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Accessibility analysis to Private Schools by Private vehicle and transit in Manizales (Colombia), It is fair?

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Abstract

In the present investigation, the coverage indexes for Manizales in the field of school education through public and private transport are evaluated, through the application of geographic accessibility analysis and the use of geostatistical models for the graphic representation of results and the spatial correlation with the socioeconomic information of the municipality. The main results show good service coverage in less than five minutes for both means of transport.

Keywords: Accessibility, Colombia, coverage, education, public transport.

I. INTRODUCTION

The city of Manizales, capital of the department of Caldas, in the central-western zone of Colombia, within the South American continent, is part of the golden triangle of Colombia (Fig. 1). The municipality is located on the Andes mountain range in its central ramification, at a height of 2150 masl and it has 572 km^2 of area, it presents a steep topography with strong elevations that generate numerous difficulties and limitations in the urbanization process [1]. According to the National Administrative Department of Statistics (DANE), Manizales has a projected population for 2020 of 402,998 inhabitants, where 52.3% are women and the remaining 47.7% correspond to men. In addition, 28% are citizens under the age of 20 [2,3].

The neighboring municipality of Villamaría will be included in the study due to its proximity and high degree of social and economic relationship with Manizales, making it broadly an additional neighborhood of the capital. Regarding the Manizales and Villamaría educational institutions, they have 190 facilities that provide the service from preschool to medium level in their urban area, in this distribution there are 85 private institutions, which are the focus of this research and are currently distributed in its different neighborhoods and socioeconomic strata. (Fig. 2). In recent years, the Mayor's Office of Manizales has promoted road infrastructure projects through the Manizales Valorization Institute (INVAMA) and the National Highway Institute (INVIAS) that seek to improve the city's mobility conditions, reducing vehicle congestion and improving the travel times of citizens, both urban and municipal. These projects are framed in following the purpose of the national government to consolidate transport infrastructure seeking to benefit the growth of the economy and the quality of life of the inhabitants [4].

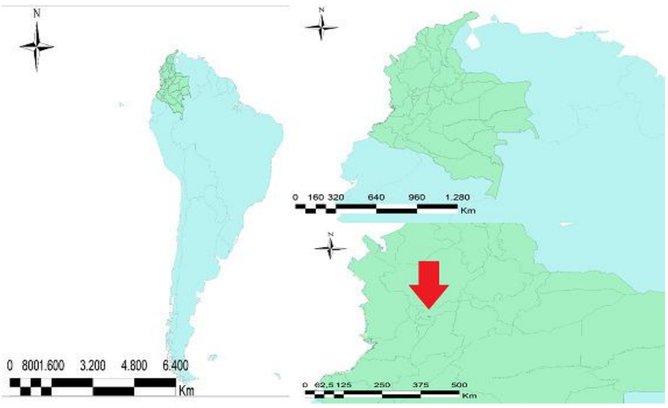

Fig. 1. Geographic location of Manizales. Source: self-made

In the literature related to accessibility, Hansen defines the term as the potential for opportunities for interaction [5] and later, various authors continue using and complementing it as in the case of Geurs, who proposes classifications of different types of accessibility and considers this as a measure of infrastructure [6], additionally, accessibility calculations can have different perspectives and make use of various factors to enrich the analysis, such as: mode of transportation, purpose of travel, age, gender, socioeconomic groups, among many others. [7, 8]. Researchers have used accessibility measures for decades to analyze various topics such as: urban development planning and land uses [9,10], public transport [11], equity and social exclusion in transport [12], sustainable transport [13], coverage of health systems [14], economic development [15], social cohesion [16], provision and location of services [17], road redirections [18], transportation planning [19], connectivity analysis [20], among many other studies.

Seeing how accessibility has been used for various types of studies, we will use it in this case to obtain discretized results of travel times in means of public and private transport, with which we can expose the degrees of affectation that the different strata are suffering when accessing institutions; additionally, thanks to geostatistical models it is possible to clearly see where the highest travel times are emerging.

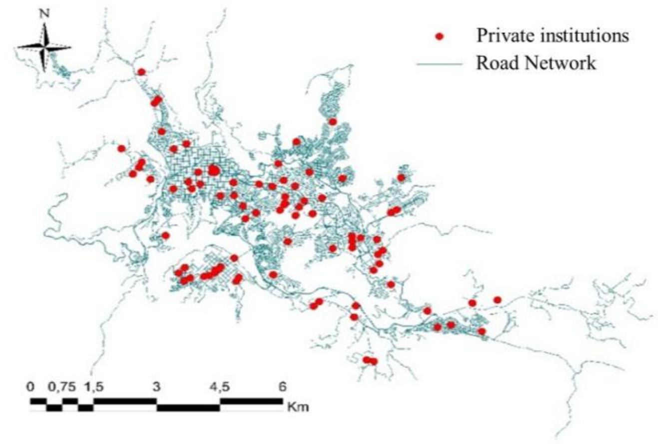

Fig. 2. Location of private institutions in Manizales. Source: self-made

II. METHODOLOGY

The methodology to establish the route of our research (Fig. 3) is made up of four stages and the opening of data as broken down below:

II.I Input Data

As input data, the following are configured: i) georeferenced transport infrastructure network loaded with operational data [8]; and ii) a neighborhood division data layer loaded with official sociodemographic data. From a previous study carried out by Escobar and García [21] called "Diagnosis of Urban Mobility in Manizales", it was possible to obtain the geo-referenced road network with data such as the average slope and average speed in the arches; likewise, the neighborhood division layer of the city, which in addition to the sociodemographic data, was complemented with the socio-economic stratum data, this being a measure of the social and economic conditions that each neighborhood possesses [8].

II.II Georeferencing

In this stage, we proceed to geo-reference the private institutions of Manizales, and we make the spatial location of the network, updating it with the works carried out in recent years and changes of direction in the streets. Fig. 4 shows the division by typology in the network and its percentage corresponding to the total kilometers.

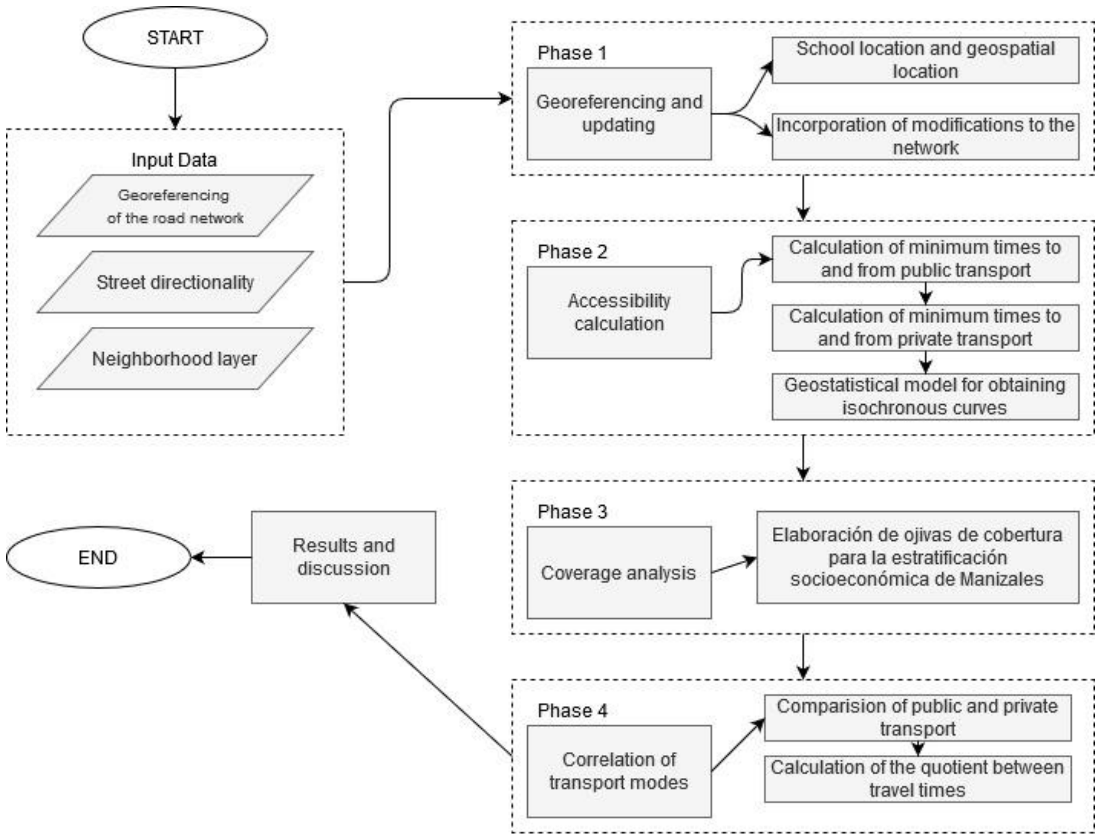

Fig. 3. Research methodology. Source: self-made

II.III Accessibility Calculation

We proceed to calculate in the Transcad software, the minimum travel times to private educational institutions and return from schools to the rest of the nodes in our network, this calculation will be based on the algorithm of minimum paths [22], which uses Transcad internally to determine the route with the shortest travel time from one point to another. When obtaining the minimum times, the trip time matrix is constructed, which relates the geographical coordinates with the times found for all the nodes. Subsequently, the matrix is processed by ArcMap, using the Geostatical Analyst extension, in which the ordinary Kriging method is immersed with a linear semivariogram as a projection model [23]. This projection method considers the spatial dependence between points of the same sample. [12,24] (1):

$$\overline{\gamma_{(h)}} = \frac{\sum (Z_{(x+h)} - Z_{(x)})^2}{2n} \quad (1)$$

Where = value of the variable at the x, y coordinate node; = next sample value at a distance h; n = number of pairs that are spaced by distance [13].

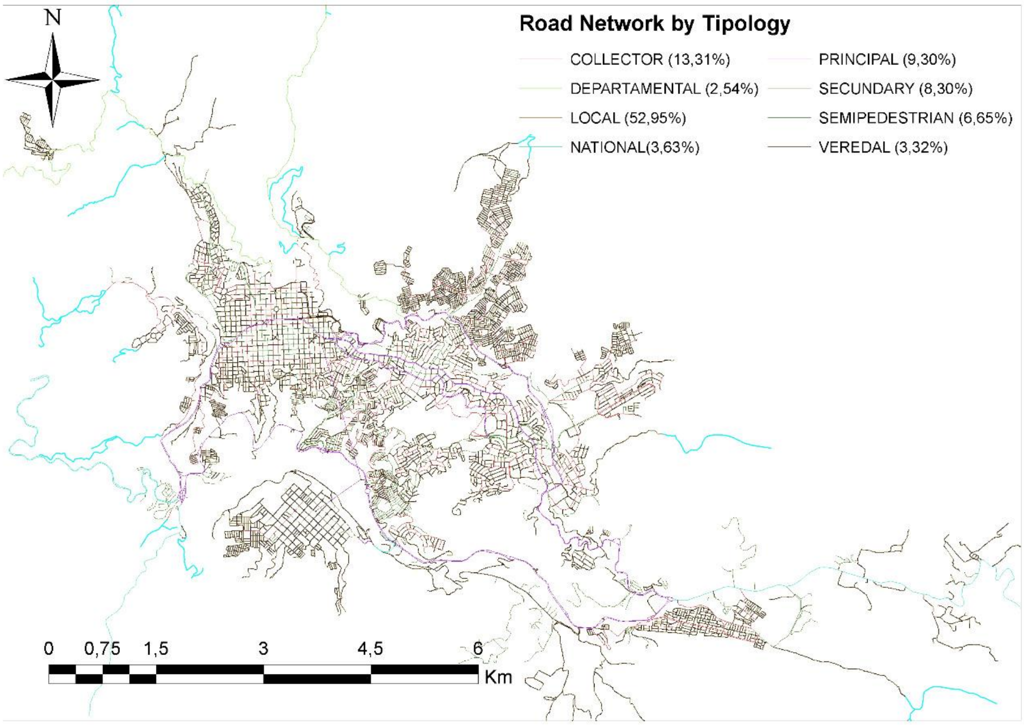

Fig. 4. Road network. Source: self-made

II.IV Coverage Analysis

With the data obtained from Kriging, the isochronous curves are overlapped with the neighborhood layer using the ArcMap intersect tool, thus having the population and socioeconomic information for each strip of travel times. Then we work them in Microsoft Excel, obtaining the ogives percentages for each of the socioeconomic strata.

II.V Correlation of Modes of Transport

It is carried out within the ArcGis program, the information union of the nodes corresponding to travel times in public and private transport. Later the quotient of these times is found by dividing the public travel times over the times obtained for private transport; this quotient is plotted, and new isochronous curves are obtained using the ordinary Kriging method through to the Geostatistical Analyst tool.

III. RESULTS AND DISCUSSION

III.I. Integral Accessibility in Public Transport

III.I.I. Towards private institutions.

As a result of the analysis, the isochronous curve map (Fig. 5) is obtained, representing the travel times to private institutions by means of public transport. It can be seen how the curves start from five minutes and present a greater increase towards the north-western areas reaching critical travel times of 90 minutes to access institutions, which represents the difficulty that this sector faces in the provision of private educational services. On the other hand, the southeastern area presents travel times to the closest institution around 60 minutes, the strip with travel times of 5 minutes in the central area extends in a high percentage of the territory and presents the strip with the best accessibility coverage given that it is possible to access the service in less than five minutes due to the large number of institutions found in this area.

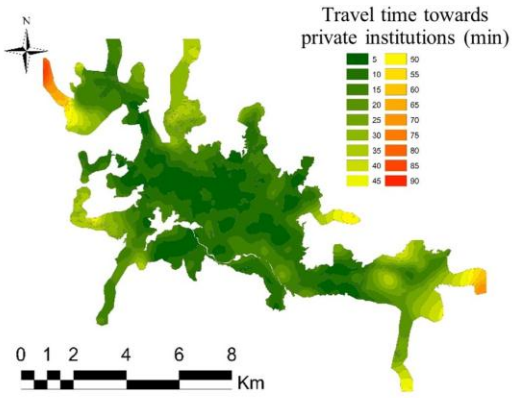

Fig. 5. Integral accessibility to institutions through public transport Source: Self-made

Then, the coverage ogives are presented according to the socioeconomic strata (Fig. 6), relating the amount of population covered by the isochronous curves for public transport to the private school.

By means of this graph we can observe that the accessibility conditions are different for each stratum, since strata 5 and 6 are covered in 90% within the curves for up to 10 minutes, while stratum 1 has complete coverage in times travel greater than 25 minutes.

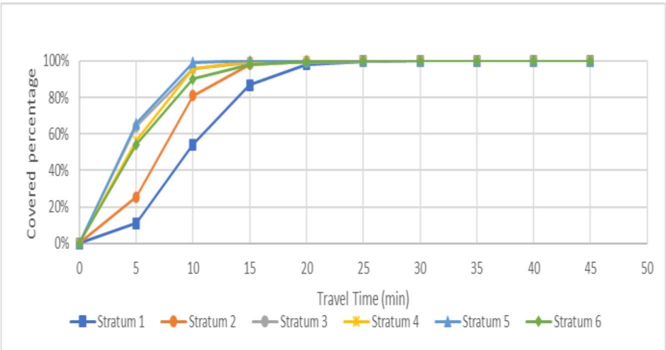

Fig. 6. Ogives of population coverage in public transport to private institution according to stratum. Source: self-made

III.I. II. From private institutions.

The isochronous curves are obtained as a result (Fig. 7) representing the travel times from private institutions through public transport. The behavior is very similar to that shown in the analysis to the institutions, observing travel times of more than 50 minutes for zones in the east of the city and critical zones with travel times of 90 minutes in the north-western part but in this case, the curves of low times such as 5 and 10 minutes show an increase in their area due to the presence of the bus stops in locations close to schools.

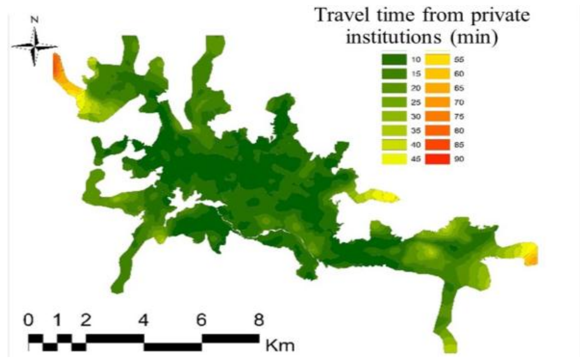

Fig. 7. Integral accessibility from institutions through public transport Source: Self-made.

Once again, the central area stands out with travel times within five minutes, reflecting the benefits for the inhabitants of the sector with respect to the coverage of private educational institutions by means of the current public transport.

Then, the relationship of the strata with the incidences of the isochronous curves from private institutions in public transport are presented (Fig. 8).

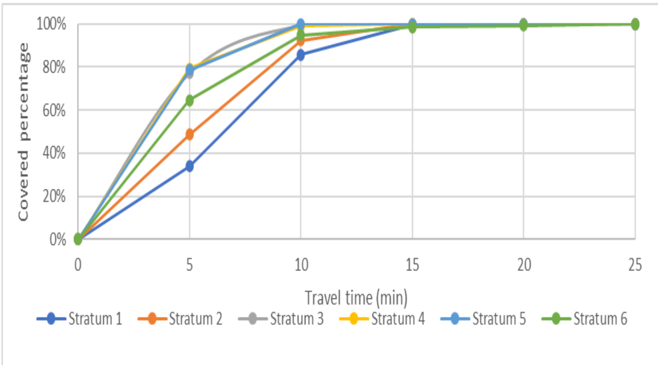

Fig. 8. Ogives of population coverage in public transport from private institution according to stratum. Source: self-made.

It is observed that strata 3,4 and 5 have a 100% coverage from travel times of up to 10 minutes and the other strata from travel times of 15 minutes, thus representing a fairly homogeneous coverage. When comparing the ogives with those found for the analysis towards the institutions, it is observed how the percentages increase almost 20% for all the strata from the curve corresponding to times between the first five minutes, also obtaining a coverage close to the total in shorter times.

III.II. Integral Accessibility in Private Transport

III.II.I. Towards private institutions

In the results map (Fig. 9), the isochronous curves are shown representing the travel times to the private institutions through private transport. Different modifications can be visualized that are undergoing the curves towards the ends of the city, being Northwest and Southeast areas the critical points with a travel time of more than 35 minutes. It can be seen how the times of this analysis are much shorter than those recorded for public transport, in which the curves reach up to 90 minutes. Also, a strip can be observed throughout the entire southern area, on the border with the municipality of Villamaría, mainly due to the lack of equipment. It can be seen then that a very high percentage of the city has access to private educational institutions in less than 10 minutes, commuting in private transport.

The percentage ogives of socioeconomic coverage for private transport to private institutions are presented (Fig. 10), which denote that for travel times of 5 minutes, stratum 5 has the best coverage over the other strata with 92% while the Stratum 1 is the one that has the greatest difficulty in coverage, as it only presents coverage of 49%, for travel times of 10 and in longer times, all strata will be fully covered.

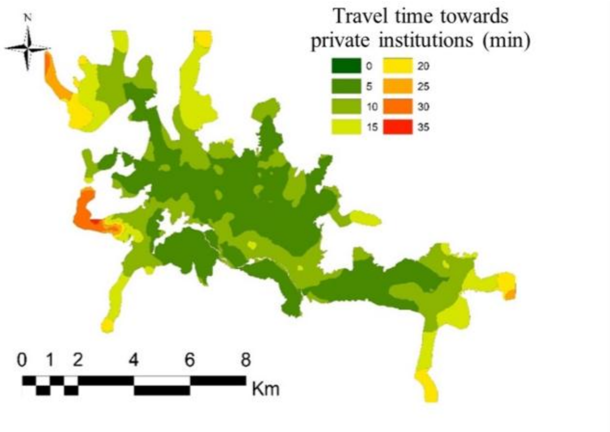

Fig.9. Integral accessibility to institutions through private transport. Source: Self-made.

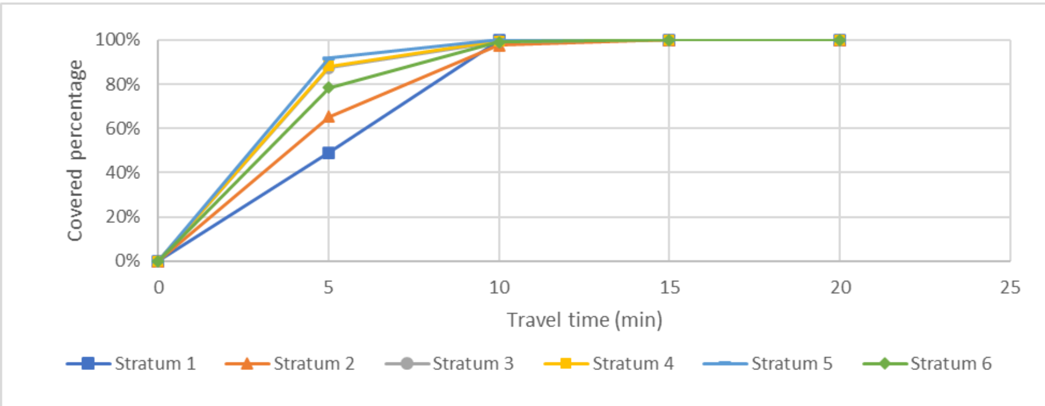

Fig. 10. Ogives of population coverage in private transport to private institution, by stratum. Source: self-made.

III.II.II. From private institutions

As a result of the analysis, we have the isochronous curves shown in Fig. 11, which presents the travel times from private institutions by means of private transport to the different sectors of the city. It is observed that the situation has a high degree of similarity with the presented to the institutions, with a maximum travel time of 35 minutes and homogeneous sectors. There is a greater symmetry in the relationship to and from in this analysis since the connections through the private transport infrastructure network are not influenced by waiting times or whereabouts, therefore the journey in both directions requires very similar times.

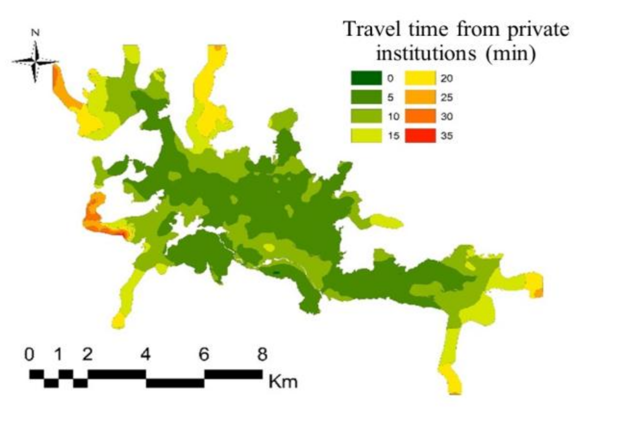

Fig. 11. Integral accessibility from institutions by private transport. Source: Self-made.

The relationship of the strata with the coverage provided by the isochronous curves of travel time from private institutions in private transport is presented in Fig. 12, the incidence of Figure 10 is repeated, where stratum 5 is the one with the highest percentage of coverage for travel times of up to 5 minutes, and for travel times of 10 minutes all strata are covered in a minimum of 98%.

III.III. RELATIONSHIP PUBLIC TRANSPORT VS PRIVATE TRANSPORT

The results of relating travel times on public and private transport are presented below, showing the areas with the shortest travel time to the closest institution through one mode or the other (public or private). The areas which result of the relationship is less than one, represent areas in which the private vehicle has shorter times than the public when it comes to connecting with private educational facilities. On the other hand, areas with values greater than one, present the areas in which is more favorable the use of public transport when connecting with institutions. Finally, the areas marked with a relation to one, show that it takes the same amount of time to go to the nearest school by private or public transport.

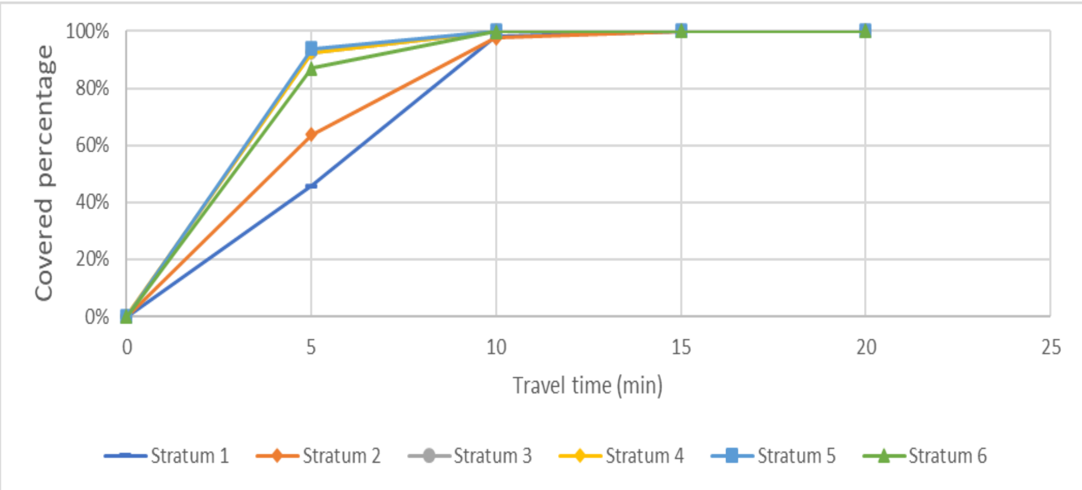

Fig. 12. Ogives of population coverage in private transport from private institution, by stratum. Source: self-made

The map with the relations of travel time to private institutions is observed (Fig. 13), in which it is possible to see how Manizales in most of its extension presents preferential travel times for the private mode of transport.

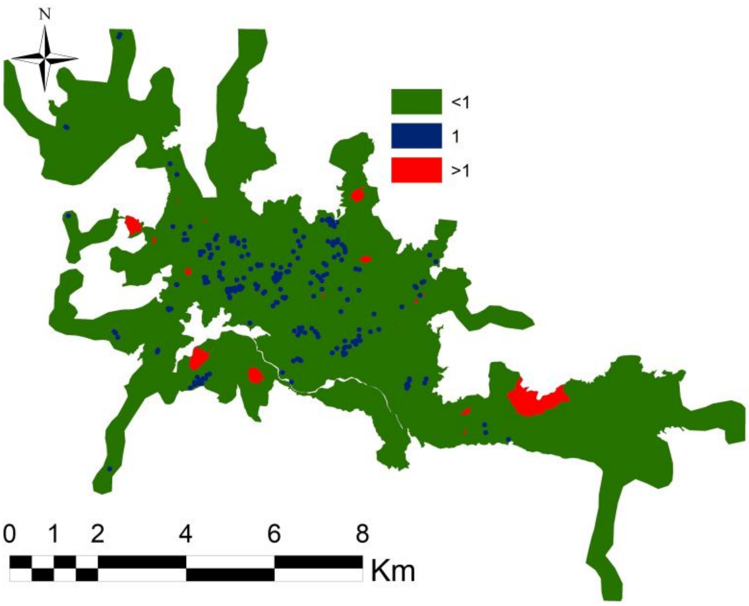

Fig. 13. Relationship of modes of transport to private institutions. Source: self-made

Despite this, there are also scattered points on the map in which travel times by private and public transport are homogeneous. On the other hand, in a smaller percentage, there are areas in red for which private transport has longer travel times than the public. It is worth noting at this point that the analysis for travel by public transport involves walking speed without direction restrictions for those arches of the road network that do not have the presence of collective public transport.

As a complement to Fig. 13, the population coverage for each stratum through Table 1 and coverage by area and stratum in Table 2 are presented. There, it is possible to appreciate how in strata 2 and 3 it is found in a greater proportion the population covered by areas with a ratio greater than one, even though the highest percentage of area corresponds to the lowest socioeconomic stratum.

Table 1. List of transport modes to private institutions by strata and covered population. Source: self-made

COVERAGE BY POPULATION				
Stratum	**<1**	**1**	**>1**	**Total**
1	45529,168	2396,686	420,058	**48345,912**
2	80118,529	13662,955	3579,495	**97360,980**
3	161756,142	18790,591	4050,443	**184597,177**
4	47066,055	5344,763	118,634	**52529,453**
5	13911,351	1520,148	0,000	**15431,500**
6	21007,140	3490,306	530,160	**25027,607**
Total	**369388,387**	**45205,453**	**8698,791**	**423292,631**

Table 2. List of means of transport to private institutions by strata and covered area. Source: self-made

AREA COVERED				
Stratum	**<1**	**1**	**>1**	**Total**
1	6,796	0,078	0,502	**7,377**
2	5,624	0,361	0,213	**6,198**
3	11,086	0,703	0,273	**12,062**
4	5,615	0,291	0,009	**5,916**
5	1,613	0,105	0,003	**1,723**
6	4,614	0,252	0,128	**4,995**
Total	**35,350**	**1,793**	**1,130**	**38,274**

In the results map for the relationship of travel times from private educational institutions (Fig. 14), the analysis is presented with the same significant values previously performed for the times to schools. In this case, a prevalence of private transport but more points with values of one appear to a large extent, representing a homogeneity between the two modes analyzed. On the other hand, the areas with the best travel times in public transport are reduced to four spots on the map.

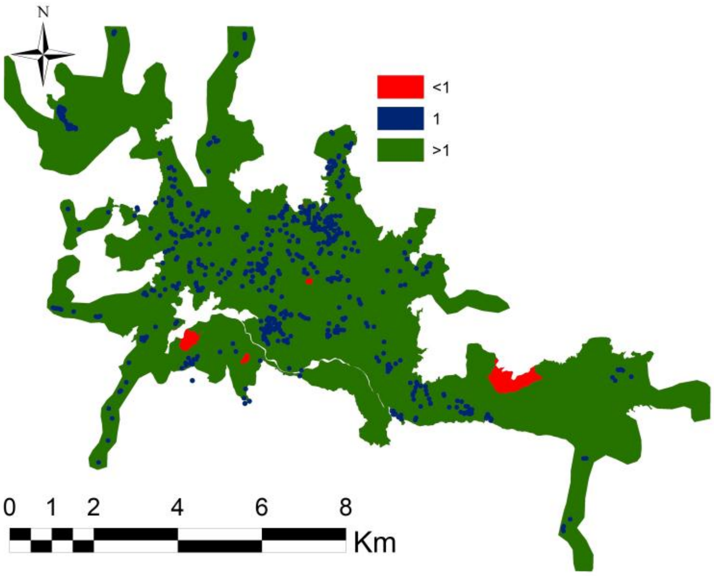

Fig 14. Relationship of modes of transport from private institutions. Source: self-made.

Table 3 shows how the inhabitants of each social stratum are distributed in the area for which the ratio is greater than one, with a total coverage of 3707 inhabitants. Additionally, Table 4 shows the coverage by discriminated area in socioeconomic strata, highlighting that less than a square kilometer in total has better conditions in public than private transport in the case of trips from institutions.

Table 3. List of means of transport from private institutions by covered population. Source: self-made.

COVERAGE BY POPULATION				
Stratum	**<1**	**1**	**>1**	**Total**
1	40185,146	8045,675	123,013	**48353,836**
2	62017,731	33443,716	1911,801	**97373,248**
3	146309,159	36919,388	1370,586	**184599,133**
4	41543,780	10969,100	16,572	**52529,453**
5	12560,713	2870,786	0,000	**15431,500**
6	20564,243	4177,532	285,831	**25027,607**
Total	**323180,774**	**96426,199**	**3707,804**	**423314,778**

Table 4. List of means of transport from private institutions by covered area. Source: self-made

AREA COVERED				
Stratum	**<1**	**1**	**>1**	**Total**
1	6,665	0,285	0,426	**7,377**
2	5,018	1,156	0,024	**6,199**
3	10,254	1,634	0,174	**12,063**
4	5,303	0,611	0,001	**5,916**
5	1,520	0,192	0,011	**1,723**
6	4,583	0,344	0,067	**4,995**
Total	**33,345**	**4,224**	**0,705**	**38,275**

IV. CONCLUSION

The precarious coverage that the neighborhoods receive to the north-west and south-west of Manizales, require an intervention by the administration, to provide an improvement in the travel times calculated in this investigation, and thus reduce the trauma that is being suffered at the time of having to travel to and from the different private educational institutions.

Socioeconomic stratification is evident when accessing a comfortable travel time, given that most short travel times occur in stratum 5 and 6 neighborhoods, while neighborhoods 1 and 2 represent areas with higher incidences of high travel time.

The significant difference between travel times when preferring the private mean of transport in the city of Manizales, shows how the Manizales still lacks an optimal public transport system that generates coverage to the most remote areas of the city.

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