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Accessibility and urban mobility by bus in Belo Horizonte/Minas Gerais – Brazil

Daniela Antunes Lessa[a,*], Carlos Lobo[a], Leandro Cardoso[b]

[a] Postgraduate Program in Geography, UFMG, Av. Antônio Carlos, 6627, Belo Horizonte, MG 31270-901, Brazil
[b] Postgraduate Program in Geotechnics and Transportation, UFMG, Av. Antônio Carlos, 6627, Belo Horizonte, MG 31270-901, Brazil

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ABSTRACT

Accessibility and mobility are fundamental conditions of urban life today, which reinforces the need to evaluate the dynamics of access to and use of the public transport system in large cities that have experienced serious traffic and congestion problems. The present article analyses the levels of accessibility by bus in the city of Belo Horizonte / MG, including its relationship with the levels of urban mobility. To this end, accessibility indicators for bus and the mobility of the population are proposed. In addition, indicators of global and local regression models were evaluated, considering accessibility as an explanatory variable. In general, the results indicate a strong regional variation in the municipality of Belo Horizonte and suggest that accessibility to public transport by bus does not directly lead to effective mobility. Some regions have a greater discrepancy between the levels of accessibility and mobility, especially those located in peripheral areas where access to the bus transport system is lower than expected by the methodology, given the existing levels of mobility. The results, albeit essentially exploratory, may be useful to support the formulation of constructive measures, in order to minimize possible distortions in the provision of accessibility, encouraging the best use of mobility opportunities in urban space.

1. Introduction

The general purpose of a public transport system is to guarantee the mobility, access and integration of individuals with different economic and social activities, which are directly and indirectly conditioned by the form of land use and occupation, as well as the costs of production, trade flows and the determining of market areas (Mitra and Saphores, 2016). Brazilian cities, particularly in the last decades of the twentieth century, have experienced high demographic growth, which has had a strong impact on the demands for urban transportation. However, what actually happened in the country was that the car ended up shaping the cities, reformulating the concept of space and distance, besides changing people's habits (Scarlato, 1989).

Some issues, such as the inadequate supply of public transport, congestion, noise pollution, air pollution, accidents and lack of access to the city, have led to a general understanding that most cities should review their strategies for the management of the transport system (de Oliveira and da Silva, 2015). The National Urban Mobility Policy, known as the “Mobility Law”, was established in the country in 2012, whose declared purpose is to contribute to universal access to the city, fostering and achieving conditions that contribute to the realization of urban accessibility and mobility. Objectives and guidelines of urban development policy were also established, based on the democratic planning and management of the National Urban Mobility System (Brasil, 2012).

According to data from the last Demographic Census, in 2010 the municipality of Belo Horizonte, the administrative capital of the State of Minas Gerais / Brazil had a resident population of approximately 2.5 million. As is the case in most Brazilian state capitals, there is the reproduction of numerous precarious conditions in the provision of transport for the population, which contributes to the aggravation of situations of social vulnerability and environmental degradation.

Thus, spatial accessibility and mobility are characterized by a series of inequalities resulting from the structuring of a circulation space in which the privileges of individual transport are maintained and the concerns of the most vulnerable groups related to circulation have been passed over (Lobo et al., 2013). According to the 2017 Urban Mobility Master Plan of Belo Horizonte, in 2002, 45% of the daily trips in the city were carried out by urban bus / train and 26% by automobile / motorcycle. Non-motorized forms (on foot or by bicycle) represented 29%. According to projections by the same diagnosis, the absence of new investments in public transport improvements will encourage an appreciable change in this scenario. In 2030, it is estimated that 52% of journeys will be carried out by automobiles and 48% by public

* Corresponding author.
E-mail addresses: dani.antunes@gmail.com, dlessa@ufmg.br (D.A. Lessa), carloslobo@geo.igc.ufmg.br (C. Lobo), leandro@etg.ufmg.br (L. Cardoso).

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transport. Given the managerial lack of capacity, this advance of individual motorization has contributed to the loss of efficiency of the whole system, as well as favoring the prevalence of low average speeds of public transportation by bus, which in 2008 was 19.8 km/h in the municipal road network and 14.3 km/h in the central area at peak times (Belo Horizonte, 2012).

Given this scenario, with the strong expansion of motorized individual mobility and the recurrent difficulties in controlling the systems of traffic and transit faced in the large Brazilian cities, such as Belo Horizonte, some issues deserve to be evaluated, such as: Are there expressive regional differences in the level of accessibility to transport by bus in the municipality of Belo Horizonte? Given the availability of bus stops and bus lines, to what extent does the level of accessibility to this system materialize in the effective mobility of the population, measured by journeys carried out in the municipality? Are there regions where there is a strong discrepancy between the access to the system and the effective use of bus transport? Based on these questions, the main objective of this study is to analyze accessibility by bus in the municipality of Belo Horizonte / MG, including the evaluation of the supposed prediction / influence of access to the systems at the levels of urban mobility.

To estimate the travel matrix, databases extracted from the Origin and Destination Survey of 2012 (OD 2012), produced by the Development Agency of the Metropolitan Region of Belo Horizonte (RMBH), were used. The analysis of conditions of spatial mobility and accessibility, based on the specific indicators proposed in this paper, allowed the elaboration of a diagnosis that surpasses the simple (re) cognition of a condition, perceived in daily life. The comparison of indices of accessibility and mobility allows the recognition of certain spatial patterns. It also enables the evaluation of discrepancies between access and the effective use of the bus transport system. These indicators can be useful to public administrators and subsidize the formulation of policies and proposed measures aimed at supporting political decision making, in order to minimize possible distortions in the distribution and provision of mobility and urban accessibility.

2. Accessibility and urban mobility: concepts and meanings

The academic literature recognizes that the transport system has a direct influence on production costs, trade flows, social welfare and the articulation of market areas, playing an essential role in the economic growth and development of cities (Mitra and Saphores, 2016). There is, therefore, a close relationship between transport strategies and policies, which comprise a cycle involving land use, the exchange of activities, transport, and accessibility and mobility (Rodrigue et al., 2009). In fact, accessibility is perceived as a complex concept that is difficult to measure (Geurs and van Wee, 2004; Handy, 2005; Páez et al., 2012). Frequently, their vast use leads to misunderstandings in interpretation, they are sometimes considered as synonymous (Koenig, 1980). Although some authors recognize their importance and conceptual complementarity, there are few who have sought to verify the real influence one has on the other (Raia Junior, 2000).

Since the last century, the term accessibility has been used in different strands of scientific knowledge, notably in the areas of urban planning, geography and transport engineering (Karou and Hull, 2014; Morris et al., 1979; Vulevic, 2016). These involve the analysis of the forms of land use (Cervero, 1989; Harris, 1954; Levinson, 1998); agents and measures of socio-spatial segregation (Bocarejo and Oviedo, 2012; Pyrialakou et al., 2016; van Wee and Geurs, 2011); of indicators of pedestrian access to the circulation infrastructure (Ewing and Handy, 2009; Vale et al., 2016). As Gould (1969, p. 64) points out, in the late 1960s “accessibility is a slippery notion (...) one of those common terms that everyone uses until faced with the problem of defining and measuring it!”. Gould's observations are still valid, despite the subsequent theoretical and empirical investment. Some definitions include interpretations such as “the potential of opportunities for interaction” (Hansen, 1959, p. 4); “the ease with which any land-use activity can be reached from a location using a particular transport system” (Dalvi and Martin, 1976); “the freedom of individuals to decide whether or not to participate in different activities” (Burns, 1979); and “benefits provided by a transportation / land-use system” (Ben-Akiva and Lerman, 1985).

Accessibility can also be defined as the ability to reach activities, individuals or opportunities, if necessary, by moving to the places where those needs are located (Geurs and Ritsema van Eck, 2001; Handy, 2005); or understood as a product of land use and the transport system (van Wee and Geurs, 2011; Vickerman, 1974). As an indicator and socioeconomic value, accessibility also permits an approach that goes beyond access to transportation systems (Cardoso, 2007), considering the gains resulting from the circulation of goods and people. When considering the social dimension of the term, especially in a context of poverty and non-development, coupled with the problems related to the limited physical and tariff integration between the various public modes that are components of transportation systems and the insufficient incidence of alternative modes of transport, accessibility reflects a process of socio-spatial segregation, since a significant portion of the population has fewer opportunities for work, study, consumption and leisure (Bocarejo and Oviedo, 2012).

In general, accessibility measures include both an (*individual-based*) impedance indicator, represented by time / space (Hägerstraand, 1970) or cost constraints to reach a destination; as well as an (*place-based*) indicator of attractiveness, represented by the potential qualities of desired destinations (Handy, 2005; Koenig, 1980; Kwan, 1998; Vale et al., 2016). In both interpretations accessibility is estimated by the spatial distribution of the destination, by the ease of reaching it and by the quality and characteristics of the activities encountered (Handy and Niemeier, 1997). Place-based accessibility analyses of the transport system are also noteworthy (Geurs and Ritsema van Eck, 2001). The infrastructure-based measures are based on features of the road and transportation network and are not sensitive to the location of activities in space. In this respect, accessibility can be evaluated as the combined effect of the weight of opportunities and the impedance of the displacements. Utility-based measures are developed based on the microeconomic theory of random utility and describe accessibility as a result of a choice in relation to the set of transport and destination alternatives (Vale et al., 2016).

The concept of mobility also involves multiple aspects. In view of the most recent literature about transport planning, it is considered that mobility refers to the ability to travel, defining the potential of movement (Handy, 1994, 2005). This is a qualitative term that generically represents the capacity of a group of individuals to move from an area, which depends essentially on the availability of the different types of modes of transport (Handy, 1994; Morris et al., 1979). It also assumes interpretations related to social, spatial and residential mobility (Cardoso, 2007). In addition to the relationship with the condition of movement, mobility may also suggest processes of regional change and transformation.

The expression urban mobility itself has been noticeable and given theoretical support to urban and transport planning (Belo Horizonte, 2017; Meurs and Haaijer, 2001); in the influence of spatial distribution (Chen et al., 2017); or as an indicator of sustainable urban mobility (Costa, 2008; Miranda and da Silva, 2012). Mobility is related, in this sense, to the capacity of a given population in an urban space to carry out daily movements. It refers not only to their actual occurrence, but also to the possibility or ease of such trips (Cardoso, 2007). For Vasconcellos (2001), the concept of mobility involves two central components: the performance of the transport system and the individual's characteristics. There are, however, factors that directly affect mobility, such as income, employment, gender, age, and local mode of transportation, which begin to differentiate and determine individual and collective conditions in terms of displacement in urban areas (Costa, 2008). Mobility thus appears as the need for transportation, shaped by the population's way of life (Raia Junior, 2000). In practice, the problems of social inequalities in access to the city remain mainly formulated in terms of access to mobility (Fol and Gallez, 2013).

Aside from this vast conceptual amplitude, which suggests the current relevance and scope of this theme, there are convergences between the meanings of accessibility and mobility, which demonstrate different aspects of urban transport. On the one hand, improving travel conditions is a reflection of improved conditions of accessibility, as a fast transport infrastructure favors access to various urban services, such as health and education. However, the development of transport networks also induces urban sprawl and the creation of low-density peri-urban areas, which can favor a deterioration in accessibility itself (Handy, 2005). Thus, contrary to the generally positive link between mobility and regional integration, differences in individual mobility are difficult to interpret in terms of social inequalities or social integration. High mobility can result from strong access restrictions for low-income people (Jouffe, 2007). Conversely, low mobility may be a choice, especially for affluent populations who are able to live in the denser central areas in urban facilities (Fol and Gallez, 2013). Therefore, mobility is not a sufficient condition to amplify accessibility (Handy, 1994). Similarly, greater accessibility, especially to the public transport system, does not directly translate into gains in mobility, neither in the volume of flows, nor in efficiency and quality. Besides proposing indicators to describe and evaluate urban accessibility, it is therefore relevant to analyze the possible relationships and/or interactions with effective mobility, offering additional relevant parameters to the planning and management of the urban transport system.

3. Database and research methodology: the indicators and indexes proposed

The data used to obtain the internal travel matrix in Belo Horizonte were extracted from the Origin and Destination Survey of 2012. This is a periodic and sample-based survey, produced in the MRBH since 1972. The latest version, whose sample plan involved a total of 21,340 domiciles (only in the municipality of Belo Horizonte) was elaborated and made available by the Development Agency of the MRBH, a body linked to the Government of the State of Minas Gerais. The digital vector meshes that identify the bus stops (Fig. 1) were provided by the Transport and Traffic Company of Belo Horizonte (BHTRANS). The data referring to the resident population stock were extracted from the Demographic Census 2010 (IBGE), originally aggregated by census tracts. For the purposes of processing and analysis, spatial units named *Campos* (Fig. 1) were used, whose cuts were detailed in Fig. A1 (Appendixes A1). These *Campos* comprise aggregations of Homogeneous Areas (lower level of spatial disaggregation spatially compatible with the census tracts) and are considered key units for the analysis of urban space. They often coincide with the limits of neighborhoods, which makes information more tangible to the public and the public authorities. In Belo Horizonte, according to the space cut established in the Origin and Destination Survey of 2012, 120 *Campos* were determined, divided into nine administrative regions: Barreiro, West, South Center, Northwest, East; Pampulha, Northeast; North and Venda Nova (Fig. 1).

The Accessibility Index (*IA*) was proposed as part of the methodological procedure. This is an aggregate indicator that represents three dimensions of the accessibility of the population to the public transport system by bus in each *Campo*, based on the lines and the points of embarkation. This index was derived from the following variables, statistically with low correlation level (Appendixes A2):

1. Point Density Ratio (RDP_i): ratio between the number of bus stops (PO_i) and population (P_i) in each *Campo* (Eq. 1):

$$RDP_i = \sum_i^n PO_i \times 1{,}000/P_i \tag{1}$$

Given that: P_i is the population of each *Campo*.

2. Frequency Ratio (RF_i): relationship between the total number of bus journeys by the boarding points of each *Campo* (Eq. 2).

$$RF_i = \sum_i^n F_i/PO_i \tag{2}$$

Given that: F_i is the frequency of journeys passing at each bus stop of a given *Campo*; and PO_i the number of bus stops in each *Campo*.

3. Ratio of lines (RL_i): the number of bus lines that pass at the boarding points of each *Campo* (Eq. 3).

$$RL_i = \sum_i^n L_i/PO_i \tag{3}$$

Given that: L_i is the number of boarding lines that pass at each bus stop of a given *Campo*; and PO_i the number of bus stops in each *Campo*.

The values of RDP_i, RF_i and RL_I were standardized (R_z), converted on units of standard deviation (Z scores), as described in eq. 4:

$$R_z = (R_i - R_\mu)/R_\sigma \tag{4}$$

Given that: R_i is the Ratio of a given *Campo*; R_μ the average of all *Campos* Ratio; and R_σ the standard deviation of all *Campos* Ratio.

The Accessibility Index (*AI*) was obtained by the arithmetic mean of the three standardized indicators (RDP_p, RL_p and RF_p).

Mobility was measured by the daily volume of displacements by bus originating in each of the Belo Horizonte *Campos*, given the resident population. The Mobility Ratio (RM_i) was therefore defined by the ratio between the division of journeys and the resident population in a given *Campo* (Eq. 5).

$$RM_i = \sum_i^n V_i/P_i \tag{5}$$

Given that: V_i is the number of journeys that depart from a particular *Campo*; and P_i the population residing in the same *Campo*.

For the purpose of analysis of the Mobility prediction Ratio (dependent variable), based on the values of the *AI* (explanatory variable), the global (OlS) and local (GWR - Geographically Weighted Regression) regression models were used. According to Brunsdon et al. (1996), GWR is a relatively simple technique that extends the traditional regression and allows the local variations of the rates of change to be described in the coefficients of the model. Instead of using global estimates, the parameters are specific to a local arrangement. It is a tool developed to analyze phenomena that suffer variation in the studied area, derived from spatial heterogeneity. It is based on the adjustment of a local regression model for each element in the data set, weighting the observations by the ratio of the distance. It is assumed that the points closest to the point of study have greater influence on the regression parameters than the ones that are further away (Tobler, 1979; Brundson et al., 1996; Carvalho et al., 2006). In this work, the method used to define the bandwidth or neighbors was the AICc (Akaike Information Criterion), which considers a performance measure useful for comparing different regression models. In a complementary way, the Kernel was used as a classification method, which takes into account the distance of each sample element, whose centroid corresponds to the nearest point of the observed values for the respective element (Mingoti, 2005). In addition to the local regression indices (Local R_2) estimated for each *Campo*, the spatial distribution of the standardized residues, which represent the degree of adjustment / explanation of the

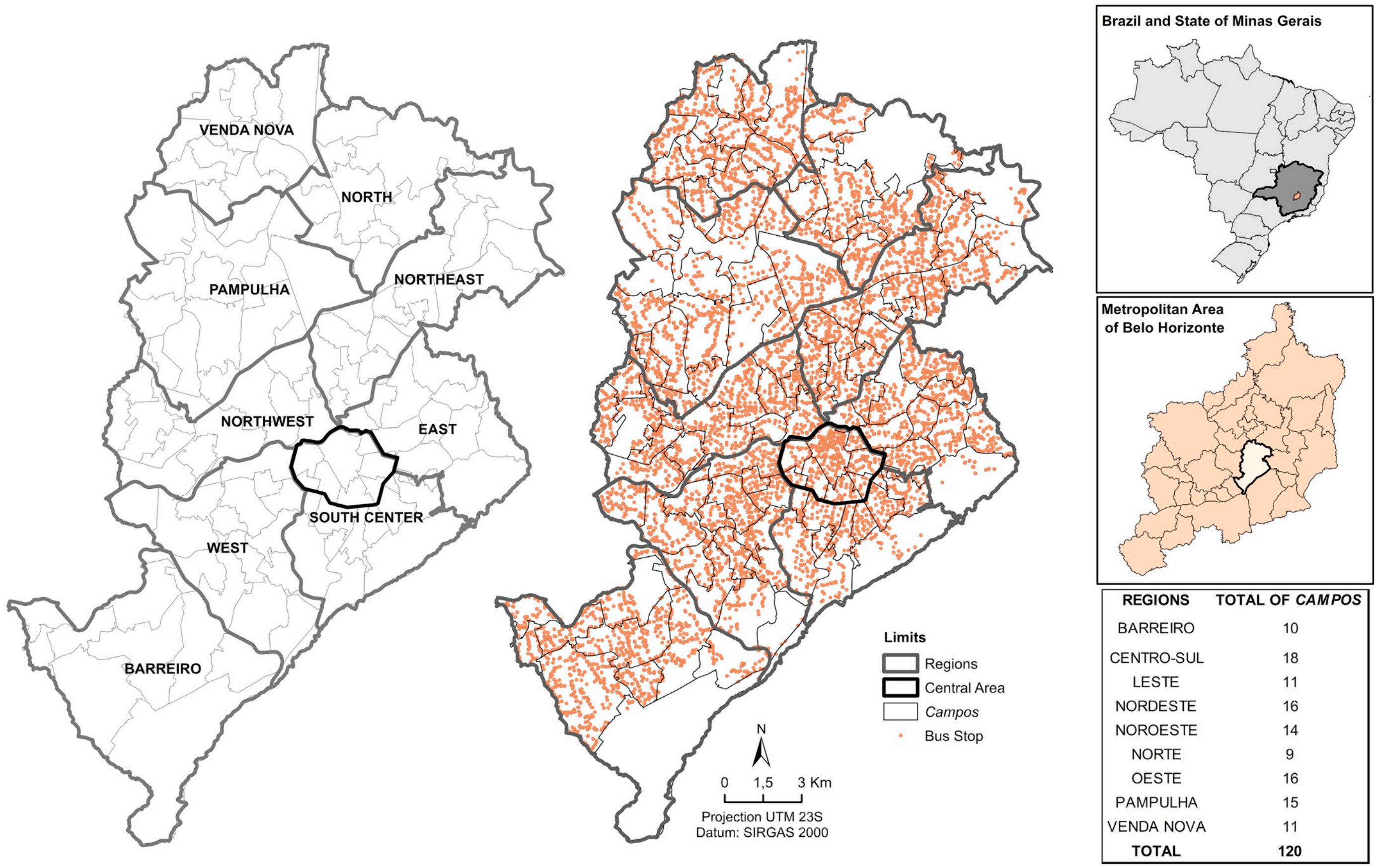

Fig. 1. Distribution of bus stops by *Campos* in the Administrative Region of Belo Horizonte / MG.
Source of data: Digital base of PRODABEL and BHTRANS territorial units.

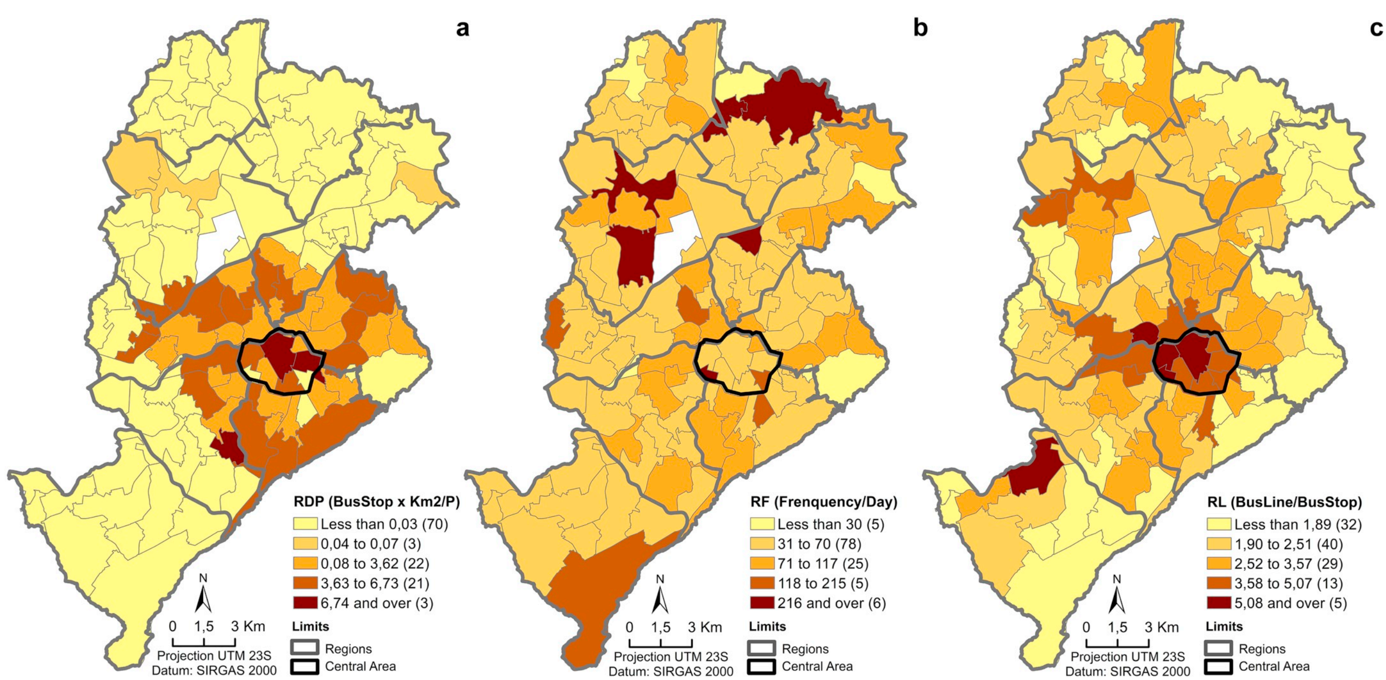

Fig. 2. Ratios of Density, Frequency and Bus Lines in the *Campos* of Belo Horizonte / MG, 2012.

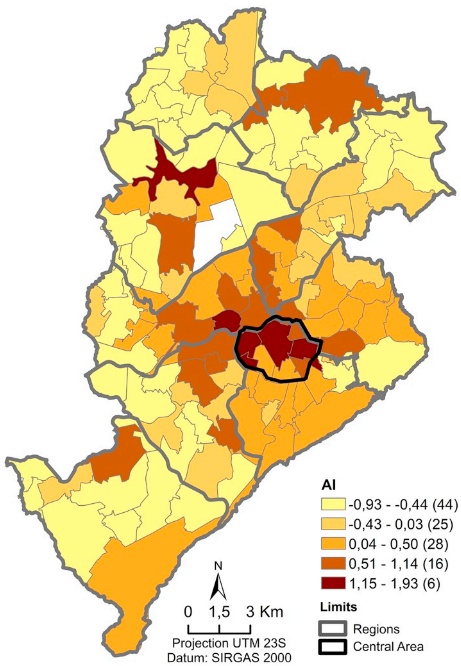

Fig. 3. Accessibility Index (***AI***) in the *Campos* in Belo Horizonte / MG, 2012. Source of data: Digital base of the points, itineraries and timetable of the bus lines of the municipality - BHTRANS and Demographic Census 2010.

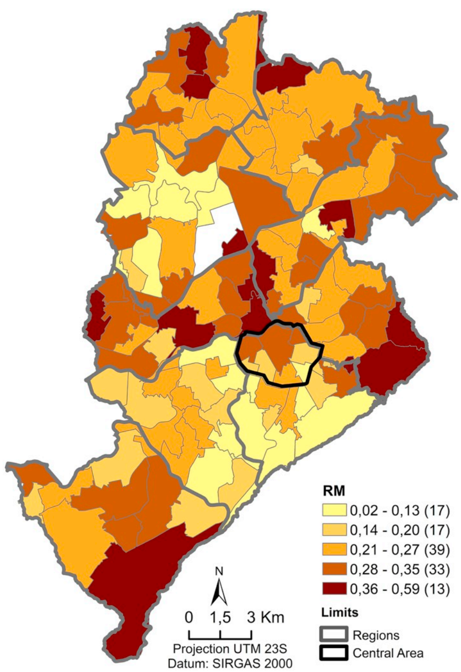

Fig. 4. Ratio of Mobility (***RM***) in the *Campos* in Belo Horizonte / MG, 2012. Source of data: Origin and Destination Survey of 2012 and Demographic Census 2010.

local model, was analyzed. To classify the data related to the cartograms presented herein, (Figs. 2, 3, 4 and 6) the Natural Breaks method was selected. Also known as natural break (Jenks, 1967), this model aims to find the class intervals in order to minimize the internal variance, identifying the largest differences between the limits of each interval. Thus, this classification method seeks clusters that occur "naturally" in the data set, to obtain a greater internal homogeneity for each class and the lowest between classes.

4. Analysis and interpretation of the results: evidences for the case of Belo Horizonte / MG

The cartograms set forth in Fig. 2a and Fig. 2b allow us to observe distinct patterns in the spatial distribution of the proposed indicators. Whilst the Density Ratios (*RDP*) and Line Ratios (*RL*) show a clear spatial concentration, preferentially located in the central and *peri* central areas of Belo Horizonte, in *RF* (Fig. 2c) the *Campos* do not show a clear spatial concentration. The *Campos* with the highest *RDP* (above 6,74) were Centro, São Lucas and Mansões (Center-South and West Region). Regarding the *RF*, the *Campos* classified with a higher level (more than 216 buses a day) are located in Pampulha, North Center-South regions. Concerning the Line Ratio (*RL*), the highest values are concentrated in the Center-South region of the municipality. Of the five *Campos* classified in the highest level (above 5.08 bus lines per bus stop), three are located in this region (Centro, Barro Preto, Santo Agostinho). This feature was expected, considering the radial-concentric configuration of the roads and the municipal bus transport system. The *Campos* which had higher *RL* values follow the line of the municipality's Metropolitan Train (surface subway). The limited regional capillarity of this system (which is only a single line) requires a modal "complementation" of transport. Although there is not much physical and tariff integration of the subway and bus systems in Belo Horizonte, the systems act in a relatively integrated way, extending the spatial reach of the services.

Source of data: Digital base of the bus stops, itineraries and the timetable of the bus lines of the municipality - BHTRANS.

The *AI* values, shown in Fig. 3, evidenced patterns and differences in the spatial distribution of accessibility to bus transport mode in Belo Horizonte. The central and peri-central area, as well as part of the Pampulha, North and Northeast regions, have the greatest level of accessibility. In general, the *Campos* with higher *AI* are served directly by important infrastructures aimed at transport by bus, either by a BH*Bus* integration station (Integration Stations of public transport lines), or by an important road corridor, with a high density of passenger boarding and disembarkation points, as is the case of the *Campo* of Carlos Prates, bordered by two major roads (i.e. Pedro II and Tereza Cristina Avenues); and the *Campos* of Pampulha, Vilarinho and Barreiro de Baixo, served by BH*Bus* stations. The west, northwest, and southwest of the municipality evidence a greater difficulty of accessibility by bus, indicating areas in which more expressive investments are necessary to extend the access to public mode in the municipality. In general, in these regions are located the *Campos* which have an *AI* of less than −0,44.

According to the analysis of Fig. 4, the *RM* indicates a distinct pattern of spatial distribution. Unlike accessibility, which is markedly higher in the central and pericentral urban area, the *Campos* with a higher displacement by bus are more concentrated in the more peripheral parts of the municipality, notably Venda Nova, Northwest, East and Barreiro Regions. It should be noted that *Campos* which have higher MRs, consequently, are those served by major roads, such as the Ring Road and Presidente Antônio Carlos, Pedro I, Tereza Cristina and Cristiano Machado Avenues. On the other hand, South Center, West and part of Pampulha Regions have a higher degree of use of the individual motorized mode (especially the automobile).

Going beyond the description of each of these indicators in an isolated manner, in an initial comparative exploratory analysis, it is evident that there is no direct association between the levels of accessibility (defined according to classification by the natural breaks model - Fig. 3) and the mobility by bus in the *Campos* of Belo Horizonte.

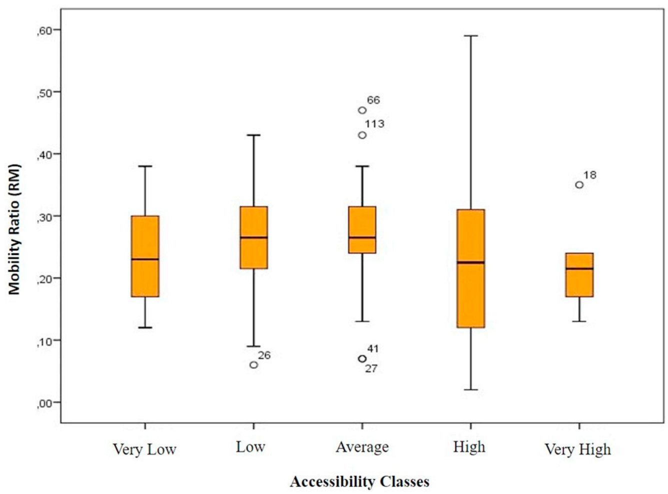

Fig. 5. Bloxplot – Ratio of Mobility by bus, according to groups of accessibility (grouped by the Natural Breaks method).
Data source: Origin and Destination Survey of 2012.

According to the analysis in Fig. 5, the *Campos* with a level of accessibility (classified as "Very Low " and "High"), do not correspond to those with a greater effective mobility. The actual group called "Very Low" accessibility did not have mobility values lower than the rest.

The analysis of the global regression parameters (OLS) indicates that *RM* (dependent variable) values are not directly determined by the potential access to public transport by bus. The overall prediction factor of the global model is extremely low (R^2 = 0,008, without statistical significance) (see more details in Appendix A3). Using the GWR model, which evaluates the local adjustment, the results are also not consistent (Fig. 6a). The R^2 location does not indicate a high predictive power based on *AI* values, which reinforces that greater access to public transport by bus is not determinant in the volume of people's level of daily commuting. Although they allowed the identification of some peculiarities in the spatial distribution, the indexes were very low (in general they did not surpass the value of 0,04). However, the standardized residue scores (Fig. 6b) evidenced certain spatial patterns, identified in the *Campos* located in the more peripheral regions, with greater adjustment to the model. These *Campos* correspond to those with the greatest discrepancy between the indicators of accessibility and mobility and concentrate the majority of the low-income population that uses the public mode by bus on a large scale. The population involved have no alternative but to rely on the public system, given the high costs of using a private car. Thus, these are regions that require more investment to increase their access to the system, either by amplifying boarding points, or, especially, by a higher offer of lines and the frequency of journeys. On the other hand, the regions where the population with the highest average household incomes are concentrated in Belo Horizonte, the *Campos* located in the Center-South region have low and negative values of standardized residue (less than −1,0). In the cases, the mobility is below that expected, given the accessibility data.

In general, the data presented are similar to the evidence presented by Handy (2005), when analyzing Northern California / USA, that indicate sensitive levels of disassociation between accessibility and mobility. The fact that there are fewer obstacles to travel does not necessarily mean greater efficiency in mobility by bus. In addition to the availability of transportation services, other social variables can also influence the effective mobility of the population, such as the dimensions of urban space, the complexity of the economic activities, as well as the living conditions and the income standards of the resident population, sometimes determined by the possibilities and choices of the mode of displacement (or not).

5. Conclusions

The spatial analysis of the *AI* and the other indicators revealed a significant regional difference in the level of accessibility to the mode of bus transport in the city of Belo Horizonte. The central region, as well as a good part of the *Campos* in the regions of Pampulha, North and

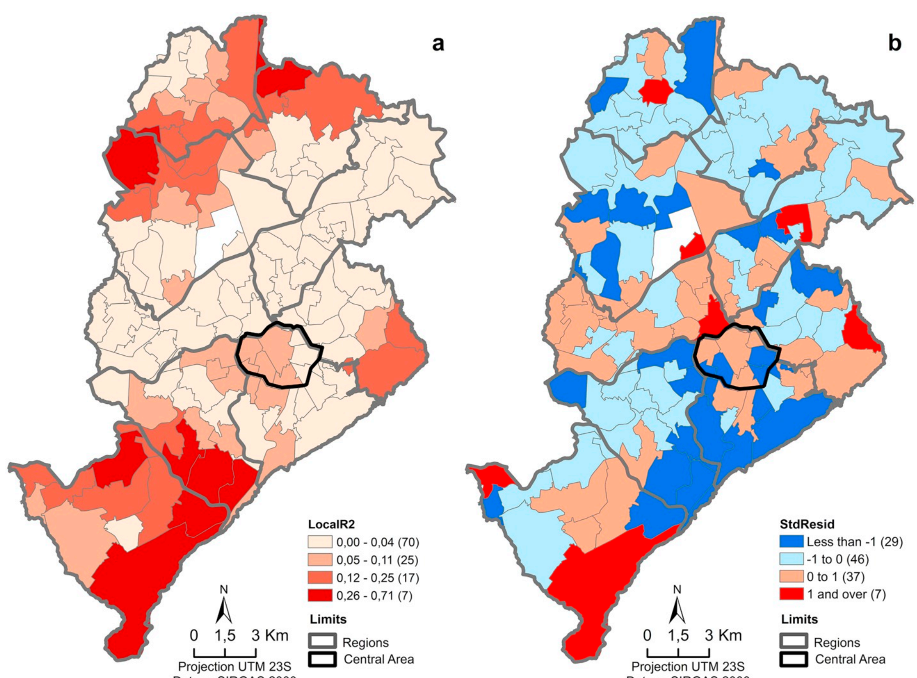

Fig. 6. Location R^2 and Standard Residual in the *Campos* of Belo Horizonte / MG, 2012.
Data source: Origin and Destination Survey of 2012.

Northeast, have the greatest potential of accessibility to the public transport by bus. Conversely, the extremes of the northwest, east and west portions of the municipality have greater restrictions of access to the bus. The *RM* also reveals significant differences in bus movements in Belo Horizonte. Unlike the *AI*, the regions of Venda Nova, Northwest, East and Barreiro have a higher volume of mobility by bus, indicating a higher demand for this form of transportation.

Local regression analysis based on the GWR model did not indicate clear prediction patterns, indicating a direct linear relationship between accessibility and the effective mobility of the population. The potential of using a mode of transport does not materialize itself on the intensity of the displacements carried out, since mobility also depends on the individual's particular characteristics and social and economic conditions However, the analysis of the adjustment to the model evidences local distribution patterns, identifying areas whose access to the system falls short of that expected given the pressure exerted by the effective use of bus transport.

In general, the results converge on at least two main strands: a) the need for municipal government intervention to reduce the discrepancies in access to the public transport system, especially in the bus mode in higher-use regions. This need for intervention is more pressing in determined less favored areas, since they exert greater demands on transportation by bus, given the low level of use of individual means, which require a higher purchasing power; and b) the potential offered by indicators capable of assessing the accessibility conditions in urban areas. In addition to the need for methodological improvement, including complementary methods of spatial analysis and the incorporation of the analysis variables, given the actual limits and scope of this work, the indicators proposed can serve as a subsidy to the formulation of constructive measures aimed at supporting the formation of public opinion and better decision making, in order to minimize possible distortions in the distribution and provision of accessibility to the urban public transport system.

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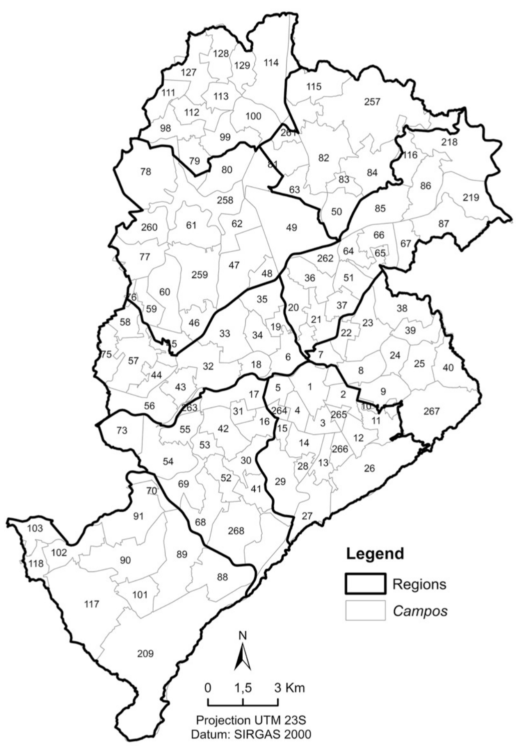
Appendices

A.1. Identification of Belo Horizonte Campos



CAMPOS NUMBER	*CAMPOS* NAME	*CAMPOS* NUMBER	*CAMPOS* NAME	*CAMPOS* NUMBER	*CAMPOS* NAME
1	Centro	41	Mansoes	84	Tupi
2	Sao Lucas	42	Jardim America	85	Sao Gabriel
3	Savassi	43	Dom Cabral	86	Vila Sao Gabriel
4	Lourdes	44	California	87	Gorduras
5	Barro Preto	45	Ipanema	88	Olhos Dagua
6	Lagoinha	46	Jardim Alvorada	89	Bonsucesso
7	Floresta	47	Cid Universitaria	90	Santa Helena
8	Santa Tereza	48	Sao Francisco	91	Barreiro de Baixo
9	Santa Efigenia - Paraiso	49	Jaragua - Aeroporto	98	Ceu Azul
10	Novo Sao Lucas	50	Aarao Reis - 1o Maio	99	Santa Monica
11	Favela da Serra	51	Vilas Reunidas	100	Venda Nova
12	Serra	52	Nova Barroca	101	Barreiro de Cima
13	Carmo - Sion	53	Salgado Filho	102	Tirol
14	Santo Antonio - Sao Pedro	54	Cabana	103	Lindeia
15	Cidade Jardim	55	Hospital - Quartel	111	Lagoa
16	Gutierrez - Grajau	56	Alto dos Pinheiros	112	Rio Branco
17	Prado - Calafate	57	Gloria	113	Leticia
18	Carlos Prates	58	Maria Emilia	114	Serra Verde
19	Sr Bom Jesus	59	Alipio de Melo	115	Sao Benedito
20	Cachoeirinha	60	Castelo	116	Ribeiro de Abreu
21	Renascenca	61	Bandeirantes	117	Vale do Jatoba
22	Sagrada Familia	62	Sao Luiz	118	Jatoba
23	Horto	63	Sao Bernardo	127	Nova America
24	Pompeia	64	Sao Paulo	128	SESC
25	Vera Cruz	65	Sao Marcos	129	Jardim Europa
26	Mangabeiras	66	Maria Goretti	209	Sul do Barreiro
27	Belvedere	67	Vila Brasilia	218	Nordeste Aglomerado
28	Favela Santa Lucia	68	Palmeiras	219	Leste Aglomerado
29	Santa Lucia - Sao Bento	69	Betania	257	Isidoro
30	Favela da Barroca - Querosene	70	Bairro das Industrias	258	Lagoa da Pampulha
31	Barroca	73	Santa Maria	259	Ouro Preto - Eng Nogueira
32	Padre Eustaquio	75	Pindorama	260	Jardim Zoologico
33	Caicara	76	Ressaca Velha	261	Vilarinho
34	Santo Andre	77	Serrano	262	Palmares
35	Aparecida	78	Braunas	263	Gameleira
36	Ipiranga - Santa Cruz	79	Leblon	264	Santo Augustinho
37	Cidade Nova	80	Jardim Atlantico	265	Funcionarios
38	Santa Ines	81	Planalto	266	Cruzeiro - Anchieta
39	Sao Geraldo	82	Floramar	267	Baleia
40	Flamengo - Taquaril	83	Guarani	268	Buritis

Fig. A.1. Identification of Belo Horizonte *Campos*.
Data source: Origin and Destination Survey of 2012.

A.2. Appendices A2: Correlation Test

Descriptive Statistics

	Mean	Std. Deviation	N
RD	,0112	,01060	119
RF	2,6343	1,19107	119
RL	73,5630	56,32437	119

Correlations

		RD	RF	RL
RD	Pearson Correlation	1	-,068	,146
	Sig. (2-tailed)		,464	,113
	N	119	119	119
RF	Pearson Correlation	-,068	1	,096
	Sig. (2-tailed)	,464		,299
	N	119	119	119
RL	Pearson Correlation	,146	,096	1
	Sig. (2-tailed)	,113	,299	
	N	119	119	119

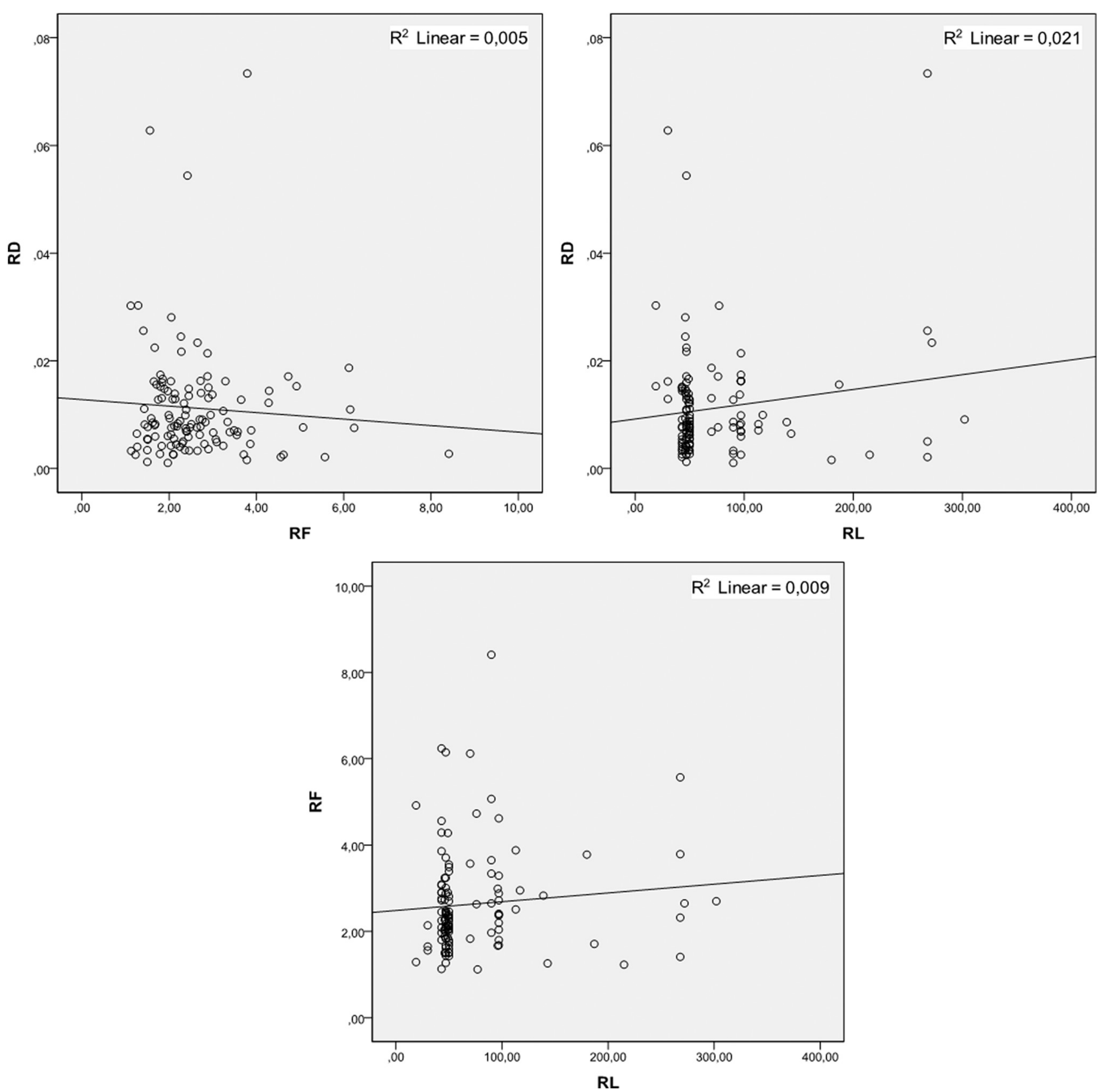


Fig. A.2. Correlation test between the pairs of variables.

A.3. Appendices A3: Regression

Descriptive statistics

	Mean	Std. Deviation	N
RM	,2499	,09467	119
AI	,1804	,10,503	119

Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,088[a]	,008	-,001	,09470

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,008	1	,008	,919	,340[b]
	Residual	1049	117	,009		
	Total	1057	118			

Coefficients[a].

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,264	,017		15,271	,000
	AI	-,080	,083	-,088	-,958	,340

[a] Predictors: (Constant), IA.
[a] Dependent Variable: RM.
[b] Predictors: (Constant), AI.
[a] Dependent Variable: RM.

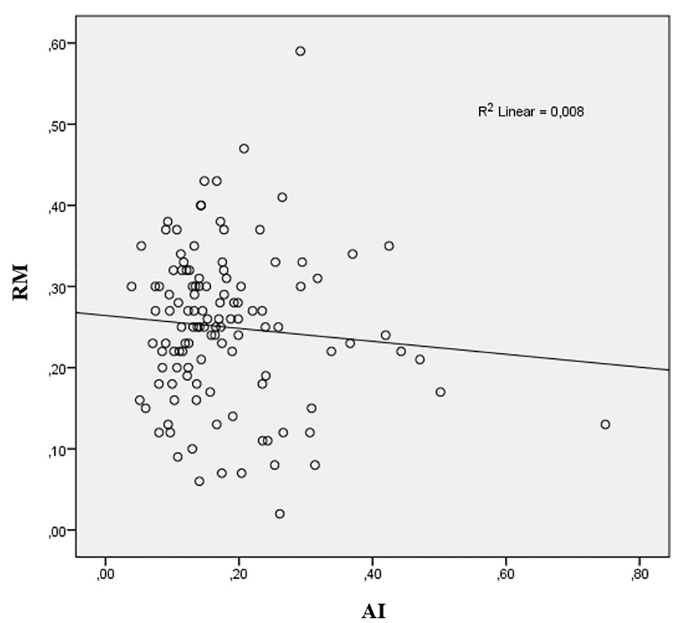


Fig. A.3. Global Regression Parameters (OLS).

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