Transport and population density in the urban area of the city of Salvador

Daniel S. A. Carvalho. Student of the Programa de Pós-graduação em Economia – UFBA. E-mail: dan1elsilva@hotmail.com

Gervásio F. Santos. Dr. in Economics from FEA / USP. Professor of the Programa de Pós-graduação em Economia – UFBA. E-mail: gervasiofsantos@gmail.com

Resumo:
O objetivo deste artigo é identificar o efeito da acessibilidade ao emprego sobre a distribuição espacial da densidade populacional na área urbana de Salvador, a primeira cidade planejada e capital do Brasil. Salvador é uma cidade com uma dinâmica sócio-espacial complexa, marcada principalmente pela evolução heterogênea da ocupação histórica de seu espaço urbano, alta segregação entre brancos e negros e entre pobres e ricos, e uma configuração espacial policêntrica de centros de emprego. Esta pesquisa fundamenta-se na literatura da economia urbana sobre a intensidade do uso do espaço urbano e seus padrões de centralidade e acessibilidade. Consideramos o uso corrente dos sistemas de transporte público e privado para calcular um índice de acessibilidade por subzona de transporte para identificar a relação entre densidade populacional (total, negros e brancos) e acessibilidade. Nossa estratégia de identificação considerou o controle por componentes invariantes no tempo, como variáveis históricas de formação e ocupação da cidade. Em seguida, aplicou-se uma estimação de dois estágios baseada em uma variável instrumental hidrológica, uma vez que a evolução das avenidas da cidade acompanhou a rota de seus rios. Os resultados por raça mostraram que a acessibilidade teve um efeito positivo na densidade populacional, com sinais e valores semelhantes aos da população em geral. Menor possibilidade de alcançar empregos deve justificar menor demanda por moradias em espaços urbanos mais distantes.
Palavras-chave: acessibilidade ao emprego; densidade populacional; economia urbana, sistemas de transporte público e privado.

Abstract:
The objective of this paper is to identify the effect of job accessibility on the spatial distribution of population density in the urban area of Salvador, the first planned and capital city of Brazil. Salvador is a city with a complex socio-spatial dynamic, marked mainly by the heterogeneous evolution of the historical occupation of its urban space, high segregation between white and black and between poor and rich people, and a polycentric spatial configuration of job centers. This research lies on the urban economics literature about the intensity of the use of urban space and its patterns of centrality and accessibility. We considered the current use of public and private transportation systems to calculate an accessibility index by transport subzone to identify the relation between population density (total, blacks and white) and accessibility. Our identification strategy considered control by time invariant components, such as historical variables of formation and occupation of the city. Then, a two-step estimation based on a hydrological instrumental variable was applied, since the evolution of avenues of the city followed the route of its rivers. The results by race showed that accessibility had a positive effect on population density, with similar signs and values to those for the general population. Lower possibility of reaching jobs should justify lower demand for housing in more distant urban spaces.
Key-words: job accessibility; population density; urban economics, public and private transportation systems.

JEL Classification codes: R1; R14; R4.
Área ANPEC: Área 10 - Economia Regional e Urbana

1. Introduction

Salvador is the capital city of the state of Bahia and was also the first planned and capital city of Brazil, from 1549 to 1763, when the federal capital was transferred to the city of Rio de Janeiro, remaining there up to 1960. From then on, the planned city of Brasília has been the Brazilian capital. The primary urban nucleus of Salvador was planned, and its adjacent areas formed the main urban center of the city until the second half of the 20th century, when its social, economic and political axis was displaced towards the Atlantic border to form a second main urban nucleus. Currently, the central and most important urban areas of the city are inhabited predominantly by a white population, which represents only less than 1/5 of the total residents. This implies a strong socio-spatial segregation of population. On the other hand, deficits of public transport led workers from peripheral regions far away from dynamic urban spaces that concentrate the economic activity of the city, resulting in strong inequality in the access to employment opportunities for different population groups in the city.

On this socio-spatial urban context, this research lies on the urban economics literature about the intensity of frictions in the use of the urban space and its patterns of centrality and accessibility, aiming to identify the effect of job accessibility on the spatial distribution of population density. The accessibility to employment expresses the relationship between regional economic activity and transport infrastructure and can be measured by indicators which are sensitive to changes in the transportation system and the pattern of land occupation (CASCETTA et al., 2013; GEURS; VAN WEE, 2004; INGRAM, 1971). Taking the monocentric system of the first generation of urban economics models of Alonso (1964), Mills (1967) and Muth (1969), this literature supposes a homogeneous link structure covering a representative city and the demographic density distancing from the Central Business District (CBD). However, because of the important role that accessibility has in population distribution and in the formation of different patterns of agglomerations and centralities within metropolises, this paper searches theoretical support in the literature on non-monocentric urban configurations of cities, such as Fujita and Krugman (1995), Henderson and Mitra (1996), and Lucas and Rossi-Hansberg (2002).

Transport infrastructure has a long-term impact on land use patterns. Since land use itself can determine the distribution of public investments in transportation that directly affects accessibility, the causality between accessibility and land use is not clear. Identification strategies that can be used to identify the effects of accessibility on population density might be found in Baum-Snow (2007), Garcia-Lopez (2012) and Haddad and Barufi (2016). This latter applies a hydrographic instrumental variable to identify the causal effect of accessibility in a large urban area, considering pre-urban watercourses as a determinant for the location of transport infrastructure, and is the reference for the identification strategy of this paper.

Our first research question is: what is the effect of accessibility on the pattern of population density in the city of Salvador? Considering the socio-spatial segregation in this city, the hypothesis of the paper is that the unbalanced use of urban space among different segments of the population can also be explained by job accessibility and that this effect varies between population groups of whites and blacks. To capture the vectors of employment distribution and the quality of transportation, different accessibility indexes were produced, considering the commuting among the city's transport subzones by private car and public bus, both with and without congestion. Because of the restrictions imposed by a cross-section dataset used, the identification strategy considered control by time invariant components first, such as historical variables of formation and occupation of the city. After that, a two-step estimation based on a hydrological instrumental variable was applied, given that the evolution of urban avenues of the city followed the route of its main rivers.

The paper is composed of 5 sections more. Section 2 presents the formation and land use distribution of the population of Salvador, which resulted in an unbalanced access to job opportunities and a racial socio-spatial segregation. Section 3 deals with the theoretical reference and applied research literature. In Section

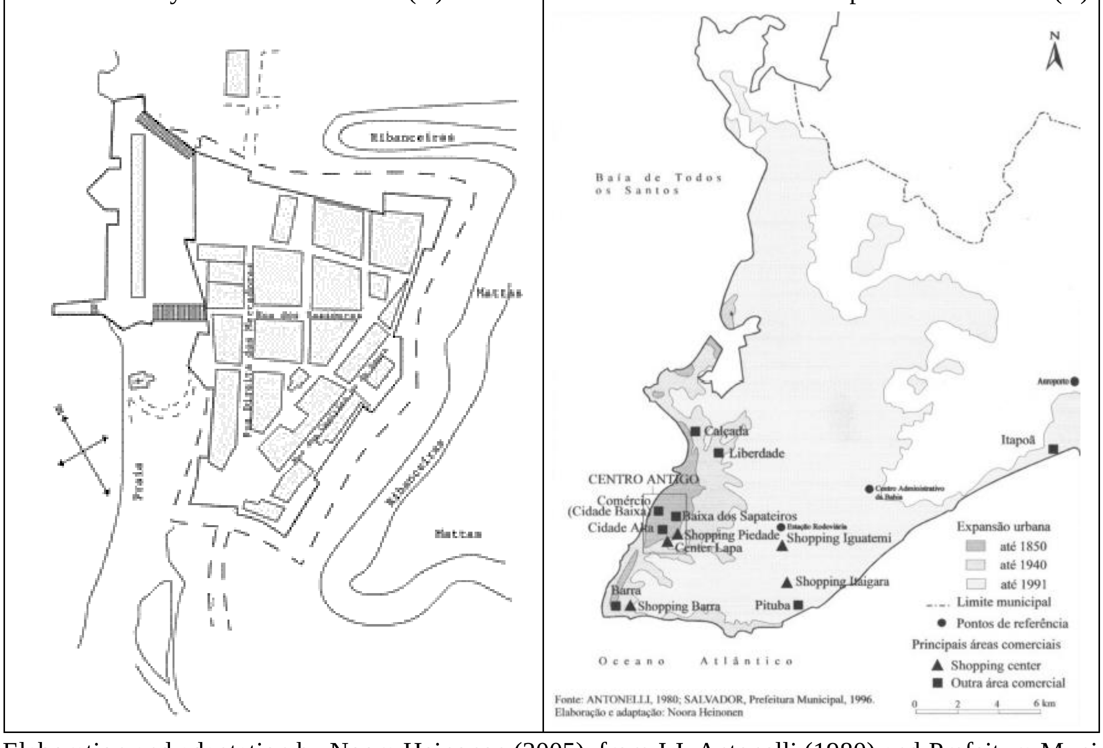
4, the details of the database and accessibility index are present. Section 5 presents the statistical and econometric results. The final remarks are reported in Section 6.

2. Historical formation and occupation of the urban space of the city of Salvador

Founded in 1549, Salvador was the first planned and capital city of Brazil (from 1549 to 1763), in the early stages of the country's colonization by the Portuguese Kingdom, to centralize the planning of development and administration of the colony and its hereditary captaincies. The municipality's building process took advantage of the natural conditions of the landscape, and that is why the primitive nucleus of the city was built at the margins of a navigable bay, the Baía de Todos os Santos (All Saints Bay), in the Northeast coast of Brazil. With the purpose of protecting the city, it was also built above a geological fault that divided the urban area into Cidade Alta and Cidade Baixa ("Hightown" and "Lowtown"), which can be seen in Figure 1 (A). In these earlier times, Salvador was a municipality with Portuguese architecture and with complex urban form, since its formation.

Figure 1 - Foundation and growth of the city of Salvador

Plant of the city of Salvador in 1549 (A) | Evolution of the urban occupation of Salvador (B)



Source: (A) Elaboration and adaptation by Noora Heinonen (2005), from J.J. Antonelli (1980) and Prefeitura Municipal de Salvador (1986). (B) Original elaboration by Teodoro Sampaio (1949).

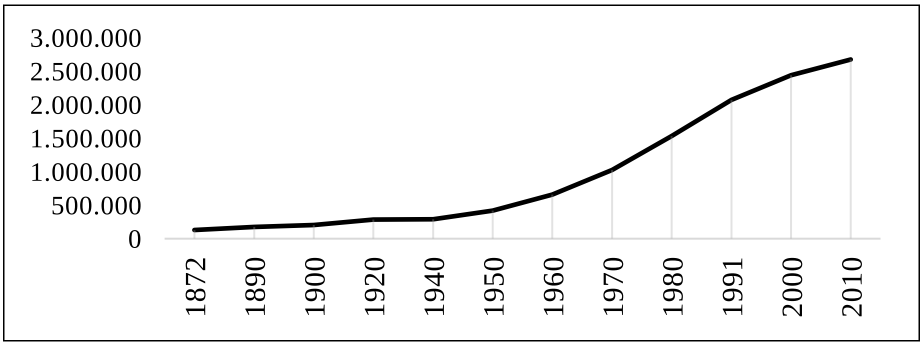
From the 16th to the 18th century, the city grew under administrative divisions created by the Catholic church, and the population was composed of free residents and slaves. These divisions were recognized by the public administration as parishes. Catholic temples were built, with the wealth derived from slavery and mercantile activities, to become the headquarters of the parishes (NASCIMENTO, 2007). Parish priests were responsible for the religious divisions and, for this reason, became strategic for the population estimates that were carried out via ecclesiastical censuses. In 1757, Salvador had 28,410 inhabitants, which increased to 39,209 in 1780 and 45,000 in 1805 (TAVARES, 2011).

Urban improvements regarding the transportation system were implemented before the 20th century. The railway system was inaugurated from 1860 to 1863 to link the city to other surrounding municipalities

(Bahia’s Recôncavo region) (SANTOS et al., 2010). Steam engine vehicles connected the urban center to the multiple parishes surrounding it in 1872. In 1873, a large-scale elevator (the well-known *Elevador Lacerda*) started to work to transport population from *Cidade Alta* to *Cidade Baixa* (and vice versa). The main streets had service of coal gas lighting since 1863 to facilitate night traffic across central spaces (TAVARES, 2011). The population of the city increased to more than 144,000 by the end of the 19th century, distributed over 13.10 km², and already faced serious urban problems related to unhealthiness (NOGUEIRA, 1997). By the end of the 19th century, the landscape of a dirty and ruined city was joined with the economic decline of the state of Bahia due to the sugarcane crisis. In that time, the state lost national economic representation compared with the Center-South of Brazil, which already hosted the federal capital, in Rio de Janeiro, since 1763. The Center-South was demanding labor for coffee plantations and, as a local consequence, the demographic and economic growth of Salvador declined (AGUIAR, 1958).

In the mid-twentieth century, the economic / political situation of the State of Bahia was very fragile. The state remained relatively poor, backward and lacking national prestige, despite its natural wealth and historical importance for the country (AGUIAR, 1958). The economy derived from the old colonial structure meant that the state did not collect enough taxes for government initiatives of the early 20th century. Foreign and domestic borrowing became scarce and the debt picture worsened after the decline in cocoa exports in the period post-crisis period of 1929. Finally, the lack of perspective in the countryside, which was linked to the concentration of land and semi-labor relations, pushed the migration of thousands of families to Salvador, as shown in Figure 2 (TAVARES, 2011).

Figure 2 - Population residing in Salvador by demographic census

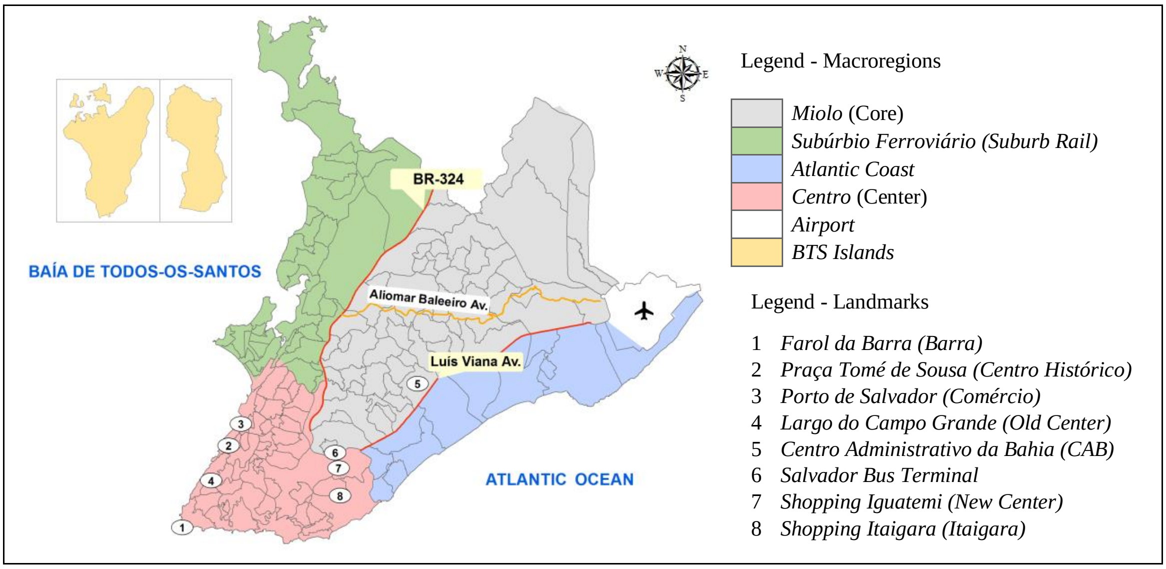


Source: Own elaboration with data from IBGE, 2016

The demographic disorder of Salvador began with the occupation of Corta-Braço Street by rural migrants. After the invasion, the government of Otavio Mangabeira (1947-1951) began to authorize concessions of suburban spaces for new residents (TAVARES, 2011). Thus, the so-called Miolo town began to be filled by low-income population, through government housing programs and spontaneous occupations. This region, which covers an area of approximately 115 km², comprises the territories bordering Luís Viana Filho Avenue, known as Paralela Avenue, and BR-324 Highway, as shown in Figure 3. The relatively accelerated settlement of this region became more evident from the 1970s onward and was conditioned not only by the existence of large territorial voids and the rural exodus from the state’s countryside, but also by the new municipal legislation for land use. Law no. 2,181 of 1968 broadened the logic of real estate capital in central regions and brought increasing pressure on land use (FERNANDES; REGINA, 2005).

In the 1970s, the neighborhood of Comércio, which had been the largest commercial center in Salvador since the 18th century, permanently lost its status as the “heart” of the city due to the change of social, political and economic axis towards the Atlantic coast, more precisely to the region of Iguatemi-Tancredo Neves Avenue. The development of the new center happened as a result of the new dynamics of capital circulation in the metropolitan region, with the Old Center lacking the infrastructure and space available for the expansion required by the new productive structure of the state. The settlement of the New Center and adjacent neighborhoods, evidenced by residential projects for segments of the upper middle class, was directly linked to the transformations of the city’s road system that were carried from the late 1960s onwards. These enterprises would later compete with commercial and service companies that migrated to the region, further increasing the price of real estate (SANTOS et al., 2010).

Figure 3 - Macroregions of the city of Salvador



Source: Own elaboration based on information from the Superintendência de Trânsito de Salvador (the Salvador Traffic Authority).

After two decades of stagnation, the beginning of the 21st century was characterized by a period of positive economic context that contributed to the recovery of a certain dynamism of the past through the expansion of commercial activities, services and tourism. In this perspective, the advances made did not avoid the serious structural problems of Salvador. The significant growth of the fleet of motor vehicles for the middle and upper classes was accompanied by severe diseconomies. This implied a reduction of mobility in the main roads of the city, which increased the average time of travel and the proportion of long trips of the residence-work type. Moreover, the great reliance on relatively slow public transportation by the workers from the popular regions, which were already scattered across the outskirts of the city, amplified the distance of most people from the employment centers (DELGADO, 2014).

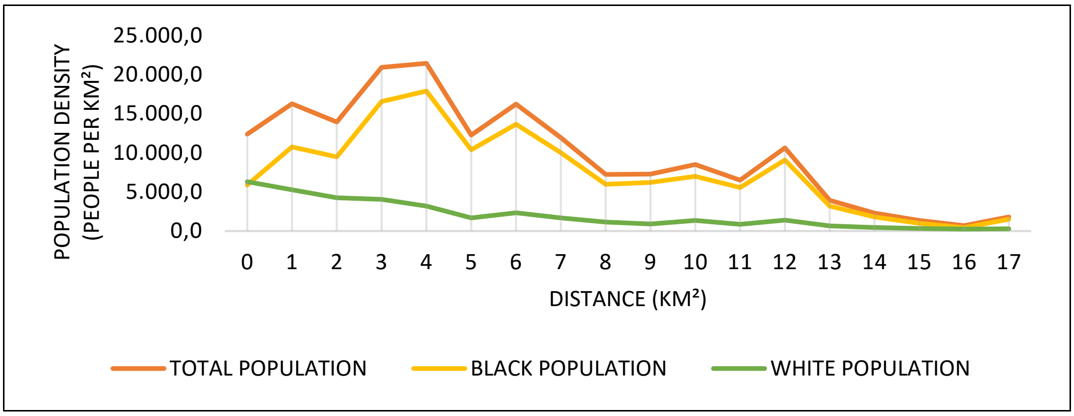
This problem of socio-spatial segregation was investigated by Silva (2014) through the composition of residents of Salvador by race. The author reinforces that the black population, which corresponds to about 4/5 of the inhabitants, are scattered across poor and/or peripheral districts that lack public services and/or goods. In contrast, whites accounting for less than a fifth of the population generally occupy the central and valued spaces of the municipality. The study uses the terminology of the book *Casa Grande & Senzala* for the analysis of this contradiction, which would be enhanced by the State itself by preferentially serving the most privileged segments of the city. Thus, blacks from regions away from the nuclei destined for the white population had less possibility of access to employment, education, leisure, etc.

Population access to employment opportunities is therefore typically unbalanced in Salvador. The disparity between density and ethnic patterns coincides with the strong concentration of economic activities within the New Center and parts of the Old Center. Such a picture can be explained from the transformations of the second half of the 20th century, which spatially segregated the population of the city by income and race[1]. By way of illustration, the distribution of the black/white population regarding the physical distance

[1] For Kustner and Santos (2006), the current context of segregation refers to the former colonial slave system, at which time ethnic-racial relations were the main factors of social disaggregation.

to some of the centers is available in Figure 4. The relative use of car/bus for workers belonging to the more black/white regions is shown in Tables 1 and 2. From these numbers, one can see that residents of predominantly white neighborhoods not only have geographical advantages for the physical movement towards some of the centers, but also make the most emphatic use of the faster mean of transportation: private cars.

Figure 4 - Population density as a function of distance from the centers of Salvador in 2010



Source: Own elaboration with data from IBGE, 2011; BAHIA, 2012.

Table 1 - The most populated spaces by blacks per traffic zone

Traffic Zone	Corresponding Neighborhood	Pop. Density (people/km²)	Percentage of blacks	Type of transport (residence - work) Private	Public	Non-motor.
188	Fazenda Coutos	28559.94	89.98%	13.88%	61.90%	24.22%
159	Pirajá	1102.85	89.58%	20.34%	63.72%	15.94%
167	Nova Brasília	957.73	89.30%	9.49%	83.70%	6.81%
79	Santa Cruz	52506.73	89.26%	12.06%	69.18%	18.75%
125	Lobato	19510.16	89.07%	12.73%	76.55%	10.72%
126	Boa Vista de São Caetano	24341.82	88.77%	14.66%	69.53%	15.81%
199	Itinga	1706.86	88.76%	13.37%	57.32%	29.31%

Source: Own elaboration with data from IBGE, 2011; BAHIA, 2012.

Table 2 - The most populated spaces by whites per traffic zone

Traffic Zone	Corresponding Neighborhood	Pop. Density (people/km²)	Percentage of whites	Type of transport (residence - work) Private	Public	Non-motor.
87	Itaigara	8676.579	64.62%	87.75%	8.21%	4.04%
89	Caminho das Árvores	7983.712	62.86%	92.11%	5.72%	2.17%
53	Vitória	17726.218	62.33%	82.88%	17.12%	0.00%
54	Graça	21685.273	61.11%	73.11%	20.73%	6.17%
55	Ondina	16610.09	60.24%	51.45%	35.08%	13.47%
88	Caminho das Árvores	9462.456	59.42%	80.76%	17.21%	2.03%
90	Pituba	13651.138	56.21%	71.85%	19.49%	8.66%

Source: Own elaboration with data from IBGE, 2011; BAHIA, 2012.

Given the historical, urban and socio-spatial context of the city, this paper aims to answer the following question: what is the effect of accessibility on the pattern of land occupation in the city of Salvador? The hypothesis raised is that the unbalanced use of urban space between different segments is explained, at least in part, by transportation differentials and physical access to employment opportunities. These differentials attribute distinct levels of attractiveness to housing across the territorial divisions of the city, although selectivity over where to live is restricted to the wealthier families, which are predominantly white. In order to capture the vectors of employment distribution and the quality of transportation in the municipality, aggregate accessibility is investigated for two types of motorized transport: the private car and the collective bus, with/without congestion. In view of this, this article allows a better understanding of the distribution of different population groups in space, whites and blacks, from the relation between population densities and accessibility.

3. Urban spatial structure: accessibility and distribution of the population

3.1 Theoretical evolution of urban economics and accessibility to employment

The formal basis for the development of urban models was the classic monocentric model developed by Alonso (1964), following the precursory contribution of Von Thünen (1966). The author started from the formulation of concentric rings, where the "Isolated State" is replaced by the "Central Business District" (or CBD). Alonso's successors theoretically outlined the process of population and firm concentration within the urban environment, in particular Mills (1967) and Muth (1969). Subsequent efforts gave rise to non-monocentric general equilibrium models, such as the Fujita and Ogawa (1982) models. These showed that the monocentric, non-monocentric or multicentric structure does not necessarily persist when changes occur in the switching rate, the level of production and others.

Fujita and Krugman (1995) depart from a monopolistic competition structure, with the inclusion of the "location equilibrium condition" and technological factors for the conduct of comparative statics. In the model, the monocentric configuration is stable only if the productivity gains from agglomeration are stronger than the transport costs generated by the city's growth. The dynamic element was introduced in modeling by Henderson and Mitra (1996), who explored the phenomenon of suburbanization and analyzed the role of urban planning, illustrating the need for an emerging center that complements the old one. By introducing the dynamic element into polycentric modeling, the authors show that, between an old center and a new center of a metropolis, there develops a kind of competition with effects on the distribution of jobs and population. The geographic approximation between agglomerations would imply productivity gains due to spillovers and losses related to rental and commuting costs for economic agents within the edge city.

Later, Lucas and Rossi-Hansberg (2002) developed the first two-dimensional analyzes within the non-monocentric approach. The authors broke some of the key assumptions of Fujita and Ogawa (1982), from the substitution between land and labor within the production function and the freedom of consumption, given the restriction of wealth. The equilibrium of this modeling involves the deduction of a mixed region that has commuting costs equal to zero and varies in size according to the existing transport technology. Specifically, this central region grows/decreases when worker switching becomes relatively more/less costly. Such strategy allows the contextualization of internal competition to the city in transformations related to transport infrastructure.

In the context of the endogenous centrality structure of cities, accessibility to employment can be understood as a concept that expresses the relation between the economic activity of any region and the transport infrastructure that serves it (CASCETTA et al., 2013). For Hansen (1959), the more accessible an area is in relation to the various production activities, the greater its growth capacity and intensity of development. In the model of Fujita and Ogawa (1982), this concept appears through the "locational potential" that would be related to the agglomeration forces that favor the concentration of jobs/population. Quigley (1985) conceives accessibility as factors of infrastructure that ensure the mobility of the workforce. In general, greater accessibility would be linked to an efficient transport system, which encourages the spatial dispersion of the population and attenuates the negative effects of congestion in central regions.

The essential idea of accessibility as a determinant of urban form and function is, as a rule, uncontroversial in the literature. However, there is no consensus on the specific methodology for measuring accessibility.

Geurs and van Wee (2004) even write that the concept is generally misunderstood, poorly defined, and thus poorly measured among policymakers. The authors suggest that, for a reasonable estimation of accessibility, a measure should be employed with particular sensitivity to the distribution of jobs/services and the specific effect of the traffic network that is available to the population.

The original effort to quantify accessibility was derived from Newtonian mechanics, from a potential interaction, or physical attraction, between origin and destination (CASCETTA et al., 2013). In gravitational models, the attractiveness factor within the region under analysis generally refers to the number of jobs available. This factor is weighted by the existing impediment to travel, which can be expressed by the distance of the course, the switching time or the monetary cost of travel. From Hansen's (1959) gravitational formulation, Ingram (1971) proposed a new measure, called "integral accessibility," that is, the total number of opportunities attainable for each chosen source. This way of estimating accessibility has significant advantages of interpretation and communicability, in addition to being able to explain the distribution of aggregate population. However, such a metric does not compute variations of individual characteristics, and does not contain components of temporal constraints.

3.2 Applications: transport and density

Among the more recent research that has directly investigated the effect of the transport factor on population density, Baum-Snow (2007) tested the hypothesis that new transport technologies explain the population decline in large American cities from the second half of the 20th century. During this period, there were significant governmental actions for the expansion of the interstate highway network, which would grow from 341 to 43,420 miles between 1950 and 1990. In order to control the endogeneity resulting from a non-random distribution of highways, a plan approved in 1947 was used as the instrument, which designated the construction of a national road network according to trade and defense criteria. The results indicated that the construction of the new mesh contributed to the decline of the aggregate population in central cities.

Garcia-Lopez (2012) investigated and extended Baum-Snow's (2007) conclusions concerning spatial dispersion/concentration of population. The author focused on the characteristics of rail and road transport of the Metropolitan Region of Barcelona, between 1991 and 2006, to show how commuting differentials affect population density in a European metropolis. While the rail system was not physically modified during the period, the region's highway network grew by 191 km with the construction of 104 new ramps between 1991 and 2001, which coincided with the ongoing suburbanization phenomenon. Due to the probable simultaneous determination between the explained variable and the transport factor, it became necessary to obtain exogenous variations from ancient Roman roads and important connections of the 19th century. The results showed that the transport systems have effect on the density, but the population tends to grow only in areas where the development process was previously consolidated.

Epifani and Nicolini (2017) used a Bayesian approach to analyze the distribution of population density over time. Specifically, the study investigated how accessibility to the CBD had influenced population location decisions in the state of Massachusetts, USA, between the decades of 1880–90 and 1930–2010. The authors adopted a function of probabilistic density where the space in question is assumed as a pole of persistent attraction. In addition to accessibility, the authors identify the following determinants of influence on density: ethnic composition of territories, education, age composition, and amenities. Empirical research shows that the distance factor lost some relevance for Boston in the post-1960 distribution function. However, the ethnic composition gained remarkable importance over time, which would be linked to the discrimination of the real estate market and the formation of urban ghettos from the second half of the 20th century.

4. Methodology and data

4.1 Measure of "integral accessibility"

The methodology used to quantify accessibility follows the proposal of Ingram (1971), which counts the total number of jobs attainable from an origin. This number is weighted by the existing impediment to travel. The so-called "integral accessibility" was recently calculated by Vieira and Haddad (2012), so that the basic model used by the authors is composed of the following equations:

$$A_i = \sum_{j=1}^{n} \frac{w_j}{d_{ij}} \tag{01}$$

$$d_{ij} = e^{\alpha \cdot t_{ij}} \tag{02}$$

where A_i is the accessibility in territory i, w_j corresponds to the quantity of jobs available in any territory j, while d_{ij} is the impediment existing to travel between i and j. This repulsion factor is represented by an exponential function composed of the parameter α and the average time spent on the way from source i to destination j, that is, t_{ij}. In particular, the value of the parameter α is defined from $e^{\alpha \cdot t_{ij}} = 2$. Thus, a job vacancy that does not require switching costs has a weight of 1 in A_i, a weight that falls continuously as travel time becomes longer.

For the study on Salvador, the values of w_j were extracted from the origin-destination research organized by Bahia (2012). The study provides aggregated information on the travel of the resident population, which is spread across 713 traffic subzones. In this logic, residence-restricted travel-type matrices serve as a measure of available opportunities, since they offer the final destination of the labor force employed in the city.

The average travel time is based on the Google Maps webpage. The collected values refer to the time of the best travel trip for a common business day of 2012, assuming that the working day starts at 08:00. The references to origin/destination are centroids of the traffic divisions. In view of this, the server allows the calculation of the travel impediment function by private (car) and public (bus) transport.

4.2 Econometric modeling

In the context of urban economics, the distribution of population density has been historically measured within a monocentric configuration, based on the density value in the central region and physical distance from the CBD. On the other hand, polycentric investigations use the distance from some subcenter as explanatory variable. However, these formulations, as a rule, presuppose the homogeneity of transport infrastructure, which is not empirically reasonable. To evaluate the effect of transport differentials on the urban spatial structure, Garcia-Lopez (2012) suggests the following density function:

$$lnD_{it} = A_0 + \gamma_{inf} d_{inf,it} + A_1 X_{it} + \varepsilon_{it} \tag{03}$$

where D_{it} is the population density of area i in time period t, $d_{inf,it}$ is the distance from subarea i to the road and subway infrastructure of the metropolitan area, γ_{inf} is the gradient that measures how much density increases or decreases with the distance from i to the ramp road and nearest train station, X_{it} corresponds to a set of geographical, historical and location factors that do not change over time, while ε_{it} is the error term.

The density model of this work replaces the vectors of the transport infrastructure with physical access variables or accessibility with congestion. The values of X_{it} take the form of the initial period of urbanization of *i*, existence or not of beach in *i*, physical distance of *i* from some ecological park and from some public square. As in Epifani and Nicolini (2015), a variable of ethnic composition will be introduced into the density function to control possible factors related to racial segregation in residential regions. The high correlation between ethnic composition and socioeconomic characteristics for the specific case of Salvador makes it possible to control vectors of income, schooling, etc.

In the proposed modeling, the density is estimated in natural logarithms by regressions of the reduced form. However, the analysis period is restricted to the year 2010 due to the greater availability of data, and it is not possible to make a longitudinal analysis. In particular, functions with distance gradients serve didactic purposes, while functions with accessibility vectors allow us to capture the effect of transport differentials on the access to employment opportunities.

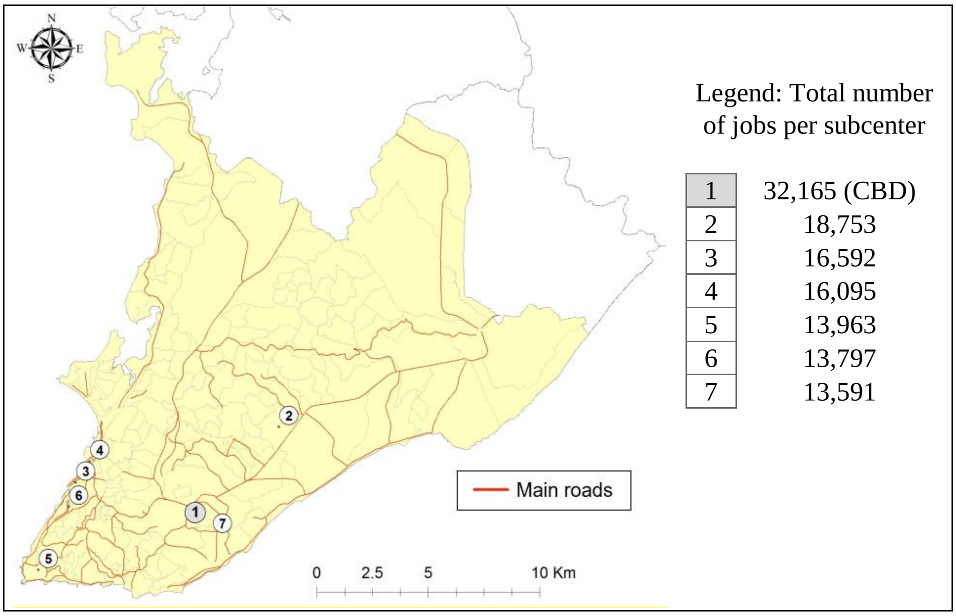
To estimate the density gradient in relation to the distance from some center, we adopted the procedure of Muñiz et al. (2008) to identify the employment poles in the metropolitan region of Salvador, according to Figure 5. Specifically, the authors propose a procedure for the determination of employment subcenters, which is based on statistical values of:

$$D_{i,t} \geq \overline{D}_{RM,t} \tag{04}$$

$$E_{i,t} \geq E_{RM,t}/100 \tag{05}$$

In the above inequalities, for the time period t, $D_{i,t}$ represents the gross employment density in subarea i, $\overline{D}_{RM,t}$ is the mean employment density for the metropolitan region, $E_{i,t}$ is the number of job opportunities in i, and $E_{RM,t}$ refers to the total number of jobs in the region studied. Thus, an urban subarea can only be qualified as a subcenter of employment if it has values large enough to simultaneously satisfy inequalities (04) and (05).

Figure 5 - Employment Subcenters in Salvador - 2012



Source: Own elaboration with data from BAHIA, 2012.

The database, with information on the variables used in the econometric regressions, is detailed in the next section.

4.3 Database

A database was elaborated by subdivisions of traffic and it allows to contemplate different aspects about the municipality of Salvador. The variables that constitute this bank are specified in Table 3. For the aggregate population variables, we used microdata per census tract of the Censo Demográfico 2010, produced by the Brazilian Institute of Geography and Statistics (IBGE). The values of accessibility to employment were generated from origin-destination matrices of the 2012 Mobility Survey of the Metropolitan Region of Salvador (Pesquisa de Mobilidade da Região de Metropolitana de Salvador – 2012), and traffic projections using Google Maps. The lowest physical distance numbers for some public good were generated from geographic coordinates available in Google Maps and centroids of traffic divisions provided by Bahia (2012). In order to identify the presence of shore in analyzed areas, the digital cartographic base of Google was again consulted. Finally, the dummy variables referring to the beginning of the occupation in each traffic division were projected according to Heinonen's (2005) map, which is available in Figure 1 (B).

Table 3 - Database Variables

Variable	*Code*
Demographic density of the absolute population (people per km²) for the year 2010	*dens_total*
Demographic density of the white population (people per km²) for the year 2010	*dens_white*
Demographic density of the black population (people per km²) for the year 2010	*dens_black*
Physical distance (in kilometers) from the CBD – Iguatemi-Tancredo Neves Avenue	*dist_cbd*
Physical distance (in kilometers) from the nearest subcenter of employment	*dist_sub*
Accessibility to employment in 2012 for private transport with congestion - car	*access_car*
Accessibility to employment in 2012 for public transport with congestion - bus	*access_bus*
Ethnic composition of the territory - proportion of whites in the total local population - for the year 2010	*ethnic_ comp*
Territory with urban expansion until 1850 - categorical variable	*urb_1850*
Territory with urban expansion after 1850 and until 1940 - categorical variable	*urb_1940*
Territory with urban expansion after 1940 and until 1991 - categorical variable	*urb_1991*
Physical distance (in kilometers) from the nearest ecological park	*dist_park*
Physical distance (in kilometers) from the nearest public square	*dist_square*
Coastal region with beach - categorical variable	*beach*

Source: Own elaboration.

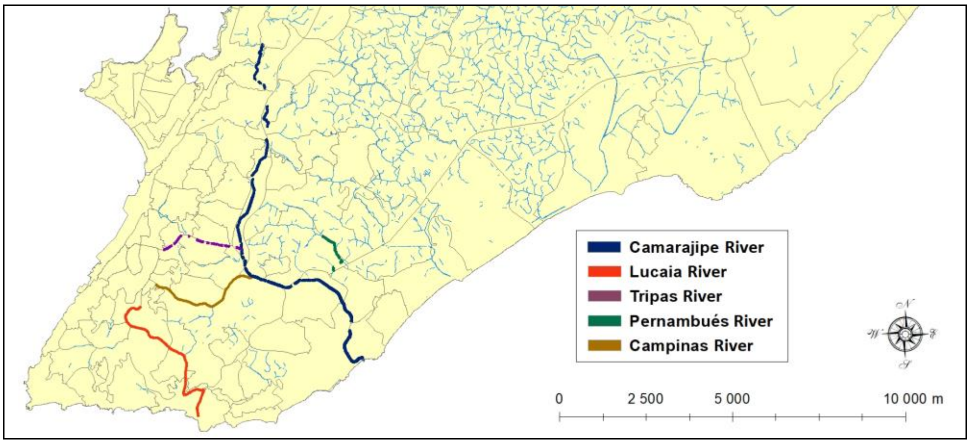
4.4 Econometric estimation and empirical strategy

Although transport infrastructure is considered by the literature as a factor that has a long-term effect on urban land use, the direction of causality is not very clear. It is possible that a future perspective of density or density itself determines a greater/lesser need for public investments in transportation in certain spaces, which may have a direct impact on the values of accessibility. Therefore, the identification of the causal effect of interest will be done from a cross-section bank by city traffic divisions, with the respective application of the instrumental variable estimator (IV). As a rule, this procedure is used for multiple applications, where least-squares estimation is compromised due to the correlation between explanatory variables and the error term.

In this logic, Baum-Snow (2007) and Garcia-Lopez (2012) seek exogenous variations in old projects or old transportation infrastructures, which could not be replicated for Salvador. In view of this, the strategy proposed in this article is to find geographical factors that precede the distribution of the current population and the municipality's own road network. This strategy was implemented by Haddad and Barufi (2016), who make use of distance from the river that gives access to the primitive nucleus of the city of São Paulo as a tool to investigate the effect of accessibility on income. Specifically, the authors argue that hydrography acted as a determinant for the distribution of transport infrastructure, so that the road network has a strong spatial correlation with pre-urban watercourses. In addition, the agents are unaware of the existence of large rivers and streams in the region, because they are currently decharacterized, which reinforces the exogeneity of the instrument.

Initially, the course of the Camarajipe River, which is the largest river in Salvador, with a length of 14 kilometers (Figure 6), was chosen as instrument. The river, which was already very important for the supply of water in the city before the mid-20th century, is at an advanced stage of pollution and exposes a completely degraded ecosystem along its banks. Among the natural tributaries of the Camarajipe, the Lucaia River has its own watershed after its transposition in the 1970s. The flow of the Lucaia River is also compromised because the streambed is quite silted due to human activity. Well-served by avenues and important road links, the divisions near Lucaia have privileged access to important points of the city (SANTOS et al., 2010).

Figure 6 – Watershed of the Camarajipe and Lucaia rivers



Source: Own elaboration with information from SANTOS et al., 2010.

Thus, two instruments for accessibility in Salvador were determined: (i) the shortest distance from the Camarajipe River or some of its tributaries and (ii) the shortest distance from the Lucaia River. The statistical and econometric results of the study will be detailed below.

5. Results

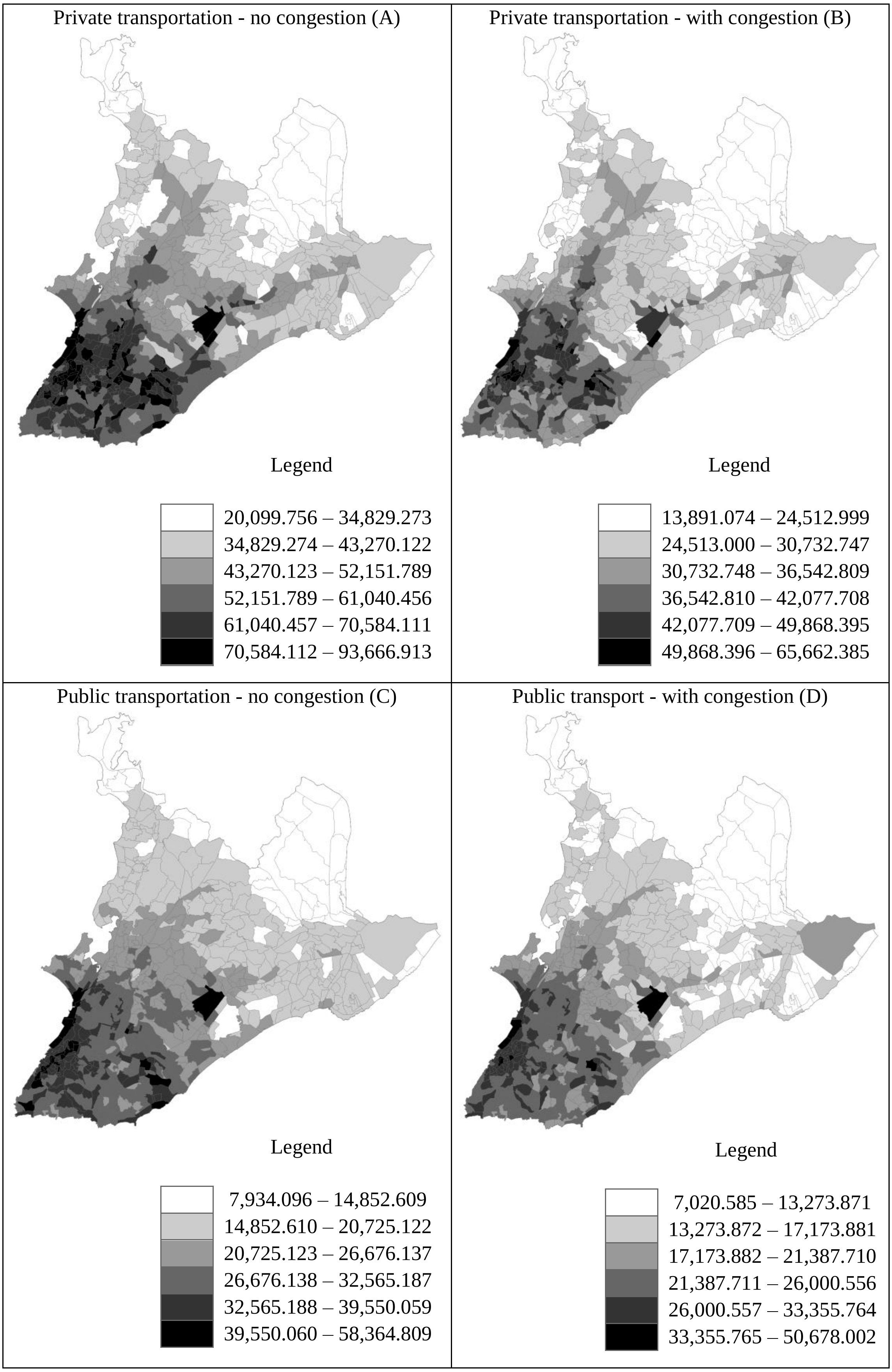
5.1 Analysis of the integral accessibility index

Table 4 - Descriptive statistics of accessibility by traffic subzone

	Private transp. – without congestion	Private transp. – with congestion	Public transp. – without congestion	Public transp. – with congestion
Minimum	20,099.76	13,891.07	7,934.10	7,020.59
1st quartile	41,750.81	27,087.82	18,600.47	14,933.11
Median	52,890.19	33,534.22	25,634.41	19,635.43
Maximum	93,666.91	65,662.38	58,364.81	50,678.00
3rd quartile	63,162.76	39,796.94	30,719.81	23,322.74
Average	52,937.21	33,809.73	25,411.09	19,653.96
Standard deviation	13,391.17	8,478.71	7,899.70	5,811.36

Source: Own elaboration with data from GOOGLE INC., 2015; BAHIA, 2012.

Figure 7 - Accessibility index by traffic subzone - 2012



Source: Own elaboration with data from GOOGLE INC., 2015; BAHIA, 2012.

In the mobility research organized by SEINFRA, the Soteropolitan space is fragmented into 720 traffic subzones, which makes it possible to gauge accessibility at a reasonable level of detail[2]. In general, the analysis in Table 4 suggests that access to employment opportunities is considerably unequal among users of different means of motorized transportation. The average value of accessibility without congestion is 108.3% higher for private transport than for public transport, while the standard deviation is 45.9% higher. In the presence of traffic jams, the average accessibility is 72.0% higher for private transportation than for public transport, while the standard deviation is 69.5% higher. However, the bus is still the most used mode of motorized transportation in the city, including for residence-to-work trips (68.71%). This suggests a dangerous possibility of expansion of the car fleet and/or a poor financial condition of a large part of the population, which is forced to use a relatively inefficient means of mobility.

Figure 7 shows the spatial distribution of accessibility for the classification of traffic subzones. As a rule, spaces filled with the darker colors are clustered in central regions of Salvador, except for the CAB, which serves institutional purposes. In the case of private transport without congestion, in (A), there are large pockets of the highest class of values covering regions and adjacencies of the Old Center and the New Center. With the congestion factor introduced in (B), there is a greater distribution of intermediate values in the macro-region of the Centro, while the distant suburbs continue to cluster relatively low values. In distributions for public transport, (C) and (D), it can be observed that these differ less emphatically, although the concentration of high values within the Old Center is detachable.

In sum, the findings for Salvador show that private transportation always allows better access to employment in relation to public transportation. Once the congestion factor has been introduced, the accessibility values substantially decrease both for private and for public vehicles. It is therefore reasonable to assume that the city needs a better mass public transport system, which balances access to employment between the different user profiles of the transport system and mitigates the negative effects of congestion.

5.2 Test for the validity of instrumental variables

To estimate the causal effect of transportation differentials and physical access to employment opportunities on the distribution of the population in Salvador, it is necessary to identify sources of exogenous variation for the explanatory variable. In the presence of simultaneous determination of demographic density and accessibility, the Instrumental Variables (IV) method can help to obtain consistent and unbiased estimates of the respective causal effect. From this perspective, the following hydrographic instruments were assumed to be exogenous: (i) minimum distance from the waters of the Camarajipe River; (ii) minimum distance from the Lucaia River.

The values referring to rivers are taken as valid for both accessibility vectors, in classification of agglomerates of subzones. In light of this, procedures were performed to capture the relevance of the instruments, qualifying them as strong or weak. Initially, the simple regression of car/bus accessibility over the distance from the Camarajipe/Lucaia River was estimated. Then, the following covariates were integrated into the equation: *ethnic_ comp*, *urb_1850*, *urb_1940*, *urb_1991*, *dist_park*, *dist_square*, *beach*. Since the accessibility vectors have very strong linear association, the regression of two instruments to an endogenous variable was not tested, avoiding problems related to multicollinearity. Table 4 details the test numbers for each instrument.

In both instrument examples, the coefficient of interest is statistically significant with probability of rejection at 1% for each type of regression. For simple regressions, the reduced-form model explains from 49.14% to 74.79% of the variation of the explained variable, in this case, accessibility. In general, the inclusion of new variables in multiple regressions raises the degree of adjustment of modeling, but hardly affects the coefficient of the instrumental variable, which remains considerably strong. For practical

[2] For Salvador, $\sum_{j=1}^{n} w_j = 947.594$.

purposes, the distance from the Camarajipe River and tributaries will be taken to capture the variation of access to employment by private transport, while the Lucaia River variable will be used to estimate some exogenous variation referring to commuting by bus.

Table 5 - Results of regressions in reduced form by agglomerates of traffic subzones

Instrument 1				
Dependent Variable:	*ln(access_car)*		*ln(access_bus)*	
	(A)	(B)	(C)	(D)
Distance from the Camarajipe River (km)	-0.0500***	-0.0427***	-0.0662***	-0.0501***
	(0.0020)	(0.0025)	(0.0025)	(0.0022)
Covariates	No	Yes	No	Yes
Adjusted R^2	0.4914	0.6011	0.5896	0.7393
p-value for F test	0.0000	0.0000	0.0000	0.0000
Instrument 2				
Dependent Variable:	*ln(access_car)*		*ln(access_bus)*	
	(A)	(B)	(C)	(D)
Distance from the Lucia River (km)	-0.0448***	-0.0412***	-0.0588***	-0.0477***
	(0.0019)	(0.0013)	(0.0018)	(0.0013)
Covariates	No	Yes	No	Yes
Adjusted R^2	0.6355	0.6702	0.7479	0.7984
p-value for F test	0.0000	0.0000	0.0000	0.0000

*, ** and *** represent the statistical significance, respectively, at 10%, 5% and 1%.

Source: Own elaboration.

5.3 Econometric results

Density regressions were performed for four measures of physical access to employment: less physical distance from the CBD, less physical distance to any subcenter of employment, accessibility to private transportation and to public transportation. In the occurrence of simultaneous determination between demographic density and accessibility to employment, the hydrographic instruments referring to the minimum distance from the Camarajipe and Lucaia rivers were used. The first four equations were estimated using the Ordinary Least Squares (OLS) method, while the last two followed the Instrumental Variables (IV) method. It is assumed that the IV estimators are consistent and unbiased.

The estimates of the density regressors are expressed by agglomerates of traffic subzones in Table 6. First, the p-value of the F statistic is null for any model employed, which guarantees the joint statistical significance of the explanatory variables. These variables explain from 31.76% to 33.62% of the variation related to the dependent variable, according to the determination coefficient R^2. In general, distance signs for employment and accessibility centers do not contradict the theoretical discussion developed earlier. Regarding the individual significance of these regressors, almost all of them have statistical validity with probability of rejection at 1%, which suggests the importance of the factor of access to employment on the distribution of the population within the municipality.

Comparatively, the coefficients of accessibility for public transport have the greatest weight to explain variations in density of residents per square kilometer. In the model (IV A), it is possible to interpret that the decline of 1% in the access to the number of jobs implies a density decrease of 0.71%. For private motor vehicles, this effect is relatively lower, 0.43%, and statistically significant with probability rejection at 5%. The possible endogeneity for accessibility variables requires the use of instruments, which, when included in (V A) and (VI A), capture elasticities of 1.0448 and 1.0224. This suggests that the accessibility effect may be much larger and more balanced between different transport technologies. Alternatively, the geographical distance from the CBD or from the nearest subcenter of employment should be accompanied by the reduction of population density by 5.19% and 6.23%, respectively.

Regarding the other explanatory variables, estimates of ethnic composition suggest that density falls with the highest proportion of whites. As whites account for less than 1/5 of the aggregate population and have the best levels of schooling and income in the municipality, this factor can capture new components linked to segregation, which go beyond the simple definition of race[3]. Urbanization coefficients have statistical significance for 1940 and 1991, capturing the fact that settlement tends to be relatively larger in regions already urbanized during the demographic pre-explosion of the second half of the 20th century. In this perspective, distance from squares suggest that the distribution of public goods may have great relevance in explaining the current density of the city. However, the distance from ecological parks has very low coefficients and no statistical significance. Finally, the beach dummy variable has statistical significance at the 5% level and points out that the settlement in coastal divisions tends to be relatively smaller. This makes sense when considering the existence of specific norms for the densification and verticalization of these spaces, expressed in templates of height of buildings.

Table 6 - Econometric estimates of population density by agglomerates of traffic subzones

Dependent variable: ln(dens_total)

Regression Type	(I A)	(II A)	(III A)	(IV A)	(V A)	(VI A)
dist_cbd	-0.0519***					
	(0.0141)					
dist_sub		-0.0623***				
		(0.0179)				
ln(access_car)			0.4265**		1.0448**	
			(0.2070)		(0.3795)	
ln(access_bus)				0.7056***		1.0224***
				(0.1976)		(0.2738)
Instrument - Camarajipe					Yes	
Instrument - Lucaia						Yes
ethnic_ comp	-2.3495***	-2.4068***	-2.2497***	-2.3568***	-2.3571***	-2.4381***
	(0.2923)	(0.2963)	(0.2927)	(0.2931)	(0.2998)	(0.2976)
urb_1850	0.2528	0.1617	0.2762	0.0165	0.0473	-0.1709
	(0.2265)	(0.2347)	(0.2355)	(0.2502)	(0.2646)	(0.2746)
urb_1940	0.8426***	0.8659***	0.9706***	0.7601***	0.7819***	0.6072***
	(0.1701)	(0.1691)	(0.1684)	(0.1821)	(0.1952)	(0.2040)
urb_1991	0.4797***	0.5847***	0.6541***	0.5216***	0.5520***	0.4304***
	(0.1365)	(0.1258)	(0.1248)	(0.1321)	(0.1361)	(0.1431)
dist_park	-0.0381	-0.0397	-0.0377	-0.0336	-0.0182	-0.0257
	(0.0302)	(0.0302)	(0.0309)	(0.0304)	(0.0327)	(0.0309)
dist_square	-0.8146***	-0.8100***	-0.8342***	-0.7575***	-0.7602***	-0.7001***
	(0.1053)	(0.1059)	(0.1072)	(0.1096)	(0.1144)	(0.1150)
beach	-0.4015**	-0.4213**	-0.4215**	-0.4126**	-0.2961	-0.3698**
	(0.1687)	(0.1682)	(0.1726)	(0.1684)	(0.1853)	(0.1742)
Constant	10.2976***	10.1639***	5.4003**	2.9803	-1.0065	-0.0894
	(0.2316)	(0.2158)	(2.5100)	(1.9246)	(3.9367)	(2.6603)
Observations	660	660	660	660	660	660
R^2	0.3362	0.3348	0.3268	0.3354	0.3176	0.3328
Adjusted R^2	0.3281	0.3267	0.3185	0.3273	0.3092	0.3246
p-value for F test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

*, ** and *** represent the statistical significance, respectively, at 10%, 5% and 1%.

Source: Own elaboration.

[3] The coefficient of correlation referring to the ethnic composition and average income of the household (in log) is very strong: 0.9315. On the other hand, the degree of linear association obtained through the relation between ethnic composition and average schooling of the head of the household is 0.9093. The new data have as primary source the aggregates by census sectors of the Censo Demográfico (2010 and 2000), produced by IBGE.

Table 7 shows the values for the white density regressions for the city of Salvador. In any estimated model, the p-value of the F statistic remains null, which implies the statistical significance of the set of explanatory variables. The values of the coefficient of determination R^2 now range from 0.3339 to 0.3490, which differs little for the example with the total population. As a rule, the estimated coefficients have equal signs and values similar to those previously discussed, except for the ethnic composition variable. In this case, the greater proportion of whites probably implies a greater number of whites per km², which at first seems rhetorical. However, the linear association between the variables is negligible (0.26), thus reinforcing the importance of the regressor previously employed in Epifani and Nicolini (2015).

For the accessibility research, the records in Table 7 are that the positive variation of 1% of the indicator for private motor vehicles should be accompanied by the highest population of whites per km² by 0.48%. This effect remains low when compared to the collective transport indicator: 0.78%. This can perhaps be explained by the fact that the number of jobs attainable has already been markedly higher for private transport, with or without congestion. Another justification for the estimates refers to the very restriction of the cumulative opportunity indicator, which does not allow to capture individual preferences or even to differentiate between the different types of employment. However, it is possible that the parameters themselves are biased due to the simultaneous determination of accessibility and density. The numerical discrepancy between indicator and instrument coefficients in both transport technologies reinforces this possibility.

Table 7 - Econometric estimates of the density of whites by agglomerates of subzones

Dependent variable: ln(dens_white)

Regression Type	(I B)	(II B)	(III B)	(IV B)	(V B)	(VI B)
dist_cbd	-0.0543*** (0.0145)					
dist_sub		-0.0691*** (0.0183)				
ln(access_car)			0.4828** (0.2124)		0.9687** (0.3884)	
ln(access_bus)				0.7848*** (0.2026)		1.0653*** (0.2806)
Instrument - Camarajipe					Yes	
Instrument - Lucaia						Yes
ethnic_ comp	1.4734*** (0.3001)	1.3991*** (0.3038)	1.5714*** (0.3004)	1.4537*** (0.3005)	1.4870*** (0.3068)	1.3817*** (0.3050)
Controls (X_{it})	Yes	Yes	Yes	Yes	Yes	Yes
Constant	7.7690*** (0.2377)	7.6506*** (0.2213)	2.2659 (2.2095)	-0.3374 (1.9732)	-2.7686 (4.0287)	-3.0566 (2.7261)
Observations	660	660	660	660	660	660
R^2	0.3481	0.3482	0.3393	0.3490	0.3339	0.3471
Adjusted R^2	0.3401	0.3402	0.3311	0.3410	0.3258	0.3391
p-value for F test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

*, ** and *** represent the statistical significance, respectively, at 10%, 5% and 1%.

Source: Own elaboration.

The same density models were estimated considering only the black population, according to Table 8. Again, the p-value of the F statistic is null for any form of estimation, thus determining the significance of the set of regressors. The values of the coefficient of determination R^2 vary from 0.3971 to 0.4132, thus suggesting that the modeling employed explains better the settlement of blacks in relation to the population of whites per km². In the estimations (I C) and (II C), the density decreases with the physical distance of 1 km from the employment centers follow the percentage values of 5.25% and 6.33%, respectively. This decline in instrumental variables is 1.04% for the decrease of 1% in the accessibility indicator, whether for private or public transportation. In particular, the ethnic component variable has coefficient between -3.85 and -4.04 for the density of blacks, values that were between -2.24 to -2.44 for the integral density. This suggests that there is in fact racial segregation in residential areas of Salvador, which is possibly linked to real estate speculation and the formation of ghettos in poor or peripheral neighborhoods.

In general terms, the parameters estimated to measure the effect of transport differentials and physical access to employment opportunities are valid at acceptable levels of significance, regardless of the dependent variable employed. Therefore, comprehensive accessibility measures explain at least in part the distribution of different population groups in the city of Salvador. Thus, a smaller physical distance from the dynamic nuclei of the city or a smaller possibility of reaching a certain variety of jobs should justify a lower demand for housing and concentration of people in more distant peripheral spaces.

Table 8 - Econometric estimates of density of blacks by agglomerates of subzones

Dependent variable: ln(dens_black)

Regression Type	(I C)	(II C)	(III C)	(IV C)	(V C)	(VI C)
dist_cbd	-0.0525*** (0.0141)					
dist_sub		-0.0633*** (0.0179)				
ln(access_car)			0.4390** (0.2073)		1.0430*** (0.3801)	
ln(access_bus)				0.7206*** (0.1979)		1.0382*** (0.2742)
Instrument - Camarajipe					Yes	
Instrument - Lucaia						Yes
ethnic_ comp	-3.9525*** (0.2928)	-4.0118*** (0.2968)	-3.8531*** (0.2933)	-3.9619*** (0.2935)	-3.9579*** (0.3003)	-4.0434*** (0.2981)
Controls (X_{it})	Yes	Yes	Yes	Yes	Yes	Yes
Constant	10.3674*** (0.2320)	10.2342*** (0.2161)	5.3354** (2.1570)	2.8996 (1.9278)	-0.9232 (3.9426)	-0.1782 (2.6647)
Observations	660	660	660	660	660	660
R^2	0.4132	0.4121	0.4049	0.4127	0.3971	0.4104
Adjusted R^2	0.4060	0.4048	0.3976	0.4055	0.3897	0.4032
p-value for F test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

*, ** and *** represent the statistical significance, respectively, at 10%, 5% and 1%.

Source: Own elaboration.

6. Final considerations

This study aimed to analyze the effect of accessibility on the patterns of population location in the city of Salvador. In particular, it also sought to investigate the spatial distribution of whites and blacks in this city, based on the relationship between densities and accessibility, in a polycentric spatial configuration in relation to the location of jobs. The hypothesis raised was that the unbalanced use of urban space between different segments of the population is explained, in part, by transportation differentials and physical access to employment opportunities. These differentials attribute different levels of housing attractiveness to the territorial divisions of the city, although selectivity over where to live is restricted to the wealthier families, which are predominantly white.

The integral accessibility index allowed us to capture the vectors of employment distribution and quality of transportation in Salvador. This indicator, by car/bus without/with congestion, provided the number of attainable employment opportunities for each traffic division of the city. Thus, it was possible to affirm that physical access to employment is considerably unequal among users of motorized means of transportation. When considering traffic congestion, the index was substantially decreased for any form of transportation.

This reinforces that the city needs a better public transportation system, which balances access to employment between different user profiles and mitigates the negative effects of congestion.

The identification strategy based on the use of hydrographic instruments to isolate the causal effect of accessibility on density presented important results. For each validity test, the instrument coefficient is statistically significant with probability of rejection at 1%. As a rule, the final estimates suggested that the factors of access to employment had a positive effect, and statistically significant on the population density of the city. With regard to the other variables, we highlight the ethnic composition control, which captures components linked to racial segregation. This control had opposite signs for distinct population groups, but its effect on black density was markedly higher. On the other hand, the population per km² was higher in regions already filled during the demographic pre-explosion of the second half of the 20th century.

The analysis of the results by race segment showed that the estimated parameters presented similar signs and values similar to those found for the general population. The ethnic composition variable showed a higher number of whites and a lower number of blacks per km², as the proportion of whites in the local population is higher. This observation has some importance due to the cited variable having a very strong correlation with income and average schooling, which were not included directly in the regressions. In general terms, the coefficients for the population density accessibility effect showed that a lower possibility of reaching jobs should justify a lower demand for housing in more distant peripheral spaces. This applies to blacks and whites regardless of the technology of transportation, car or bus.

This work allowed a better understanding of the distribution of different population groups in space, whites and blacks, from the relation between population density and accessibility. The findings are potentially useful by providing new information and figures on the level of access to job opportunities among different population groups in the municipality. However, due to the non-availability of data, the analysis was restricted to a single period of time, which does not make it possible to evaluate the effect of any specific policy. In the same logic, it will be necessary to expand the object of study for the other municipalities of the metropolitan region. These municipalities jointly account for 20.9% of the workforce and 24.4% of the metropolitan area jobs. For future extensions, it will be important to investigate the feasibility of the full accessibility index itself, capture individual preferences or qualify the different types of employment.

References

AGUIAR, M. P. *Notas sobre o "enigma baiano".* Salvador: Livraria Progresso, 1958.

ALONSO, W. *Location and Land Use.* Cambridge: Harvard University Press, 1964

BAHIA. Secretaria de Infraestrutura do Estado da Bahia. *Pesquisa de Mobilidade da Região de Metropolitana de Salvador*. Salvador: SEINFRA, 2012.

BAUM-SNOW, N. Did highways cause suburbanization? *The Quarterly Journal of Economics*, v.122, n.2, p.775-805, may.2007.

CASCETTA, E.; CARTENÌ, A.; MONTANINO, M. A new measure of accessibility based on perceived opportunities. *Procedia - Social and Behavioral Sciences*, v.87, p.117-132, 2013.

DELGADO, J. P. M. Organização social do território e mobilidade urbana. In: CARVALHO, I. M. M.; PEREIRA, G. C. (Org.). *Salvador:* transformações na ordem urbana. Rio de Janeiro: Letra Capital, 2014. p.199-235.

EPIFANI, I.; NICOLINI, R. *Modelling Population Density Over Time:* How Spatial Distance Matters. Regional Studies, v.51, n. 4, 2017.

FERNANDES, R. B.; REGINA, M. E. A Segregação Residencial em Salvador no Contexto do Miolo da Cidade. *Cadernos do Logepa*, v.4, n.1, p.39-46, 2005.

FUJITA, M.; KRUGMAN, P. When is the Economy Monocentric? Von Thünen and Chamberlain United. *Regional Science and Urban Economics*, v.25, n.4, p.505-528, 1995.

FUJITA, M.; OGAWA, H. Multiple Equilibria and Structural Transformation of Non-Monocentric Urban Configurations. *Regional Science and Urban Economics,* v.12, n.2, p.161-196, may.1982.

GARCIA-LOPEZ, M.-À. Urban spatial structure, suburbanization and transportation in Barcelona. *Journal of Urban Economics,* v.72, n.2-3, p.176-190, 2012.

GEURS, K. T.; VAN WEE, B. Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography*, v.12, n.2, p.127-140, 2004.

GOOGLE INC. *Google Maps. Conjunto de aplicativos Web.* Available in: < http://www.google.com.br/maps>. Access in: 12 jun. 2015 a 21 dec. 2015.

HADDAD, E. A.; BARUFI, A. M. B. *From Rivers to Roads:* Spatial Mismatch and Inequality of Opportunity in Urban Labor Markets of a Megacity. São Paulo: TD-Nereus, 2016.

HANSEN, W. G. *Accessibility and Residential Growth.* Massachusetts Institute of Technology, 1959.

HEINONEN, N. A cidade alta em alta? Circuitos e cenários das dinâmicas comerciais do centro velho de Salvador. *Geotextos,* Salvador, v.1, n.1, p.81-116, 2005.

HENDERSON, J. V.; MITRA, A. The new urban landscape: Developers and edge cities. *Regional Science and Urban Economics,* v.26, n.6, p.613-643, dec.1996.

IBGE. *Censo Demográfico 2000:* Agregado por Setores Censitários dos Resultados do Universo. Rio de Janeiro: IBGE, 2003.

________. *Base de informações do Censo Demográfico 2010:* Resultados do Universo por setor censitário. Rio de Janeiro: IBGE, 2011.

________. *População e Demografia.* Available in: < http://seriesestatisticas.ibge.gov.br/lista_tema.aspx?op=0&no=10 >. Access in: 22 fev. 2016.

INGRAM, D. R. The concept of accessibility: a search for an operational form. *Regional Studies,* v.5, n.2, p.101-107, feb.1971.

KUSTNER, R. C.; SANTOS, A. S. Participação cidadã em torno do Dique de Campinas, SSA/BA? *Cadernos Metrópole,* n.15, p.145-160, 2006.

LUCAS, R. E.; ROSSI-HANSBERG, E. On the Internal Structure of Cities. *Econometrica,* v.70, n.4, p.1445-1476, jul.2002.

MILLS, E. S. An Aggregative Model of Resource Allocation in a Metropolitan Area. *The American Economic Review,* v.57, n.2, p.197-210, may.1967.

MUÑIZ, I.; GARCIA-LÓPEZ, M.-À.; GALINDO Anna. The Effect of Employment Sub-centres on Population Density in Barcelona. *Urban Studies,* v.45, n.3, p.627-649, mar. 2008.

MUTH, R. F. *Cities and Housing:* The Spatial Pattern of Urban Residential Land Use. Chicago: University of Chicago Press, 1969.

NASCIMENTO, A. A. V. *Dez freguesias da cidade do Salvador:* aspectos sociais e urbanos do século XIX. Salvador: EDUFBA, 2007.

NOGUEIRA, R. C. C. Saneamento da cidade de Salvador - de 1850 a 1925. In: ENCONTRO NACIONAL DA ANPUR, 7, 1997, Recife. *Anais...* Recife: UFPE, 1997. p. 636-654.

QUIGLEY, J. M. Consumer choice of dwelling, neighborhood and public services. *Regional Science and Urban Economics*, v.15, n.1, p.41-63, feb.1985.

SALVADOR, Prefeitura Municipal, Centro de Planejamento Municipal. *Salvador em Números*. Salvador, 1996. 46 p.

SANTOS, E.; PINHO, J. A. G.; MORAES, L. R. S.; FISCHER, T. (Org). *O Caminho das Águas em Salvador:* Bacias Hidrográficas, Bairros e Fontes. Salvador: CIAGS/UFBA; SEMA, 2010.

TAVARES, L. H. D. *História da Bahia.* 11. ed. Salvador: EDUFBA, 2008. 552 p.

VIEIRA, R. S.; HADDAD, E. A. *An Accessibility Index for the Metropolitan Region of São Paulo.* São Paulo: TD-Nereus, 2012.