Social inequality to access the educational service, application of geographic accessibility as a planning tool

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Abstract*– This research aims to evaluate the spatial equity of the educational service provided in the urban area of the municipalities of Manizales and Villamaría, having as hypothesis the existence of a strong inequity in the provision of the service at all levels (initial, basic, middle and higher), the methodology involves territorial accessibility analysis based on GIS, using travel times from a network of transport infrastructure, in public and private transport mode separately, the location of all formal education establishments whether public or private. This methodology is developed in such a way that it can be applied to different locations and populations throughout the world. The main results show sectors with disparate values with respect to the provision of educational services, showing how the lower strata have lower conditions than the higher socioeconomic strata.

Keywords*-- Education, equity, geographical accessibility, Colombia.

I. Introduction

Education is a fundamental component for all kinds of regions, influencing the progress and development of modern societies, necessary for all inhabitants, starting from a basic level to achieve comfortable living, advancing towards better economic and social levels. World experience shows the existence of a close correlation between the level of development of countries with the strength of their educational systems and scientific and technological research. According to studies by the Organization for Economic Cooperation and Development (OECD), an additional year of schooling increases a country's per capita gross domestic product by 4% to 7% [1].

Education has come to be classified as a basic need by the United Nations [2], which gives it significant weight, especially when it comes to developing countries such as those found in Latin America. Colombia is an unequal country [3], heavily damaged and fragmented due to the violence in the 20th century. Colombia is currently in a period of growth and general development, facing important challenges to closing gaps [3] for which education plays a key role.

Manizales, capital of the department of Caldas, located in the Colombian coffee region, with geographic coordinates 5° 03' 58" north latitude and 75° 29' 5" west longitude (Fig. 1). Manizales has a steep topography with an elevation average of 2,150 meters above sea level, limiting the processes of urban expansion and intervention (Robledo, 1996). The population registered in the 2018 national census is 400,436 people [4]. The study area has 57,184 hectares, of which only 3,819 hectares correspond to its urban area [5]; however, in the present investigation an area of 5,429 hectares is used, considering sectors with influence of transport and public services.

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Currently, the term spatial equity refers to the equality that different residents have, when accessing a certain service regardless of their social class, income, or ethnicity [6] and the measurements mainly include analyzes based on geographic accessibility, the coefficient of Gini, the Lorentz curve method, the coefficient of variation and the Teil index [7].

Regarding accessibility concept, in 1959 Walter Hansen defined it as "the potential of opportunities for interaction" [8], this being the first definition of the term in the geographical context, the potential for opportunities to interact that a certain group of people has in a specific area is then taken as a basis. That definition was complemented with the argument that accessibility is a measure of spatial distribution from a point, adjusted by the ability and desire to overcome spatial separation. The concept has also been defined as the ease of getting to an activity from a site through a particular mode of transport [9] and taken together with mobility as influencing the individual's ability to travel in daily life [10]. Accessibility studies regarding the location and coverage of educational service providers have been carried out in different parts of the world, using various methodologies that assess accessibility to this service.

For example Ireland, using distance measures for their accessibility calculations [11], Canada, taking additional variables from the distance such as parental education and economic factors [12], England, using the distance between the homes of origin and the universities [13], Portugal, analyzing the variables involved in the decisions of study outside the place of origin [14], the Netherlands, analyzing the impact of geographic accessibility to higher education institutions and the influence of school background [15], Germany, including socio-economic variables [16] and Colombia performing analyzes of territorial accessibility to nodes of primary activity [17] and evaluations of the spatial equity of the educational service at the basic level [18].

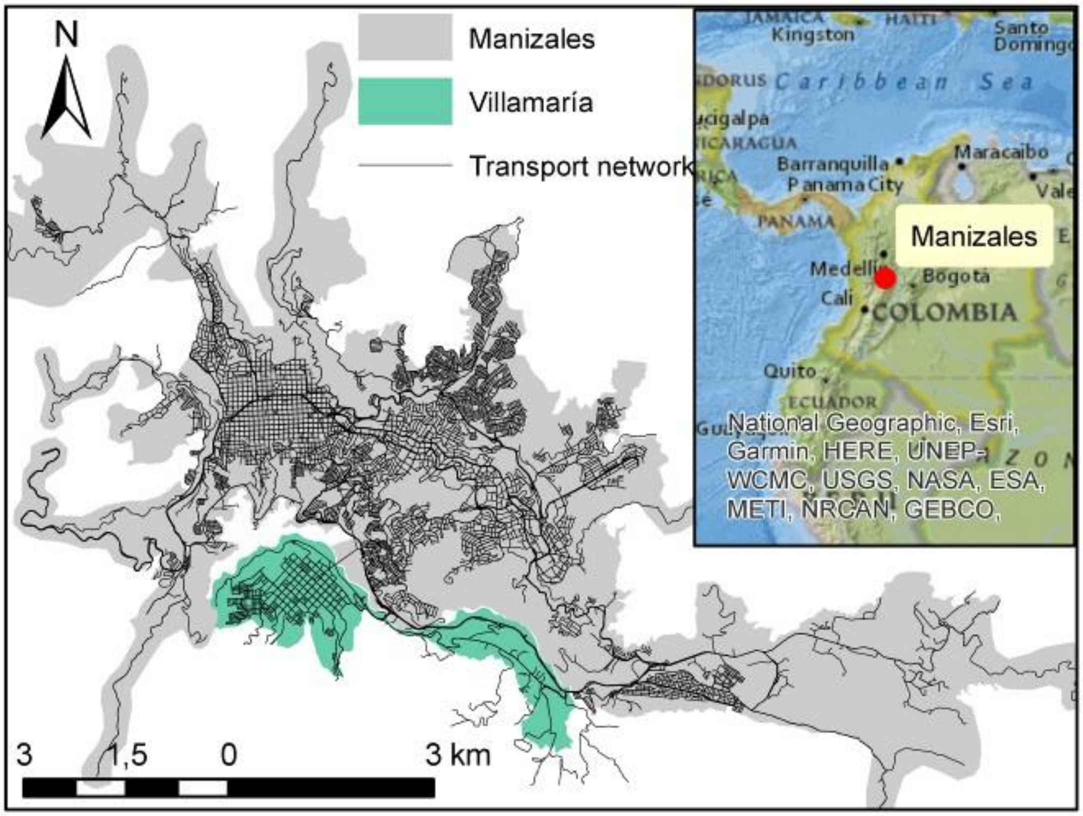

Fig. 1: Geographic location of the researched area.

Studies regarding the location of equipment and coverage in education have focused on establishments with a single educational level, for the vast majority of cases in higher education. Few studies involve measurements of spatial equity, highlighting the evaluation of the disparities of spatial accessibility to primary and secondary schools carried out in China [19], but, in general, they point to other objectives, fulfilled using accessibility measured through distance as an evaluation value. Studies that involve the entire educational service, comprise spatial equity and use travel time as the main variable in accessibility levels are nonexistent so far. That is why this research aims to close the knowledge gap.

The main objective of the research is to propose a methodology for calculating the Educational Equity Index (EEI), based on the analysis of social, economic, demographic, geographic, operational, spatial, and physical variables, using measures of territorial accessibility and geostatistical models, through geographic information systems (GIS). Assuming the existence of a strong inequity in the provision of educational services at all levels (initial, basic, intermediate, and higher) in the study area, given the geospatial configuration of the institutions and transport networks and the present conditions of the variables.

II. METHODOLOGY

A. Updating and validation of the transport infrastructure network and sociodemographic information

The update process was carried out in the ArcMap program, using its network editing tool. The private transport network on which the calculations are based has 10,133 nodes and 12,766 arcs. On the other hand, the public transport network contains 19,838 arches and 15,380 nodes.

The difference between the two networks is that the second one considers the pedestrian routes to reach any access location to the Transit System. As a basic input for the process, it is necessary to have the travel times calculated within the digitized network. These times are obtained considering the length of the links and the calculated average speed. The population involved in the analysis corresponds to people of school age, defined in case of this study as those inhabitants aged less than 30 years, since it considers institutions from the first to the last educational stage.

B. Location of educational facilities

The geographical location of all educational establishments was verified in the field and in the GIS, so that there were no overlaps with other properties, occupied part of the public space or were not in their real address. Having optimized the corresponding database, the institutions were geo-spatially located, in a new layer of polygons within the ArcMap, through the tool to create new Shape-type entities, differentiating them by the educational level.

C. *Calculation of the Educational Equity Index – EEI*

Initially, external nodes to the network must be created, positioned in the location of the equipment to be analyzed, connecting to the closest node of the network through a new arc with travel time equal to zero, so that it only generates connection, without increasing the distance or travel time. Then, we proceed to obtain the vectors of mean travel times in the different analysis conditions, for which it is necessary to incorporate an additional computational tool: the TransCAD software, which specific mathematical processing capacity for transport models is better optimized than ArcMap and does not require a very powerful hardware.

Using the "multiple paths" extension of the TransCAD software, which involves the minimum paths algorithm born in 1959 [20] and allows to obtain the travel times in matrix form between the desired points of the network. In the case of this study, from the generated ones the for the blocks, towards the institutions in a first moment, and then, between all blocks. On the other hand, based on the general gravitational potential model, spatial equity models have been born that integrate different modes of transport [21], considering the aforementioned results and the model developed on them by Hu to assess the spatial equity of the nursing homes in Changchun [7], within which it incorporates the competence factor and the attraction factor of the evaluated equipment.

It is proposed to follow the development line and use a similar equation, calculating the attraction factor based on the series of variables incorporated for educational establishments and the competition factor between blocks using travel times as proximity value.

The Educational Equity Index (EEI) is calculated from (1), which condenses the procedure for obtaining the index, as a relationship between the offer given by the educational establishments within the area of influence (20 minutes of travel time) and the population competition (2) multiplied by the population-weighted average travel time for each mode of transport. According to data from the area of influence of the educational sector, where a time of 20 minutes is an average value related to a walking speed of 4 km/h [18].

$$IE_i = \frac{\sum_{j=1}^{m} M_j * S_j}{V_i * (a_{1i} * p_i * T_{i(pub)})} + \frac{\sum_{j=1}^{m} M_j * S_j}{V_i * (a_{2i} * p_i * T_{i(priv)})} \quad (1)$$

$$V_i = \sum_{k=1}^{n} \frac{P_k}{D_{ik}^{\beta}} \quad (2)$$

Where:

IE_i= Educational equity index of block I; Mj= Student capacity of the educational institution j measured from the registered enrollment; S_j = Attraction factor of each institution, normalized through the min-max normalization, it varies between 0 and 1 taking into account the academic level according to the state tests, the number of educational levels in which it has service, the available area and the monthly value of the education, the last aspect being evaluated inversely, that is, that the higher the cost, the less attractive it generates. Institutions whose travel time exceeds the limit range of 20 minutes automatically have $S_j = 0$, since they are not within the area of direct influence; V_i= Coefficient of competition of the block; a_{1i} and a_{2i}= Percentages of the population of the block that make their study trips in the private and public transport mode respectively, according to the ZAT (Zone of Traffic Analysis) to which belongs, based on the division and travel percentages recorded in the Manizales 2017 Mobility Plan; p_i= School-age population of block i; $T_{i(priv)}$ and $T_{i(pub)}$ are the average travel times to reach the institutions educational through private and public transport mode respectively; P_k is the population less than 30 years old of block k, corresponding to the rest of different blocks ai within a range of 1 minute; D_{ik} is the separation between blocks measured in travel times; β= Coefficient friction, taken as 2 for study trips [9]

The value of V_i is uniform for both modes of transport, since in this section, the spatial proximity is the same regardless of the mode. The calculations of equations 1 and 2 are performed through computational programming in Python, using the "Pandas" and "Numpy" libraries that allow the management of large databases and the performance of mathematical operations in a simple and fast way.

The results are represented graphically in the ArcMap program, using the representation by quantities clustered in groups of colors corresponding to the quantiles that are considered necessary. Additionally, the minimum, maximum, mean, and standard deviation values of the public and private components are obtained separately, in addition to the values for the result, so that a comparison of the index is possible.

Finally, the Moran spatial autocorrelation index is calculated, which assesses how a phenomenon varies through geographic space, having that, if the analyzed aspect tends to cluster in uniform areas, forming conglomerates, then there is a positive autocorrelation. On the contrary, if the measures of the variable in nearby units are different, that is, if the phenomenon tends to be dispersed, then the spatial autocorrelation is negative, and when the phenomenon behaves randomly and no defined or structured behavior is identified, there is no spatial autocorrelation.

Using again the ArcMAp software, the Moran index is calculated with the results per block of the IE, using the tool "Spatial Autocorrelation (Morans I)". Having as inputs the layer and field corresponding to the calculated value of EEI in its two components and in a grouped way, with an inverse square distance spatial relationship and using Euclidean distance of 200 meters to designate neighboring entities. This tool gives the results of the Moran index, the z-value and the p-value. Additionally, the program generates a report where it presents the results together with a graph and a basic analysis.

III. RESULTS AND DISCUSSION

The resulting value is made up of two parts; a first, corresponding to the section studied in transit (Public transport) and the other in private transport, the sum of both making up the final value. Taking this into account, the results are presented in three different ways: for each part and in aggregate form, displayed in 10 quantiles, for each case. Polygons corresponding to blocks with indexes of zero are not shown on the maps, making the presentation cleaner.

Figure 2 presents the results of the EEI for transit (Public transport), presenting a somewhat heterogeneous distribution on the map, but despite this, a concentration of the upper quartiles is noted along the main roads and in the center of the city, accompanied by some average values next to the current stations of the aerial cableway.

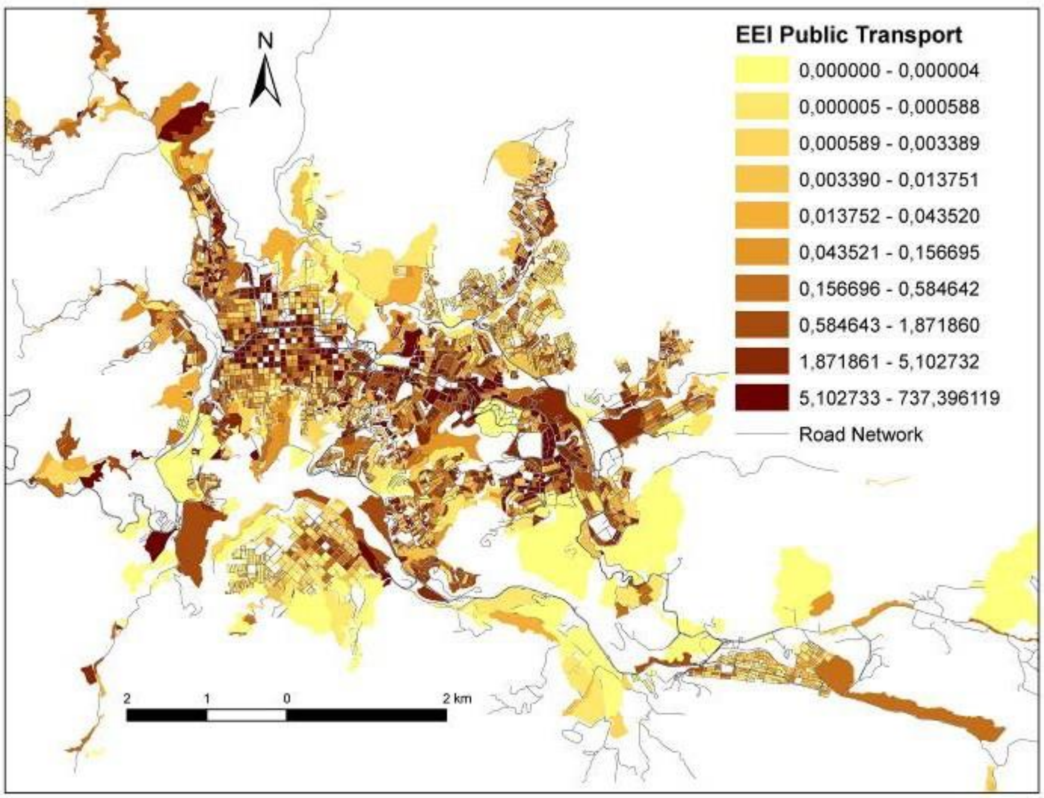

Fig. 2: Index of Educational Equity in transit (public transport).

The values in this section reach a limit of 737.39, with a mean of 2.14 and standard deviation of 15, which indicates a very high concentration of very low values, less than 1, with other singular points at high values. The mean value for stratum one is 0.94, for stratum two 0.80, three 3.72, four 3.99, five 4.24 and six 5.03, noting a clear inequality for the lower strata.

The Moran index calculated in ArcMap gave as a result 0.055, with a z score of 7.31 and p value = 0.00, indicating that the probability that the values are randomly distributed is very small, and since Moran's I. is greater than 0, tends to generate clusters, however, being such a low value, it is considered a more random distribution than an aggregate one.

In the case of private transport, the results are shown in Figure 3, with a maximum value of 3,162.21, a mean of 26.30 and a standard deviation of 116.46, indicating a low grouping of the values. The levels of spatial equity are much higher than in transit (public transport), due to the ease with which this mode of transport can access institutions within the time limit. Concentration differences are noted with respect to the transit (public transport) map, reducing the strongest tones in the central point, near the Cable sector, while high values increase in the peripheries of the city, especially in the eastern zone.

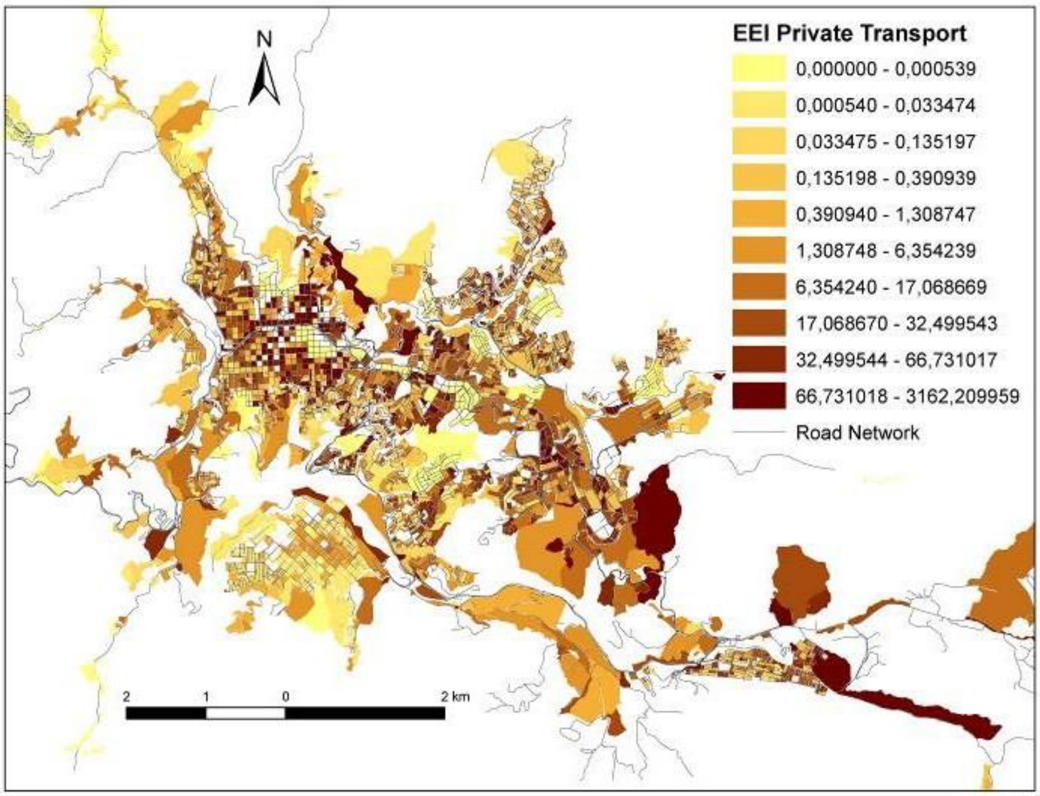

Fig. 3: Index of Educational Equity in private transport.

The mean values per stratum from one to six result in a mean of 21.09, 18.72, 40.03, 42.00, 24.98 and 45.69, respectively, again indicating better conditions for the high strata versus the low strata. The Moran Index is 0.124, a little higher than in private transport, a z score of 13.88 and a p value of 0.00, which also represents a distribution with a tendency to generate clusters, but very close to random.

Analyzing both modes of transport together, the maximum values are segregated in the area without a defined concentration (Figure 4), apparently in sectors with a low population of student age such as the historic center, where equity values are increased because there is the same supply for few applicants, while blocks with a high concentration of young people have low values due to high competition. A general look, when comparing the results between public and private transport, allows us to identify that the greatest differences exist in the eastern sector of the city, precisely in the sectors where there is a greater number of people in a high socioeconomic stratum.

Sectors located near the main universities such as the Universidad Nacional de Colombia or the Universidad Autónoma, also stand out with moderately high values. The average results per stratum are: for stratum 1 = 22.03; stratum 2 = 19.53; stratum 3 = 43.75; stratum 4 = 46.00; stratum 5 = 29.22 and stratum 6 = 50.73, indicating how the highest stratum tends to obtain better results while the two lowest remain with the lower values.

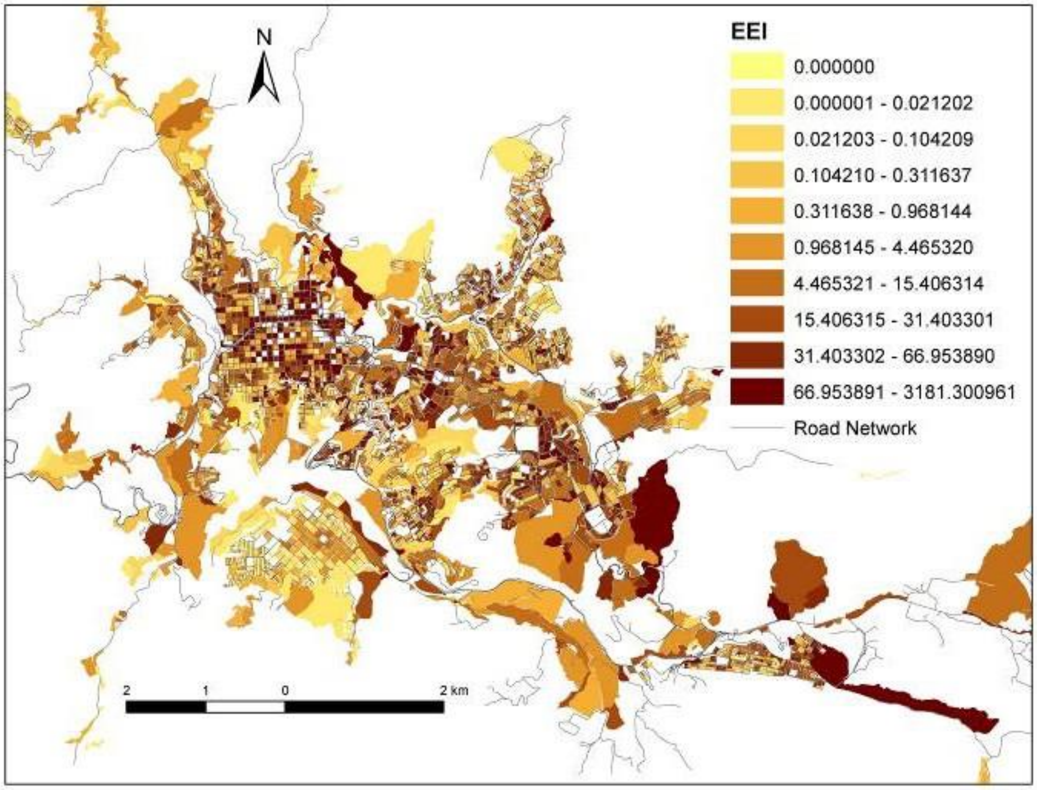

Fig. 4: General Educational Equity Index.

It is necessary to highlight that it is possible to have a model of social inequity more complex, which includes variables such as housing, nutrition level, clothing, among others. On the other hand, the methodology could be applied in different fields, such as health, tourist, administrative facilities, commercial areas, etc.

IV. CONCLUSIONS

The proposed model to measure educational spatial equity manages to evaluate the coverage characteristics for each block individually, considering the institutions covered in each time, the studying age population itself and the neighborhood, also recognizing the modal distribution that has been part of the study in its analysis. Being a replicable methodology in any city if the base information is properly ordered.

The results of the index have a low impact of small institutions such as kindergartens where a single educational level is taught to few students with a minimal area compared to large university campus, showing that despite having good levels of integral mean accessibility towards initial or basic education institutions, the general levels are not very good.

The spatial equity values do not show a sectorized concentration of values, nor a homogeneous distribution on the map, so that there is a distribution with a very random trend of the result; influenced by the density of the student population and the mode of travel of their preference, where strata one and two represent the lowest average values of the index, pointing out shortcomings in the access of this service due to having high concentrations of student population in small areas which the main mode of transport corresponds to collective public transport, that has shown to be in unequal conditions compared to the private one in terms of the number of opportunities achieved in a given time.

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