Analysis of Coverage for Armed Force Land Use in

Pitalito (Colombia), through Territorial Accessibility

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Abstract

The expansion and growth of the municipalities, is influenced by different social and cultural problems that affect the normal functioning; among them, insecurity, which requires a high degree of commitment from the government entities to minimize the high impact on citizenship. For this reason, it is proposed to conduct a coverage analysis through territorial accessibility to assess the current condition of the security equipment system in the municipality of Pitalito, department of Huila, in order to identify the sectors with flaws and formulate possible solutions. The mechanics of evaluation considers the incorporation of geostatistical models through the use of statistical and GIS-type software, with which the construction of graphs and images of easy interpretation is possible.

Keywords: Security, Territorial accessibility, Geostatistics, GIS, Coverage
1 Introduction

The vital functioning components of every society, facilitate the orientation of the development that is to be established in the future, allowing focusing resources and locating existing flaws in each field of action; considering as "fields of action" or primary activity nodes: health, education, recreation, culture and security [8]. Within our field of application, we will focus on the security component, which can be understood as the absence of risk for the population, although the conceptualization of it hinders the form of measurement to be presented in a multidimensional and subjective way [2], therefore alternative evaluations must be chosen to execute solutions with high safety impacts. Taking into account the above, it is proposed to perform an alternative analysis of territorial accessibility and coverage of security institutions in the municipality of Pitalito, department of Huila, among which we find: Police Department, Municipal Prison, Institute of Legal Medicine and Forensic Sciences, as well as the Volunteer Fire Department of the municipality. The municipality of Pitalito is located in southern Colombia, on the vertex of origin of the Andean and eastern cordilleras at 76° 03'05" west longitude and 1° 51'14" north latitude (figure 1); having a total area of 666 km2 and an average altitude of 1 318 masl. [1]. According to the last projection of the National Administrative Department of Statistics - DANE, it has an estimated population of 133 205 inhabitants [6], however, in order to use the existing digital information in official databases, it is decided to incorporate the population referred to the year 2015 (125 839 inhabitants).

Figure 1. Geographic location of the municipality of Pitalito.

Some security indicators in the municipality show increasing tendencies in recent years in terms of robberies, homicides, extortions, homicide being the most worrisome when presenting values of more than 40 events per 100 000 inhabitants.
In terms of thefts, the variation over the years tends to rise, being the most realized, the theft to people and motorcycles with values of more than 200 events per year for each variable [17]. It is important to highlight that aggressions or affectations by third parties are not the only cause of insecurity, for this reason it is important to consider situations such as fires, traffic accidents, and natural events, among others, which are served by risk units that in the case of Pitalito are the Volunteer Fire Department.

Thus, it becomes evident the need to assess the accessibility and coverage condition by the security institutions, allowing to observe the cost in travel time to attend to any eventuality within the municipality, as well as the possibility of intervention in future situations, minimizing the loss of resources and maximizing the use of institutions. As a prelude to the evaluation, it is prudent to internalize a little about the accessibility term, in order to interpret and analyze the results correctly. The term in itself represents the possibility of accessing something, however, in our medium of application it extends its meaning to the means by which access is achieved [14]; therefore there are different definitions of the term although they are all based on the one established by Hansen in 1959 "the potential of opportunities for interaction" [9]. Some definitions of accessibility in the environment relate to the measure of the ease of access to different activities or services from the existing infrastructure [5, 22], however, there are variations in the term from other points of view [10, 16]. Some applications of accessibility in different fields of application are education [20, 22], sustainability [3, 8], demography [11], security [18], and social cohesion [12], among others.

2 Methodology

The methodological sequence addressed in the research links different points or construction items, as shown in Figure 2, which range from the collection of information, to the construction and structuring of results.

2.1 Collection of existing information

As a baseline of research, we proceed to develop an intensive search in the existing official databases, in order to collect information related to road infrastructure and security in the municipality of Pitalito, managing to establish physical and operational components required in the accessibility evaluation with the limitation of the date of update of the information, which is placed in 2015.

2.2 Construction of infrastructure networks and incorporation of equipment

Once the information regarding the infrastructure of the official databases has been obtained, the transport networks to be evaluated are constructed, each of which links physical and operational characteristics with which the evaluation is made. Additionally, security equipment is incorporated from digital tools.
Within this sub-sequence the road network of the municipality of Pitalito is structured to the year 2015 (see figure 3), in which the different corridors and road intersections existing at the time, are established and optimized; similarly, the existing security equipment is spatially linked and distributed; taking into account that each equipment represents a "facility" within the ArcMap program [13].
In the same way as in the previous sub-sequence, the road network of the municipality is structured to the year 2031, considering the different proposals made by the municipal administration in its Land Management Plan still under construction, the different interventions are shown in figure 4. For the case of the equipment, a new security institution is linked to the northern sector, in order to minimize costs in travel time.

Figure 4. Network and equipment by the year 2031.

2.3 Territorial accessibility assessment

Once the infrastructure networks are formed with their respective characteristics and equipment, each one is linked to the ArcMap software through its Network Analyst - New Closest Facilities extension. Within this extension 3 elements of vital importance for the evaluation are formulated: Facilities (equipment of analysis), Incidents (points of origin of displacement) and Routes (road segments for the route) [20], as it is observed in the figure 5 After the elements are linked, the tool is executed and with this the travel time cost for each facility is determined from each incident; the mathematical mechanics behind obtaining the cost in time is based on the Dijkstra algorithm, which determines the minimum path to travel despite the multiple existing options [15, 19]. With the obtained travel time values, the time matrix is constructed, which links the geospatial coordinates of each incident and the cost obtained from traveling to any of the facilities; later they are incorporated into a new extension of ArcMap, Geostatical Wizard, where the accessibility cures are elaborated, based on the ordinary Kriging method as a projection model. As a complement to the analysis of territorial accessibility, the saving curves are constructed, which link the results obtained for the 2015 and 2031 networks, by means of equation 1 and the Geostatical Wizard extension.
\[ \text{Saving percentage } \_i \% = \left( \frac{t_{time_{i, act}} - t_{time_{i, fut}}}{t_{time_{i, act}}} \right) \times 100 \] (1)

2.4 Coverage

The last item applied to the research consists in the linking of the variables of area and population, through polygons, with the objective of evaluating the coverage in each network. For the case of 2015, the base population of 125,839 inhabitants is linked, while for the year 2031, the projected population is included, which is estimated in 150,532 inhabitants [4].

3 Results and discussion

Figure 6 shows the results obtained from the displacement cost for the security institutions to the year 2015, the established variation evaluates the cost every 0.5 minutes, with a maximum obtained of 15 minutes towards the northern sector of the municipality. It is shown that the location of security institutions facilitates access to users who are residents in the city center and nearby areas; however, there is an important density of road network with difficulty of access to the sector where the maximum displacement cost is located, reason why the implementation of new equipment to this area can be argued.

Taking into account the population and area established as urban perimeter for 2015, Figure 7 was constructed, which shows the behavior of the coverage genera-
ted by the security institutions on the municipality. It is identified that for a coverage of 60% in both variables there is a discrepancy of up to 2 minutes, requiring a population of 8.4 minutes, while for the surface only 6.6 minutes. This behavior can be argued for the provision of safety equipment and the composition of the road network, which allow access to sectors with lower population density.

![Territorial accessibility map for safety equipment by 2015](image)

Figure 6. Territorial accessibility map for safety equipment by 2015.

![Coverage curves for safety equipment by 2015](image)

Figure 7. Coverage curves for safety equipment by 2015.

Once the respective interventions in road infrastructure were made, as well as the incorporation of the new equipment, it was possible to build a map of future accessibility observed in figure 8; in relation to 2015, there is an increase in the cost of displacement, generated largely by the expansion of the urban perimeter as well as by the decrease in speed due to the high impact of the population by the year 2031. The variation presented for the year 2031 is set at 2.5 units, with a maximum of 22.5 minutes localized to the eastern sector of the municipality; on the northern
sector, where the year 2015 presented the highest displacement cost, a reduction was achieved up to 7.5 minutes, mitigating the need of the population. Additionally, there is evidence of the need to incorporate new equipment into the expansion sectors, in order to meet the demand of the population by the year 2031.

Figure 8. Territorial accessibility map for security equipment by 2031.

Complementarily, figure 9 is constructed, where the variation in coverage generated by the interventions by year 2031 for area and population can be observed. A more homogenous behavior among variables was observed in relation to the year 2015; on the other hand, the coverage for each variable with respect to the percentage considered to 2015 (60%) requires a longer time of displacement, however, considering the expansion in urban area as well as the increase in population allow us to assume that the cost to 2031 does not imply a deterioration in accessibility.

Figure 9. Coverage curves for safety equipment by 2031.
Taking into account the results obtained for the years 2015 and 2031, the savings map presented in Figure 10 was elaborated; the variation of savings in percentage is observed for intervals of 10 units, with a wide sector of the municipality with values of 0. The greater perception of savings is located on the sectors with high intervention in road infrastructure, as well as on the northern sector where the new security institution is incorporated. It is evident that the connection via road rings in the peripheries greatly improves the accessibility of these sectors; however, in a possible case, it could be more beneficial to build new equipment to these areas.

Figure 10. Savings map for safety equipment in the municipality of Pitalito.

Finally, figure 11 shows the results obtained for the graphs of percentages of perceived savings by area and population; a high perception of savings of up to 20% is identified for both variables, being able to be perceived by up to 60% each; however, there are considerable perceptions of up to 40% in 20% of the population, which infers an optimal intervention by 2031.

Figure 11. Curves of perceived savings by area and population towards the security equipment in the municipality of Pitalito.
4. Conclusions

The accessibility assessment in 2015, allows identifying the failures in coverage for security institutions; however, it allows formulating the possible intervention sectors, guaranteeing coverage in the future to meet the needs of the citizens.

The condition of future accessibility demonstrates, largely, that the analysis carried out directly intervenes in decision-making in the future, facilitating the targeting of resources and maximizing the benefit of the community.

Additionally, in future research, it is recommended to analyze the incorporation of new equipment on urban expansion sectors in the municipality, in order to determine the impact generated in accessibility by the implementation, in addition to possible reductions in travel costs for the community.

Acknowledgements. The authors express their gratitude to the working group in charge of the construction of the Plan of Territorial Ordering of Pitalito, in the same way we thank the students belonging to the research group in Sustainable Mobility of the National University of Colombia, Manizales headquarters.

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Received: August 1, 2018; Published: August 20, 2018