

Access to opportunities in the informal city: characterizing the role of accessibility in the built environment and mobility in precarious settlements of Fortaleza

*Acesso às oportunidades na cidade informal: caracterizando o papel da
acessibilidade no ambiente construído e na mobilidade em assentamentos
precários de Fortaleza*

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ABSTRACT

Despite recent advances in the literature dealing with socio-spatial inequalities in urban accessibility, and its complex network of causes and consequences, relevant gaps are recognized in relation to the context of informal housing. In this sense, this paper aims to analyze the patterns of built environment and mobility in groups of precarious settlements with different levels of locational accessibility. Based on the crossing of secondary data from different sources and on the construction of representative indicators, an exploratory analysis of the terciles of precarious settlements was carried out, using Fortaleza as a case study. The results obtained allow the conclusion that more accessible precarious settlements present more intensified occupation, less diversity of uses and more sustainable urban mobility patterns, reinforcing the need for public policies to bring people and activities closer together.

RESUMO

Apesar dos recentes avanços na literatura que trata das desigualdades socioespaciais na acessibilidade urbana, e de sua rede de causas e consequências, reconhecem-se lacunas relevantes em relação ao contexto da habitação informal. Nesse sentido, o presente artigo se propõe a analisar os padrões de ambiente construído e mobilidade em grupos de assentamentos precários com níveis distintos de acessibilidade locacional. A partir do cruzamento entre dados secundários provenientes de diversas bases e da construção de indicadores representativos dos fenômenos analisados, realizou-se uma análise exploratória nos terços de assentamentos precários, utilizando Fortaleza como estudo de caso. Os resultados obtidos permitem concluir que assentamentos precários mais acessíveis apresentam ocupação mais intensificada, menor diversidade de usos e padrões mais sustentáveis de mobilidade urbana, reforçando a necessidade de políticas públicas de aproximação entre pessoas e atividades.

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1. INTRODUCTION

Emerging as one of the main challenges faced in metropolises of the Global South, socio-spatial inequalities in access to urban activities have gained prominence in recent literature (Blanco et al., 2018; Vasconcellos, 2001). Especially since urban transformations in recent decades, these inequalities have been associated with other urban agenda issues such as segmentation, segregation, and the exclusion of vulnerable groups (Pequeno and Rosa, 2015). In this sense, studies on this issue in the Brazilian context have provided evidence of lower access to activity opportunities by low-income groups (Boisjoly et al., 2020; Pereira et al., 2019). Thus, it reinforces an assertion that has been highlighted for Brazilian metropolises since the 1960s: the growing spatial disconnect between low-income residential areas, workplaces, and urban facilities, which acts as an important facet of socio-spatial inequalities, simultaneously serving as their promoter (Maricato, 2003; Rolnik and Nakano, 2009).

Understanding the effects of the locational context of low-income populations on accessibility in Brazilian cities proves to be complex, given a reality marked by a formal housing market coexisting with informal housing production mechanisms and state intervention through housing policies (Pequeno and Rosa, 2015). However, research on urban accessibility focusing on informal housing reality is scarce (Maia et al., 2016), especially concerning the understanding of its heterogeneity (Nadalin and Mation, 2018). The complexity of precarious settlements, one of the most significant manifestations of informality in Brazilian housing, can be interpreted mainly through physical, social, and political dimensions (Pasternak and D'Ottaviano, 2016). The locational situation of settlements in the urban environment emerges as one of these aspects that bring heterogeneity to the informal housing market because, despite recognizing the peripheral context in which many of them are located, it is also possible to identify, especially in large metropolises, settlements remaining in central areas or close to centralities (Maia et al., 2016).

The different locations of precarious settlements in cities provide heterogeneous conditions of access to low-income groups, notably regarding proximity to work, health, cultural, and leisure opportunities. Accessibility emerges as a central element in understanding the complexity of cities and the interdependence between urban subsystems (Lopes et al., 2020), being one of the determinants for the manifestation of different spatial production patterns, participation in activities, and mobility (Assis et al., 2022; Siqueira, 2020). The central question of this research, therefore, lies in investigating how the locational conditions of low-income populations living in precarious settlements influence the materialization of these urban spaces and the interactions of this group in space. Thus, this article aims to characterize the patterns of accessibility, mobility, and the built environment in precarious settlements, seeking, through this exploratory effort, to enable future research to investigate possible explanations for the influence of accessibility on housing and mobility conditions of low-income populations in Brazilian cities. The city of Fortaleza will be used as a case study, a Brazilian metropolis that, like others, has its socio-spatial inequalities materialized in the precarious housing conditions of the most vulnerable socio-economic groups.

2. LOCATION AND ACCESSIBILITY IN PRECARIOUS SETTLEMENTS

2.1. Impacts of locational accessibility in precarious settlements in Brazilian cities

The informality of housing production among lower-income groups has been an expanding process in Brazilian cities for decades. However, since the late 20th century, this process has intensified, presenting greater diversity in its manifestations (Fernandes, 2010). Looking specifically at the context of major metropolitan areas, several aspects stand out: (i) spatial heterogeneity, interpreted

both at the city and precarious settlement scales, contrasting with the simplified idea of a dual center-periphery city (Marques, 2014); (ii) new dynamics of recent production in popular territories, driven by consolidation movements, densification, and verticalization in part of the precarious settlements, and by large-scale removals linked to housing provision policies (Pasternak and D'Ottaviano, 2016); (iii) increased cohabitation in central areas; as well as (iv) proliferation of front-and-back houses; and (v) expansion of favelas in extremely peripheral regions, public areas, and environmental protection zones (Pequeno et al., 2022; Fernandes, 2010).

This array of variations is strongly associated with the “myth” of favela homogeneity, as brought up by Pasternak (2006). Mentioning the rarity of comparative studies between favelas, the author points out some of the distinguishing aspects that contribute to understanding them as complex, multiple, and heterogeneous socio-spatial territories. Among these aspects, the locational situation of precarious settlements stands out. The process of residential location decision-making for low-income families is multifactorial, depending on aspects such as housing quality, neighborhood quality (urban amenities), strategic location within the city, social neighborhood structure, and preference for certain lifestyles (Nadalin and Mation, 2018; Abramo, 2003). Locational accessibility, i.e., the proximity of housing locations to activity opportunities (work, study, shopping, etc.), therefore plays an important role in the decision-making process that culminates in the spatial situation of low-income families.

Locational preferences are subject, in the formal housing market, to a certain capacity to pay, so that budgetary constraints make well-located housing options in good neighborhoods inaccessible for the poorest families. In addition to these constraints, involvement in an informal labor market itself can act as a barrier to the formal housing market (Abramo, 2003). In cases where location preference outweighs other factors, such as quality, physical security, and land tenure status, the possibility of meeting this demand through informal housing arises. However, it is noteworthy that the reference to “locational decisions” is not entirely appropriate for many vulnerable social groups, precisely because of the restrictions that make them captive to certain alternatives. This idea is associated with what the literature recognizes as imposed or involuntary segregation (Corrêa, 2013).

Informality offers, in Brazilian metropolises, access options to land close to central areas – regions of job concentration, housing for upper classes, and urban amenities and services (Lago, 2002). The spatial conditions of settlements located in central areas are multiple: there are occupations in areas intended for environmental protection; in transport infrastructure domains; in areas that would be part of public or private property; etc. Despite the diversity, these contexts share characteristics related to insecurity, whether physical or land-related. The occurrence of settlements in areas better endowed with infrastructure allows them to absorb a portion of these locational advantages, establishing an inter-favela differentiation (Abramo, 2003), complemented by urban interventions and/or community actions in the built environment of the settlements (Cardoso and Denaldi, 2018; Pequeno et al., 2022). However, the scarcity of open spaces for urbanization and real estate speculation contribute to making centrally located precarious settlements constant targets of removal actions, given the real estate market’s interest in these strategic locations.

Therefore, it is considered that understanding the city as a complex environment, formed by the interaction between different urban subsystems, enables the interpretation of some characteristics of precarious settlements and their residents that may be associated with locational accessibility. Lopes et al. (2020) argue that, for planning purposes, the city can be understood from the interactions between *activity, land use, and transport subsystems*. Accessibility, thus, represents the interrelationships between them, being defined as the capacity of land use and transport subsystems to enable individuals to reach activities or destinations through transport networks (Geurs and van Wee, 2004).

2.2. Hypotheses on the relationships between accessibility, built environment and mobility

Amidst the distinct locational accessibility conditions of precarious settlements in Brazilian metropolises, we propose as the central hypothesis of this research that different levels of access to opportunities lead to distinct manifestations in terms of the built environment, levels of participation in activities, and consequently, mobility patterns of their residents.

In this regard, Abramo (2009) highlights the relationship between land competition and densification, via the informal market, of already consolidated settlements. According to Pasternak and D’Ottaviano (2016), ten years ago, 30% of favela households in Brazil already had more than three floors, and in 72.6% of cases, there was no spacing between households. We understand that such examples of intensifying occupancy in precarious settlements are interpreted as expressions in the land use subsystem, as they represent transformations in the built environment. We, therefore, raise the fundamental hypothesis that increasingly intense occupancy (*land use subsystem*) of settlements is associated with more favorable accessibility conditions.

On the other hand, the relativization of other disadvantages, in favor of a locational situation closer to central areas, can also be associated with the level of participation in activities and, consequently, the displacements made by resident individuals. It is possible that low-income families who choose to informally reside in central areas or their surroundings perceive benefits in terms of labor market insertion and greater access to public and private services (Marques and Torres, 2004). These potential benefits in activity participation materialize in mobility patterns, whether by the quantity of daily displacements, the duration of compulsory displacements, the ability to choose the mode of transport, among others. Thus, we also formulate the complementary hypothesis that changes in the accessibility conditions of precarious settlements influence the levels of participation in activities (*activity subsystem*) and mobility (*transport subsystem*) of resident individuals.

The hypotheses to be explored in this article are based on locational accessibility as a determinant of the reality of precarious settlements, concerning the production of the built environment, participation in activities, and travel decisions. This locational accessibility stems from the location of settlements relative to the spatial distribution of activity opportunities. We refer to the *built environment* as the form of the built urban space; *participation in activities* as the ability to perform activities in time and space, based on locational conditions, socioeconomic restrictions, and given a time budget throughout the day; and *mobility* as the result of interactions made by individuals across urban territory, arising from the need to access activities distant from residential locations. The relationship between these aspects is established a priori, as presented in Figure 1.

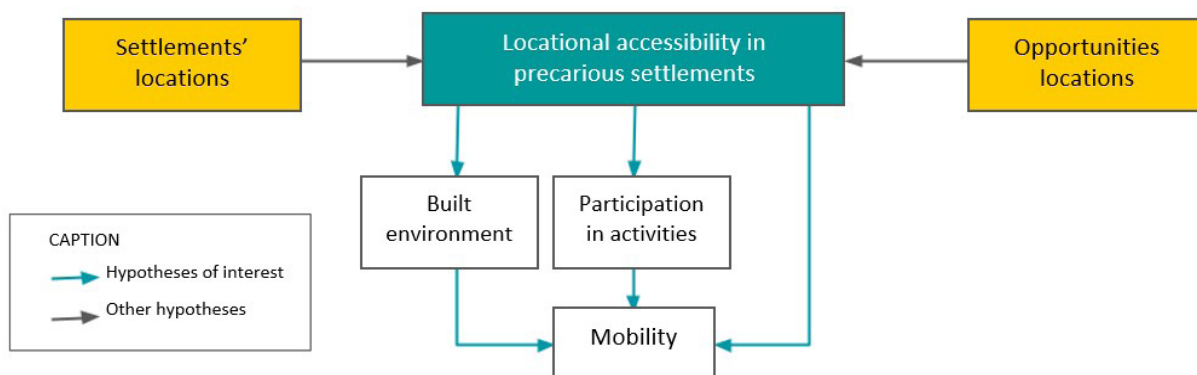


Figure 1. Hypotheses of the relationships between accessibility, built environment and mobility.

3. METHODOLOGICAL PROPOSAL

In this section, we detail the proposed method for characterizing the socio-spatial manifestations in precarious settlements, allowing for an exploratory analysis of the hypotheses raised. The nature of these hypotheses requires gathering and cross-referencing information obtained from various databases of urban subsystems (Table 1), as described below.

Table 1: Secondary databases considered in the study.

SOURCE	DESCRIPTION	TYPE/AGGREGATION	YEAR
PMF, PLHIS-For	Delimitation, categorization, and diagnosis of low-income precarious settlements in Fortaleza	Geographic database (settlements)	2013
IPEA, "Access to Opportunities" project	Locational accessibility data by public transport	Geographic database (hexagonal grid)	2019
SEFIN-For	Fortaleza's Multifunctional Territorial Registry Databases	Geographic database (tax lots)	2021
PMF, PASFOR	Origin-Destination Household Survey (O/D)	Database (households)	2019

The analyses conducted were based on secondary data, which required the combination of different databases that adequately represented the context of precarious settlements. The delimitation of the areas of interest, referring to precarious settlements, was based on the diagnosis presented by the Social Interest Housing Plan of Fortaleza - PLHIS-For (HABITAFOR, 2013). Thus, population characteristics were gathered from the PLHIS-For diagnosis, which, for the purposes of this study, was more detailed and up-to-date than the IBGE's 2010 Census surveys. To characterize the built environment, cadastral databases from the Fortaleza Finance Secretariat (SEFIN-For) were used, whose minimum unit is the *tax lot*, which is not dependent on the regularity condition of the properties and provides information on land use type and buildings. Information about activity patterns and mobility came from the 2019 household O/D survey in Fortaleza (collected considering trips made on typical weekdays), which also provides data on employability and other socio-economic information of interest. Finally, the accessibility metric used was calculated as proposed by Pereira et al. (2019) in the context of the IPEA's "Access to Opportunities" project.

It is worth noting that, by adopting the PLHIS-For survey from 2013, we assumed as a premise that the precarious settlements identified in 2013 retained their spatial layout in 2019, the year of the O/D survey. However, we believe that the differences in the reference year between the databases do not constitute a limitation for the analyses, as changes in land use tend to occur more slowly than changes in activity patterns and mobility.

3.1. Cross-referencing of databases and definition of indicators

Given the existence of geographic databases with different area aggregations, it became necessary to perform the harmonization and cross-referencing of information, aiming to filter and assign it to the precarious settlements identified by the PLHIS-For. This geoprocessing operation was

conducted in the R programming language through spatial overlay of the databases, transferring the attributes of the features from different databases that intersected with the settlement polygons. Subsequently, we georeferenced the O/D survey databases, which contain fields related to the geographic coordinates of the interviewed households/residents. The network distances of the trips made were estimated using the *dodgr* package (Padgham, 2019). The georeferenced households/residents and associated information were then assigned to the settlements in which they were located. The proposed indicators for precarious settlements, calculated from the cross-referencing of the presented databases, are displayed in Table 2 and can be grouped into accessibility, built environment, activity participation, and mobility indicators.

Table 2: Proposed indicators in precarious settlements.

GROUP	INDICATOR	UNIT
Accessibility	(1) Accumulated job opportunities within 60 minutes by public transport	Accessible jobs
Built Environment	(2) Tax lots density	Lots/km ²
Built Environment	(3) Population density	Inhab/km ²
Built Environment	(4) Land use occupancy rate	% occupancy
Built Environment	(5) Average building height	Meters
Built Environment	(6) Proportion of residential area (<i>versus</i> other land uses)	% residential
Built Environment	(7) Area accessible within 60 minutes by public transport (PT)	accessible km ²
Partic. in Activities	(8) Proportion of individuals (< 18 years) as students	% students
Partic. in Activities	(9) Proportion of individuals (>= 18 years) who work	% work
Partic. in Activities	(10) Proportion of residents (>=18 years) with formal job	% formal
Partic. in Activities	(11) Proportion of residents (>= 18 years) who do not work	% do not work
Partic. in Activities	(12) Average number of trips per person (typical weekday)	Trips
Mobility	(13) Proportion of distance traveled by active modes	% distance
Mobility	(14) Proportion of distance traveled by public transport	% distance
Mobility	(15) Average total distance traveled (typical weekday)	Meters
Mobility	(16) Average total time spent on travel (typical weekday)	Minutes
Mobility	(17) Average time spent on work-related travel (typical weekday)	Minutes
Mobility	(18) Mobility range	Meters
Mobility	(19) Distance to workplace (average for employed individuals)	Meters
Mobility	(20) Distance to study location (average for students)	Meters

Accessibility was measured to translate the proximity of the settlement to formal job opportunities through a cumulative opportunities indicator (Pereira et al., 2019), which simultaneously captures the influence of land use components (location of jobs) and transport (access within 60 minutes by public transport, assumed as characteristic of the population of interest). Built environment indicators were established based on the dimensions proposed by Ewing and Cervero (2001), notably *density* (indicators 2 to 5), *diversity* (indicator 6) and *distance to public transport* (indicator 7). It is worth noting that indicator 7, calculated using the *OpenTripPlanner* package (Morgan et al., 2019), is actually an indicator of infrastructural accessibility (Geurs and van Wee, 2004), as it captures the ability to access locations in the public transport network; however, although it

depends on factors related to the supply of the transport subsystem, the proper interpretation of its results should interact with the results of other built environment indicators, in order to understand what materializes in these areas (in terms of use, density, land occupation, building height, etc.). Therefore, to have a proper understanding of the results, indicator 7 was grouped as built environment.

Regarding participation in activities, the following were measured: the proportion of young people in school (indicator 8); the employability of adult individuals, through indicators 9 to 11; and the average daily number of trips per person, understood as a proxy for participation in activities outside the home. Finally, mobility indicators seek to translate modal choice (indicators 13 and 14), as well as transport in terms of distance and duration of trips (indicators 15 to 20). It is noteworthy that indicator 18, interpreted as the maximum distance reached by individuals from their places of residence, corresponds to the highest value of distance traveled, given all trips originating from each settlement. This is a mobility metric that seeks to translate the ability to reach distant spaces from residences in the territory. While this indicator was calculated as Euclidean distance, the others were calculated based on network distances.

In the following sections, the hypothesized influence of accessibility on the other elements is analyzed by dividing precarious settlements into three groups, referring to accessibility terciles, with the 1st tercile being the worst in accessibility. *Built environment*, *participation in activities*, and *mobility* indicators were then calculated for settlements present in each accessibility tercile. Subsequently, to have only one result per indicator per accessibility tercile, the mean of the previously obtained results was calculated for each indicator. It is worth mentioning that the averages of built environment indicators were weighted by the area of each settlement, and those of participation in activities and mobility were weighted by the resident population in each one.

4. CASE STUDY PRESENTATION

According to the diagnosis conducted in the PLHIS-For, Fortaleza had a total of 843 precarious settlements with an estimated population of 1.08 million people in 2013 (44% of the municipal population, according to IBGE data). In this Plan, precarious settlements were defined as “areas irregularly occupied (from a legal and/or urbanistic point of view) with infrastructure deficiencies that require government action,” encompassing typologies such as slums, self-built settlements, precarious housing complexes, tenements, and irregular subdivisions (HABITAFOR, 2013). In the present study, the last two typologies were disregarded because they were selectively surveyed in the PLHIS-For only in some regions of the city, leading to a final aggregate of 798 settlements analyzed and considered for the subdivision into accessibility terciles, as well as for the calculation of built environment indicators. These 798 settlements, following the delimitations established in the PLHIS-For (which, it is worth noting, accurately identifies the spatial boundaries of each diagnosed precarious settlement unit through a methodology that involved on-site visits and interviews with residents), are spatialized and appropriately categorized into accessibility terciles in Figure 2.

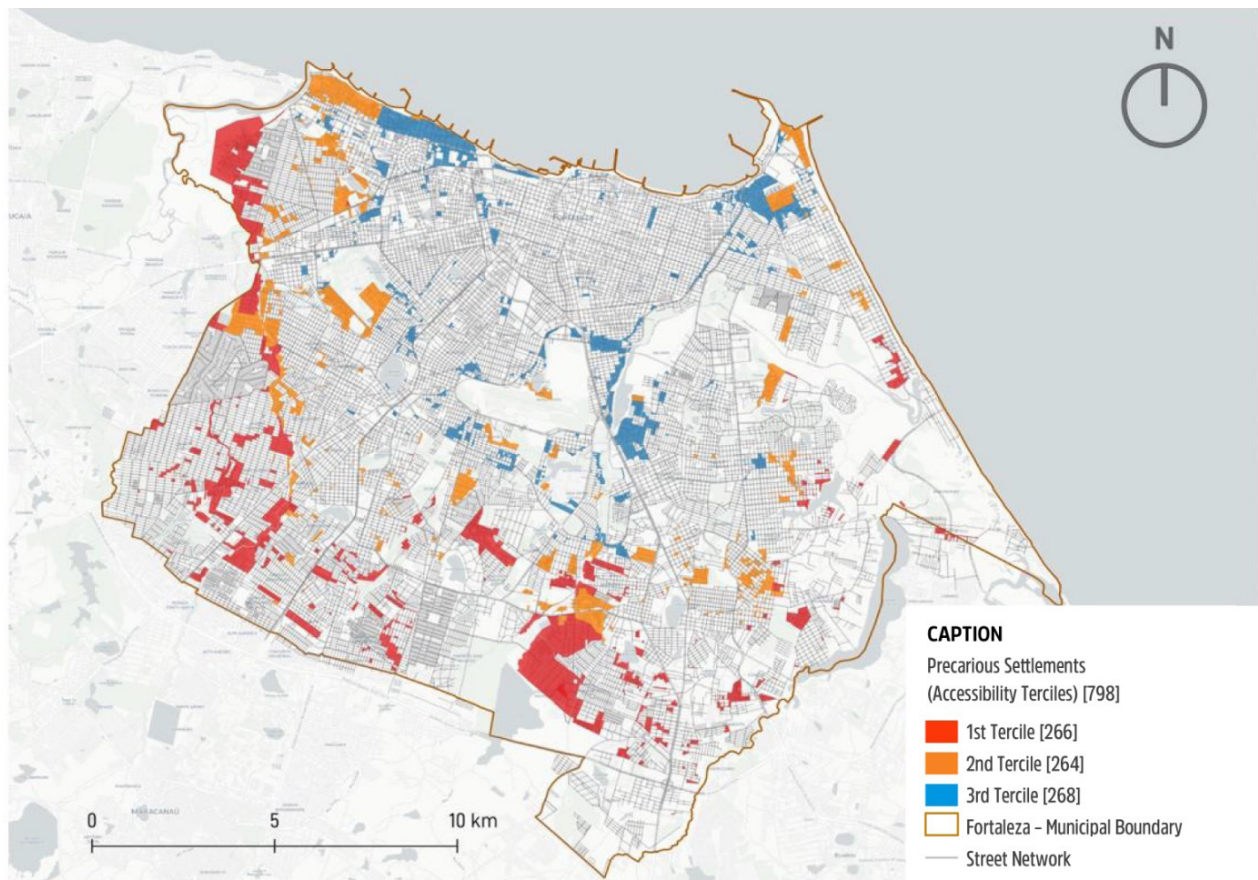


Figure 2. Location and classification into accessibility tertiles of precarious settlements.

For the specific case of participation in activities and mobility indicators, obtained from the household O/D survey data, we had to restrict the calculation to a smaller subset of settlements. As the survey has sampling limitations (thus, not having records for the entire universe of 798 precarious settlements), the indicators calculated from its data considered a smaller subset of 278 settlements. It is worth noting, however, that these correspond to approximately 70% of the population residing in settlements in Fortaleza, indicating that the vast majority of settlements without information in the O/D survey correspond to those with smaller populations.

The subdivision of precarious settlements into accessibility tertiles reinforces the theory that locations with poorer degrees of accessibility are located in the most peripheral areas of the city. Settlements located in the region of the 1st tertile mainly correspond to favelas where the process of consolidation is more recent and urban precariousness is more intense (Pequeno et al., 2022). Information about each tertile (Table 3), presented for contextualization purposes, shows that in the most peripheral tertile, settlements are larger and other typologies besides favelas occur more significantly (such as “mutirões”, a type of collective land occupation).

In the most accessible settlements, there is a tendency towards slightly higher income levels, indicated by the lower proportion of people with income up to 1 minimum wage. More accessible areas seem to have slight improvements in education levels, a trend towards reducing the number of cars and motorcycles per household, and an increase in the proportion of residents reliant on Public Transport (PT). Although there is a slight improvement in socioeconomic indicators in the 3rd tertile, the analyzed groups, regardless of their location, show significant constraints and vulnerabilities, low motorization, and high dependence on PT.

Table 3: Descriptive analysis of the average characteristics of precarious settlements.

VARIABLE	1 st TERCILE	2 nd TERCILE	3 rd TERCILE
Average area of settlements (ha)	5.80	4.10	3.04
Proportion of “favela” settlements	71%	76%	86%
Proportion of residents (>=18 years) with high school diploma	36%	37%	42%
Proportion of residents (>= 18 years) with personal income up to 1 minimum wage	77%	63%	62%
Average number of cars per household	0.28	0.22	0.21
Average number of motorcycles per household	0.29	0.26	0.23
Proportion of residents dependent on public transport	58%	61%	64%

5. ANALYSIS AND DISCUSSION OF RESULTS

In this section, the empirical evidence for the two hypotheses raised based on the literature review is analyzed: i) the association between the intensity of settlement occupation and more favorable accessibility conditions; and ii) the influence on levels of participation in activities and mobility by changes in the accessibility conditions of settlements. For each of these hypotheses, the weighted average indicators of settlements by tercile of accessibility are presented, seeking to investigate how the variation in the locational accessibility of settlements may be associated with variations in the magnitude of the indicators. The adopted accessibility indicator, previously detailed in Section 3, has average values of around 120,000 jobs in the 1st tercile (less accessible), 235,000 jobs in the 2nd tercile (intermediate), and 360,000 jobs in the 3rd tercile (more accessible).

5.1. Accessibility and built environment

The indicators of the built environment of the precarious settlements by tercile of accessibility are presented in Table 4.

Table 4: Indicators of built environment in precarious settlements.

DIMENSION	INDICATOR	1 st TERCILE	2 nd TERCILE	3 rd TERCILE
Occupancy Intensity	Population density [inhab/km ²]	23,281	33,008	36,386
	Density of tax lots [lots/km ²]	1380.1	1812.3	4343.0
	Occupancy Rate [% occupied]	53%	72%	83%
	Average building height [m]	4.30	4.41	4.68
Diversidade	Proportion of residential area [% residential]	61%	54%	69%
Transporte Público	Accessible area within 60min by TP [km ²]	78.0	101.0	118.2

5.1.1. Occupancy intensity

The results of the indicators highlight the high population density in the precarious settlements, significantly higher than the average for Fortaleza of 7,786.5 inhabitants/km² (IBGE, 2010), which even presents the highest population density among state capitals in the country. When comparing the indicators across the terciles, a pattern of increased occupancy intensity with increased accessibility is evident, demonstrated by land fragmentation (more parcels per km²), population density, occupancy rate, and building height. It is noteworthy that the intensification seems to be more related to land fragmentation and its intense occupation than to verticalization.

It should be emphasized that, in all three accessibility terciles, the average number of residents per household is close to 3.4 people, indicating that the increase in population density is not caused by larger family compositions, but by the increase in households and families within the settlements. The intensification of land use in more accessible areas possibly reflects the greater desire of low-income populations to live in places that, although informal and irregular, are closer to activity opportunities.

5.1.2. Diversity

The results obtained seem to indicate a trend towards greater land use monofunctionality in the most accessible tercile, given the higher proportion of residential area (69%) compared to other uses (non-residential and mixed), while greater diversity is observed in the more peripheral terciles. This pattern appears distinct from the land use patterns observed in the formal real estate market of Fortaleza, where there is greater diversity of uses in more accessible (central) areas, according to data from SEFIN-For.

One possible explanation for these results may lie precisely in the abundant supply of services and commerce near settlements in more accessible locations, which reduces the need to establish an informal economy within the settlements to meet the internal demand of the residents themselves. Additionally, the high desirability of land in central areas may make residential use preferable, given the advantages of living in these locations. On the other hand, in more peripheral locations, the greater distance to centralities may be fostering the need for diversity of uses. However, it is acknowledged that greater diversity of uses is not necessarily associated with a significantly greater supply of employment opportunities, as this diversity may refer, for example, to establishments at a local scale, primarily serving the community itself, and employing only a few staff members.

5.1.3. Public transport

The adopted public transport indicator seeks to measure the connectivity and coverage of the public transport network in the territory, measured through the area accessible within a 1-hour travel time by this mode (isochrone). We can observe that the population in peripheral settlements may have less mobility in the public transport network compared to settlements in central areas, as they have a smaller accessible area. This aspect is distinct and complementary to the distance to centralities: not only are opportunities further away from the most peripheral settlements, but public transport in these areas also exhibits lower service levels. These are indications of an unequal provision of the public transport network in Fortaleza, as the supply is lower in areas further away from opportunities. Finally, we emphasize that the population in the most accessible tercile, being closer to opportunities, would be less dependent on the use of public transport, as the distances are more conducive to the use of active modes (walking and cycling).

5.2. Accessibility and participation in activities

The calculated indicators of participation in activities (Table 5) reveal a tendency of relative consistency in employability across the terciles, evidenced by the relatively constant proportion of adult individuals who work, work with formal employment contracts, or are not occupied. A similar pattern was observed among young students (up to 17 years old), although a slight trend of increasing proportion of students can be identified with higher accessibility. The greatest effect appears to be on the average number of trips per person, indicating that more accessible areas may stimulate greater participation in non-compulsory activities. The results obtained, therefore, point to a secondary influence of accessibility on participation in compulsory activities. It is possible, thus, that other determinants, such as socio-economic factors (family composition, education level, etc.), may have a greater influence on employability.

Table 5: Indicators of participation in activities in precarious settlements.

INDICATOR	1 st TERCILE	2 nd TERCILE	3 rd TERCILE
Proportion of individuals (< 18 years) as students	79%	82%	83%
Proportion of individuals (>= 18 years) who work	50%	53%	52%
Proportion of residents (>=18 years) with formal job	20%	23%	23%
Proportion of residents (>= 18 years) who do not work	16%	14%	14%
Average number of trips per person (typical weekday)	1.43	1.53	1.56

5.3. Accessibility and mobility

The mobility indicators (Table 6) reveal distinct mobility patterns among groups of settlements. When observing modal split percentages, it's possible to identify a trend of increased mobility by active modes (walking and cycling) in more accessible settlements, accompanied by a trend of reduced mobility by public transport. There seems to be a modal choice tradeoff between active modes and PT, as the rates of use of individual motorized transport (car/motorcycle) are relatively constant among the terciles (1st: 34%; 2nd: 32%; 3rd: 35%).

Residents living in precarious settlements in Fortaleza generally exhibit a high dependency on public transport (PT), followed by individual motorized modes as a secondary means of mobility. It is evident that, despite the high degree of PT captive users in precarious settlements (Section 4), the low-income population demonstrates significant usage of individual motorized vehicles. These findings challenge simplistic assumptions that vulnerable groups rely solely on PT, prompting further reflections: it is possible that, even in the 3rd tercile, widespread adoption of active modes is hindered by the considerable distances to workplaces. Furthermore, the significant participation of individual motorized modes, even in central areas with better PT service, suggests the limited attractiveness of this system in Fortaleza, especially considering the financial constraints faced by the low-income population.

Regarding transport distances, the average total distance traveled daily experiences a noticeable decline in the 3rd tercile, which is the expected consequence of greater proximity to activities.

The increased accessibility of settlements tends to result in workplaces and educational institutions being closer. Particularly, the more evenly distributed schools throughout the territory of Fortaleza tend to make distances to these establishments shorter than to workplaces, even in peripheral areas (Braga et al., 2020). We can also observe a similar pattern to the previous ones in the analysis of the mobility range radius, showing that not only do residents of more accessible settlements travel less, but they also travel to destinations that are closer.

Table 6: Indicators of mobility in precarious settlements.

DIMENSION	INDICATOR	1 st TERCILE	2 nd TERCILE	3 rd TERCILE
Modal choice	Proportion of daily distance traveled by active modes	13%	18%	20%
	Proportion of daily distance traveled by public transport (PT)	51%	49%	43%
Momento de transportes	Average total distance traveled [m]	8,192	6,620	5,991
	Daily time spent on commuting [min]	46.5	45.1	41.0
	Daily time spent on commuting for work purposes [min]	37.5	33.4	29.5
	Mobility range radius [m]	2,890	2,210	1,998
	Distance to workplace (average of employed individuals) [m]	7,923	6,656	6,170
	Distance to place of study (average of student individuals) [m]	3,018	2,611	2,342

The daily time spent on commuting for work purposes follows the trend of reducing distances to these activities in more accessible locations, with a reduction of about 20% between the 1st and 3rd terciles. We also observe a decrease in the total time spent on commuting (for all purposes) in more accessible locations, although there is a smaller decrease from the 1st to the 3rd tercile (12%). This seems to indicate that, faced with the reduction in the duration of compulsory commutes, the saved time may be used to carry out more activities/trips. This explanation aligns with the higher levels of travel production in more accessible settlements, possibly as a consequence of reducing time budget pressures for these users.

6. CONCLUSIONS AND RECOMMENDATIONS

This article aimed to contribute to the understanding of the issue of low accessibility levels for low-income populations in Brazilian cities, focusing on precarious settlements. The data used are from various public databases, all published in the last decade, which positively contributes to the reliability of the analyses performed. Additionally, it is worth noting that, as mentioned in Pizzol et al. (2021), the population residing in precarious settlements is considered a hard-to-reach group, thus enhancing the relevance of discussions presented in this article.

In summary, the analyzed indicators highlighted: more intense levels of occupancy, slightly higher activity participation, and mobility with more sustainable characteristics in settlements with better accessibility levels. It can be inferred that there is a desire for housing among the low-income population in certain city locations, which, among other reasons, is also justified by the various and facilitated interaction possibilities inherent to central areas. However, central areas and their immediate surroundings in national metropolises tend to become true spaces of contention, as they also attract the interest of socioeconomically advantaged groups. Thus, in documentary and bibliographic research, various practices of resistance and insurgency by certain low-income populations can be identified. Using informality as a viable path, these groups seek to guarantee their right to the city by housing in areas connected to the urban fabric and inserted into an abundant context of equipment, services, and infrastructure supply.

However, in most cases, peripheral alternatives prove to be the only ones possible, even with the series of imposed disadvantages resulting from low accessibility to activity concentration hubs. Reflecting on the consequences of this condition, we identified in Maia et al. (2016) findings that could be interesting starting points for future research. The authors, when investigating mobility patterns in precarious settlements in Recife, encountered residents who perform most of their activities in their own neighborhoods. This scenario allows for some possible interpretations: are we developing polycentric cities, where there is a relative local microeconomy in neighborhoods that contribute to reducing dependence on major hubs? Or are we stimulating the development of a fragmented city, where isolated urban nuclei proliferate, focused on themselves, and disconnected from the rest of the territory?

Despite the intensity of occupancy in precarious settlements benefiting from better accessibility levels, here interpreted as a material manifestation of the desire and interest of the low-income population to reside close to centralities, in all major Brazilian cities, their peripheries have proven to be the focus of housing production coming from the State. Thus, the need to strengthen public policies aimed at bringing socioeconomically vulnerable populations closer to urban activity opportunities is reinforced. In terms of city planning, such policies can include interventions in land use and/or transport subsystems. Examples of possible land use policies include: stimulating the development of new centralities; reducing evictions; establishing and regulating Special Social Interest Zones; densification in vacant or underutilized areas; and reclaiming abandoned properties in central areas. Examples of possible transport policies include: fare reductions for low-income groups; provision of complementary transport services within communities; improvements in infrastructure conditions for active modes in communities and their surroundings, promoting short-distance travel.

Still, looking at the results obtained regarding the intensity of occupancy in precarious settlements with better accessibility levels, it is recommended that the analysis be complemented by also observing the time of settlement occupancy in the context of urban expansion in Fortaleza. Another recommended complementary analysis is related to possible economic benefits associated with better accessibility levels. The article showed that, in the analyzed case, no significant differences are perceived when looking at employability; however, would there be differences between the accessibility terciles when comparing the salary incomes of their inhabitants, for example? It should also be noted that maintaining relatively constant levels of employability among the three terciles may be associated with a limitation of the proposed method for calculating the accessibility indicator, which considers only formal jobs. If it were possible to work with an indicator that also included estimates of access to informal job opportunities, would we still obtain similar results?

Based on the empirical evidence observed in the case study, we recommend, therefore, the continuation of the diagnosis initiated in this article, notably through the causal inference paradigm and the use of multivariate statistical models, with the aim of measuring the causal relationships between the determinants of locational decisions of low-income groups and their respective effects on their levels of activity participation and mobility patterns. Finally, with a more specific focus on the municipality of Fortaleza, we recommend the development of comparative analyses between public policies implemented in recent decades and the expansion and intensification of occupancy of precarious settlements in the city, investigating possible associations between the two types of processes.

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