INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 16, Issue 2, 2025: 1087-1098 www.ijcs.ro
DOI: 10. 36868/IJCS.2025.02.21

# MULTI-CRITERIA ANALYSIS METHODOLOGY FOR THE LOCATION OF PARKS AND RECREATION AREAS IN AN URBAN AREA. CASE STUDY: MANIZALES, COLOMBIA

Andrés MURCIA HERNÁNDEZ[1,*], Diego Alexander ESCOBAR GARCÍA[1], Carlos Alberto MONCADA ARISTIZABAL[2]

[1] Universidad Nacional de Colombia, Sede Manizales. Facultad de Ingeniería y Arquitectura, Departamento de Ingeniería Civil, Grupo de Investigación en Movilidad Sostenible, Campus La Nubia, Carrera 37 – Calle 94, Bloque S2 – oficina 208, Manizales, 170003, Colombia
[2] Universidad Nacional de Colombia, Sede Bogotá. Facultad de Ingeniería, Departamento de Ingeniería Civil y Agrícola, Programa de Investigación en Tránsito y Transporte – PIT, Ciudad Universitaria, edificio 214, oficina 417, Bogotá 111321, Colombia.

***Abstract***

*The objective of this research is to develop a proposal based on the direct relationship between disease reduction and accessibility to parks and recreational areas in an urban area. This is developed based on a Multicriteria Analysis Weighted Superposition applied in the city of Manizales, Colombia; it is based on four main criteria: calculation of geographic accessibility to parks, effective public space index, age group age rate and rate of mental and cardiovascular diseases. The weighting mechanism used is the Analytic Hierarchy Process, which, by making a pairwise comparison, helps to establish a consistent system by distributing the importance in percentage terms.The results show the areas of the city with the most critical conditions according to the criteria proposed, highlighting the poor demographic conditions of the population and how these are related to urban planning. In these areas, the implementation of new parks and areas that function as effective public space is proposed, to later measure in population terms the benefits that this brings. In conclusion, it is established that the methodologies presented function as objective mechanisms for decision making in the field of urban planning.*

**Keywords:** *Multicriteria Analysis; Geographic Accessibility; Demographics; Park; Public Space*

## Introduction

Urban planning in cities is directly influenced by the demographic conditions of the population, as stated by *S. Xhafa* [1] in his publication. Given this, decision-makers in the area of urban planning are forced to innovate with new strategies that take advantage of new technologies and the different objective methods available for decision-making that allow them to adapt to the conditions of the working population. This points to the publication made by *J. Gehl* [2], where he points directly to the human scale thinking, which consists of taking advantage of spaces to create environments that are used based on the needs and experiences of the actors who always have the priority in social and civil terms, the people.

Sustainable development has become, for many professionals, an irrefutable parameter of mandatory application in their work, as stated by *S. Wheeler* [3]. This, articulated with the area of

* Corresponding author: anmurciah@unal.edu.co

urban mobility, seeks to encourage people to make the most convenient decisions in the social sphere with respect to their modes of transport, travel frequencies and destinations, without neglecting their own interests; this can be exemplified by encouraging the use of public transport or active means of transport over private and individual transport, as *S. Chakrabarti* [4].

The city of Manizales (Fig. 1), located in the Colombian coffee-growing region, is also known informally as the "bubble" city, since, although its population is characterized by being friendly and intelligent, on many occasions it becomes indifferent to various complications that may be the daily life of the inhabitants of some other place in the Colombian territory. This, seen in broad strokes, translates into a media polarization on the part of the population and the competent entities that hinders the dissemination of information and creates a bias in the proposed solutions to different internal problems, as stated by *M. R. Lopez et al*. [5].


**Fig. 1.** Geographic location of Manizales. Source: Own elaboration

One of the aspects that works as a scourge for Manizales, and which was not given enough strength of disclosure is the health conditions, both physical and mental, of the population of Manizales, as this is one of the Colombian cities with higher rates of suicidal behavior; for example, in 2020, according to the report of *Instituto Nacional de medicina legal y ciencias forences* [6], with a rate of 7.2, Manizales occupied the tenth place among the Colombian cities with the highest rate and by 2023, this rate presented an increase of approximately 2.7 points, reaching 9.9, according to the reports of *Manizales cómo vamos* [7].

The identification of these problems makes it necessary for professionals to consider the alarming number of cases of mental illnesses such as depression and anxiety presented mostly in young people and in early adulthood, according to *L.P. Delgado et al*. [8], since these conditions prevail in percentage terms among mental illnesses, as explained by *A. Prieto Rodríguez* [9]. Likewise, it is important to consider the large percentage of inhabitants, mostly elderly, who present physical limitations and cardiovascular diseases, mainly triggered by sedentary lifestyles, poor eating habits and a lifetime of hard work.

Similarly, the lack of actions to remedy inequity in terms of accessibility to green spaces, effective public space areas or parks has become an indirect problem, given poor planning and lack of both usable space and mechanisms to help make decisions in terms of urban planning.

Synthesizing and defining a linkage between the different problems exposed, we arrive at the existing direct correlation that associates the ease of access to green or recreational spaces and the physical and mental health conditions of people, as stated by *T. Astell-Burt* [10]. Therefore, it is valid to quote *M. Kondo* [11]: "We found a consistent negative association between exposure to urban green spaces and mortality, heart rate and violence and a positive association with attention, mood and physical activity."

Following the different currents mentioned and using as a basis the theory described in the previous paragraph, this project proposes a possible solution to the problems in Manizales, which proposes the implementation of an objective mechanism based on a weighted superposition in a multi-criteria analysis (SPAM) named by *D.H. Prasetyo* [12] that extracts the percentages of respective importance of the quantitative method of pairwise comparison, Analytic Hierarchy Process (AHP). The core criteria to be used in the mentioned mechanism correspond to (1) the Effective Public Space Index (EPE), which was used in a similar way by *M. Jaramillo*. [13] and (2) conditions measured in time of the Geographic Accessibility (GA) calculation, as expressed by *W. Hansen* [14], to the Geographic Accessibility (GA) of the cities of the region, as expressed by *W.M. Aristizabal et al*. [15]. *W. Hansen* [14], to the points of interest corresponding to ornamental and children's parks, purely public sports scenarios and bio-healthy gyms, which are machines installed in public places that allow, by means of mobility, flexibility and resistance exercises, the improvement of the general health and physical condition of the population, as concluded by *T. Abelleira-Lamela et al.* [15]. For the purposes of this project, the set of these elements of interest will be called "*Blue Points."* (3) Index of tendency to suffer from mental and cardiovascular diseases (ITEMC) and (4) the population rate of the chosen age groups discretized by districts (TPGE).

To make it possible to measure the expected improvement with the implementation of this proposal, the project is divided into two phases: a) the initial phase, corresponding to the situation modeled with the current conditions and b) the future phase, which is modeled based on the addition of areas of Effective Public Space and Blue Points.

Finally, the identification of the areas of Manizales in the most critical conditions according to the SPAM analysis is giving way to the identification of these areas, which function as solid arguments for the subsequent recommendations to the competent entities seeking an integral improvement of the population. In addition, with the recommendation of new Blue Points and areas of Effective Public Space, the decentralization of the city of Manizales is strengthened and supports the urbanistic thinking dictated by the concept of the 15-minute city, a term coined by *C. Moreno* [16], which seeks to provide spatial equity to a population through the improvement in terms of geographic accessibility with the specific distribution of services as expressed by *J.E. Aristizabal et al.* [17].

## Methods

In order to organize the project in a consistent and methodical manner, in addition to being separated into two phases (Initial and final), it is divided into five stages, which contribute to the systematization and correct understanding of the project. These stages (Fig. 2) are described below.

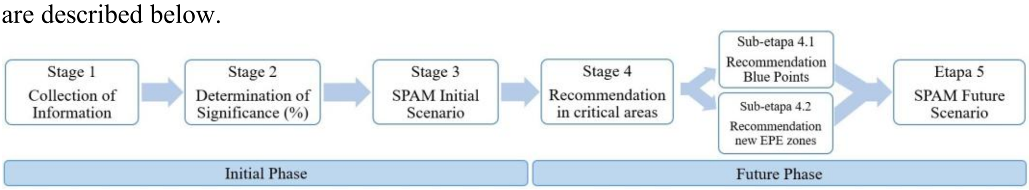


**Fig. 2.** Flow diagram graphically describing the methodology

***Stage 1.*** In order to correctly superimpose the four main criteria, two aspects must be clarified beforehand. The first is that this is done only in the area defined as the urban area of the city, taking advantage of its geographic limits, as shown in the geoportal of the Mayor's Office of Manizales [18-19] and as a consequence of the lack of information of the variables worked on corresponding to the rural area and the second aspect corresponds to the data entry. These are, respectively, (1) Atardeceres, (2) San José, (3) Cumanday, (4) La Estación, (5) Ciudadela del Norte, (6) Ecoturístico Cerro de Oro, (7) Tesorito, (8) Palogrande, (9) Universitaria, (10) La Fuente and (11) La Macarena.

*a.* ***The Effective Public Space (EPE)*** corresponds to the areas duly intervened with the objective that the citizenship is appropriated and used properly; these are mostly characterized by their area and by their primary objective for which they were built. For the purposes of this project, the areas of the EPEs are taken from the Public Innovation Laboratory of Manizales and the Secretariat of Urban Planning, represented with the help of the Open Street Maps (OMS) tool of the ArcMap geographic information system of the ArcGIS family, since this has become the best example of voluntary geographic information on the Internet, as expressed by *J. Arsanjani et al.* [20]. In order to make this variable comparable and valid, the calculation of the index that links the georeferenced EPE areas with the number of inhabitants of each district (NHC) is performed. These data are validated by the population projections shown in the Public Innovation Laboratory of Manizales [21]. The calculation is shown below, with "i" being the number that corresponds to each district.

$$\frac{EPE\ district\ i\ (m^2)}{NHCi} \tag{1}$$

*b.* ***The calculation of geographic accessibility (GA)***, is used in the field of urban planning as it is a model of the measurement of the spatial or temporal separation of human activity through the use of available transportation modes, as explained by *J.M. Morris et al.* [22]. For the purposes of this project, this calculation is performed taking the data provided by the municipal scenario coordination of the location of the Blue Points, which become the target after being properly georeferenced. In addition, the pedestrian network of Manizales is used, considering the average walking speeds and the lengths of each arc, to thus give way to the use of the macro modeling software of transportation, TransCAD and using the basic equation of $t = d/v$. The minimum travel times that people must spend, depending on their position in the city, to access any of the Blue Points can be identified.

*c.* ***The calculation of the index of tendency to suffer from mental and cardiovascular diseases (ITEMC)*** is defined by equation 2, which arises from the collection, cleaning, and reorganization of information obtained from reports on various strategies, such as campaigns and outreach policies offered by the Manizales mayor's office, such as, for example, the Health Situation Analysis Campaign (ASIS) of Manizales mentioned by *C. Humberto* [23], which serve as a source of useful information for the purposes of this project, such as the number of people with a tendency to suffer from cardiovascular (PTEC) or mental (PTEM) diseases. All this, combined with its demographic particularities and being properly georeferenced, allows discretizing each of the districts of Manizales "i."

$$\left(\frac{PTEM\ district\ i}{NHCi} + \frac{PTEC\ district\ i}{NHCi}\right) * 100000 \tag{2}$$

*d.* ***The calculation of the rate of persons in age groups (TPGE)*** takes place at the culmination of *Stage 1*. *L. Martinez* [24], from the definition of the age groups to be targeted according to the previously mentioned demographic conditions; its determination starts from separating the population according to their age into the following four groups: PGE1 or Younger (0 to 24 years), PGE2 or Adults (25 to 49 years), PGE3 or Older Adults (50 to 74 years) and PGE4 or Seniors (over 75 years); of which, for the purposes of this project we work only with the first and last group respectively named, in addition to all the conditions for which they were chosen, we add the temporary availability in terms of workloads and the intentions of these groups to take advantage of the availability of the Blue Points or EPE's. To calculate this rate, *Equation 3* is used, which considers the number of people in the age groups (PGE) and the number of people living in the analyzed district "i."

$$\left(\frac{PGE1}{NHCi} + \frac{PGE4}{NHCi}\right) \quad \textbf{(3)}$$

***Step 2.*** Having defined and organized the criteria with which it is desired to work, it is processed to use the method of the Saaty matrix or Analytic Hierarchy Process (AHP), which allows relating in a qualitative way a scale of values that goes from 1/9 to 9 with a scale of importance with respective similarity that goes from the term of "No Absolute Importance" (Value of 1/9) to "Absolute Importance" (Value of 9). Now, this scale is used to make comparisons of the variables in pairs, with which the hierarchical comparison matrix is formed in which, at all times, the elements of the main diagonal will be 1 and the rest of the values correspond to the percentage of importance that each of the criteria has so that when added together they give a hundred percent of analysis, as explained by *S. Omkarprasad* [25]. These comparisons allow the weighting system to be proposed once the Inconsistency Ratio (IR) has been measured, as explained by *E.A. Nantes* [26].

To calculate these percentages, different equations are used in which the value of "n" corresponds to the number of axis criteria (from 1 to 4 in this case). These are defined below:

We = Normalized weight of each variable to be compared.

$$We = (C1 * C2 * \ldots * Cn)^{\frac{1}{n}} \quad \textbf{(4)}$$

Cfe = Coefficient of importance of the variable to be compared.

$$Cfe = We/\Sigma We \quad \textbf{(5)}$$

Pe = Sum of the values given to the compared variable.

As the AHP method supports the comparison between multiple variables, it measures its reliability and consistency with several values, which are shown below:

λe = Individual coefficient of the variable to be compared.

$$\lambda e = Ce * Pe \quad \textbf{(6)}$$

λmax = Sum of all the λe.

Ce = System Inconsistency Index.

$$Ce = \frac{\lambda max - n}{n - 1} \quad \textbf{(7)}$$

Rce = Saaty's Random Coefficient.

$$Rce = \frac{1{,}98 * (n - 2)}{n} \quad \textbf{(8)}$$

CR = System Inconsistency Ratio (between 0 and 0.1).

$$CR = Ce/Rce \quad \textbf{(9)}$$

***Stage 3.*** Using the percentages of importance established in *Stage 2* for each of the criteria, the "Weighted Overlay" tool of the ArcMap geographic information system is used, which allows the initial SPAM analysis to be fully executed and allows the identification of the four different zones resulting from the internal categorization of the aforementioned tool, as also expressed by *A. Kuru* [27]. These zones are named in alphabetical order, where "A Zones" are those in which the population has the most favorable conditions and "D Zones" are those in which the population is in the most critical conditions.

***Stage 4.*** To begin the *Future Phase*, it is necessary to interpret the results obtained in *Stage 3,* since, thanks to the appearance of the categorical zones, the area of focus is reduced to the two most critical zones, corresponding to Zones C and D. With the objective of reducing the area of these zones or, in other words, the number of people living within these areas, several recommendations are made, which, for a better understanding, are divided into two sub-stages: 4.1) the recommendation of adding new Blue Points to seek an improvement in terms of geographic accessibility and 4.2) recommending the adaptation, creation or restoration of various places that contribute to the improvement of the EPE.

For the determination of the suitable spaces in which sub-stage 4.1 can be made effective, five conditions determined by the authors are used, which are the most appropriate for the realization of these "filters" and are applicable with the information obtained. These conditions depend directly on the information obtained from the National Geostatistical Framework integrated with the National Population and Housing Census made by the National Administrative Department of Statistics (DANE) in 2018, as expressed in the DANE Geoportal [28]; these conditions are (a) that the area corresponds to an unbuilt space (vacant land), (b) that the space is a green area without due use, (c) that the space does not correspond to an industrial area, (d) that the area is not part of any natural reserve or protected place and (e) that the area is located within the area of Zones C or D of the initial SPAM.

In order to make the recommendation for sub-stage 4.2, three specific conditions are established, which are determined by the authors with the objective of facilitating the identification of suitable areas. These are a) that it is a green area without proper use (abandoned or in a deplorable state), b) that it is a sports venue in poor condition or not initially considered and c) in cases where pedestrianization of streets is considered, that the pedestrian flow that passes through it is considerably greater than the vehicular flow. These new areas, as in sub-stage 4.1, are formulated to be located in Zones C and/or D in order to contribute to the reduction of their respective areas.

***Stage 5.*** With the initial criteria already modified according to the results obtained in the previous stages, the "Weighted Overlay" tool of ArcMap is used again to perform the future SPAM analysis and thus be able to determine the improvement in integral terms according to population analyses.

## Results and Discussion

By adding the ITEMC values of each district, the TEMC is obtained, which functions as a comparative parameter that allows the respective and percentage identification of which districts are most affected by this variable. This parameter (Fig. 3) shows that the two districts that contribute most to the TEMC are district 2 (San José) and district 5 (Ciudadela del Norte) with 26% and 14%, respectively and a simple comparative analysis between the variables shows that the same two districts mentioned above have a predominant percentage of PGE1 (young people) and PGE2 (adults).

After having made the calculations of the variables corresponding to the AHP methodology, the system proposed is consistent, since the value of CR is equal to 0.0808. This makes it possible to define the intrinsic importance percentages of each criterion as shown in figure 4.

The values used for each variable in both phases are shown in figure 5. In this figure, it can be seen that the ITEMC and TPGE do not change from one phase to the other because the recommendations dictated by sub-stages 4.1 and 4.2 point to the modification of the other two variables (EPE and AG).

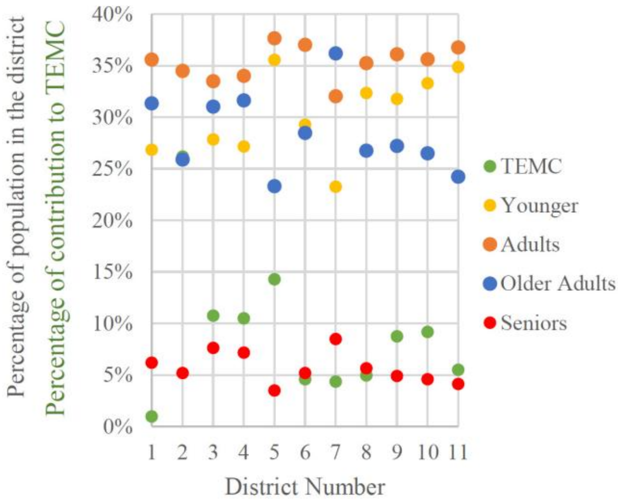


**Fig. 3**. Comparative analysis of independent variables

| | AG | ITEMC | EPE | TPGE | We | Cfe |
|---|---|---|---|---|---|---|
| AG | 1 | 0,50 | 0,50 | 3 | 0,9 | 20% |
| ITEMC | 2 | 1 | 2 | 2 | 1,7 | 38% |
| EPE | 2 | 0,50 | 1 | 4 | 1,4 | 32% |
| TPGE | 0,33 | 0,50 | 0,25 | 1 | 0,5 | 10% |
| Pe | 5,33 | 2,50 | 3,75 | 10,00 | 4,48 | **100%** |

**Fig. 4.** SAATY matrix with comparison system proposed

| *District* | *Initial Phase* | | | *Future Phase* | | |
|---|---|---|---|---|---|---|
| | *EPE* | *ITEMC* | *TPGE* | *EPE* | *ITEMC* | *TPGE* |
| *1 Atardeceres* | 13,4 | 89,9 | 0,33 | 13,7 | 89,9 | 0,33 |
| *2 San José* | 0,7 | 2442,8 | 0,40 | 1,0 | 2442,8 | 0,40 |
| *3 Cumanday* | 2,1 | 1002,2 | 0,35 | 2,6 | 1002,2 | 0,35 |
| *4 La Estación* | 1,8 | 978,7 | 0,34 | 18,5 | 978,7 | 0,34 |
| *5 Ciudadela del Norte* | 4,9 | 1332,5 | 0,39 | 4,9 | 1332,5 | 0,39 |
| *6 Cerro de Oro* | 16,9 | 427,1 | 0,34 | 16,9 | 427,1 | 0,34 |
| *7 Tesorito* | 22,7 | 405,2 | 0,34 | 22,7 | 405,2 | 0,34 |
| *8 Palogrande* | 5,7 | 462,7 | 0,32 | 6,1 | 462,7 | 0,32 |
| *9 Universitaria* | 3,0 | 815,7 | 0,38 | 3,1 | 815,7 | 0,38 |
| *10 La Fuente* | 2,4 | 855,5 | 0,37 | 2,4 | 855,5 | 0,37 |
| *11 La Macarena* | 0,8 | 512,3 | 0,38 | 1,0 | 512,3 | 0,38 |

**Fig. 5.** Variables Data for Both Phases

In figure 5, the values of the variable AG are not shown because it represents the changes in a continuous way in space and it is not correct to give a specific value to each district. In order to easily show the change between the phases with respect to this variable, figure 6 shows the improvement by means of a gradient expressed in minutes and shows the areas of the city that have benefited the most from the recommendations made in sub-stage 4.1.

Once all of the above conditions of *Stage 4* of the methodology become effective, sub-stage 4.1 recommends the placement of twenty-one new Blue Points distributed in the specific zones (these recommendations are represented in figure 5 with fuchsia-colored dots). Similarly, sub-stage 4.2 proposes fourteen new EPE areas, these correspond to: pedestrianization of carrera 23 between calles 19 and 31; pedestrianization of calle 24 between carrera 22 and 23 or also called calle del tango; use of calle 33 between carrera 19 and 22 together with the transversal sidewalks; rehabilitation of the soccer field in the Marmato neighborhood; taking into account the boulevard of calle 48; adaptation of the green area in the Las Colinas neighborhood; adaptation of the green area in the Camilo Torres neighborhood; maintenance of the secondary court in the El Carmen neighborhood; use of the green areas of buildings in the Estambul neighborhood; use of the green area of the CAI in the Estambul neighborhood; use of the green area in the Peralonso neighborhood; consideration of the boulevard on 19th Street; consideration of the velodrome at the Universidad de Caldas and maintenance of the soccer field on Carrera 27. All this results in a total of approximately 50100m$^2$ of new recreational spaces in Manizales.

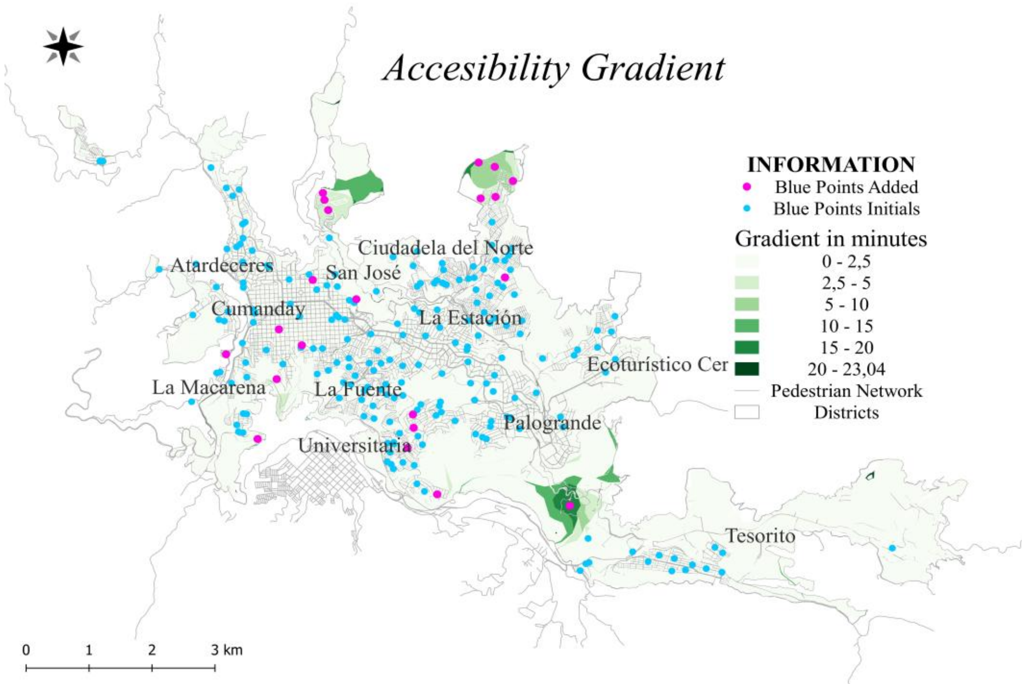


**Fig. 6.** Accessibility Gradient Map between Phases

Comparing the results of the future SPAM analysis (Fig. 7) and the initial SPAM analysis, improvements (positive zone changes) can be seen in large areas of the city, which cover approximately 12,401 people who, due to the sectors in which they reside, are directly benefited by the proposals proposed in this project. The total number of people benefited by the change of zone is translated into people who left Zone D and were distributed in such a way that 75.2% of them, corresponding to 9331 people, moved to Zone C; 0.6%, corresponding to 139 people, moved to Zone B; and 11.8%, corresponding to 2924 people, moved to Zone A (Fig. 8).

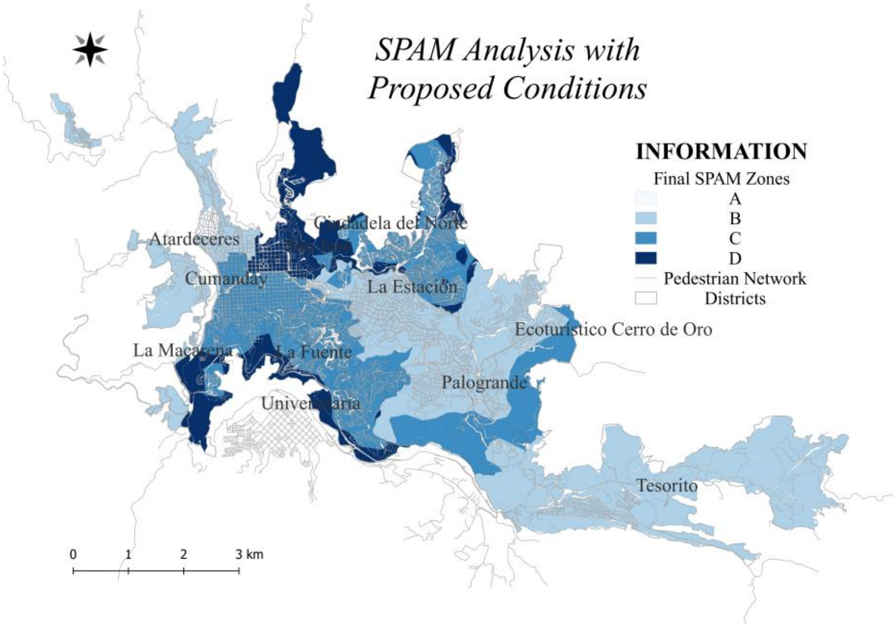


**Fig. 7.** Future SPAM Analysis Map

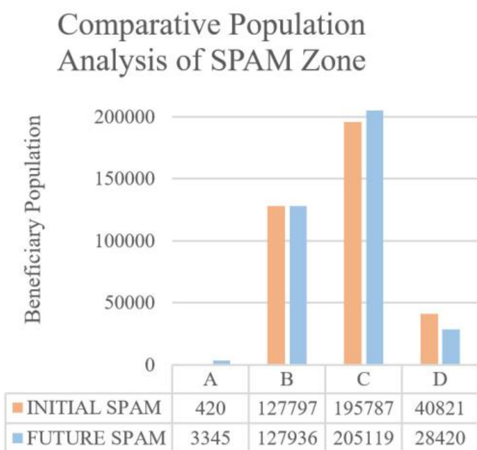


**Fig. 8.** Comparative Population Analysis of SPAM Zones

It is to be understood that the fact of placing a new Blue Point or recreational space that functions as an effective public space within an area of a city does not mean that its population will solve all its problems with this, but it does contribute to self-care thinking, to the creation of new social bonds, to civic behavior within the spaces and to the support of city thinking on a human scale, terms mentioned by *K. Franck* [29].

## Conclusions

The proposals for new recreational spaces in the city to increase the effective public space index in some districts are a sign of support for the objectives set forth in the Manizales Land Use Plan, which proposes to reach a total index of $15 m^2$/inhabitant.

Districts 2 and 5, San José and Ciudadela del Norte, respectively, in addition to being the most densely populated in the city, have the worst accessibility conditions as measured and have a population in which people under 50 years of age predominate; they are those in which the condition of tendencies to suffer from diseases is greater; therefore, it is recommended that the competent entities intervene with direct and concise solutions in these areas of the city.

The location of the existing Blue Points allows them to fulfill the individual objective for which they were installed, but, in terms of scope, they do not manage to benefit all the people who need one of these elements; therefore, the mechanisms proposed in this project work as a solution for decision-making to meet these needs.

The multi-criteria analysis proposed is a versatile mechanism that can be used in many cases in which geographic decisions need to be made, since it allows the use and relationship of different variables, interconnecting them.

With the resulting map of the future SPAM (Fig. 7), it is evident that there are still critical areas (D Zones) mostly located in the north and southwest exits of the city; these are those that, due to factors of scope, do not manage to benefit and therefore become a clear indication of the areas in which the competent entities must carry out different campaigns for the integral improvement of the conditions of the inhabitants who live there.

**Acknowledgments**

The authors express their most sincere gratitude to all the students and professionals who are members of the Sustainable Mobility Research Group of the Universidad Nacional de Colombia, as well as to the university itself for the constant dynamics of training and knowledge construction.

**References**

[1] S. Xhafa, A. Kosovrasti, *Geographic Information Systems (GIS) in urban planning*, **European Journal of Interdisciplinary Studies**, **1**(1), 2015, pp. 74-81, https://doi.org/10.26417/ejis.v1i1.p85-92.

[2] J. Gehl, **Cities for People**, Islandpress, Washington-Covelo-London, 2013.

[3] S. Wheeler, *Planning for Sustainability: Creating Livable, Equitable and Ecological Communities* (2nd ed.), 2013, Routledge. https://doi.org/10.4324/9780203134559.

[4] S. Chakrabarti, *How can public transit get people out of their cars? An analysis of transit mode choice for commute trips in Los Angeles*, **Transport Policy**, **54**, 2017, pp. 80-89, https://doi.org/10.1016/j.tranpol.2016.11.005.

[5] M.R. Lopez, D.M. Montoya, C. Dussán, *Characterization of the Attendants to the Psychological Care Center of the University of Manizales, 2006-2010,* **Hacia la Promoción de la Salud**, **17**(2), 2012, pp. 149-166.

[6] Instituto Nacional de medicina legal y ciencias forenses Cómo vamos, *Boletín estadístico mensual*, **Centro de Referencia Nacional sobre Violencia-CRNV,** 2020, https://www.medicinalegal.gov.co/documents/20143/494197/Boletin+diciembre.pdf

[7] Manizales Cómo vamos, *Informe de Calidad de Vida 2023-2024*, **Alcaldía de Manizales,** 2024, https://manizalescomovamos.org/wp-content/uploads/2024/09/ICV-MCV-capitulos-2023-2024_23sept.pdf?utm.com

[8] L.P. Delgado, D.P. Jaramillo, et al. *Mental health public policy in the department of Caldas: a contribution to well-being and inclusion*. **Editorial Universidad Autónoma de Manizales** 2017, 44. https://ridum.umanizales.edu.co/server/api/core/bitstreams/89f434be-667c-4643-a62f-aa9e7a09a177/content

[9] A. Prieto Rodríguez, *Mental Health: Status and Trends* (Vol. 4, Issue 1) (2002). 15(3) 1-5. http://www.scielo.org.co/pdf/rsap/v4n1/v4n1a05.pdf

[10] T. Astell-Burt, X. Feng, *Association of Urban Green Space with Mental Health and General Health among Adults in Australia*, **JAMA Network Open**, **2**(7), 2019, https://doi.org/10.1001/jamanetworkopen.2019.8209.
[11] M.C. Kondo, J.M. Fluehr, T. McKeon, C.C. Branas, *Urban green space and its impact on human health*, **International Journal of Environmental Research and Public Health**, **15**(3), 2018, https://doi.org/10.3390/ijerph15030445.
[12] D.H. Prasetyo, J. Mohamad, R. Fauzi, *A GIS-based multi-criteria decision analysis approach for public school site selection in Surabaya, Indonesia*, **Geomatica**, **72**(3), 2018, pp. 69-84, https://doi.org/10.1139/geomat-2018-0017.
[13] M. Jaramillo, *Espacio Público Efectivo Municipio de Manizales,* **ArcGIS StoryMaps**, 2024, https://storymaps.arcgis.com/stories/8e478df86f8246b4bf2b43bf8de5dc09
[14] T. Abelleira-Lamela, R. Vaquero-Cristóbal, N. González-Gálvez, F. Esparza-Ros, A. Espeso-García, P.J. Marcos-Pardo, *Sagittal spine disposition and pelvic tilt during outdoor fitness equipment use and their associations with kinanthropometry propor-tions in middle-aged and older adults,* **PeerJ**, **9**, 2021, http://doi.org/10.7717/peerj.12657.
[15] C. Moreno, Z. Allam, D. Chabaud, C. Gall, F. Pratlong, *Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities*, **Smart Cities**, **4**(1), 2021, pp. 93-111, https://doi.org/10.3390/smartcities4010006.
[16] J.E. Aristizábal, W. Sarache, D.A. Escobar, *Spatial Regression Model of Urban Walkability Under the 15-Minute City Approach*, **GeoJournal of Tourism and Geosites,** **49**(3), 2023, pp. 1037-1045, https://doi.org/10.30892/gtg.49319-1103.
[17] * * *, **Geo portal Alcaldía de Manizales Secretaría de Planeación Municipal.** *Boundary Municipality of Manizales*, 2017, https://geodata-manizales-sigalcmzl.opendata.arcgis.com/datasets/sigalcmzl::l%C3%ADmite-municipio-de-manizales.
[18] * * *, **Geo portal Mayor's Office of Manizales Secretariat of Municipal Planning**. *Boundary of the municipalities of Manizales,* 2020, https://geodata-manizales-sigalcmzl.opendata.arcgis.com/maps/l%C3%ADmite-comunas-municipio-de-manizales.
[19] J.J. Arsanjani, P. Mooney, A. Zipf, A. Schauss, *Quality assessment of the contributed land use information from OpenStreetMap versus authoritative datasets*, **OpenStreetMap in GIScience. Lecture Notes in Geoinformation and Cartography**, (Editors: J. Arsanjani, J. Zipf, A. Mooney, P. Helbich), Springer, Cham, 2015, pp. 37-58, https://doi.org/10.1007/978-3-319-14280-7_3.
[20] **Mayor's Office of Manizales.** *Population Module*, 2023, https://laboratorio.manizales.gov.co/mas-datos/.
[22] J.M. Morris, P.L. Dumble, M.R. Wioan, *Accessibility Indicators for Transport Planning* **Transportation Research***,* **13**(3), 1979, pp. 91-109.
[23] C. Humberto, O. Tellez, S. de Despacho, J. Diego, L. Palacio, J. Edgar, V. Sanchez, (n.d.). *Health Situation Analysis with the Social Determinants of Health Model Manizales 2021.* **Secretaría de Salud Pública de Manizales**, 2021, https://observatoriosalud-manizales-sigalcmzl.hub.arcgis.com/documents/sigalcmzl::asis-manizales-2021/about
[24] L. Martinez, *Organized crime and homicidal violence in intermediate cities*. **Editorial Universidad Tecnológica de Pereira.** (2020). https://www.academia.edu/43534455/Crimen_organizado_y_violencia_homicida_en_ciudades_intermedias
[25] O.S. Vaidya, S. Kumar, *Analytic hierarchy process: An overview of applications*, ***European Journal of Operational Research,*** **169**(1), 2006, pp. 1-29, https://doi.org/10.1016/j.ejor.2004.04.028.
[26] E.A. Nantes, *The analytic hierarchy process method for decision making: review of methodology and applications. Operations research*, **RIDCA,** **3**(2), 2019, pp. 1-5,

https://repositoriodigital.uns.edu.ar/bitstream/handle/123456789/6060/El%20método%20analytic.pdf?sequence=1&isAllowed=y .

[27] A. Kuru, F. Terzi, *Determination of New Development Area in Kirklareli by GIS Based Weighted Overlay Analysis*, **International Journal of Environment and Geoinformatics, 5**(3), 2018, pp. 244-259, https://doi.org/10.30897/ijegeo.427330.

[28] **Geoportal of the National Administrative Department of Statistics**. *National Geostatistical Framework integrated with the 2018 National Population and Housing Census. MGN-Block level integrated with the CNPV 2018. Version 2021*. https://www.dane.gov.co/files/geoportal-provisional/ (file: MGN2018 Integrado con CNPV2018, zona Censal Urbana).

[29] K. Franck, Q. Stevens, *Loose space: possibility and diversity in urban life*, 1st Edition, **Routledge**, 2006.

*Received: Octomber 02, 2024*
*Accepted: April 24, 2025*