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ORIGINAL

Accessibility analysis: Travel times in high-density sectors in Pasto

Análisis de accesibilidad: Tiempos de desplazamiento en sectores de alta densidad en Pasto

Karen Larisa Pabón Jaramillo[1]

[1]Universidad CESMAG. Colombia.

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Corresponding Author: Karen Larisa Pabón Jaramillo

ABSTRACT

The study analyzed the urban configuration of Pasto from the perspective of mixed land use, mobility and pedestrian accessibility. It was observed that city planning had developed spontaneously, without a clear coherence with the guidelines of the POT 2015-2027, which generated territorial fragmentation and inequality in access to services and facilities. Urban densification led to land uses being defined more by the practices of the inhabitants than by regulations, producing tensions between housing, commerce, services and infrastructure. It was also found that the road network consisted mostly of local and intermediate roads, which limited structural connectivity and the implementation of sustainable mobility. The methodology used, of an empirical-analytical nature, integrated GIS, CAD and cartographic database tools to calculate accessibility and mixed-use indices. Four study areas were identified with densities higher than 175,9 inhabitants/ha, where residential use largely predominated over the others. Despite this, imbalances were found in the distribution of commerce, facilities and public space, reflecting a low functional integration of the land. The results showed that Areas 1 and 3 presented better conditions of connectivity and proximity to services, thus approaching the 15-minute city model. However, the limited network of bicycle paths, unsafe crossings and the lack of continuity in the pedestrian infrastructure restricted equitable access. In conclusion, it was recommended to redistribute facilities, strengthen active mobility and design sectorized strategies that favor a more sustainable, equitable and connected urban development.

Keywords: Grass; Mobility; Accessibility; Mixed Uses; Planning.

RESUMEN

El estudio analizó la configuración urbana de Pasto desde la perspectiva de la mixtura de usos del suelo, la movilidad y la accesibilidad peatonal. Se observó que la planificación de la ciudad se había desarrollado de manera espontánea, sin una coherencia clara con las directrices del POT 2015-2027, lo que generó fragmentación territorial y desigualdad en el acceso a servicios y equipamientos. La densificación urbana condujo a que los usos del suelo se definieran más por las prácticas de los habitantes que por la normativa, produciendo tensiones entre vivienda, comercio, servicios e infraestructura. Asimismo, se comprobó que la red vial estaba compuesta en su mayoría por vías locales e intermedias, lo que limitaba la conectividad estructural y la implementación de movilidad sostenible. La metodología utilizada, de carácter empírico-analítico, integró herramientas SIG, CAD y bases de datos cartográficas para calcular índices de accesibilidad y mixtura de usos. Se identificaron cuatro áreas de estudio con densidades superiores a 175,9 hab/ha, donde el uso residencial predominaba ampliamente sobre los demás. A pesar de ello, se hallaron desequilibrios en la distribución de comercio, equipamientos y espacio público, lo que reflejaba una baja integración funcional del suelo. Los resultados evidenciaron que las Áreas 1 y 3 presentaban mejores condiciones de conectividad y proximidad a servicios, por lo que se acercaban al modelo de ciudad de 15 minutos. No obstante, la limitada red de ciclorrutas, los cruces inseguros y la ausencia de continuidad en la infraestructura peatonal restringieron el acceso equitativo. En conclusión, se recomendó redistribuir los equipamientos, fortalecer la movilidad activa y diseñar estrategias sectorizadas que favorecieran un desarrollo urbano más sostenible, equitativo y conectado.

Palabras clave: Pasto; Movilidad; Accesibilidad; Usos Mixtos; Planificación.

INTRODUCTION

Jane Jacobs' book The Death and Life of Great American Cities(1) mentions that the critical problem in urban planning is that different land uses are analyzed individually without considering how their combination affects the overall functioning of the city. This partial approach ignores some of the interactions generated in cities with densified urban areas. In the case of Pasto, densification has led to uses being defined more by user decisions than by regulations, making it necessary to balance commerce, services, infrastructure, and housing.

According to Link et al.(2), the cohesion between streets, neighborhoods, and the city, together with factors such as segregation, density, and verticalization, influences the urban environment and neighborhood relations. A high mix of land uses increases urban complexity and can generate conflicts, which requires adequate planning. In Pasto, the challenges include controlling urban planning regulations, managing public space and traffic, and coordinating urban planning instruments that trigger these new developments.

The configuration of urban corridors in the city of Pasto presents significant challenges in terms of territorial cohesion and functionality. Although commercial, institutional, and green axes have been identified, their scattered layout has limited their positive impact on mobility throughout the urban structure. Urban growth and expansion in the city has generated organic urban patterns that affect neighborhood cohesion, extend travel distances due to the uneven distribution of services, and exacerbate environmental and infrastructure problems. In response to this, urban planner Carlos Moreno's concept of the 15-minute city is proposed as a solution to balance services and reduce travel distances.

The book Cities for People Gehl(3) highlights travel times as an important factor in city design, considering the time it takes people to move from one key point in the city to another, and that shorter journeys generate greater social interaction. Similarly, Miralles Guasch et al.(4) mention that reducing travel times requires a city model where everyday services and facilities are close by.

Mobility is not only understood as the provision of road infrastructure, but also requires the integration of urban corridors and mixed land uses that articulate and integrate the functional and service structure in order to organize a more equitable and sustainable city, where people can access essential services without relying exclusively on motorized transport.

Overall, the results indicate that differentiated and targeted intervention by type of road and sector is required to improve mobility, safety, and the quality of urban public space, as well as to reduce inequalities in the distribution of urban opportunities accessible on foot. Although the 2030 Agenda prioritizes pedestrians in the mobility hierarchy, this principle is not reflected in the current configuration of the road system, perpetuating the supremacy of motorized vehicles as the central axis of urban mobility, an imbalance that highlights the need for a strategic redistribution of mobility infrastructure.

Given this situation, a sectoral strategy is needed that prioritizes maintenance, signage, accessibility, and interconnection between modes of transport. Measures such as safe pedestrian crossings, the expansion and connection of bike lanes, and the reinforcement of the arterial network can contribute to a more balanced system. In conclusion, moving towards efficient and sustainable urban mobility requires redistributing and adapting the road network, taking into account the diversity of urban routes and the integration of all modes of transport, in order to achieve a more connected, equitable, and safe city.

METHOD

The methodology used within the positivist paradigm has a mixed approach based on objective observation, the collection of verifiable data, and the accurate measurement of relevant variables integrated into a geospatial model using GIS. The method applied is scientific, empirical, and analytical, allowing for a systematic and rigorous analysis of the phenomena observed, based on empirical data obtained through technical and analytical tools.

Its type and research design are descriptive and experimental. For data collection techniques, a database was used that was constructed through the author's observation, satellite images, and secondary cartography, processed and analyzed using Excel and geospatialized. Similarly, AutoCAD was used for the survey and graphic representation of subvariables such as the layout and width of sidewalks. The methodology consists of a detailed analysis of pattern identification, trend evaluation, and interpretation of results.

On the other hand, the study areas were selected through the analysis of census sectors classified by DANE[5], taking values above 175,9 inhabitants per hectare, which resulted in four identified areas. This value is estimated by regrouping the data into intervals.

In these sectors, the variables associated with urban accessibility were evaluated by calculating the accessibility index by proximity, using map algebra in a GIS environment. The methodology comprises three processes: (1) a quantitative analysis of the coefficient of residential use, facilities, public space, commercial space, and services. (2) A qualitative analysis of the hierarchical road system, using GIS and CAD tools to determine the morphology and materiality of the road infrastructure; and finally (3) the obtaining of an accessibility index through the application of map algebra, where the previous results were integrated into a mathematical operation.

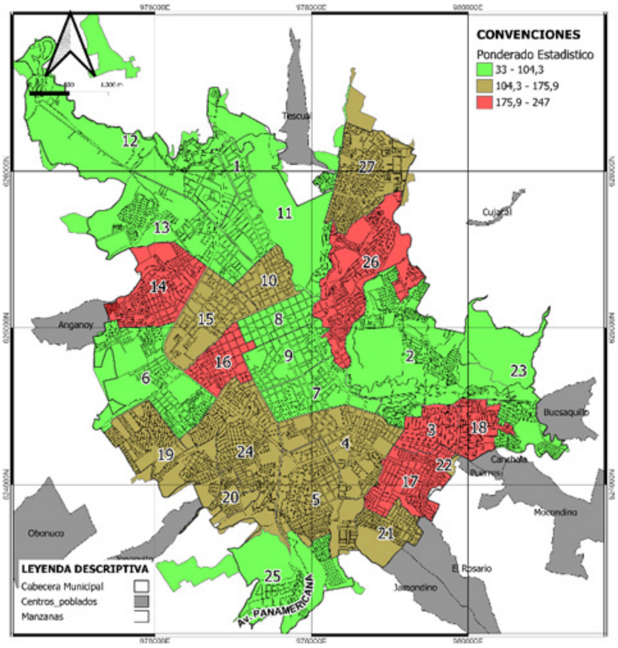

Figure 1. Population density in highly dense sectors

Table 1. Population density in highly dense sectors						
Study area	DANE census sector	Pop. (Hab)	Area (ha)	Population density (inhabitants/ha)	Gross housing density (Housing/Ha)	Net housing density (Housing/Ha)
A1	3 17,18	31 847	144,85	219,85	75,87	153,30
A2	14	17 583	85,78	204,98	85,85	207,24
A3	16	7692	42,78	179,80	73,89	140,73
A4	26	23 678	132,47	178,73	69,69	203,79

The proximity accessibility index is a dimensionless measure resulting from the normalization and combination of spatial variables such as pedestrian connectivity and the presence of urban destinations within a given travel time.[6] A methodology was developed to integrate the results of the reclassified layers into a single analysis, allowing accessibility to be evaluated from a multifactorial approach through map algebra. Seven indicators were consolidated into a cartographic product that reflects the actual conditions of pedestrian accessibility by considering the functional diversity of the environment, as well as the structure, condition, and functionality of the road network.

The formula designed assigned a weight of 50 % to the quality of the road infrastructure, given its direct impact on pedestrian travel, while intersections and mix received weights of 30 % and 20 %, respectively. For analysis, the values were classified into quartiles (Q1 to Q4).

Residential compatibility with other land uses

To understand the spatial structure and distribution of uses in the city, the study areas are analyzed based on the calculation of mixed-use indices, as presented by Vicuña M et al.[7] and adapted based on the MXI (Mixed Use Index).[8] The index relates density to diversity of uses to promote efficient and sustainable land use. It is not enough to simply understand the occupancy and construction indices of residential and non-residential properties, but also to understand how this mix is being managed and whether or not it is in balance.

The characterization of the study areas is presented according to the area designated for residential use, community facilities, service and commercial establishments, as well as the available public space, prior to its inclusion in the calculation of the mix index.

Table 2. Area of occupation and construction for residential use in the study areas

Data for each sector		Housing per sector					Occupancy		Buildability	
Study Areas	Population	Area (Ha)	Housing (Housing)	Mixed (Housing)	Non-Residential (Housing)	House holds	Occupied Area (Ha)	Residential Area (Ha)	Construction Area (Ha)	Residential Area (Ha)
A1	31 847	144,86	10 991	558	1008	9959	83,51	71,70	261,03	223,45
A2	17 583	85,78	7364	136	322	6228	40,12	35,53	127,31	111,56
A3	7692	42,78	3161	117	514	2814	26,97	22,46	108,35	92,89
A4	23 678	132,48	9233	212	689	8154	50,22	45,31	152,01	138,88

Table 3. Construction area for facilities in the study areas

Study areas	Construction area (Ha)					Total area for facilities (ha)	Total area for other facilities (ha)
	Education	Health	Social welfare	Culture	Recreation facilities		
A1	8,29	2,62	0,28	0,24	0,56	11,99	0,98
A2	0,26	0,46	0,65	0,00	0,09	1,46	7,32
A3	1,56	0,03	0,72	0,06	0,16	2,53	0,75
A4	3,51	0,96	0,40	0,11	0,16	5,13	2,97
Total	13,62	4,07	2,06	0,41	0,96	21,12	12,02

Table 4. Construction area for service and commercial establishments in the study areas

Study areas	Services (Ha)			Total service area (Ha)	Commerce (ha)			Total area of commerce (Ha)	Area (Ha)
	Supply	Personal care	Leisure		Trade	Food consumption	Beverage consumption		
A1	4,59	0,99	0,21	5,79	0,61	1,74	0,10	2,46	8,25
A2	1,58	0,34	0,01	1,93	0,21	0,49	0,07	0,77	2,70
A3	1,41	0,30	0,14	1,84	0,17	0,96	0,21	1,34	3,18
A4	1,08	0,56	0,20	1,84	0,08	0,42	0,02	0,52	2,36
Total	8,66	2,18	0,57	11,40	1,07	3,62	0,40	5,09	16,49

Table 5. Area of public space in the study areas

Study area	Public space (Ha)			
	Neighborhood sports fields	Parks and squares	Green areas	Total public space
A1	3,40	3,42	1,40	8,22
A2	0,76	1,43	1,96	4,16
A3	0,07	0,32	0,51	0,90
A4	0,72	0,71	6,71	8,13
Total	4,95	5,88	10,58	21,41

The results are used to calculate the coefficients of equipment mix (CUE), services and shops (CUC), public space (CUEP), and residential (CUR) using the following formula:

$$CU = \frac{\text{Área de construcción del uso estudiado} - \text{Área de construcción de los otros usos}}{\text{Área de construcción total}}$$

A2 has the highest percentage of equipment area in relation to the size of the study area that supports it, exceeding 56 %. Furthermore, in this area, the use is proportional between housing, population, and households, which makes it noteworthy for the study. A1, A3, and A4 have a similar percentage in terms of facilities, but only area A1 can be said to maintain a balance between commercial and services with respect to public space, as these latter categories have approximately equal percentages.

A3 is the area with the highest distribution of services and commerce, and A4 (a potential expansion zone) located on the outskirts of the city of Pasto is where residential development has not been as strong as in other areas. In addition, in this area, the urban fringe plays a predominant role for recreational and public use until it is urbanized, included in the count of public space.

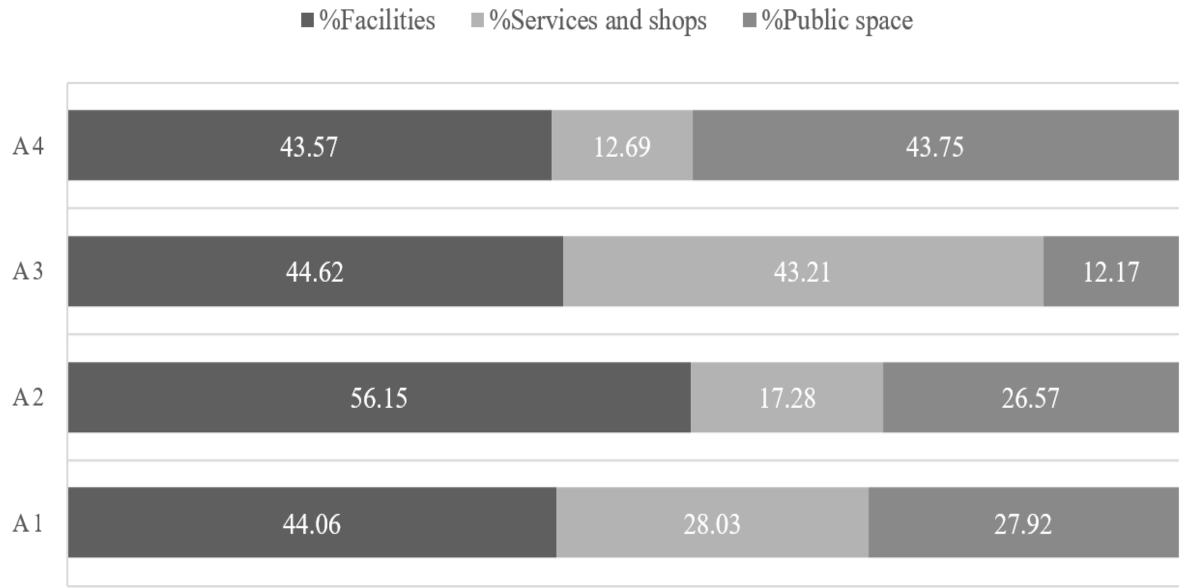

Figure 2. Percentage of facilities, services, commerce, and public space in relation to the total area of establishments in each study area

Residential use largely dominates over other land uses, which represents an opportunity to functionally diversify these areas. However, the current distribution of uses does not always comply with current regulations, probably due to the presence of pre-existing activities that were initially established informally, adapting uses other than residential, and which in some cases may be incompatible with regulations.

Despite this lack of compliance with regulations, residential use continues to account for more than 70 % of land in all study areas. According to the General Model for Building Capacity and Loads of the 2015-2027 POT, up to 40 % of the building capacity in residential areas can be allocated to other uses, which would allow at least 20 % of residential land to be integrated into mixed-use activities. However, the expansion of mixed uses must be considered in a balanced manner.

In the city, mixed uses have emerged as a response to necessity, without adequate planning or strategic distribution of similar activities. Currently, the remaining 30 % of land allocated to facilities, public space, services, and commerce has generated urban conflicts due to the lack of adequate road profiles and the concentration of incompatible establishments. Adding 20 % more mixed uses without structured planning would not be an effective solution, but could exacerbate existing problems, intensifying disorder and lack of territorial integration.

Additionally, the mixed-use coefficients analyzed reflect, a priori, a low level of functional land integration, suggesting an underutilization of its potential. The incorporation of mixed uses, under clear regulatory criteria, would not only optimize land use but also improve cohesion, urban connectivity, and ultimately proximity to and from residences. It is essential to implement strategies that balance the predominant residential use with commercial and institutional activities and public spaces, promoting a more efficient, functional, and sustainable city in line with current regulations.

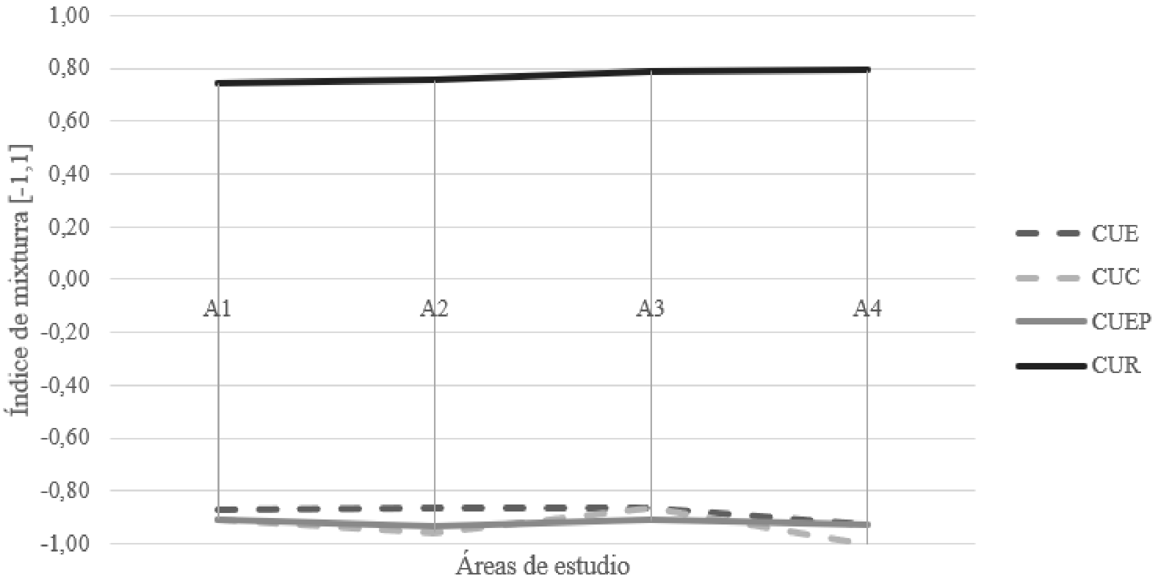

Figure 3. Index of mixed use for each study area

Road infrastructure and traceability of the areas studied

When comparing the general plans of Agreement 004, POT 2015-2027[9], with the territorial visions for sustainable and safe mobility, there is a clear disconnect between what was planned and the implementation of that planning. By spatializing the hierarchical road system, the length of the infrastructure and the percentage of participation of each one was obtained.

Table 6. Length of roads in the city of Pasto

Hierarchical road system		Length (km)	%
Pedestrian		16,25	3,23
Bike path		12,23	2,43
A1	Arterial road	19,79	3,93
A2	Foundational ring	3,18	0,63
A2	Central ring	11,38	2,26
A3	Intermediate arteries	33,73	6,70
A3	Minor arteries	58,93	11,70
L1	Primary local	75,24	14,94
L2	Secondary premises	272,87	54,19

The analysis reveals that 87 % of the road network is made up of intermediate, minor, and local roads, which, due to their design and dimensions, cannot fulfill structural functions like main arteries. This condition limits urban connectivity, hinders access to essential services, and slows down the development of sustainable infrastructure. In addition, the presence of bike lanes (2,43 %) and pedestrian-only roads (3,23 %) is low, which shows an unbalanced distribution of road space.

Once the road system survey was completed, the urban layout was analyzed to determine the configuration of the blocks and the distribution of infrastructure. The city has three main typologies: linear, orthogonal, and organic. Linear layouts follow straight axes determined by the topography, facilitating fast travel but with less cross-connectivity. Orthogonal layouts, typical of flat areas, adopt a grid pattern that favors orientation, efficient infrastructure distribution, and the implementation of public transportation.[10] Organic layouts, on the other hand, are the result of spontaneous growth and have irregular shapes that hinder accessibility and the efficient provision of services.[11]

Each type of trace poses different challenges and opportunities for mobility, social integration, and territorial planning, so analyzing them by study area is key to guiding interventions that improve connectivity and accessibility, while maintaining the morphological identity of each sector.

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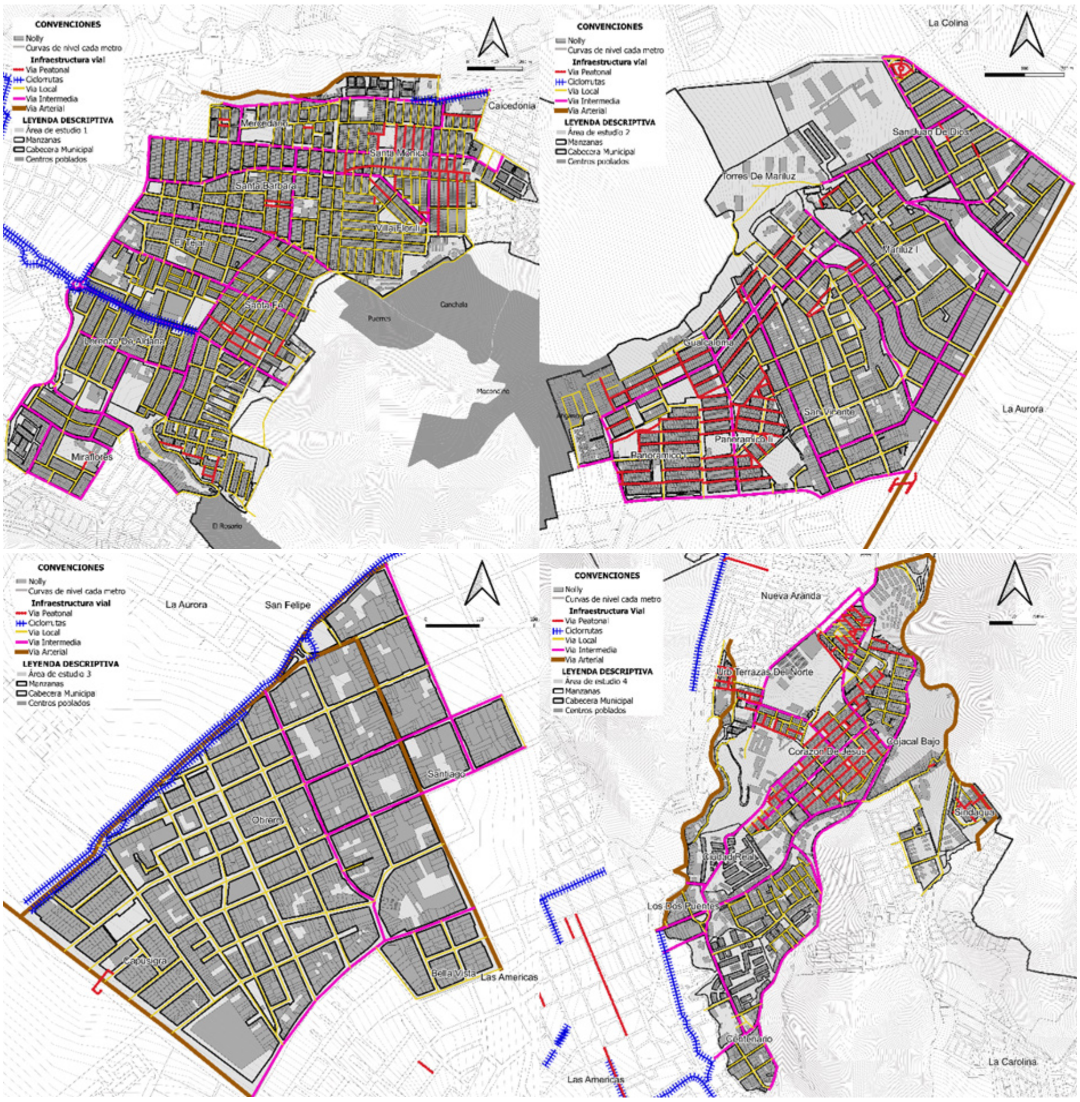


Figure 4. Traceability of the selected areas

The shape of the blocks is mainly influenced by the topography and the predominance of intermediate, minor, and local roads. In most cases, growth has been spontaneous, generating irregular occupations adapted to the relief, with elongated and narrow shapes that form linear traces. Less structured organic traces are also observed, resulting from changes in the direction of the contour lines, which interrupt road continuity and hinder connectivity.

Study area 3 is an exception, as its proximity to the historic center favored regular grid planning, the result of a structured design. A review of technical land-use planning documents and an analysis of the "Superblocks" model under Sustainable Transport Oriented Development (STOD) criteria[12] show that, although there is a connection between areas, the infrastructure does not always favor pedestrians or cyclists. This confirms that the diversity of routes not only responds to the physical shape of the territory, but also influences the quality of urban space and the possibility of implementing sustainable mobility.

Evaluation of road infrastructure

Three important documents are considered for road rating: the manual on the adaptation of effective public space, presented by Santiago de Cali[13]; the guidelines on cycle paths, presented by Ministry of Transport[14]; and the definitions and types of cycling infrastructure set out in the guide to cycling infrastructure in Colombian cities, published by the Ministry of Transport[15], which took into account four criteria: (1) continuity and availability of road profile, which assesses dimensional equality throughout the entire road profile and guarantees a safe, accessible, and efficient route for pedestrians and cyclists. (2) Road profile width, and (3) signage and connection to permanent features, defined by adequate pedestrian crossings and connection to bus stops and green areas. Finally, compliance with the standard is analyzed to determine whether the road profile corresponds to the provisions of Annex AFS1 of the 2015-2027 POT (Land Use Plan). Road profiles.[16,17]

Table 7. Weighting of the criteria analyzed in the road profiles

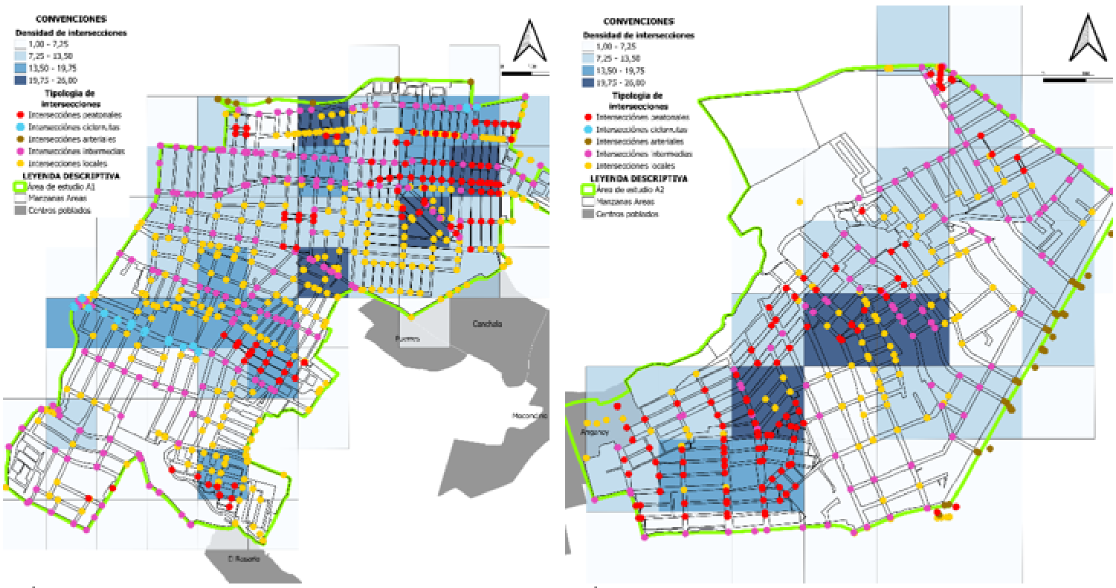
Criterion \Weighting	Poor (1pt)	Fair (2pt)	Good (3 points)
Continuity and availability of road profile in optimal conditions	The road profile has continuity of less than 20 % of its length	The road profile has continuity over 50 % of its length	The road profile has continuity over 100 % of its length
Profile width	Sidewalks and pedestrian walkways less than 1,50 meters.	Sidewalks between 1,50 meters and 2 meters Pedestrian paths between 2 and 3 meters Bike lanes of 1,40 meters	Sidewalks greater than 2 meters. Sidewalks wider than 3 meters Bicycle lanes of 2,40 meters
Signage and permanent connections	No signage of any kind	Signage is in poor condition and there is a bus stop nearby	Has pedestrian crossings and connections to bus stops and green areas
Compliance with Annex AFS1. Road profiles.	Does not comply	Complies with the layout of road elements	Complies with the layout of road elements and measures
WEIGHTED	Between 0 and 5 points	Between 6 and 9 points	Between 10 and 12 points

Road conditions in the study area vary considerably depending on the type and location. Area 3 stands out positively for having the highest percentage of bike lanes, most of which are in good condition, and for having a good proportion of well-maintained arterial roads, which positions it as an area with higher quality road infrastructure. In contrast, area 4, although it has the largest number of pedestrian and arterial roads, has high percentages in fair or poor condition, highlighting the need for improvements in maintenance and signage. Area 1, with the highest proportion of local and intermediate roads, shows a predominance of fair condition due to deficiencies in signage and connectivity.

Road connectivity measured by intersections

The diagnosis of the current infrastructure reveals the importance of ensuring safe pedestrian crossings to maintain the continuity and protection of walking routes. The lack of connection between pedestrian sections and insufficient or inadequate signage interrupt active mobility flows and reduce the accessibility of urban space. These crossings not only serve as passage points, but also act as essential links that ensure coherent and protected routes, reinforcing the pedestrian network, especially in residential areas where walkability and proximity to services are key.

To assess road connectivity and locate areas at risk of pedestrian disruption, intersection density calculations were used, a common tool in transportation and urban planning. This method, supported by a regular grid, allowed for accurate measurement and visualization of intersection density using platforms such as OpenStreetMap and QGIS.



✓ Mayores intersecciones locales
✓ Dos tramos de ciclorruta
✓ Vías intermedias conectan con vías locales

✓ Mayores intersecciones peatonales
X No tiene ciclorruta
✓ Vías intermedias conectan con vías arteriales

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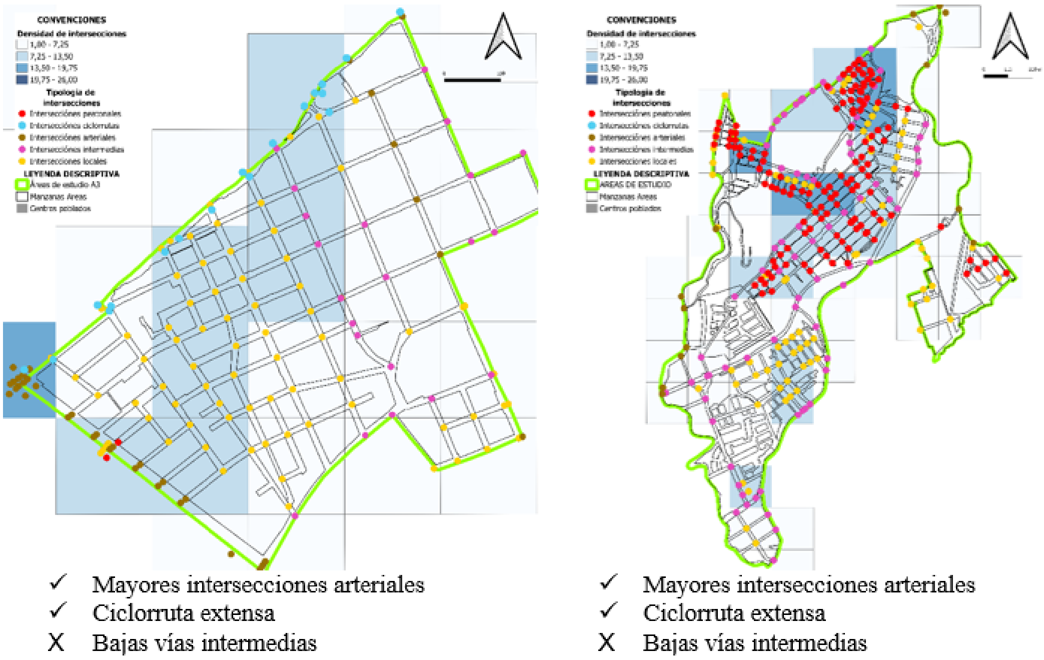

Figure 5. Intersection density in the study areas

Local and intermediate intersections account for nearly 60 % of the road network, while arterial roads have a reduced presence. This shows a structure designed for neighborhood connectivity, but with little capacity to handle higher traffic flows. In some areas, pedestrian intersections account for 43 %, highlighting the need to strengthen infrastructure that promotes sustainable mobility; however, the absence of bike lanes in several sectors reveals shortcomings in the implementation of the plan.

The areas studied show inequalities in the quality, distribution, and functionality of the roads, with a predominance of neighborhood and collector intersections that, although they provide local connectivity, fail to play a structuring role. This results in fragmentation of the network and difficulties in connecting different areas of the city. While Area 3 has better roads and an adequate proportion of bike lanes, Area 4 is dominated by sections in fair or poor condition, with problems of maintenance, signage, and continuity. In addition, the disconnect between bike lanes and their poor integration with other types of roads limits the functionality of the system.

Accessibility index

To analyze mobility infrastructure in terms of proximity, certain elements of urban space are assessed in relation to a starting point. In this regard, each of the resulting vector layers—land use, road assessment, and intersection type—was classified. Once classified, these layers were converted into raster format to subsequently create proximity maps that facilitate spatial understanding of the territory and the identification of areas with better pedestrian accessibility conditions.

Table 8. Classification of vector layers

Vector layer	Classes
Land use	Single-function (residential and environmental landscape use) Multifunctional (mixed use, commercial, institutional, recreational, green areas)
Road assessment	Good Fair Poor
Type of intersections	Pedestrian priority intersections (pedestrian and bike path intersections) Vehicle priority intersections (arterial intersections, intermediate intersections, and local intersections)

The general logic applied is based on the assumption that proximity to a positive criterion improves pedestrian accessibility; therefore, the closest elements receive a higher weighting, while those further away are considered less relevant. Conversely, proximity to a negative criterion reduces pedestrian accessibility and therefore receives the lowest weighting. The ranges were considered as follows:

Table 9. Distance ranges according to the criterion evaluated

Value	Positive Distance	Negative Distance
1	More than 500 m	Between 0 and 100 m
2	Between 100 and 500 m	Between 100 and 500 m
3	Between 0 and 100 m	More than 500 m

The analysis reveals that the neighborhoods of Santa Monica, Mercedario, Santa Barbara, and part of southeastern Miraflores have high levels of accessibility thanks to their proximity to facilities, shops, services, public spaces, good pedestrian connectivity, and favorable infrastructure conditions. In Miraflores, this condition is heterogeneous.

In contrast, areas such as Lorenzo de Aldana, Santa Fe, El Tejar, parts of Villa Flor II, and some areas of Miraflores show low accessibility, not so much due to the absence of services, but rather due to the poor quality of access routes, which are affected by deterioration, lack of continuity, or insecurity, creating so-called "radios of absence."

It was also evident that urban grid patterns with good connectivity and continuity in the infrastructure for active mobility favor accessibility, while fragmented patterns, physical barriers, and the interruption of pedestrian or bicycle networks limit it.

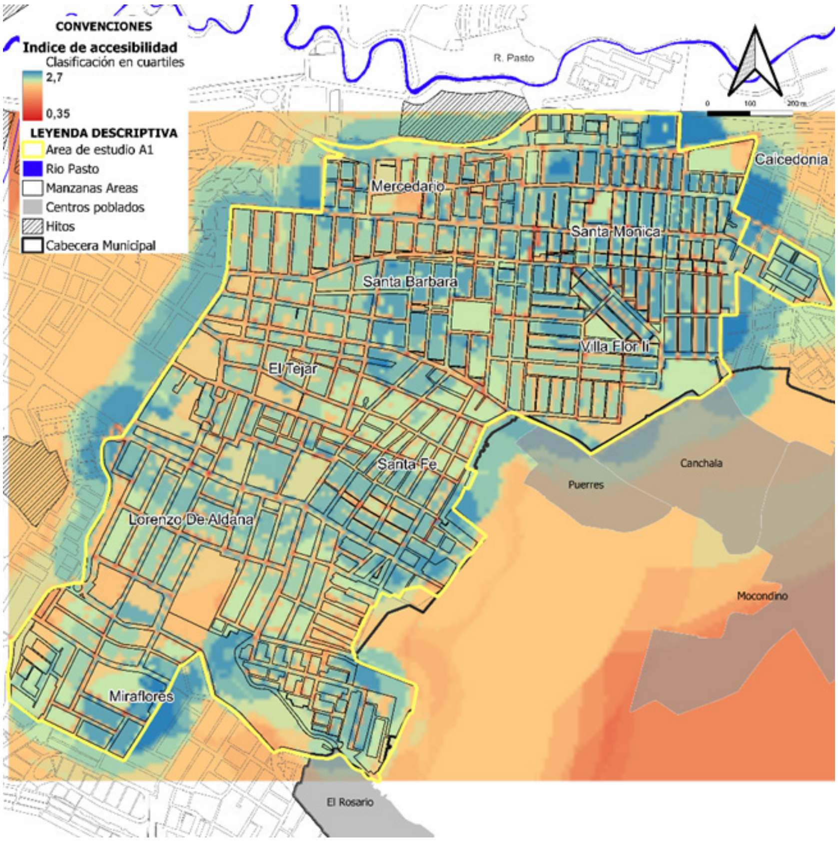

Figure 6. Accessibility index by proximity to the study area 1

The sectors with the highest accessibility are located in different parts of the territory, notably in the areas of Mariluz I, Gualcaloma, San Vicente, and Panorámico II, which are favored by an efficient road network and proximity to facilities. A similar pattern can be observed along the Pan-American Highway, where a pedestrian bridge improves access conditions in the surrounding area.

In contrast, the areas with the lowest accessibility, located mainly in the northwest and southwest, face different limitations: in the northwest, gated communities restrict pedestrian connectivity; in the southwest, near Anganoy, the poor quality of road infrastructure, limited services, and restricted mobility affect access, despite the existence of a green corridor and some pedestrian crossings, the latter of which are in poor condition and unable to improve the quality of travel.

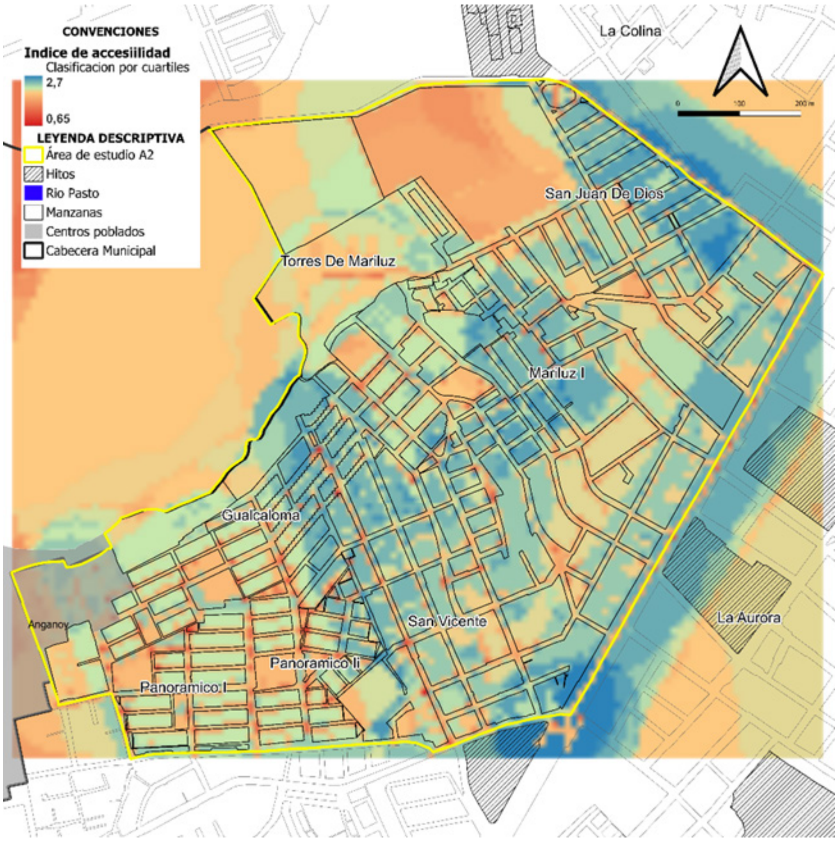

Figure 7. Accessibility index by proximity to the study area 2

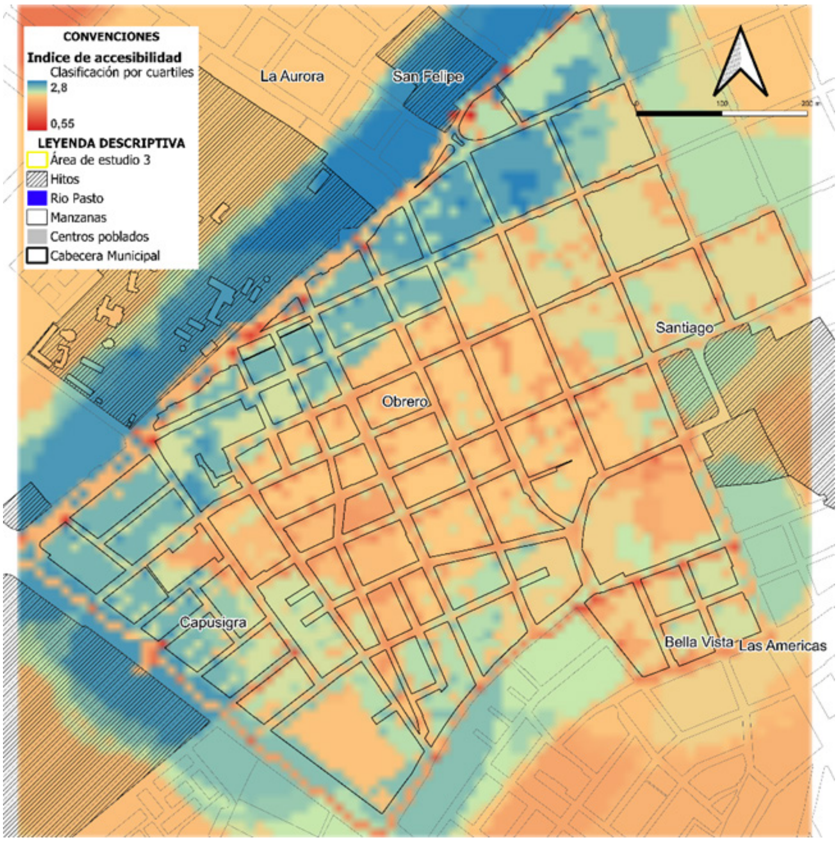

Figure 8. Accessibility index by proximity to the study area 3

Some peripheral areas, mainly to the north and southwest of the study area, show high levels of accessibility thanks to their proximity to main roads and strategic facilities. In sectors such as the Carrera 27 axis, recent urban projects have incorporated a road design that favors pedestrians, cyclists, and vehicles, improving

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connectivity. The lower building density in these areas also facilitates pedestrian mobility.

In contrast, the neighborhoods of Obrero, Santiago, and part of Bella Vista are the least accessible areas. The dense urban layout, high frequency of intersections, lack of direct routes, and deficiencies in pedestrian infrastructure (narrow sidewalks, low priority for pedestrians, and scarcity of establishments) limit travel efficiency.

In this area, accessibility is high along the central axis connecting the neighborhoods of Heart of Jesus, The Two Bridges, and Ciudad Real, favored by an efficient road network and proximity to urban facilities. In contrast, the extremes of the area, such as Sindagua, part of Centenario, and the surroundings of Nueva Aranda, have lower accessibility due to deficiencies in road infrastructure, lower connectivity of the urban fabric, and, in some cases, the presence of gated communities that interrupt the continuity of the urban fabric.

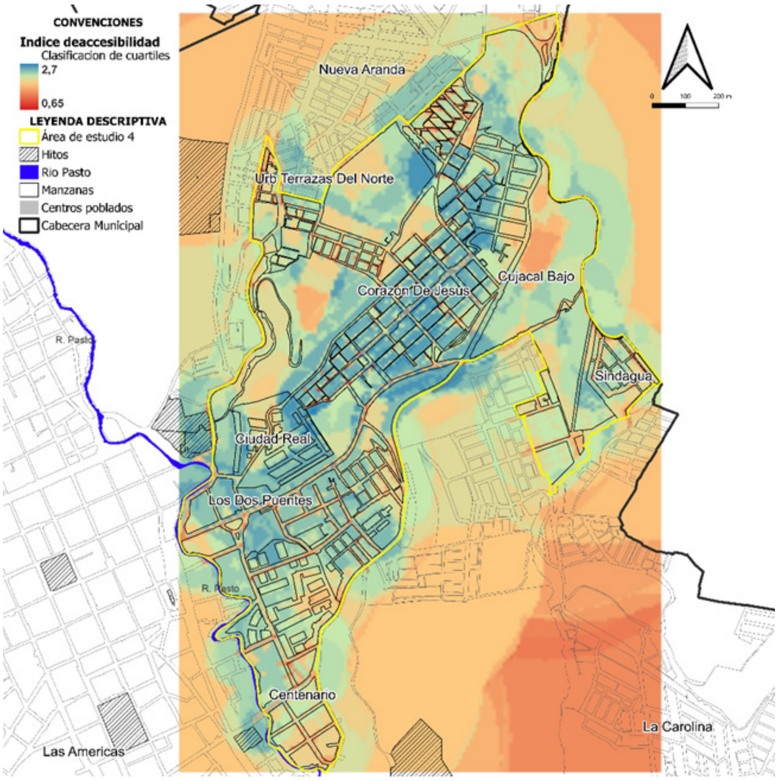

Figure 9. Accessibility index by proximity to the study area 4

Spatial analysis of the four areas evaluated reveals inequalities in pedestrian accessibility and proximity to services, which limits the consolidation of an equitable urban environment. In this context, the 15-minute city model, based on proximity to essential facilities and ease of walking, allows us to identify areas that are more aligned with its principles.

Area 1 is the closest to this model, combining a diverse range of services, continuous pedestrian infrastructure, and a connected urban structure, especially in neighborhoods such as Santa Monica, Mercedario, and Santa Barbara. It also has a low value in the first quartile (Q1 = 0,35), indicating a lower proportion of critical sectors compared to other areas. Although Area 3 achieves the highest maximum accessibility value (Q4 = 2,80) and maintains a homogeneous distribution, its main strength lies in the regularity of its urban layout, which favors connectivity and the implementation of improvement strategies.

Table 10. Classification of accessibility index quartiles

INDEX	Q1	Q2	Q3	Q4
A1	0,35	2,00	2,25	2,70
A2	0,65	2,00	2,20	2,70
A3	0,55	2,10	2,30	2,80
A4	0,65	1,80	2,15	2,70
Median	0,60	2,00	2,23	2,70

In both cases, the incorporation of mixed land uses and the optimization of pedestrian crossings through adequate signage would strengthen accessibility conditions. In contrast, areas 2 and 4, although they have nodes with good accessibility, exhibit a more fragmented distribution that is dependent on specific axes, which reduces their territorial functionality. In summary, areas 1 and 3 stand out for their greater potential to approach the 15-minute city model, provided that interventions aimed at improving equity in access and consolidating efficient and safe active mobility are prioritized.

CONCLUSIONS

Urban growth in Pasto has followed a largely spontaneous dynamic, geared toward responding to immediate needs and without planning consistent with the guidelines of the 2015–2027 POT. This pattern has generated a fragmented urban configuration, with services, facilities, and businesses distributed in a scattered and reactive manner, which weakens the cohesion of the urban fabric. Although several sectors meet spatial coverage requirements within a 500-meter radius, the lack of coordination between green, institutional, and commercial corridors reduces functional accessibility and limits the development of sustainable mobility. The current model continues to prioritize the use of private vehicles over pedestrians and cyclists, as evidenced by the lack of integrated networks of bike paths, pedestrian routes, and connected public spaces.

The territorial diagnosis indicates that road infrastructure, bicycle routes, and pedestrian paths do not form a cohesive system. In addition, 30 % of urban land has land use conflicts, as incompatible activities are concentrated in areas with insufficient road profiles. The low functional integration of land and a possible unplanned increase in mixed uses could intensify these problems. Although Area 3 has pedestrian routes and commercial concentration in the subregional center of the expanded downtown, its edges lack centrality and show scattered and poorly connected urban corridors.

To reverse this situation, it is recommended to relocate and redistribute facilities, prioritizing proximity to high-density areas, linking green, commercial, and institutional networks, and strengthening active mobility through safe pedestrian crossings and accessible infrastructure. It is also proposed to design sectorized interventions that consider population density and current accessibility deficits. Areas 1 and 3 are emerging as the most suitable for moving towards a 15-minute city model, thanks to their favorable connectivity conditions and potential for improvement.

Finally, for future studies, it is suggested that the classification and rasterization of the origin-destination matrix be incorporated, as well as the use of mixture indices as quantitative indicators, in order to more accurately assess the degree of integration and efficiency of the urban system.

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AUTHORSHIP CONTRIBUTION
Conceptualization: Karen Larisa Pabón Jaramillo.
Data curation: Karen Larisa Pabón Jaramillo.
Formal analysis: Karen Larisa Pabón Jaramillo.
Drafting - original draft: Karen Larisa Pabón Jaramillo.
Writing - proofreading and editing: Karen Larisa Pabón Jaramillo.