for the private mode for the metropolitan region was a concern due to travel time data sources being limited. A cross-city comparison considering car mode, restricted to the municipality boundaries, can be found on Pritchard et al. (2019).

3.2. Comparing accessibility spatial patterns

The Cumulative and 2SFCA Accessibility metrics were computed for São Paulo and London including: i) the total population (overall accessibility), ii) the population for G1 (higher-income workers) and iii) the population for G7 (lower-income workers), separately. Figure 3 shows the Cumulative, 2SFCA and Gravity accessibility metrics considering the thresholds of 30, 60 and 120 minutes for the total population.

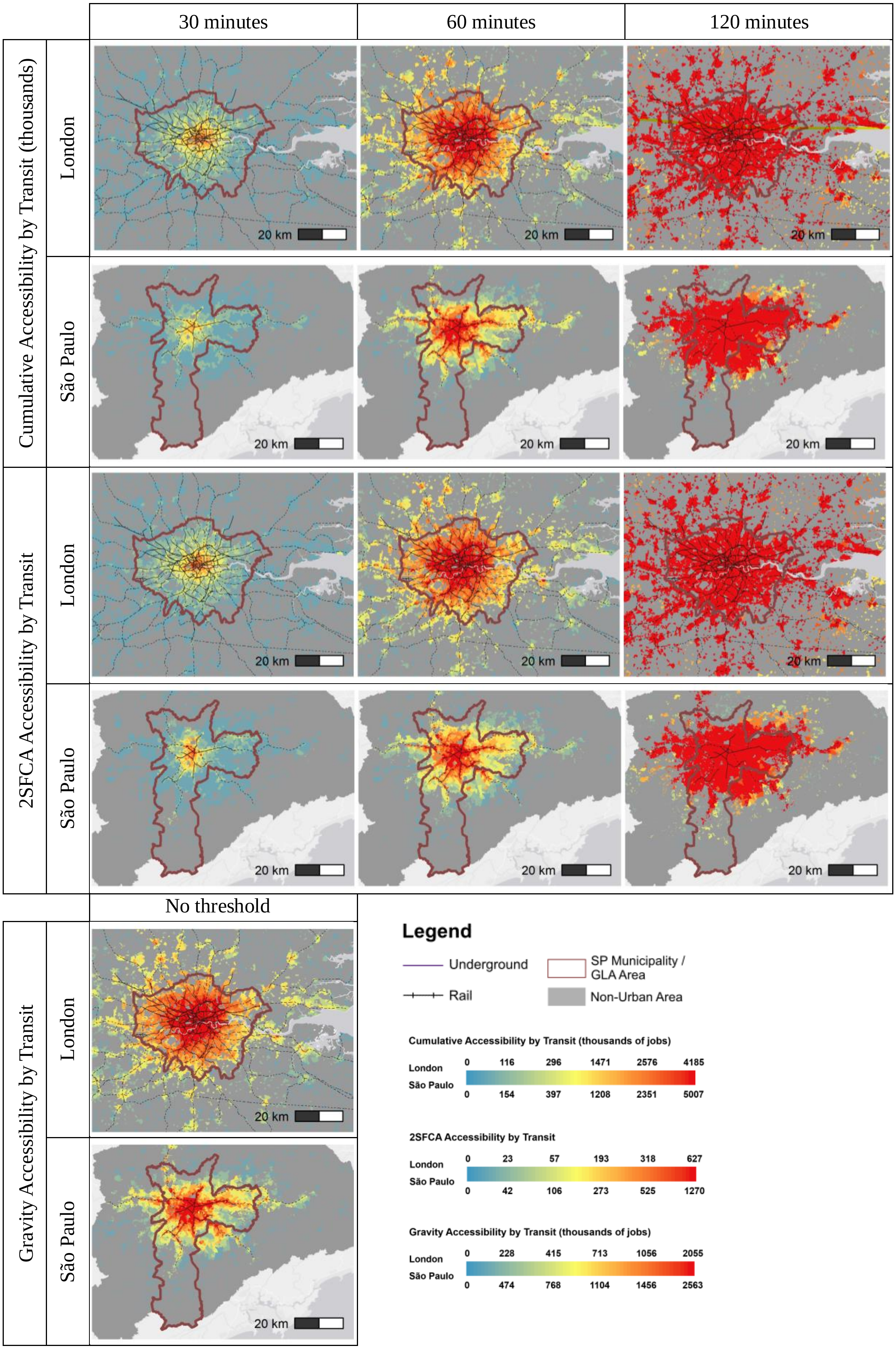
30 minutes
60 minutes
120 minutes
No threshold
Cumulative Accessibility by Transit (thousands)
2SFCA Accessibility by Transit
Gravity Accessibility by Transit
London
São Paulo
20 km
Legend
Underground
Rail
SP Municipality / GLA Area
Non-Urban Area
Cumulative Accessibility by Transit (thousands of jobs)
London 0 116 296 1471 2576 4185
São Paulo 0 154 397 1208 2351 5007
2SFCA Accessibility by Transit
London 0 23 57 193 318 627
São Paulo 0 42 106 273 525 1270
Gravity Accessibility by Transit (thousands of jobs)
London 0 228 415 713 1056 2055
São Paulo 0 474 768 1104 1456 2563

Figure 3. Comparison between transit accessibility for São Paulo and London. (Quantiles based on 60 minutes).

The accessibility maps (shown in Figure 3) also systematically reveal accessibilities levels that are lower in São Paulo than in London, as areas with lower accessibilities (in blue) are present on all maps, independent of the accessibility metric. As expected, all maps show high accessibilities in central areas in both metropolitan regions, in particular around the metro lines. Table 2 compares the percentage of the population that lives in areas in which accessibility levels achieves 25%, 50% and 75% of the total jobs opportunities available. The results presented on Table 2 reveal an interesting pattern by observing cumulative and 2SFCA accessibilities with a 60 minutes threshold. In São Paulo the difference between G1 and G7 is much higher than in London, which highlights the differences in the inequality patterns between the two regions. For example, considering cumulative method, in São Paulo 36% of population of G1 and 10% of population of G7 has access to at least 25% of opportunities, while in London 52% of G1 and 43% of G7 has access to at least 25% of opportunities.

Table 2. Percentage of population with an accessibility level of at least 25%, 50% and 75% in each metropolitan region.

	Gravity			Cumulative 60 min			2SFCA 60 min		
	> 25%	>50%	> 75%	> 25%	>50%	> 75%	> 25%	>50%	> 75%
São Paulo									
All Groups	51%	10%	2%	16%	6%	1%	15%	6%	2%
G1	58%	21%	3%	36%	20%	4%	33%	15%	3%
G7	64%	12%	1%	10%	3%	1%	11%	4%	2%
London									
All Groups	53%	22%	3%	46%	31%	7%	45%	21%	3%
G1	56%	26%	5%	52%	43%	24%	51%	37%	9%
G7	54%	22%	3%	43%	20%	3%	42%	14%	1%

Differences among the results obtained using gravity-based accessibility compared with cumulative and 2SFCA metrics are revealed in Table 2 and Figures 3 and 4. As expected, the 2SFCA results are slightly but consistently lower than those obtained with the cumulative metric, which is a consequence of including both demand and supply dimensions as discussed in the foregoing section. Striking differences exist when comparing the results obtained with cumulative and 2SFCA metrics to those computed using the gravity metric. Differences are noticeable across the results and an example of the results obtained for São Paulo's G7 (lower income workers) are particularly stark. While the gravity accessibility for G7 suggests that more than 64% to at least 25% of opportunities, the results for cumulative and 2SFCA metrics indicate that less than 10% of the population benefit from this accessibility level. Different metrics present diverse views from the inequality issue, but all in the same direction in the sense that higher groups have always better conditions of transit accessibility when compared to the lower groups, in both studied metropolitan regions.

4. REVEALING GROUPS ACCESSIBILITY INEQUALITIES ON LORENZ CURVES

The Gini coefficient and Lorenz curve have been highlighted as fruitful and robust methods to explore income inequalities and its adaptation in transport and accessibility studies (Neutens et al. 2010; Delbosc and Currie, 2011; Lucas et al., 2015; Niehaus et al. 2016). Despite the increasing theoretical exploration of Gini index as a measure for inequality, the application to empirical studies of accessibility, including comparisons among different study areas and groups, is not so frequent.

The application of the Lorenz curve to both metro regions reveals a significant difference in the accessibility distribution across the population, which denotes more unequal conditions in São Paulo from an egalitarian perspective. The differences between São Paulo (yellow lines) and London (blue lines) are notable in the graphs presented in Figure 4.

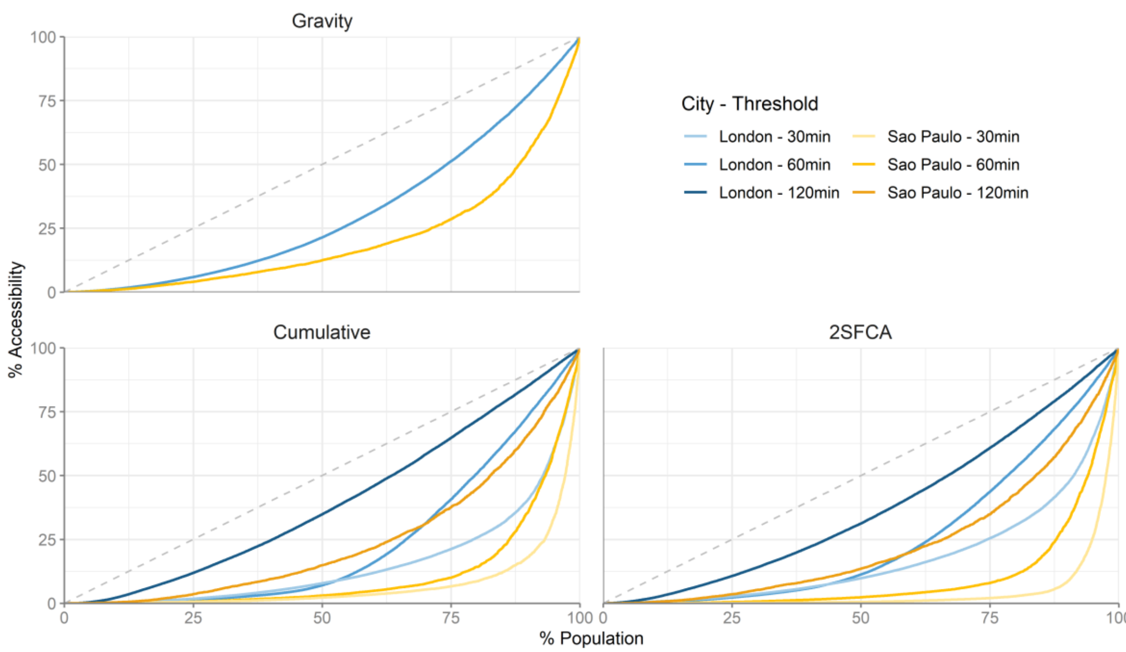

Figure 4. Comparative of Lorenz Curves for São Paulo and London.

The accessibility results presented for São Paulo are aligned with the general trends highlighted by other studies (Haddad et al., 2015; Moreno-Monroy et al., 2017; Boisjoly et al. 2017).

The cumulative and 2SFCA accessibility metrics enable an extended analysis as the difference in the impact of the transit travel time thresholds on the equality distribution can be observed. Lower thresholds (light colours) are more distant to the equal distribution line, which indicates that the equality distribution for a 30 minutes threshold is worse than 60 minutes and so on. The Lorenz curves indicate that the 2SFCA always produces slightly sharper curves.

Beyond the comparison between the two metropolitan regions including aggregated accessibility metrics for each region, an effort was made to figure out how to better explore the proposed metrics by group. This study explores an alternative in which the median accessibility conditions are used in a comparison lens perspective. To the best knowledge of the authors there was no previous study that succeeded in revealing the groups specific conditions within the Lorenz curve. On Figure 5 each group´s corresponding accessibility median values was represented in the Lorenz curves, G1 (higher income workers) as dark blue and G7 (lower income workers) as red. In addition to the disparity of the Lorenz curves for London and São Paulo (the former is considerably closer to the equity line), note that the difference between the medians for Group 1 and Group 7 in São Paulo is substantially higher than that for London. This finding reinforces the evidence that the inequality on transit accessibility between the two extreme occupational groups is remarkably stronger in the São Paulo Metropolitan Region.

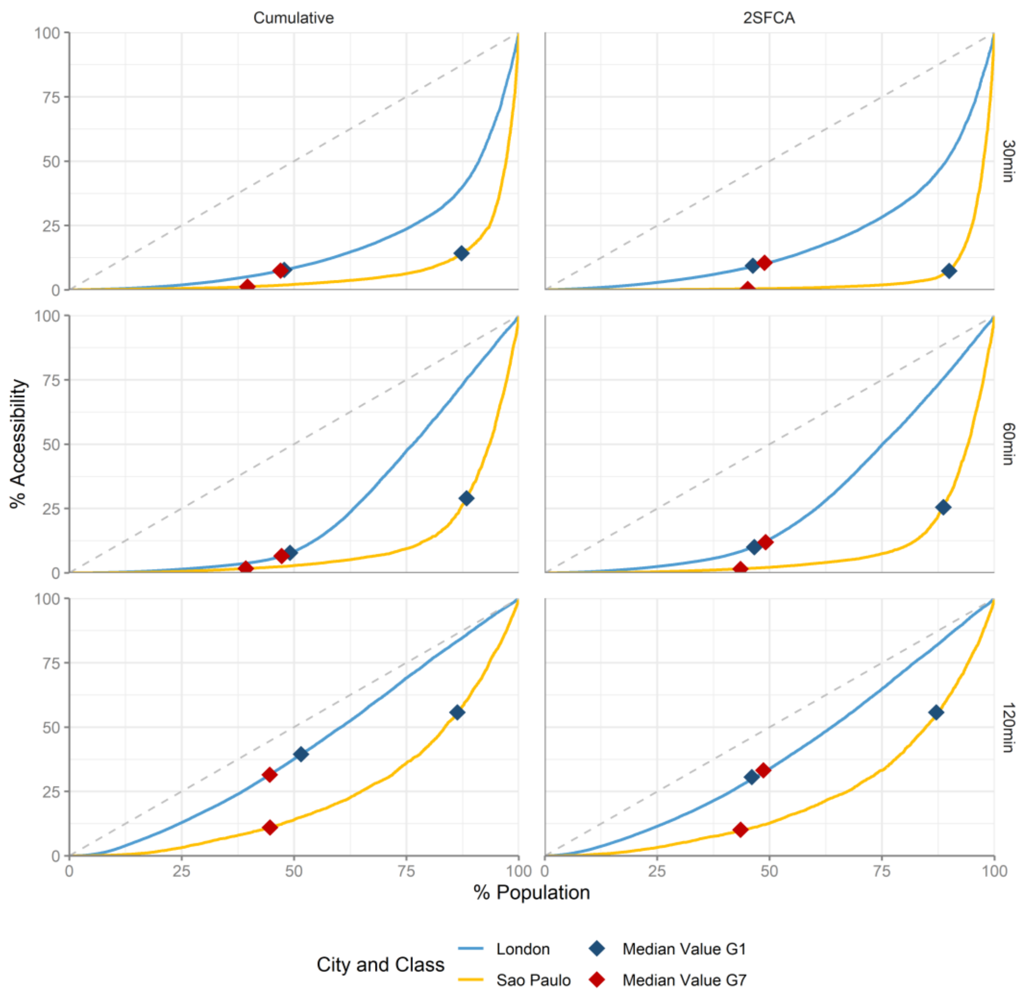

Figure 5. Comparative of Lorenz Curves between Cumulative and 2SFCA for São Paulo and London.

The Gini values enable a quantitative observation of these differences, as presented in Table 3. In addition to the Gini calculated according to the total population accessibility metrics, the Gini that is based only on the two study groups (G1 and G7) was also computed.

Table 3. Gini values for London and São Paulo accessibility dimension.

		GINI for all groups		GINI for G1 + G7	
Accessibility	**Threshold**	**London**	**São Paulo**	**London**	**São Paulo**
Gravity		0.37	0.63	0.32	0.6
Cumulative					
	30	0.7	0.87	0.68	0.86
	60	0.53	0.81	0.49	0.79
	120	0.23	0.56	0.17	0.53
2SFCA					
	30	0.65	0.91	0.67	0.91
	60	0.5	0.8	0.49	0.82
	120	0.25	0.54	0.15	0.54

Higher values of Gini represent larger areas between the computed curves and the equal distribution line in the Lorenz approach, which indicates a more unequal condition. São Paulo presents systematically higher levels of Gini than London for all tested accessibility measures. Higher time thresholds for cumulative and 2SFCA present stronger inequalities, therefore 120 minutes threshold indicates higher inequality than 60 and so on. While comparing London with São Paulo, it is clear that the distance between Gini values from both areas increases with higher thresholds, and the São Paulo Gini achieves more than twice the London value for a threshold of 120 minutes.

The groups expressed in the Lorenz curve and by the Gini indexes reveals how different are the conditions faced by Global South and North cities. Although mapped accessibility absolute values for all groups are lower in London than São Paulo, differences between groups are astonishing. This brings new insights that possibly it would be better to adopt different strategies while dealing with both cases. In the Global North it seems to be feasible to follow a sufficientarianism approach, as discussed by Lucas et al. (2016), by stablishing a threshold from which policies would tackle all the population. The 30 minutes city proposed by Levinson (2019) for example, is an interesting strategy considering a more developed, and less unequal, urban environment. On the other hand, for a city like São Paulo with its huge inequalities, it is unfeasible on practice to achieve a reasonable threshold for everyone in the medium term. In this case a target could be to diminish the differences between the groups. For instance, an evaluation of a new public transport infrastructures would have to consider if the outcomes could avoid enlarging the distance between groups, by adopting metrics like the ones proposed in this paper.

5. CONCLUSIONS

Comparison between accessibility patterns in Global South (São Paulo) and North (London) metropolitan regions revealed, as expected, a starker pattern of inequality for São Paulo than for London. The pronounced inequalities in São Paulo in comparison to London were consistent across analyses, which were carried out using different accessibility metrics.

The study proposed adaptations to accessibility metrics by groups, allowing to calculate gravity, cumulative and 2SFCA accessibilities for Group 1 (managerial, administrative and professional occupations related to higher-income workers) and Group 7 (positions with a basic labour contract, in which employees are involved in routine occupations that characterize lower-income workers).

The accessibility per occupational groups and the Lorenz curves, expressing the medians for each group, disclose more about the inequalities condition when compared to the total accessibility for the entire population. Although many accessibility metrics have been proposed in the literature, group analysis from an aggregate perspective has not been much explored to date.

The empirical comparative study developed here provides evidence that the proposed approach is effective in unveiling inequalities which are not revealed when analyzing total population and using traditional mapping itself, thus highlighting an important avenue of research of social exclusion in transport.

In addition, the present research brought insights on an alternative to advance from an ‘egalitarianism’ to a sufficientarianism perspective. The sufficientarianism approach, as discussed by Lucas et al. (2016) precedes the use of a threshold from which a minimum level of social exclusion can be established. Defining this threshold is a challenge (Lucas et al., 2016), especially considering the unequal and heterogeneous environment similar to conditions in São Paulo, as discussed by Marques and Saraiva (2017). A complementary possibility is to evaluate how far different groups are from each other, which is inspired by the empirical outcome revealed in this research through the comparison between the groups at Lorenz curves. Hopefully this will be explored in future research.

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