Coverage of Educational Centers from

Territorial Accessibility in the Municipality

of Pitalito – Huila, Colombia

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Abstract

Education as an element of first necessity, intervenes in the formation and growth of a society, empowering the economy as well as the interaction of the different existing ethnic groups; for this reason, it is necessary to make an evaluation of the current condition of access to each of the existing educational institutions, in our case Pitalito - Huila, in order to determine the level of accessibility and coverage generated by the equipment system, guaranteeing the lowest displacement cost and maximizing the utility of the institutions. The evaluative mechanics developed in the present investigation, considers the use of territorial accessibility from geostatistical models structured by means of digital tools, which allow the optimal interpretation and replication of results.

Keywords: Accessibility, education, geostatistics, coverage, development

1 Introduction

Education, as a component of development, plays an important role in the constru-
ction of a city, considering that it is a first quality element [7] and of high quality, which must have qualities of accessibility [24] capable of mitigate the demand generated by the community. In this way, it is evident the need to maintain an adequate educational coverage in order to increase the population's growth and development; Therefore, the possibility of access should be evaluated and guaranteed, based on interventions in infrastructure by the municipal administration. For our case study, the evaluation of accessibility to educational centers takes place in the municipality of Pitalito (Department of Huila), which is located in the southwestern Colombian region, on the Magdalena Valley at 1° 51'14" latitude north and 76° 03'05" west longitude (figure 1) [1]. The geographical characteristics of the municipality place it on the 1318 m.a.s.l. in close proximity to the vertex of origin of the central and eastern mountain ranges, with a total extension of 666 km2 [1].

The municipality of Pitalito, at present, has a total population of 133,205 inhabitants [6], however, in our study process, we link the population information referred to the year 2015 (125,839 inhabitants); considering the possibility of using existing cartographic information. Taking into account the study population, in education, 51.7% of the population has a primary education level, 23.9% secondary, 0.47% technical and 0.58% university; 23.3% of the remaining population does not have any type of official educational training [19]. For the components of primary and secondary education, there is a strong promotion of official (state) education, taking into account that 88.43% of active students are enrolled in public institutions while 11.57% are linked to private institutions [2].
In the case of educational institutions of a technical and higher order, it has a coverage of more than 1,700 students, linked to different institutions such as: Uniminuto, Surcolombiana University, Antonio Nariño, National Service of Learning (SENA), Higher School of Administration Public (ESAP), Gran Colombiana University, among others [2]. Considering this, it is prudent to affirm that the educational level of the municipality supplies a large part of the population, however, it is necessary to strengthen the institutions in order to access sectors with a service deficit; for this reason, it is proposed to make the analysis of educational coverage in the municipality, allowing the identification of possible isolated sectors, as well as the variation in accessibility in future years.

In this way, territorial accessibility is considered as a primary tool for evaluation in research, which is why it is prudent to conduct a literature review in order to formulate clear foundations on the subject. The construction of the concept "Accessibility", in the present investigation, focuses on the definition established by Hansen in 1959, where he centers the term as the potential of opportunities for interaction [11]; however, there are different formulations since the beginning of the 20th century [3], although in some cases, existing enriching foundations are lost [21]. Thus, we establish accessibility as a measure of the ease with which citizens interact among different activities from different modes of transport [15], facilitating economic development and growth [17]. Some researches related to accessibility and education in the literature [7, 20, 24, 13] facilitate the growth of our case study; similarly, there are varied applications from other fields of science: [4, 5, 10, 16, 12, 14, 22, 23].

2 Methodology

The mechanics of evaluation is based on the execution of 5 fundamental processes, each of these with its respective subroutines, which guarantee an adequate execution of the research. The procedures discussed are presented in Figure 2.

2.1 Collection of existing information

From the execution in data mining, we proceed to investigate the existing databases, both of the municipal administration, and external entities, managing to establish and base the digital resources necessary for the preparation of the research, within these, formulation of variables to be considered, digital base of educational establishments, base infrastructure network of the municipality of Pitalito.

2.2 Formulation, execution and optimization of necessary digital elements

Within this methodological procedure, the variables acquired from digital tools are synthesized, generating the different entities type shape, able to support the accessibility evaluation; within these: network of road infrastructure (base and future) of the municipality, georeferencing of educational institutions, polygon construction of variables.
2.2.1 Red infrastructure base road

From the characteristic elements obtained in the collection of information, the road infrastructure network of the municipality is constructed and refined, refining each of the components and facilitating the execution of the evaluation; The main elements existing in the road network are the nodes and arcs, which represent the road connections and intersections in the operating software [8] (figure 3).
2.2.2 Red of future road infrastructure

In order to assess the level of impact on future accessibility, the vehicular infrastructure network is established with the different interventions proposed for 2031, as shown in Figure 4, it is important to note that the interventions are not executed in a single moment, that is, they are a series of interventions to be made over the years, in order to achieve total execution on the target year.

![Figure 4. Future network and location of educational equipment. Source: Authors.](image)

2.2.3 Georreferencing of educational institutions

Once the transport networks are built, we proceed to geographically locate the existing educational facilities in the municipality, as shown in Figure 4, each equipment at the time of being evaluated acquires the name of facility, term linked to ArcMap software and fundamental pillar of the evaluation.

2.2.4 Construction of polygons of variables

Parallel to the construction of transport networks, we proceed to formulate the polygon of variables, in which the basic structure of the urban perimeter of the municipality is intertwined with the population and area values considered in the study. For this case, the populations of the base network (125,839 inhabitants) are linked, both for the future network (150,432 inhabitants) [6], the procedure is carried out from shape-type entities in the ArcMap software.
2.3 Preparation of accessibility ogives

Once the base conditions of the research have been established, each element is linked using the New Closets Facility tool of ArcMap. Within this, 3 fundamental terms are denoted: incidents (nodes of the network from which the displacement is generated), facilities (nodes of the network or added to which the trip is directed), routes (route made over the network to access the facility) [9]. The methodology of internal calculation in the named extension, is based on the use of Djikstra algorithm or algorithm of minimum paths, which uses the cost of travel over each arc to determine the lowest value in travel time from an incident node to some facility [18]. After obtaining the values in time for each minimum path, the matrix of travel times is built, on which the geospatial coordinates of each node are linked; The matrix is then entered into the Geoprocessing intersect extension and, using the ordinary kriging method with linear semivariogram, the accessibility curves for the base and future network are elaborated.

2.4 Construction of savings ogives

In order to evaluate the impact generated by the interventions in the future road network, the accessibility results for each network are related and with this, the percentage of savings in accessibility is determined by means of equation 1. With the obtained values, the matrix of savings is formulated as in the case of accessibility and later the Geoprocessing intersect tool is accessed, with which we obtain the representative savings curves.

\[
\% \, \text{ahorro}_i = \left( \frac{t_{V_i(\text{act})} - t_{V_i(\text{fut})}}{t_{V_i(\text{act})}} \right) \times 100
\]  

(1)

2.5 Correlation of variables through coverage

Finally, the variables of population and area are correlated through the intersection between the accessibility ogives and the variable polygon, later the values are obtained by variable for each accessibility curve for later, using Microsoft Excel, construct the coverage graphs.

3 Results and discussion

3.1. Base road infrastructure network

As a result of the analysis made to the base road infrastructure network, figure 5 was obtained, which shows the variation in travel time to educational establishments at intervals of 0.5 minutes; a radial behavior is identified with a strong inclination toward the south central sector of the municipality, achieving the minimum displacement cost; on the other hand, towards the periphery a maximum travel time of 8.5 minutes is obtained, which does not imply a strong disconnection.
In Figure 6, the behavior obtained from the correlation of variables from the intersection of polygons is shown; it is appreciated that, for a percentage higher than 50 points, in both variables, a maximum time of 3 minutes is required, which evidences an excellent accessibility for the base network. On the other hand, a parallel behavior is observed between the graphs with a discrepancy of up to 12 points, however, the behavior characterizes a similar accessibility for each variable.

Figure 5. Turning time curves in the base network. Source: Authors.

Figure 6. Variation in coverage by variable in the base network. Source: Authors.

3.2 Future road infrastructure network

As a result of the evaluation in accessibility to the educational centers of the future road infrastructure network, Figure 7 was obtained, in which the variation of the
cost of displacement throughout the municipality can be appreciated at intervals of 2.5. It is appreciated, as in the base road network, a behavior in radial coverage with preference towards the center of the municipality, with a high coverage by the representative ogives of 2.5 and 5 minutes, covering about 40% of the surface; On the other hand, a maximum of 17.5 minutes of travel costs is identified, generated by the expansion of the road corridors to the peripheral sectors, however, the sectors under this maximum value do not represent a considerable percentage.

![Displacement time (Min)](image)

**Figure 7.** Curves of travel time in the future network. Source: Authors.

Additionally, figure 8 is presented, on which the percentage of coverage generated by each variable is analyzed; It is important to remember that the number of inhabitants analyzed in this scenario shows a strong increase, based on the population expansion recorded by the municipal administration (DANE). The separation between curves reported, in relation to the base network, presents a decrease of 5 percentage points, achieving a separation of up to 7%; the level of coverage for 50% of the variables (population and area) requires a time of up to 6 minutes, which despite being twice the time reported in the base network, continues to be an optimal coverage when considering that the number of inhabitants until the year of intervention grows considerably.

### 3.3 Savings ogives

In order to observe in a more detailed way the impact generated in the accessibility by the road interventions towards the educational centers, figure 9 was constructed in which the savings warnings are observed at intervals of 10 percentage points; the relationship of the future road network with respect to the base network, evidences
sectors of savings of close to 35%, achieving maximums of up to 100% despite the fact that the highest proportion is centered between 30% and 60%. The remaining 75% does not show savings for the carried out interventions, however, it does not imply an affectation, considering the population growth at the year of study.

Figure 8. Variation in coverage by variable in the future network. Source: Authors.

Figure 9. Saving curves in travel time. Source: Authors.

Figure 10 shows the percentages of perceived savings, showing that the behavior between curves is identical, which implies that the proposed interventions affect
both surface and population equally. Additionally it is observed that at least for 40% of the variables they perceive a saving of up to 10%, which, at the study horizon, evidences an improvement in accessibility.

![Graph showing variation in coverage for savings for each variable. Source: Authors](image)

Figure 10. Variation in coverage for savings for each variable. Source: Authors

4. Conclusions

The evaluation of accessibility to schools in the municipality of Pitalito, for the base network, demonstrates an efficient access level, managing to move to at least one of the centers in a travel time of less than 8 minutes.

For the future situation, the level of accessibility conserves a percentage of population and covered area in a time of travel less than 8 minutes, that in spite of increasing the number of inhabitants, continues guaranteeing an efficient access level towards at least one of the schools.

It is important to consider that the study does not take into account the location of registered users in each institution, which is why it is not guaranteed that travel times are met for the entire population, however, it is possible to consider the study as an input base for the allocation of quotas for resident citizens in the vicinity of the educational centers.

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