Road Redirection Analysis. Case Study:

Araucarias Avenue, Manizales, Colombia

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Abstract

The purpose of this article is to study the road infrastructure of Manizales, Caldas, which presents a complex network of connections. It analyses road mobility in terms of geographical accessibility in the Araucarias Avenue, based on the study of the variations in times of travel between the place to be analyzed and the general context in the city by choosing specific points to evaluate the routes, taking into account aspects of territorial use, routes and dynamics linked to schedules and the direct relationship between accessibility and connectivity. The article exposes the results obtained in the investigation of the Avenue, presenting them as conclusions, differentiating between the methodology of analysis, the results and 3 scenarios with different road management conditions that impact the approach of the solutions to the problems.

Keywords: accessibility, mobility, coverage, road direction
1 Introduction

Araucarias Avenue is part of the road network of the municipality of Manizales, located in the Department of Caldas, in the Central-Western region of Colombia at 2150 a.m.s.l., with an average temperature of 16.7°C. The development of the region in an urban perimeter of 59.68 km² has led to a remarkable growth in the different mobility dynamics, taking into account that Manizales has been one of the most populated cities in the country, having an average density of 6,222 inhabitants/km², totalling 371,345 inhabitants [3]. The city of Manizales has presented notorious growth in population and projects itself as a tourist destination. This is significant for the development of the country, for it generates a great increase in the dynamics of mobility, conditions the systems of infrastructure development [4], and optimizes the condition of the city's route, avoiding traumas with respect to time [5,6]. An accessibility analysis [1,10] in the road network of a city was carried out, mainly for reasons regarding learning and knowledge, as it is a key element for the improvement of mobility which will have a positive impact on the people's quality of life [8,12]. In this article, a structured process is elaborated to define an optimal road directioning through different alternatives that generate a better mobility in the city, specifically in the Araucarias Avenue. The Araucarias Avenue is an important connector between Paralela Avenue and Santander Avenue, where mainly local flower shops are located due to the proximity to the San Esteban Cemetery.

A systematized analysis model is proposed, starting from the study of the accessibility of the area, taking into account the direction in both ways of the avenue. The accessibility term, derived from different indicators fitted to the geometrical fields, is defined as follows: smaller or greater disposition of a place to be reached through other places [15]. Based on the results of the first approach to the object of study, a simulation methodology was developed, that proposed changes to the direction of the road. First, the Avenue was postulated in a one-way direction and, after this approach, two alternatives were derived: a South-North redirection that would generate the direct connection with Santander Avenue or the North-South direction that would connect with Paralela Avenue. The proposal is delimited by the size in the coverage area, which has quick access to the avenue regarding the weather conditions, that is, the route with the shortest time. To achieve results in the development of the city, it is pertinent to encourage the development of this type of studies from the different disciplines to which they are related. It is necessary to know the points of proximity from one place to another and the ease of connection through the use of geographic information systems [9,11,18] that would conclude in the analysis of the impact of the presented alternatives as a solution to the deficiencies in the dynamics of mobility.

The results gathered, immersed in the dynamics of mobility and connection of road networks in the city of Manizales and compared with the Araucarias Avenue, are important. The relationship between the investigation’s argument and the use of
geographic information system tools is clear and its importance for building the improvement of the city plays a very significant role.

2 Methodology

The research process was developed in 4 stages: a) Assembly of the transport network of Manizales in a geographic information system (GIS); b) Georeference of the Araucarias Avenue; c) Calculation of the integral average accessibility offered by the network in the 3 possible scenarios; and d) Calculation of the population percentages covered by the isochronous curves obtained from the analysis.

2.1 Network Determination

The infrastructure network of Manizales used for this study is composed of road segments (more than 10,000 arcs and more than 8,000 nodes), a fundamental basis for the designation of analysis criteria. First, an analysis of the entire network was carried out in the 3 scenarios and then an area close to the avenue, comprised of 93 nodes and 154 arcs, was considered to perform a more precise analysis of the areas close to the avenue.

2.2 Georeferencing of Araucarias Avenue

The 24, 24a and 24b roads cross through the Araucarias Avenue (45th street between 23rd and 25th roads). The latter is a very significant secondary route to make the connection between two major avenues of Manizales, Santander Avenue and Paralela Avenue, because it enables the possibility to change avenues regardless of the direction in which the person is traveling and of the destination.

2.3 Accessibility calculation

This study analyzes the accessibility of the Araucarias Avenue from different sectors of the city according to the characteristics of the network through the use of a GIS. Accessibility is calculated from the vector of the mean travel time (Tvi) between a specific node (i) and the rest of the nodes that make up the network studied. The Araucarias Avenue is favored compared to other streets since it is located in the central zone of the network because the travel times to the other nodes is less than if it were in the perimeter zone. To perform the calculation, a GIS algorithm was used to estimate the smallest distance between a specific group of nodes and the others of the network, forming a distance matrix. With the distance matrix and knowing the average speed of operation of the arcs (ESCOBAR & GARCIA, 2010), the matrix of minimum mean travel times was calculated and later the vector of mean travel time (Tvi) by means of equation 1, where: n = Number of nodes in the network, m = (n - 1), Tvi = minimum mean travel time between node i and the other nodes. With the vector of average time of travel (n x 1) that was
obtained, the relationship with the geographic coordinates (longitude and latitude) of each one of the nodes was established thus generating a matrix of order \((n \times 3)\), for the development of the isochronous curves of average travel time for the study area, by applying a geostatistical model that allows the analysis of comprehensive accessibility.

\[
\bar{T}_{vi} = \frac{\sum_{j=1}^{m} t_{vij}}{n-1} \quad i = 1,2,3, \ldots, n; j = 1,2,3, \ldots, m
\] (1)

For the prediction of average travel times, the Ordinary Kriging geostatistical model was used [2, 16, 17]. This model allows statistical relationships between the measured points, that is, this method also provides measures of certainty or accuracy of predictions. The general formula for this interpolation is a weighted sum as shown by formula 2, where: \(Z(S_0)\) = The value of the i-th location, \(\lambda_i\) = An unknown weight for the value of the i-th location, \(S_0\) = The location of the prediction, \(N\) = The number of measured values.

\[
Z_0 = \lambda_1 Z_1 + \lambda_2 Z_2 + \lambda_3 Z_3 + \lambda_4 Z_4 + \ldots + \lambda_n Z_n = \sum_{i=1}^{n} \lambda_i Z_i
\] (2)

As can be seen in the formula, this model not only takes into account the distance to the predicted location as the other models, but is also based on the weights between the measured points and the location of the prediction. The accessibility analysis was carried out for 3 situations, the current one and another 2 scenarios (North-South and South-North) of road redirection proposals, which will be analyzed according to the average time of travel and the percentage of coverage they have.

### 2.4 Percentage of coverage calculation

With the results obtained in the different scenarios, the percentage of coverage that each one has was calculated, and a relation was established between the isochronous curves and other graphs that make a correct comparison and propose which would be the best road alternative for the Araucarias Avenue.

### 3 Results and discussion

For a clear presentation of the connectivity of Araucarias Avenue and the city, the relationship between the average travel time and the coverage area will be shown graphically, by means of isochronous curves and bar diagrams. An organized analysis of accessibility on the avenue related to the entire urban area of Manizales will also be presented. This area was defined by a perimeter that demarcated the network so that the calculations were not made in places where there were no nets. This will allow establishing which places have greater accessibility and which do not have a good coverage, and then it will show how the direction of the road affects the area where the avenue is located. This will be done for the 3 different scenarios.
3.1 Global average accessibility in its current situation, year 2017

Because the accessibility was calculated for the 3 scenarios and it gave very similar results, only the current scenario is shown. Each one is analyzed later in an area near the avenue. Figure 1 shows that the Araucarias Avenue is located at the center of the network, which gives a shorter time to a node that was on the perimeter. There is more coverage to the north and less to the south, as in the case of Villamaria and Enea, which have the highest average travel times. This is due not only to the distance between these places and the Araucarias Avenue, but also to the short number of possible routes to get from one place to another.

![Figure 1: Global average accessibility for Manizales in the current situation. Source: Authors.](image)

Figure 2 shows the model of the avenue with orientation of mobility in both directions, which generates the connection with Paralela Avenue and Santander Avenue. It is observed that it has the sectors with greater travel times to the north and also to the side, similar to the other two alternatives. It should be noted that the 43rd street is at a close distance and has a higher average travel times than other more distant routes. Shorter times are obtained from Santander Avenue (North) than to Paralela Avenue.

3.2 Accessibility of Araucarias Avenue, Model direction South–North

Figure 3 shows the model of the avenue with mobility orientation in the South-North direction, which generates the connection with Santander Avenue. It shows that it has the sectors with greater travel times to the north and to the south as well, but covering a larger area than the current situation and the other alternative analyzed. Smaller times are obtained from Santander Avenue (North) than from Paralela Avenue (South).
Figure 2: Approach in the area under study, Araucarias Avenue. Source: Authors.

Figure 3: Redirection accessibility in south-north direction Source: Authors

3.3 Global average accessibility gradient

Figure 4 shows the model of the avenue with mobility orientation in North-South direction, which generates the connection with the Paralela Avenue. It is shown that the sectors with longer travel times are not to the north; to the south, it is similar to the current scenario. Shorter times are obtained from Santander Avenue (North) than from Paralela Avenue (South).
Fig. 4: Redirection accessibility in the north-south direction. Source: Authors.

3.4 Global average accessibility gradient

Figure 5, Figure 6 and Figure 7 are presented below. These relate the average time of travel with the percentage of coverage to give representation and interpretation to the results obtained and carry out a comparison between the current situation and the two alternatives of redirecting analyzed.

In the figures, it is possible to observe that the option South-North (Redirecting north) is the one that presents less relation between coverage and travel time, which is shown in Figure 6 more to the right than the other two alternatives. According to the results of the percentage ogive, the best alternative is the North-South option,
as it has a greater coverage in a shorter average time of travel compared with the other two alternatives, which can be seen to the left, following the current scenario and finally the South-North alternative.

Fig. 6: Comparison of percentage ogive of coverage by ranges of average time of travel. Source: Authors.

Fig. 7: Comparison of coverage percentage by average travel time ranges. Source: Authors.

The current alternative and the redirects present very similar results. The bar graph was used to show the differences between them. The biggest difference appreciated in the 1 minute intervals is given in the period of 1 to 2 minutes in which
the north redirection is below the current one by 1.2% and 1% below the south redirection (Figure 7). For an interval of 0 to 5 minutes, the one with the greatest coverage is the southern redirection, which is 0.2% more than the current scenario and 1.4% more than the northern redirection. As for the current road, it has coverage between the north redirection and the south redirection as shown in the graphs. The north redirection has a higher percentage of access in the 0-1 interval.

4 Conclusions

The current model of circulation of the avenue, according to the comparison of accessibility data, is shown as an intermediate scenario between two other alternatives. It shows that it can be improved and the implementation of this alternative mobility proposal is recommended for the development of accessibility of the area. The use of the comparison as an approach to the entities derived from knowledge, provides effective tools for the sample of results, and allows a wide range of data by way of exemplification. The model of proposal that is presented in a more consistent way as a solution to the problems of mobility of the city, in the sector of study specifically, is the North-South redirection because it has the best relationship between coverage and time, although the difference with the other 2 alternatives have not been as big as expected. To change the direction of the route, an information campaign must be carried out so that the population knows about the new changes and knows that they will be positively affected [13, 14]. The change must also be accompanied by sufficient road signage to avoid inconveniences. When carrying out this alternative, the 2 existing crossings that connect from the Paralela Avenue and generate connection with the Santander Avenue must be eliminated, with respect to the other nearby roads they could continue functioning as they do now without changing the direction. However, it would be recommended to change not only this avenue but the entire sector.

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References


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