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APPLICATION OF TERRITORIAL ACCESSIBILITY METHODOLOGIES TO COMPARE AND UNDERSTAND THE DIFFERENCES IN EQUITY CONDITIONS BETWEEN TWO NEIGHBORHOODS OF DIFFERENT SOCIOECONOMIC STRATA IN A COLOMBIAN INTERMEDIATE CITY

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Abstract: The number of opportunities in a specific area significantly influences the planning, development, and zoning of city neighborhoods. In this study, a methodological approach was employed to analyze pedestrian accessibility between two neighborhoods of varying strata in Manizales, Colombia. The research utilized the ArcGIS program, yielding results that highlighted disparities in service access and opportunities between the neighborhoods. It was concluded that higher strata neighborhoods offer greater amenities to residents, emphasizing the need to reconsider urban planning strategies.

Keywords: pedestrian, planning, accessibility, socioeconomic strata, neighborhoods

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INTRODUCTION

Manizales, the capital of Caldas, is geographically located at a latitude of 5.0689 north and longitude of 75.5174 west, in the central-western region of Colombia (Figure 1), adjacent to the Central Cordillera and at an altitude of approximately 2150 meters above sea level. This city covers an area of approximately 510 km² (Gobernación de Caldas, 2021) and is home to over 454,494 inhabitants (Alcaldía de Manizales, 2023). The city is divided into 11 districts, each comprised of 114 neighbourhouds (Alcaldía de Manizales, 2017), classified according to a stratification scale ranging from 1-6. The neighborhoods to be analyzed in this research correspond to stratum 3 (Fátima) and stratum 6 (Palermo).

Due to the expansion and evolution of the city of Manizales, marked differences in access patterns to services and opportunities have emerged across the city. This disparity in the number of opportunities not only reflects the physical distance between locations but also the social and economic barriers that can hinder the mobility of certain groups, making it a matter of vital importance to understand and increase social equity. Before proceeding with the development of this research, it is necessary to understand the term "accessibility," which can be defined as the ability of individuals and/or businesses to access the opportunities offered by their specific environment (Hansen, 1959) or as the magnitude that allows understanding the ease or difficulty with which different activities and communities can relate to each other through multiple and different modes of transportation (Morris et al., 1978). This term has been analyzed in multiple scientific fields such as economic development (Batty, 2009; Mackinnon et al., 2008; Rietveld and Nijkamp, 1993), demographic analysis (Kotavaara, 2011), sustainability (Vega, 2011), library services (Higgs, 2013), public health (Escobar et al., 2016; Frenk, 1985), analysis of social cohesion (Chandra et al., 2017; López et al., 2008), agriculture and natural resources (Arcidiacono and Porto, 2010; Gellrich and Zimmermann, 2007), transportation access (Bruce et al., 1993; Boisjoly et al., 2017; Geurs and Van Wee, 2004; Escobar et al., 2013; Montoya et al., 2017), and even social networks (Sailer et al., 2012).

On the other hand, accessibility can be divided into 3 different categories: Relative, integral, and global (Izquierdo, 2001). Integral accessibility is a measure that arises from a point that can represent opportunities for health, recreation, safety, education, etc. Therefore, in this research, an analysis of integral accessibility will be carried out, where the degree of connection between a particular node and incidents in a specific area will be calculated (Escobar and García, 2012).

Similar to Burkey (2012), it is established that the main factors affecting accessibility are population distribution, the transportation network, and the number and location of nodes. Therefore, this research is based on the premise that

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pedestrian accessibility does not refer solely to ease of movement but also encompasses issues of equal opportunities, quality of life, and different social factors. Bert van Wee (2022) argues that individuals should have a baseline level of access to key nodes, ensuring an equitable distribution of accessibility across a city's population. This notion aligns with the concept of social equity in urban planning, where access to essential services and opportunities is considered a fundamental right for all residents. Van Wee's perspective underscores the importance of designing cities with inclusive and accessible infrastructure, fostering equal opportunities and quality of life for everyone. Thus, it can be understood that, while the quality and condition of pedestrian mobility structures represent an important part of accessibility measures, they are directly influenced by the number of opportunities that can be accessed. It is of no use to have a pedestrian structure in excellent condition if one must walk for more than 20 minutes to access the needed service.

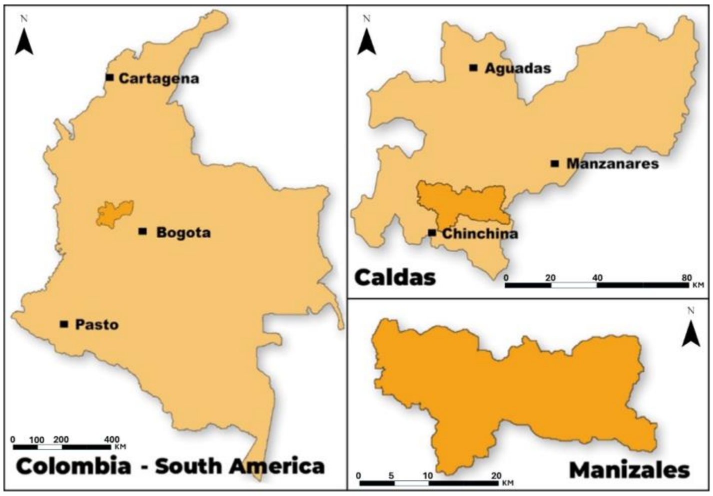

Figure 1. Geographical location of the municipality of Manizales, Caldas (Colombia) (Source: authors, 2023)

Therefore, the following research seeks to understand how the socio-economic differences influence in the accessibility to services and opportunities in the city, identifying barriers and inequalities in access to services and opportunities present in both neighborhoods of the city, using as reference studies such as the one carried out by Pritchard et al. in 2019, where they compared the level of accessibility of 3 cities or the study carried out by Quijada-Alarcón et al. (2023) in the province of Coclé. In order to propose solutions that improve the quality of life of the residents of these neighborhoods.

Throughout the following stages, the methodology and results that emerged from this analysis will be presented, which will allow a deep understanding of how the inhabitants of these neighborhoods experience pedestrian mobility in their daily lives, identifying both the barriers they face and the opportunities they can access.

MATERIALS AND METHODS

The methodological development of this research consisted of 6 main consecutive phases: 1. Neighborhood Delimitation for Analysis; 2. Identification and refinement of the pedestrian network; 3. Route and identification of issues; 4. Identification and location of the PANs (Primary Activity Nodes); 5. Pedestrian accessibility analysis, 6 Population and Area Coverage Assessment. These will be described below:

Phase 1. Neighborhood Delimitation for Analysis: According to the territorial division of the urban area (Mayor's Office of Manizales, 2017), the delimitation and identification of the neighborhoods to be analyzed were carried out (Figure 2).

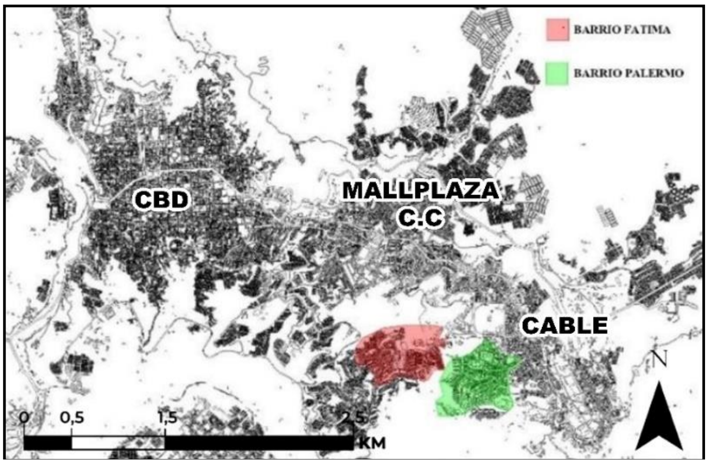

Figure 2. Neighborhood Delimitation for Analysis (Source: authors, 2023)

This was done with the aim of understanding their location, relationship with respect to the city, separation between them and the neighborhoods they border, obtaining a clear image of the boundaries and areas that need to be analyzed and traversed. It is worth noting that the delimitation of these neighborhoods was not only based on the territorial division maps of the urban area but also took into account the opinions of several residents of these neighborhoods. This is the reason why the delimitation of these neighborhoods differs in some points with respect to the territorial division maps, as several residents considered certain areas as part of their neighborhoods that did not appear in the aforementioned maps.

Phase 2. Identification and refinement of the pedestrian network: Starting from the delimitation, the identification and updating of the pedestrian network of both neighborhoods were carried out to correct imperfections and recognize both the streets and avenues that make up the pedestrian structure in each of them (Figure 3 and Figure 4). Once the shortcomings were identified, restructuring was made possible with the aim of ensuring its proper functioning when digitized in Esri's ArcMap software, facilitating the route planning and analysis process.

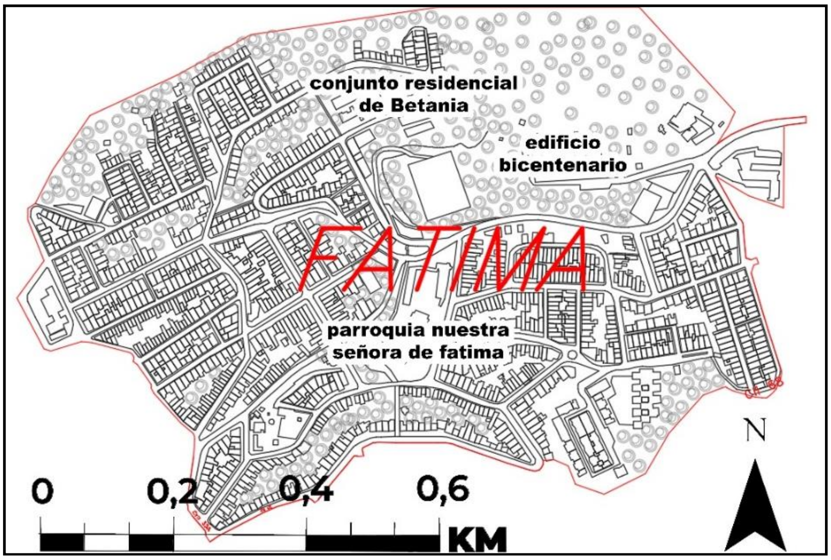

Figure 3. Fatima, Manizales. Delimitation for Analysis (Source: authors, 2023)

Phase 3. Route and identification of issues: Based on the previous stage, routes are planned in the streets and avenues of the neighborhoods to be analyzed, with the aim of observing the state and conditions of the pedestrian infrastructure serving the users, highlighting and identifying the issues present in each stretch through direct observation methodology.

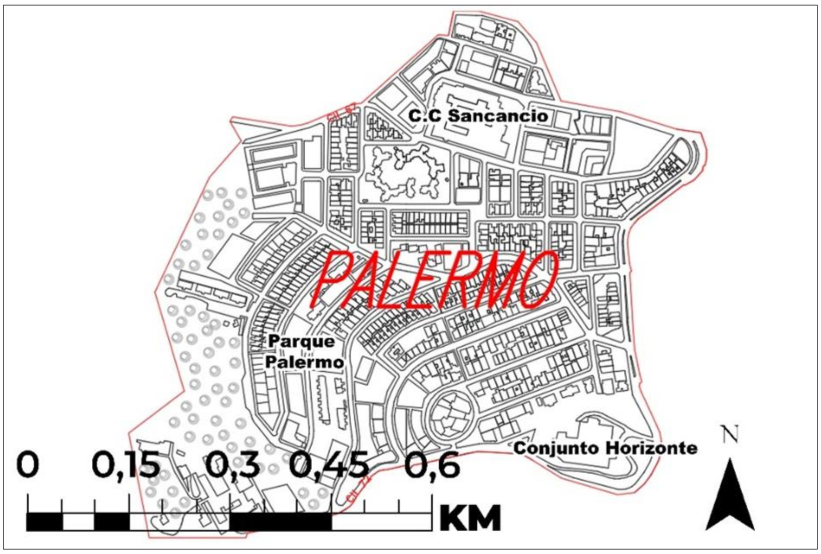

Figure 4. Palermo, Manizales. Delimitation for Analysis (Source: authors, 2023)

Phase 4. Identification and location of the PANs (Primary Activity Nodes): Based on the visual surveys conducted in each of the study neighborhoods, the existing Primary Care Nodes (NAPs) were identified (Escobar et al., 2017), understood as land uses whose main purpose is to supply, at a minimum, the population's basic needs such as education (preschools, schools, high schools, and universities), health, safety, and recreation. Subsequently, the NAPs are digitized using the ArcMap tool, thus allowing the structuring of the baseline data for the investigative analysis.

Phase 5. Pedestrian Accessibility Analysis: Once the base information has been established and the network has been structured in digital format, the next step involves assigning the pedestrian base speed to each available road segment. This speed is set at 4.32 km/h, according to parameters established in the Practical Guide to Urban Mobility (Alcaldía Mayor de Bogotá, 2019). Once the base speed has been linked to each segment, travel times for each stretch are calculated using the equation ((1) (*equation for Travel Time by Escobar et al., 2020)* provided below (when TV means travel time, length is the arch in question and pedestrian speed is the average speed of the pedestrian in the arc length) which relates the length of the stretch to the assigned speed. These travel times are crucial for conducting the initial evaluation of the model's accessibility, where control points will be connected for the calibration process.

$$TV_i = \frac{L_i}{PS_i} x60(\text{min}) \qquad (1)$$

Where TV_i is the travel time for arc *i*, L_i is the length in arc *i*, PS_i is the pedestrian speed in arc *i*.

The initial evaluation is carried out by applying Dijkstra's shortest path algorithm. This algorithm analyzes each available route within the road network and selects the one with the lowest cost between the defined origin and destination. The basic scheme of the algorithm is executed using the "New Closest Facility" extension of ArcMap's Network Analyst tool.

After characterizing the travel times, evaluation points (NAPs) are defined towards which the analysis will be conducted from each particular node of the neighborhood, allowing estimation of the required travel time to access the NAP. This assessment defines the travel time vector, which is plotted using the Geostatical Wizard extension of ArcMap, applying the ordinary Kriging interpolation method as a spatial connectivity measure.

Finally, the time range to be plotted is defined, and the points of interest are located for the respective analysis.

Phase 6. Population and Area Coverage Assessment: In this final phase, the assessment of population and area coverage for the study area is conducted by linking the neighborhoods sociodemographic data to the accessibility curves generated by the model. This process involves the intersection of graphical layers using the Geoprocessing intersect tool, where a time value is associated with each incorporated population polygon.

It is crucial to note that the intersection may alter the initial assessment of population and area due to the subdivision of areas. Therefore, a corresponding correction must be applied to minimize errors. Following the adjustment, cumulative coverage graphs are constructed based on the available population, identifying the required access to the PANs.

RESULTS AND DISCUSSION

As a result of the field assessment in identifying PANs, Figure 5 and Figure 6 are presented, where the identified facilities for the Fátima and Palermo neighborhoods are shown in various colors. The orange color represents education nodes, blue represents health nodes, green represents security nodes, and purple represents recreational nodes.

It is noted that in the Fátima neighborhood, there is a higher concentration of educational and recreational facilities, while in the Palermo neighborhood, the greatest concentration is on recreational and health facilities. For both neighborhoods, the concentration of security facilities is low.

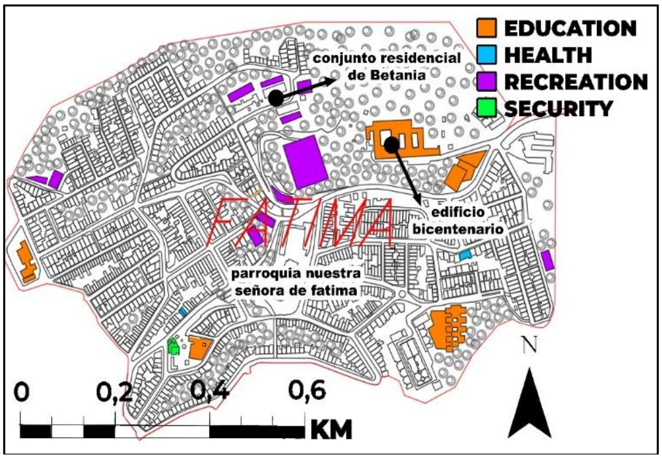

Figure 5. PANs Present in Fátima, Manizales (Source: authors, 2023)

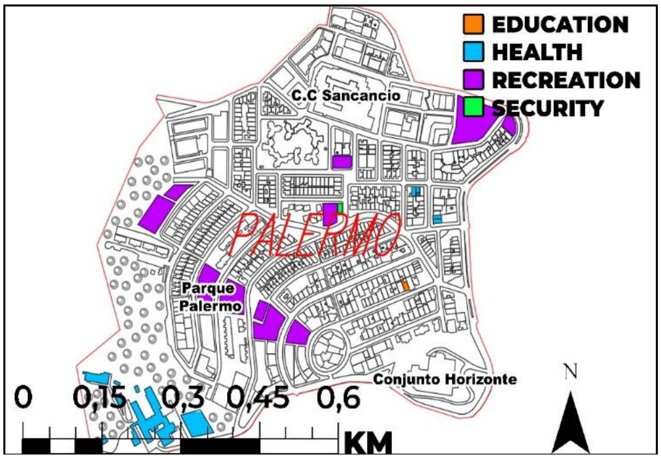

Figure 6. PANs Present in Palermo, Manizales (Source: authors, 2023)

Based on the pedestrian accessibility assessments conducted towards each set of primary facilities in the neighborhoods used as the study area, it is possible to say that the assessment in terms of access time and coverage for health facilities in the Fatima neighborhood (Figure 7) requires the highest travel cost for users, with values exceeding 15 minutes of walking to achieve a 12% population coverage. This results in users making longer trips that can be critical when seeking medical attention. Regarding assessments of education, security, and recreation, interesting evaluations are observed, with travel costs of less than 5 minutes to cover over 60% of their population, with the greatest concentration in educational facilities, which achieves a value close to 90% within the time interval of less than 5 minutes. Regarding the Palermo neighborhood (Figure 8), it is possible to observe how the travel time assessment for primary facilities reflects the highest cost towards educational facilities, with a time exceeding 10 minutes to cover nearly 20% of the population. As for security, recreation, and health facilities, a lower travel cost is observed, with a requirement of less than 5 minutes to cover 50% of the population, with recreational facilities being the most easily accessible with a time of less than 2 minutes to cover over 90% of the citizens.

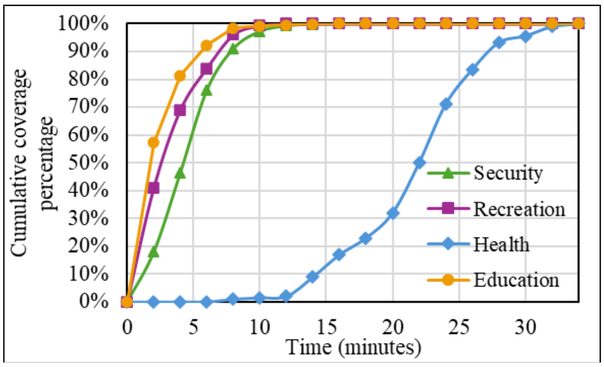

Figure 7. Cumulative percentage of coverage in Fatima (Source: authors, 2023)

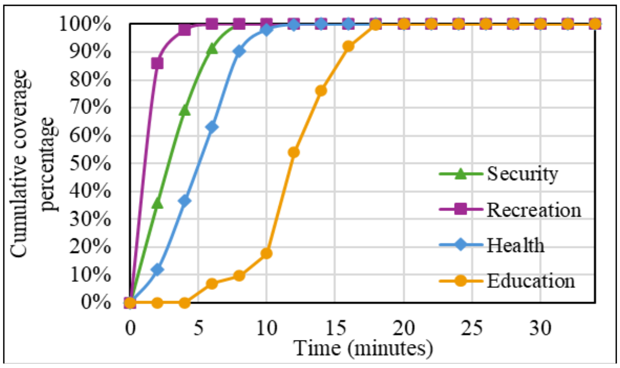

Figure 8. Cumulative percentage of coverage in Fatima (Source: authors, 2023)

As a joint assessment of the Fatima and Palermo neighborhoods, it is possible to observe that the better accessibility condition is in the Palermo neighborhood, requiring less time for access to meet the needs of its population. The critical point is the assessment of 20% of its population at the farthest facility, which is around 10 minutes for healthcare facilities, while in the Fatima neighborhood, it requires close to 15 minutes for the same population percentage coverage in healthcare. Despite this, the assessments show interesting behaviors in terms of pedestrian mobility, as access to primary services can be achieved in less than 10 minutes, a substantially low value compared to vehicular requirements, which can have similar values but with higher energy and economic costs. This suggests that the facilities are appropriately located.

CONCLUSION

Based on the previous figures, it can be concluded that the Palermo neighborhood exhibits a higher accessibility rate concerning the facilities within its territory compared to the Fatima neighborhood. There was a clear superiority in terms of travel times, with Palermo surpassing Fatima in 3 out of the 4 categories analyzed in this research. Additionally, issues related to the lack of specific opportunities were identified in each of the analyzed neighborhoods, such as the absence of educational nodes in the Palermo neighborhood or the lack of healthcare nodes in the Fatima neighborhood. This results in significant increases in the travel times required for residents of both neighborhoods to access these services. This reflects, to some extent, the need to create facilities that address these issues and reduce travel times in the analyzed neighborhoods.

On the other hand, it is possible to appreciate that accessibility assessments allow for the identification of shortcomings in the provision of basic services, thus providing tools for interpretation and decision-making for municipal administrations, guiding investment resources more effectively according to the population's needs.

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