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Physical Activity Facilities as a Public Health Policy. Methodological Proposal for a Spatial Gyms Location

Diego A. ESCOBAR[1], Santiago CARDONA[2] and Carlos A. MONCADA[3]

[1,2] Universidad Nacional de Colombia, Sede Manizales. Facultad de Ingeniería y Arquitectura, Departamento de Ingeniería Civil, Grupo de Investigación en Movilidad Sostenible. Campus La Nubia, Bloque S2-208, Carrera 37 con Calle 94, Manizales, Caldas, 170003, Colombia. daescobarga@unal.edu.co (ORCID 0000-0001-9194-1831), scardonau@unal.edu.co (ORCID 0000-0002-5032-3145)

[3] 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. camoncadaa@unal.edu.co (ORCID 0000-0003-3745-6880)

Abstract

Sedentary lifestyles account for 6% of deaths worldwide, consequently, different countries have been concerned with making public policies aimed at encouraging physical activity among their inhabitants. In this regard, gyms, due to their versatility, comfort and easy access, have become a popular strategy in the last decade resulting in a real option for people who decide to start doing any type of physical activity. The objective is to propose a methodology for calculating the Gym Space Distribution Index (GSDI) that seeks to provide and complement technical support to public health policies in cities. The methodology is a quantitative study relating five variables: demographic, social, commercial, and operational pedestrian, and vehicular network through a statistical and correlational analysis in three different scenarios: city, district, and quadrants per district. The GSDI from the scenarios shows an unbalanced or inequitable spatial distribution of these establishments.

Keywords: Accessibility, Gyms, Mobility, Physical Activity.

I. INTRODUCTION

Physical activity and fitness, and a healthy lifestyle have had great growth worldwide, accompanied by the rise and development of a variety of sports and disciplines. Physical activity is any type of body movement resulting in an energy expenditure added to the basal metabolism [1]. Performing any type of physical activity regularly, starting with a 30-minute daily brisk walk that causes an energy expenditure prevents both the occurrence of a sedentary lifestyle and diseases such as ischemic heart disease, strokes, and high blood pressure [1, 2]. The city of Manizales, capital of the department of Caldas, located in the Colombian central west is the study area location (Fig. 1). Due to its position on the central mountain range of the South American Andes at 2150 meters above sea level, it has a rough topography that hinders expansion and mobility processes, especially for the non-motorized means of transport such as walking and cycling [3]. Despite this, about 30% of its inhabitants walk [4].

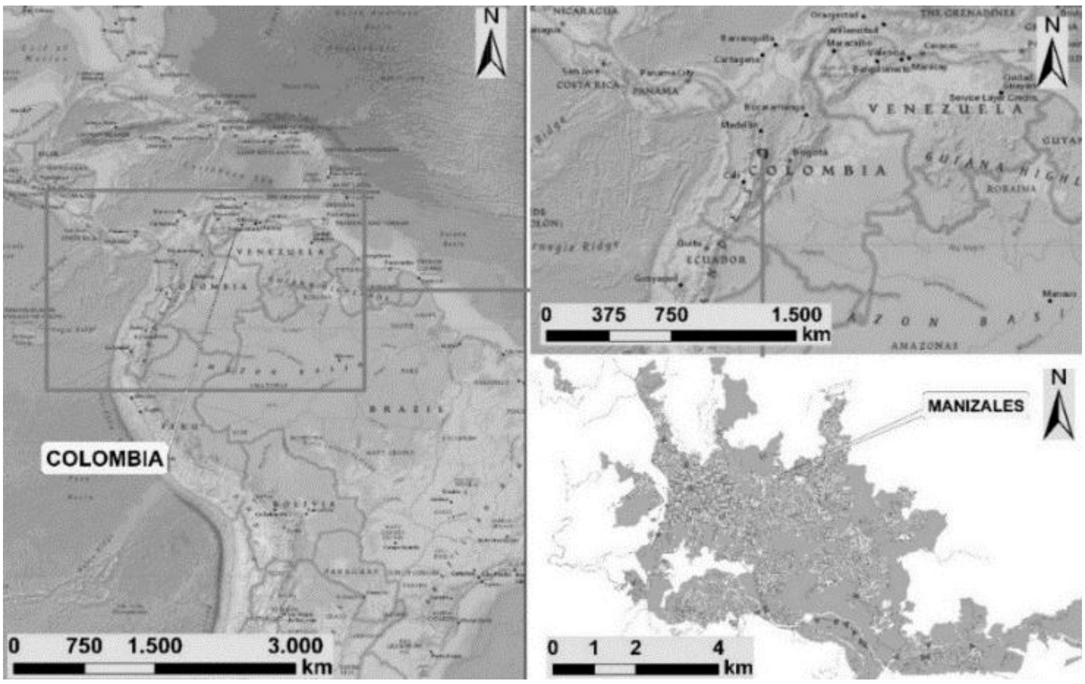

Fig. 1. Geographic location of the municipality of Manizales. Source: Authors

Sedentary lifestyles or physical inactivity account for 6% of deaths worldwide according to the World Health Organization [5] and is considered a global public health problem generating public policies for prevention in the 17% of the population where this symptom still prevails. Meanwhile, in Colombia, the sedentary population reaches a percentage of 58% [6]. In the last decade, sedentary lifestyles have been driven by the lifestyles adopted by people and by the environment in which they partake daily activities [7]. Consequently, making public policies aimed at generating lifestyle changes, and encouraging physical activity among inhabitants is of utmost importance. Gyms have become the go-to choose among people who wish to adopt a healthier lifestyle due to their versatility and relatively easy access [8]. This industry has had exponential growth, reaching nearly 6 billion dollars in nearly 65 thousand establishments in Latin America [9]. Despite this fact, about 88% of people drop out regularly [8].

This research article proposes a methodological measurement for the Gym Space Distribution Index (GSDI) based on five variable relationships namely: i) Demographics (population density), ii) Commercial (number of gyms), iii) Social (deaths associated with a sedentary lifestyle), iv) Pedestrian operational network (population coverage through the pedestrian network), and v) Vehicular operational network (population coverage through the vehicular network). The GSDI will be measured on a scale of 0 to 100, with 100 being the most desirable, that is, areas of the city where there is a wide range of fitness establishments. This is reflected in the network's large operational coverage and low death rates associated with a sedentary lifestyle. The contrary scenario will identify the areas of the city that should be prioritized for public policies promotion of the physical activity or the inclusion of new fitness centers.

Transport accessibility is a supply concept that measures the potential interaction opportunities of an individual [10], which through the years, has had many applications in multiple areas of territory planning among which is: the studies of public transport systems [11], libraries [12], hospitals [13], parks [14], security services [15], among others. In this article, the integral accessibility will be used as a method of obtaining the population coverage resulting from the gyms of the area of study, this being the measure towards specific areas of the city through the road infrastructure network [16, 17].

II. METHODOLOGY

The research methodology comprises of seven consecutive stages. (Fig. 2) shows the developed methodological sequence.

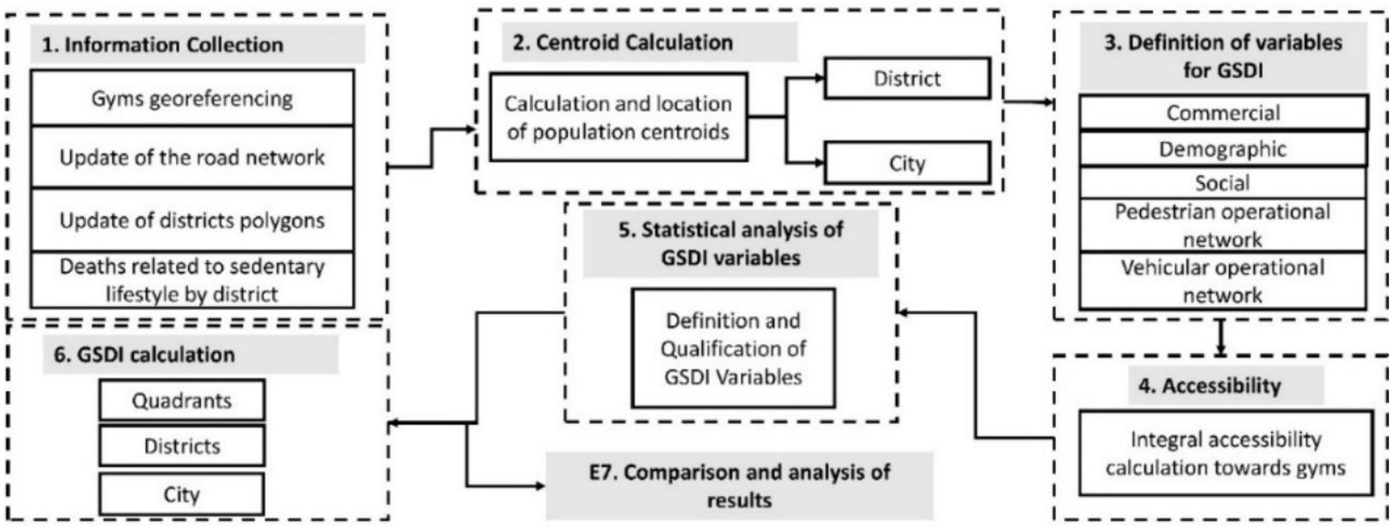

Fig. 2. Research Methodology

II.I Information Collection

This stage began with the acquirement of the official list of sites registered as gyms at the Manizales Chamber of Commerce, whose main purpose was to provide services for the engagement of some type of physical activity. The Chamber of Commerce is the entity responsible for different administrative functions, among which are the archiving of the commercial registries of all establishments in their jurisdiction. For this research, the registries of 45 officially registered establishments were obtained, which contained information related to their geographical location, facilitating geo-referencing through the application of a GIS tool. Subsequently, servicing and updating of the transport infrastructure network was carried out for both pedestrian and vehicular networks [18]. For both networks, the longitudinal distances that define them and the average travel times on each of them are calculated, considering the pedestrian speed determined by Zuluaga et al. [3] of 4.32 km/hr and the operational speeds of motor vehicles obtained in 2018 through an update carried out by Montoya [11].

From previous research, the polygon of the area of study composed of districts [18] was obtained. These are distributed in blocks. The population information per block was updated in 2018 following the population growth projections of the

National Administrative Department of Statistics – DANE [19] and the socioeconomic stratum per block is considered. Colombia's Socioeconomic stratification is made up of a 6-group residential area classification, used since 1983, assigned according to their physical environment, both urban and rural. The stratification not only describes the area's social and economic characteristics, but also serves as a factor in the application of residential public services tariffs (water, electricity, gas, etc.), and access to government subsidies as well [20]. Moreover, the database of the number of deaths and their main causes is based on the information provided by the Secretary of Health of Manizales, the Mayor's Office of Manizales and the Territorial Health Directorate of Caldas. This database aided in the identification of the number of deaths related to a sedentary lifestyle such as ischemic heart disease, strokes, and high blood pressure [1], thus establishing said value for each of the city's districts.

II.II Centroid Calculation

In this stage, we proceed to divide the geographical area of each of the districts and the geographical area of the entire city, into quadrants according to the location of the population centroid. Regarding the population centroid location, a similar procedure to the one carried out for the calculation of the centroids of two-dimensional figures in engineering vector analysis was applied [21]. Firstly, the longitude (Long.) and latitude (Lat.) coordinates of each of the blocks (n) that make up each district and the city are calculated, using GIS and a flat coordinate system defined for the area of study as "CartManizalesMagna". Secondly, we proceed to calculate the product of the coordinates of each block by its respective population (Pop.). Lastly, Eq. (1) and Eq. (2) are applied to calculate the longitude and latitude coordinates of the population centroid. Then, we proceed to divide the districts and the city into four orthogonal quadrants with a center in the longitude and latitude coordinates obtained by Eq. (1) and Eq. (2).

$$Long_{cp} = \frac{\sum_{i=1}^{n} Long_i * Pob_i}{\sum_{i=1}^{n} Pob_i} \tag{1}$$

$$Lat_{cp} = \frac{\sum_{i=1}^{n} Lat_i * Pob_i}{\sum_{i=1}^{n} Pob_i} \tag{2}$$

II.III Definition and Qualification of GSDI Variables

For the calculation of the Gymnastics Space Distribution Index - GSDI, following each scenario to be studied (quadrants by districts, between districts, and at a city level), a study of the relationship between five main variables: i) Demographic, ii) Commercial, iii) Social, iv) Pedestrian operational network and, v) Vehicular operational network is proposed. The study variables are standardized on a scale of 1 to 100 where the latter value is the most desired according to the definition of every one of them each and recalculating the rest of them according to their value.

The demographic variable is based on population density values (number of inhabitants per hectare) according to the district and city. Concerning this variable, the most desirable outcome is to register a higher population density according to international standards of sustainable cities, so that at the highest population density value in each scenario, a rating of 100 is assigned and from that maximum value a proportional rating.

The commercial variable is related to the number of gyms according to city, districts and quadrants; it is established that the highest qualification is granted to the district or quadrant that has the greatest number of establishments for physical activity and from that maximum value a proportional qualification is assigned.

The social variable refers to the number of deaths caused by diseases related to poor physical activity. In this case, a higher score is assigned to the district or quadrant where there have been fewer deaths, assuming that this is an indication of an adequate level of physical activity among its inhabitants.

The last two variables are related to the operability of the transportation infrastructure network, both pedestrian and vehicular, measured through the average comprehensive gym accessibility, which is elaborated in stage 4. For the operation of the pedestrian network towards the gyms, the percentage of population coverage for average travel times of 5, 10, 15 and 20 minutes is calculated, totaling their percentages according to the weighted mean of 40%, 30%, 20% and 10 % respectively, factoring in this hypothesis of weights owing to the assertion that people are more willing to take walks if the establishment is closer; thusly, it is established that the highest rating is given to the district or quadrant that has the highest percentage of population coverage and from that maximum value a proportional rating is assigned. Also, for the operation of the vehicular network towards the gyms, the previously above-mentioned summation is applied, however, in this case, the weighted means are inverted since people are more likely to use their cars. As the average travel time is longer, therefore, we take the hypothesis of 10%, 20%, 30% and 40% weights for the travel times of 5, 10, 15 and 20 minutes, respectively. It is established that the highest rating is given to the district or quadrant that has the highest percentage of population coverage and from that maximum value a proportional rating is assigned.

II.IV Accessibility

In this stage, the calculation of the integral average accessibility offered by the transport infrastructure network (pedestrian and vehicular) to the gyms established as travel destinations is carried out. First, the matrix of minimum travel times is obtained from all intersections of the road network to the gyms, the latter represented by the intersection of the nearest road network. In this case, the algorithm of minimum paths is used to find the route from the intersections to the gyms, minimizing the travel time of each route and considering the directions of the road network and the maneuvering difficulties and the turn penalties for the area of study [4, 22]. In this case, the presumption of destination is used for accessibility, understanding that people travel to the gyms [23], obtaining a matrix of 10 011 travel origin intersections for 45 destination intersections (gyms).

Further on, the minimum travel time vector which represents the time it takes for each intersection of the road network to reach the nearest gym is obtained [18]. This vector is related to the geographic coordinates of each of the 10 011 intersections, which will be used to construct the isochronous accessibility curves, using the Ordinary Kriging geostatistical model, which uses the linear semivariogram as a structuring equation. This model performs a spatial interpolation of travel time between the closest intersection, making a more precise prediction as the data points get closer [24, 25].

II.V Statistical Analysis of GSDI Variables

This statistical analysis is carried out to propose a variability hypothesis for the weights that each of the variables would have in the calculation of the GSDI. From the criteria of the variables explained in stage 3, the Pearson's sample correlation (rxy) is calculated to identify the variables that could be more significant in the calculation of the GSDI, considering that the variables studied are quantitative, and assuming that their relationship is linear [26]. Eq. (3) allows establishing the degree of correlation that exists between each pair of variables, where x is defined as the analysis variable number 1 and y is the analysis variable number 2 and relating each one to its respective average; This calculation is made between all possible pairs of the studied variables.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x}) * (y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad (3)$$

After defining the variables that will have the greatest weight in the calculation of the GSDI, we proceed to generate random scenarios of statistical analysis, limiting the value of the variables' weights. In this particular case, the value of the demographic and vehicular operability variables was limited to a maximum of 10% in their sum because the first did not have a direct relationship with the location of the gyms according to Pearson's correlation, and the second due to the sustainable cities vision, seeking for people abandon private vehicles in search of more sustainable ways to mobilize. Taking this into account, the other variables varied their weights, adding up to 90% maximally.

Finally, 108 random scenarios of different statistical analyzes were examined. After defining the random scenarios of statistical analysis, we proceed to calculate the GSDI for each of the districts in each scenario; subsequently, the standard deviation from Eq. (4) of the GSDI, is calculated for all random scenarios of statistical analysis of each district, taking as hypothesis that the most appropriate scenario is the one that records the lowest standard deviation. Finally, the weights of each variable are determined as the average of the weights of the best randomized statistical analysis scenario of each district [27].

$$S = \sqrt{\frac{\sum_{i=1}^{n}(GSDI_i - \overline{GSDI})^2}{n-1}} \qquad (4)$$

II.VI GSDI Calculation

After obtaining the weights of each variable, we proceed to calculate the GSDI for each study scenario (quadrants by district, between districts and at the city level) by applying Eq. (5), where Vi is each of the variables calculated and qualified in the third stage and Wi is the weight of each of the five main variables, determined in the fifth stage.

$$GSDI = \sum_{i=1}^{5} Vi * Wi \qquad (5)$$

II.VII Comparison and Result Analysis

In this stage, comparison and analysis of the main results of this methodological proposal are made, considering the value of the GSDI, obtained for the different scales of analysis (quadrants, districts and city) and conditions of equity in the access to this type of equipment to relate these results with the socio-economic strata of each district.

III. RESULTS AND DISCUSSION

III.I District, Gyms, Population Centroids and Quadrant Creation

(Fig. 3) shows the polygon of districts in the study area. Likewise, the 45 geo-referenced gyms are represented with triangles as a result of the information collected from regions of the Chamber of Commerce. Moreover, the population centroid of each district and for the city can be seen as well, with (Tab. 1) showing its longitude and latitude property in the "CartManizalesMagna's" coordinate system.

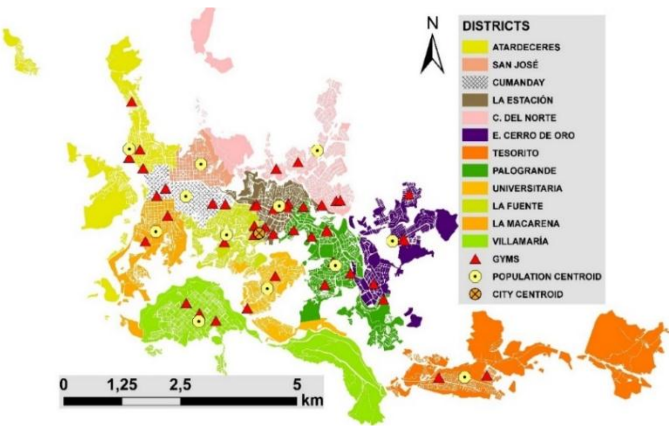

Fig. 3. Location of districts, gyms and population centroids. Source: Authors

Table 1. District information

District		Population Centroid Coordinates		Pop.	Area (Ha)	Population Density (Inh./ha)	Gyms Number	Deaths associated with a sedentary lifestyle
		Length	Latitude					
1	Atardeceres	1 171 901,648	1 053 313,005	30 676	250	123	4	86
2	San José	1 173 434,264	1 052 992,843	24 211	68	357	0	39
3	Cumanday	1 173 108,290	1 052 313,951	29 315	81	361	4	109
4	La Estación	1 175 110,852	1 052 110,910	23 098	91	253	6	70
5	C. del Norte	1 175 926,056	1 053 280,683	64 670	221	293	5	118
6	E. cerro de Oro	1 177 535,887	1 051 372,001	32 113	174	185	4	75
7	Tesorito	1 179 081,260	1 048 498,544	23 961	400	60	2	37
8	Palogrande	1 176 312,625	1 050 852,732	25 874	199	130	9	65
9	Universitaria	1 174 855,698	1 050 365,144	38 353	117	327	2	50
10	La Fuente	1 173 982,955	1 051 500,144	46 237	100	462	4	61
11	La Macarena	1 172 468,098	1 051 570,789	33 378	136	246	2	55
12	Villamaría	1 173 389,968	1 049 673,636	52 575	197	266	3	128
	Total	1 174 683,583	1 051 535,284	424 461	3135	135	45	893

The study area has 11 districts defined by the Land Ordinance Plan [28]. Furthermore, the neighboring municipality of Villamaría is factored in as an extra district since both functions as a single conurbation area, sharing resources and public transport, among other urban facilities [4]. In the neighborhood polygon, a specific classification of public space is taken, which does not have population data, so when comparing the area of the 12 districts (including Villamaría) including the area of the city, the latter will result in a little dated. Among the most representative results is that the 'Ciudadela del Norte' district has the largest population with 64670 inhabitants, which represents about 15,2% of the total city. In addition, this district has the singularity of having most of its homes classified in low socio-economic strata. On the other hand, the 'Tesorito' district is the one with the largest area, with about 400 ha, which represents 13% of the total urban area of the city, however, its population density is the lowest in the area of study with 60 hab/ ha. The main industrial zone and the airport of the city are located within this district. In terms of the number of gyms, the district with the highest entry is 'Palogrande' (9 gyms), displaying the singularity of having a broad commercial inclination as well as a large number of educational establishments of all levels. These data contrasts with that obtained for the 'San José' district, which does not have a gym entry, being the only one with this singularity, despite being the third district with the highest population density, with 357 inhabitants/ha. It is a district that is centrally located in the city; it has a great tradition since the market square is located here and it was where the cities affluent families settled in the 50s of the 20th century, however, in the last decades their social dynamics changed and people from low socioeconomic strata settled there, up triggering the population density. For these reasons, the national and local government promoted an umbrella project of national interest for the urban gentrification of the district, which has been highly criticized over the years and which has currently produced a large number of resettlements of people towards the periphery of the city, moving people from the lower strata away from essential resources and increasing social inequality [29, 30]. Regarding the number of deaths related to sedentary lifestyles, as a product of the information collected in the Ministry of Health of the city, the Mayor's Office and the Territorial Health Directorate of Caldas, it is observed that Villamaría is the one that records the highest number of deaths, followed by 'Tesorito' district. Contrarily, the 'La Macarena' and 'La Estación' districts registered the lowest number of deaths with 37 and 39 deaths respectively. (Fig. 4) shows the city distributed in the four analysis quadrants, centered on the population centroid defined for it.

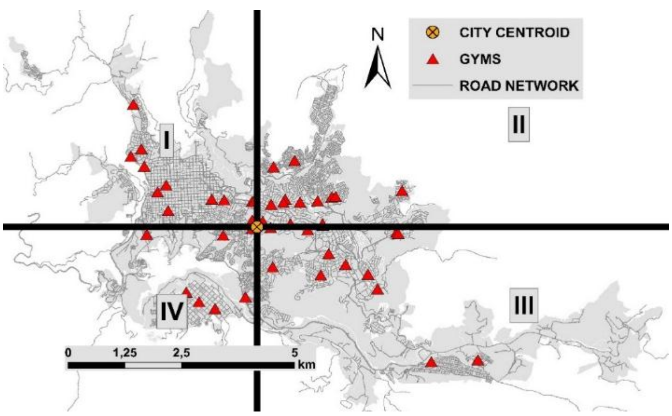

Fig. 4. Division by quadrants, Manizales. Source: Author's calculations

Similarly, the district is distributed in four quadrants according to the population centroid. (Fig. 5) shows the distribution in quadrants for the 'San José' and 'Universitaria' districts. From the division by quadrants, a distribution of the data obtained from population, area, number of gyms and number of deaths related to sedentary lifestyle is performed, which is presented in (Tab. 2).

There are notable differences between the analysis carried out at the level of district or city with the one performed between quadrants. Each of the variables has significant changes generating a more detailed analysis for the calculation of the GSDI. This table shows the results for the distribution of quadrants for the city and for the 'Palogrande' and 'San José' districts, which have the singularity of having the largest and smallest number of gyms, respectively.

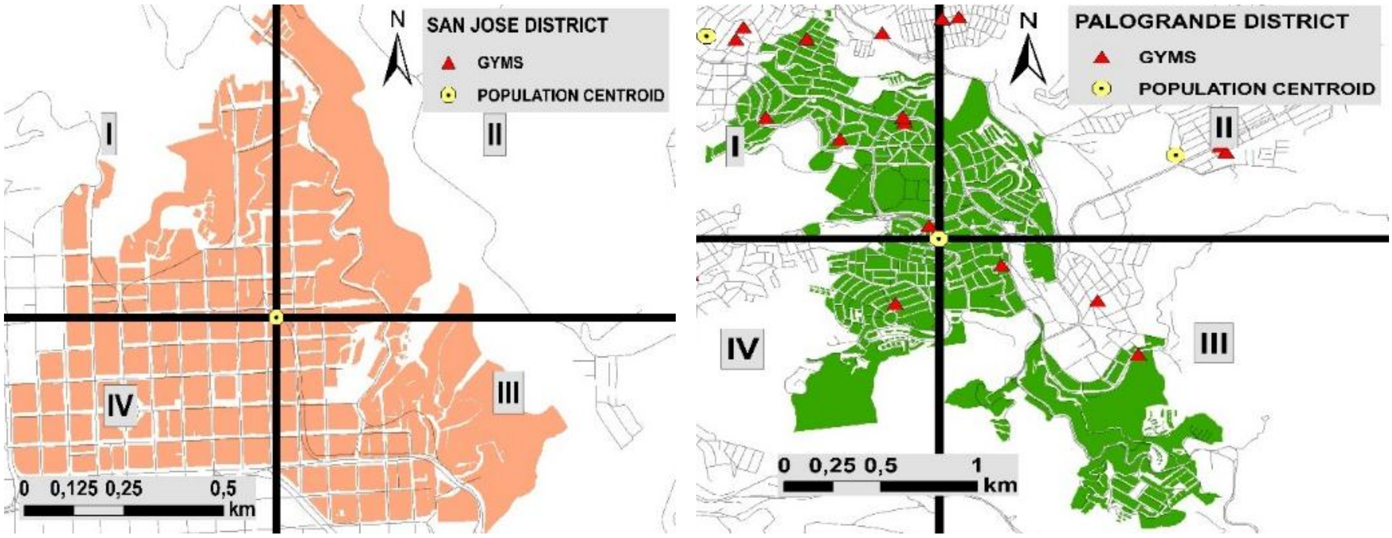

Fig. 5. Division by quadrants, 'San José' and 'Palogrande' districts. Source: Author's calculations

Table 2. Information collected per quadrant

Quadrant	Manizales	San José	Palogrande
Population			
I	131 628	5792	7915
II	105 063	5056	4433
III	89 617	7823	7284
IV	98 325	5540	6242
Area (ha)			
I	700,413	14,84	57,24
II	467,544	16,28	28,56
III	1477,834	20,87	73,05
IV	489,209	15,79	39,96
Population Density (Inhabitants/ha)			
I	187,93	390,27	138,28
II	224,71	310,49	155,23
III	60,64	374,94	99,71
IV	200,99	350,84	156,21
Number of Gyms			
I	12	0	6
II	14	0	0
III	12	0	1
IV	7	0	1
Number of deaths associated with a sedentary lifestyle			
I	237	13	15
II	189	11	9
III	162	18	14
IV	177	13	12

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Despite this excellent coverage for short travel times, there are still areas of the city with travel times greater than 30 min. reaching up to 90 min., which means that residents must use some motorized transport to access these facilities (Fig. 6) where the coverage of the isochronous curves of integral accessibility to the gyms is observed through the vehicle network, where travel times of up to 25 min. are reached. In some particular cases there are maximum times of 40 min., in areas where population records are low or nonexistent. Also, in this case, the coverage for travel times less than 5 min. shoots to 64,8%, almost double what was presented for the pedestrian network (Fig. 7). This indicates a growth in coverage, which probably diversifies people's options by being able to have greater alternatives of choice among gyms.

Another important issue is the population coverage registered by each district in the travel times given in the isochronous curves of integral accessibility. As explained in stage 3, two variables relate the population coverage by district with integral accessibility through the pedestrian and vehicular network for the calculation of the GSDI.

(Fig. 8) shows the population coverage by district through the pedestrian network. In this case the 'La Estación' district is the one with greater coverage for travel times of up to 5 min. with a 65,4% population. On the other hand, the 'San José' district has only 1,0% of the population in this same range. These values are essential when calculating the operational variable of the pedestrian network since the percentage of population covered for travel times less than 5 min. has greater participation, which decreases from 40% to 10% for percentages of population between 15 and 20 min.

On the other hand, to calculate the vehicle network variable, the population coverage percentages present in (Fig. 9) are taken. In this case, the situation described in the previous variable is reversed, so that the percentages of population with travel times between 10 and 20 min. have greater participation in the variable, which indicates that districts like 'San José' and 'C. del Norte', will score higher in this variable.

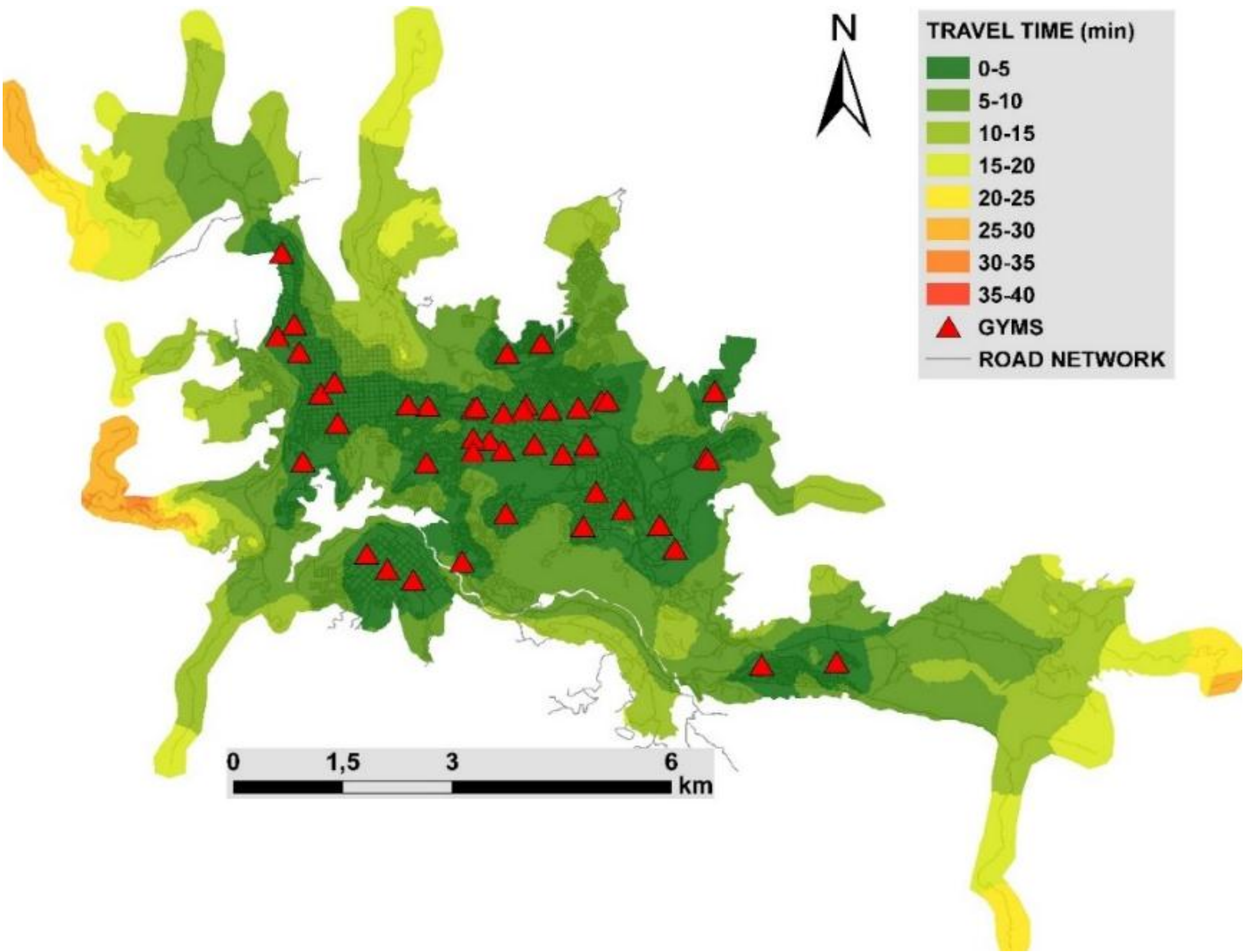

Fig. 6. Integral Accessibility, Vehicular Network. Source: Author's calculations

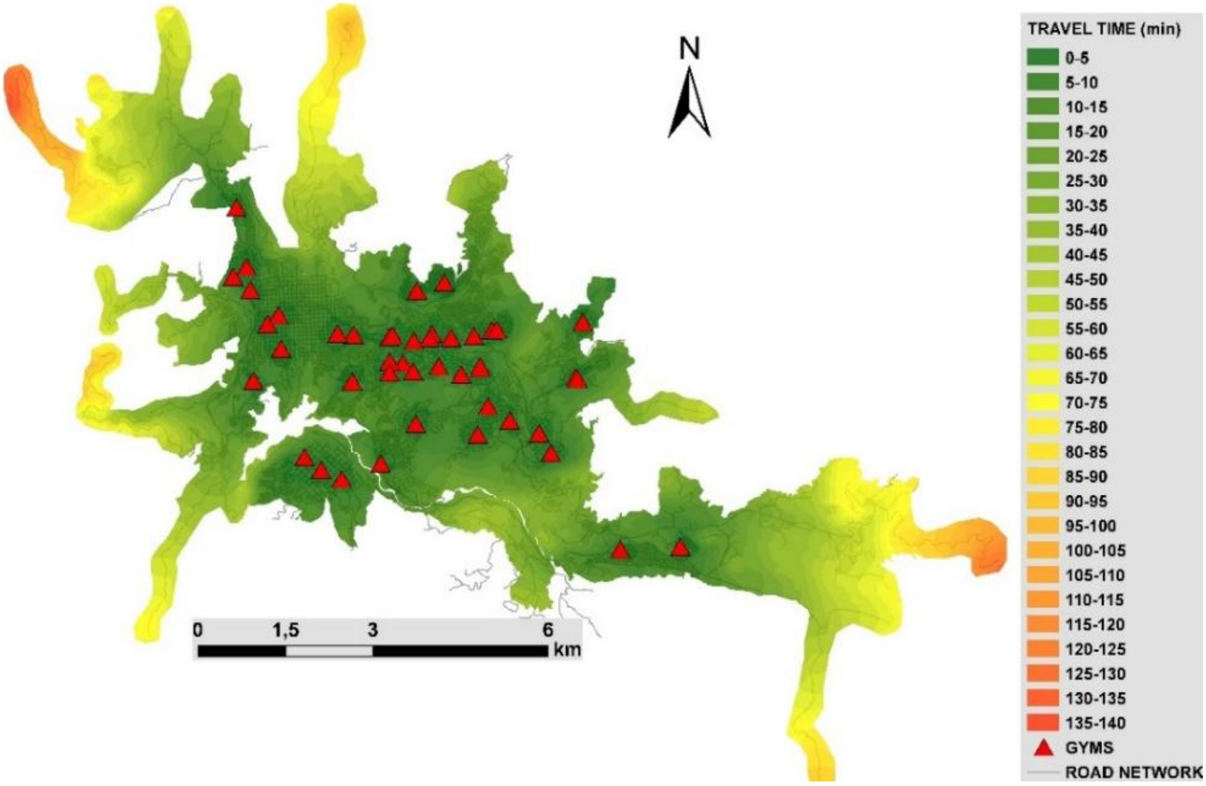

Fig. 7. Integral Accessibility, Pedestrian Network. Source: Author's calculations

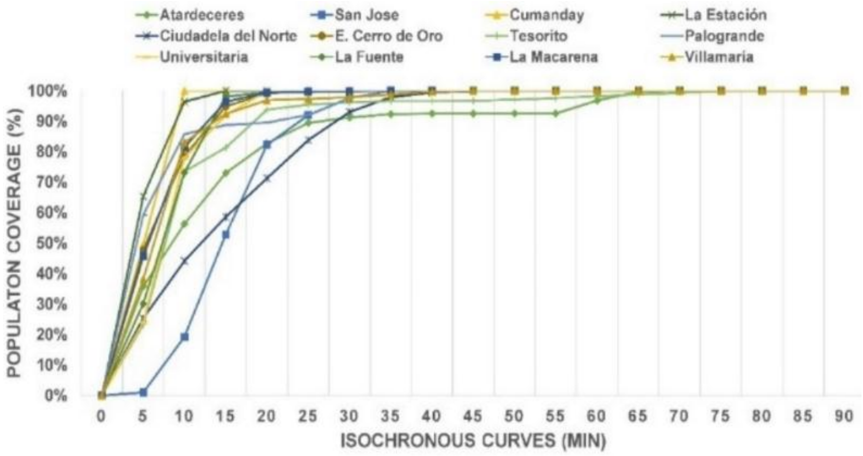

Fig. 8. Population Coverage per district, Pedestrian Network. Source: Author's calculations

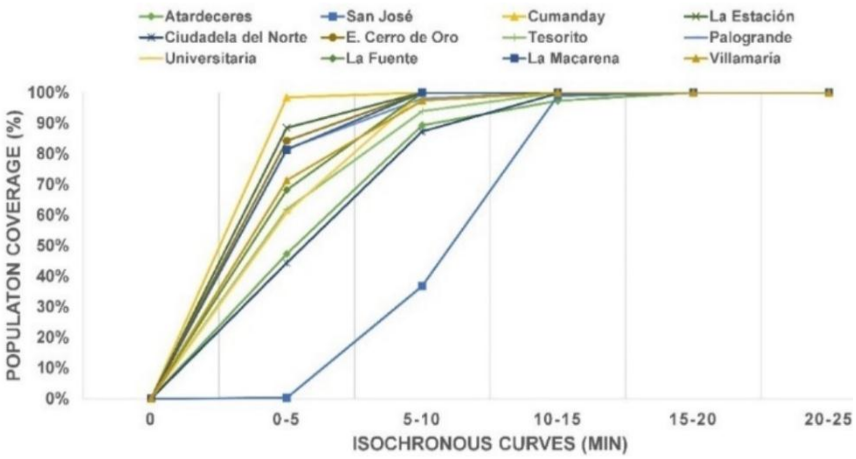

Fig. 9. Population Coverage by District, Vehicular Network. Source: Author's calculations

III.II Statistical Analysis of Variables

The standardization of the studied variables for the analysis scenario between districts is presented in (Tab. 3). In this case, the district with the highest population density was 'La Fuente', while the 'Tesorito' district registered the lowest. As already mentioned in previous sections, the 'Palogrande' district registers the largest number of gyms with 9 establishments, while the 'San José' districts record none. Similarly, with the data related to the social variable, where the 'Tesorito' district has fewer deaths due to sedentary causes, while Villamaría is the one that records the most.

Finally, for the operational variables, the 'La Estación' district is the one with the best population coverage through the pedestrian network, while the 'San José' district has the worst coverage through this mode, contrary to the one getting through the vehicular network, where it is the district that obtains the best coverage in the calculation for the variable, while the 'Cumanday' district is the one with the worst coverage in this last variable. Pearson's correlation analysis between these five variables for the data in (Tab. 3) gave us the results presented in (Fig. 10). Whereby, values closer to 1 or -1 indicate a greater correlation between the variables, so the commercial variable relates in a better way to the social variable, through a negative slope, because diseases increase as the number of gyms decreases.

Table 3. GSDI Variables by District. Source: Author's calculations

District	Demographic	Commercial	Social	Pedestrian	Vehicular
	Population Density	Gyms	Deaths associated with a sedentary lifestyle	Network operation	Network operation
Atardeceres	26,56	50,00	46,15	68,57	62,82
San José	77,34	0,00	97,80	42,92	100,00
Cumanday	78,25	50,00	20,88	96,59	38,44
La Estación	54,85	75,00	63,74	100,00	42,20
C. del Norte	63,34	62,50	10,99	55,15	63,80
E. Cerro de Oro	40,04	50,00	58,24	88,56	43,81
Tesorito	12,97	25,00	100,00	75,13	54,60
Palogrande	28,18	100,00	69,23	89,39	45,59
Universitaria	70,85	25,00	85,71	81,28	52,69
La Fuente	100,00	50,00	73,63	83,16	49,90
La Macarena	53,31	25,00	80,22	89,28	44,91
Villamaría	57,70	50,00	0,00	85,84	49,71

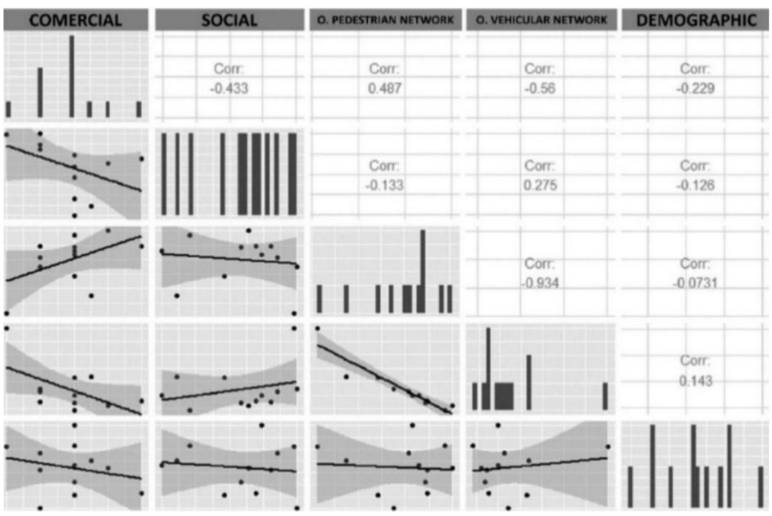

Fig. 10. Pearson's correlation between GSDI variables. Source: Author´s calculations

Comparably, there is a correlation of the commercial variable with the operational variable of the pedestrian network; a desirable factor if we want more people to access the gyms quickly, effectively and economically. There is also a broad correlation between the commercial variable and the operational variable of the vehicular network, however it does not generate broad participation because the non-motorized modes of transport prevail. On par herein, with the demographic variable, due to the low correlation it records with all the variables. The demographic and operational variables of the vehicular network will have a smaller participation in the calculation of the GSDI, of up to 10% between both, so that between the commercial, social and operational variables of the pedestrian network, a weight of up to 90% will be assigned among all of them.

Considering the maximum weights obtained by the Pearson correlation analysis, 108 statistical analysis scenarios were created where the weights of the different variables were varied and the GSDI was calculated for each of the districts. (Tab. 4) shows the Statistical Analysis Scenarios (SAS) that resulted in the lowest standard deviation (S) for each of the districts, the GSDI resulting from these scenarios (GSDIc) and the definitive weights used to calculate the GSDI. In this case, it can be seen that the commercial and operational variable of the pedestrian network has a 75% representation as a whole, indicative of the importance of being in the GSDI, so that public policies to improve access to physical activity opportunities must be focused in the offer of a greater number of equipment and in the improvement of the pedestrian access network, which will result in the decrease of deaths associated with a sedentary lifestyle.

Table 4. Statistical analysis of variables and definitive weights for GSDI. Source: Author's calculations

District	SAS	WEIGHT STAGE STATISTICAL ANALYSIS					GSDI	S
		Commercial	Social	Pedestrian	Vehicular	Demographic		
Atardeceres	36	50%	10%	30%	5%	5%	54,65	0,00852
San José	90	10%	15%	70%	0%	5%	48,58	0,03615
Cumanday	4	90%	5%	5%	0%	0%	55,53	0,03184
La Estación	36	50%	10%	30%	5%	5%	63,74	1,4300
C. del Norte	108	10%	30%	50%	5%	5%	43,48	0,03041
E. cerro de Oro	72	10%	50%	30%	5%	5%	64,88	0,03179
Tesorito	104	20%	20%	50%	5%	5%	65,94	0,01297
Palogrande	34	50%	20%	20%	0%	10%	84,54	0,05404
Universitaria	82	30%	0%	70%	0%	0%	64,39	0,02958
La Fuente	100	40%	10%	50%	0%	0%	68,94	0,02490
La Macarena	58	30%	60%	10%	0%	0%	64,55	0,09075
Villamaría	2	90%	10%	0%	0%	0%	45	0,04475
Definitive weights GSDI		40%	20%	35%	2%	3%		

III.III Gym Spatial Distribution Index (GSDI)

(Fig. 11) shows the results of GSDI for the city scenario. In this case, the first quadrant is the one with a lower GSDI, 55,9. On the other hand, quadrant II has the highest GSDI value, 87,1. In this case, it is observed how the largest number of gyms are concentrated in this quadrant, generating a higher index. Notably, the global GSDI for the city of Manizales is 73,71, which places it in the second-best quartile. In the scenario where the 12 districts of the city are compared, the calculated GSDI presented limits between 39,1 and 86,7 (see Fig. 12), varying from those recorded at the city level, especially in the lower limit. In the upper limit, is the 'Palogrande' district, whereby 95% of its inhabitants belong to a high stratum. This district has a low population density and the highest number of gyms among the districts.

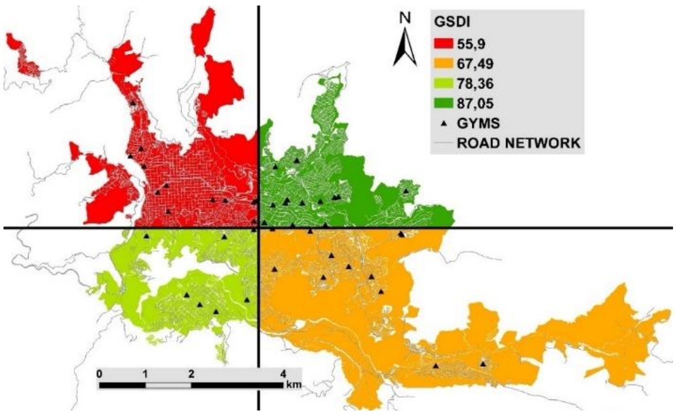

Fig. 11. GDSI by quadrants, city. Source: Author´s calculations

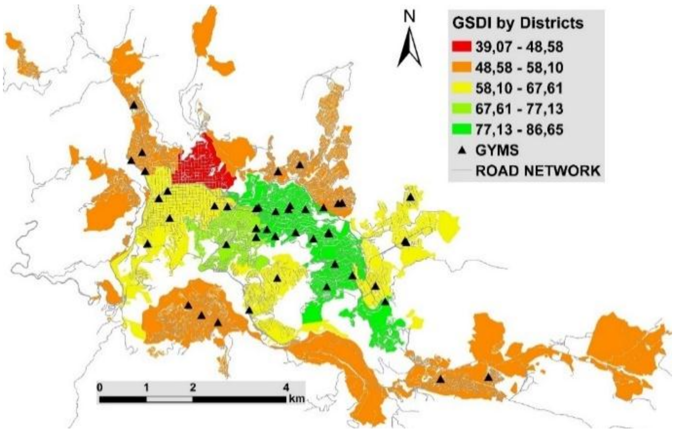

Fig. 12. GSDI by districts. Source: Author´s calculations

Likewise, the district has a low number of deaths due to causes associated with a sedentary lifestyle that together with a good pedestrian network operation, makes its GSDI, the highest among the districts, so there is a good relationship amidst the variables. The same happens with the 'La Estación' district, which has a GSDI of 80,0, with about 80% of its inhabitants in middle and upper-middle strata (4 and 5). Six gyms are located in this district and like the 'Palogrande' district, it has a low number of deaths associated with a sedentary lifestyle. Conversely, in the lower limit is the district 'San José' with a GSDI of 39,1, half of what is registered in the districts of the upper limit. This district has all its inhabitants in middle and low strata, 40% of whom belong to the lowest stratum. Moreover, this district has no gym registration and the coverage through the pedestrian network is low, so its GSDI translates to deficient levels. At numbers between 48,6 and 58,1 of the GSDI we find 4 districts, whereby 'C. del Norte' registers the lowest value, 49,7. This district has an acceptable number of gyms, however, the number of deaths from causes associated with a sedentary lifestyle is high and the operation of the pedestrian network is normal, resulting in a decrease in the GSDI. Of note is that this district has a similar condition to the 'San José' district, with 83% of its inhabitants belonging in the lower strata and 17% in the middle stratum. This condition, compared to those presented by the districts with a GSDI in the upper limit, accounts for the inequality in the distribution of these resources because the upper strata have better GSDI than the lower ones. In addition, the GSDI in the peripheral districts of the city is less than 60 in all cases. This index increases as you approach the population center of the city since these districts have a greater concentration of resources and shorter travel times compared to those located in the peripheries.

In the study of quadrants by districts, a total of 48 quadrants were analyzed; 4 for each district. (Fig. 13) shows limits between 19,1 and 89,7 for the GSDI. The upper limit represents the first quadrant of the 'Palogrande' district, while the lower limit is in the second quadrant of the 'C. del Norte'. It should be noted that the quadrant with the best GSDI is in the district with the best GSDI whereas the quadrant with the lowest GSDI is located in the district with the second-lowest GSDI. This indicates that by performing a more detailed analysis, more specific results are achieved, asserting that public policies aimed at improving this index can be more precise and impact the population that needs it the most.

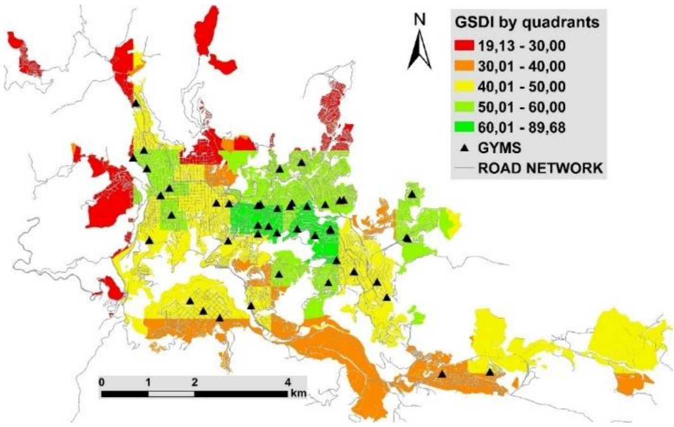

Fig. 13. GSDI by quadrants in each district. Source: Author´s calculations

IV. CONCLUSIONS

In this proposed methodology, five variables that are presumably related to the spatial distribution and the availability of gyms for physical activity were used. Firstly, it is very important to have access to the necessary information to develop the different variables, so the studied scenarios (city, districts and quadrants) give a wide range of options to researchers who decide to apply this methodology to other cities or study areas and have limited access to information. Furthermore, it is recommended to perform an analysis for each of the variables to generate the best scale of study.

It is important to highlight that statistical analysis plays a fundamental role in tentatively determining the weights that each of the variables will have in the calculation of the GSDI. It is also possible to elaborate more on the study, using a higher number of statistical analysis scenarios by varying the weight of the variables in said scenarios minutely.

The results of the GSDI at the city level indicate, preliminarily, that the spatial distribution of such resources and serves as a comparative basis with other cities of similar socio-demographic characteristics.

Moreover, the findings at the district level have a broader level of detail. As a result, the districts that should be prioritized in public policies aimed at increasing access to outdoor gyms or free physical activities, where they also coincide with the population of low socioeconomic strata and that are located on the periphery of the city, where about 46% of the total population of the study area live. It should be noted that most of the resource is located in the central part of the city, around the principal highways that cross it from east to west and vice versa. This means that people located on the periphery must travel by vehicle and spend more time and money to have access, which can be solved by bringing the resource to these places, hence reducing the number of trips. The said analysis is important for the city because the districts are conceived to facilitate the distribution of the budget and public investments of the Municipal Mayors, so this scenario can play a fundamental role in decision making.

In the same take, the analysis of the quadrant level serves to elaborate further on the population that should be subject to prioritization of public investment policies, however, it may be difficult to obtain the information necessary to complete the study.

Finally, this methodology can be applied in different studies of territorial planning like the location of new resources (hospitals, schools, commercial centers or security) and serves as a fundamental complement for market analysis.

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