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Sustainability of the neighborhood urban form: evaluation of twenty cases in Guayaquil-Ecuador

Sostenibilidad de la forma urbana barrial: evaluación de veinte casos en Guayaquil-Ecuador

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ABSTRACT The study of sustainability emerges as a response to the fragmentation and deterioration of urban territories and natural habitats. The objective of this research is to analyse neighbourhood urban form through 20 cases in the city of Guayaquil. A bibliographic study on sustainable urban form is conducted, cases are selected based on geographic and morphological criteria, and field data are collected. Variables and indicators such as compactness, connectivity, green areas, and environmental quality are also selected. For the study, evaluation parameters were established, and through normalisation, neighbourhood sustainability indices were obtained. The results determined a greater influence of the variables of connectivity and green areas on neighbourhood sustainability levels. The article concludes by addressing the value of the proposed methodology in the search for a sustainable neighbourhood urban form that improves the population's quality of life.

RESUMEN El estudio de la sostenibilidad surge como respuesta a la fragmentación y deterioro de los territorios de las ciudades y hábitats naturales. El objetivo de esta investigación es analizar la forma urbana barrial a partir de 20 casos de la ciudad de Guayaquil. Se realiza un estudio bibliográfico sobre la forma urbana sostenible, se seleccionan casos con base en criterios geográficos y morfológicos, y se relevan datos en campo. A su vez, se seleccionaron variables e indicadores tales como: compactidad, conectividad, áreas verdes y calidad ambiental. Se establecieron parámetros de evaluación, y por medio de una normalización se obtuvieron índices de sostenibilidad barrial. Los resultados permitieron determinar una mayor influencia de las variables conectividad y áreas verdes en los niveles de sostenibilidad barrial. El estudio concluye abordando el valor de la metodología propuesta en la búsqueda de una forma urbana barrial sostenible que mejore la calidad de vida poblacional.

KEYWORDS urban form, sustainability, neighborhood unity, indicators, indexes

PALABRAS CLAVE forma urbana, sostenibilidad, unidad barrial, indicadores, índices

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1. Introduction

The sustainability of urban development has become a key research topic due to the implications of climate change and global urbanization. It is projected that by 2050, 75% of the world's population will live in cities (World Bank, 2023; Khodakarami et al., 2023). Urban development has led to the exploitation and degradation of the surrounding environment, generating waste, biodiversity loss, the conversion of agricultural and forest lands, and increased social and spatial inequalities—a situation that is particularly critical for developing regions such as Latin America (Schuster-Olbrich et al., 2023; Weisser et al., 2022; Huang et al., 2015). In this context, research on urban sustainability in line with the Sustainable Development Goals set for 2030 (United Nations-Habitat [UN], 2018) becomes vital for understanding the complex interrelationships among the factors involved and promoting more sustainable and equitable development (Ungureanu and Soimosan, 2023).

For the present study, the neighborhood is used as the unit of analysis, as some authors (Kathibi et al., 2025; Mroko et al., 2020) consider it an appropriate scale for measuring neighborhood sustainability, as it best represents the relationship between the individual and the city. To this end, numerous studies have been conducted to define objectives, variables, criteria, and scales, including those by Kathibi et al. (2023), Maqsood and Zulmesu (2021), Mroko et al. (2020), Zumelzu and Espinoza (2019), and Hernández (2009).

This study analyzes the influence of urban form on neighborhood sustainability using criteria and indicators to derive sustainability indices. These indicators were contextualized within the reality of Ecuadorian cities, particularly Guayaquil.

Guayaquil, one of Ecuador's major urban centers, faces significant challenges stemming from uncontrolled urban expansion, socioeconomic segregation, and environmental degradation. There is also a shortage and unequal distribution of green spaces in urban neighborhoods. Therefore, it is essential to assess the sustainability of these neighborhoods to identify spatial and environmental deficiencies and, as a first step, to propose improvements.

1.1. Case study and problem statement

The urban context of this research focuses on 20 neighborhood units within Guayaquil's administrative boundaries, selected based on geographic location, history, size, and potential for consolidation. This study presents the final results of the research project *Evaluation of Urban Form and Its Influence on Sustainability and Residential Social Well-being, 2021–2024*, based on the preliminary results previously presented (Delgado et al., 2024; Torres and Delgado, 2023). It is important to emphasize that the selected neighborhoods are only a sample of representative cases in Guayaquil and do not aim to cover the entire universe of the city's neighborhoods and districts, due to the limitations of this study.

Guayaquil is Ecuador's most populous city, with 2,746,403 inhabitants (National Institute of Statistics and Censuses [INEC], 2012), covering an area of 34,449 ha (Guayaquil Canton Land Use Plan [PDOT], 2025), within an estuary system comprising the Guayas River and mangroves, at an average elevation of 4 m above sea level, and surrounded by tropical dry forest on its hills. As a port city, it has a historical legacy of commercial, industrial, and service-sector dynamism. It is Ecuador's second-largest city in terms of administrative area and a destination for migrants from both within the country and abroad. It forms part of a metropolitan area that includes the cantons of Daule, Samborombón, and Durán (Delgado, 2013) (Figure 1).

Regarding sustainability, the Municipality of Guayaquil has implemented several projects and initiatives in recent years, as outlined in the Guayaquil Canton Land Use Plan [PDOT] (2025). This document includes incentives through ordinances aimed at improving urban planning standards; for example, increasing the floor area ratio (FAR) by expanding permeable surfaces on properties. Additionally, an ordinance was established to promote sustainable construction in the city center (Municipality of Guayaquil, 2019). However, this is limited only to the immediate development zones of the Center and Peri-center, defined as ZP1 and ZP2.

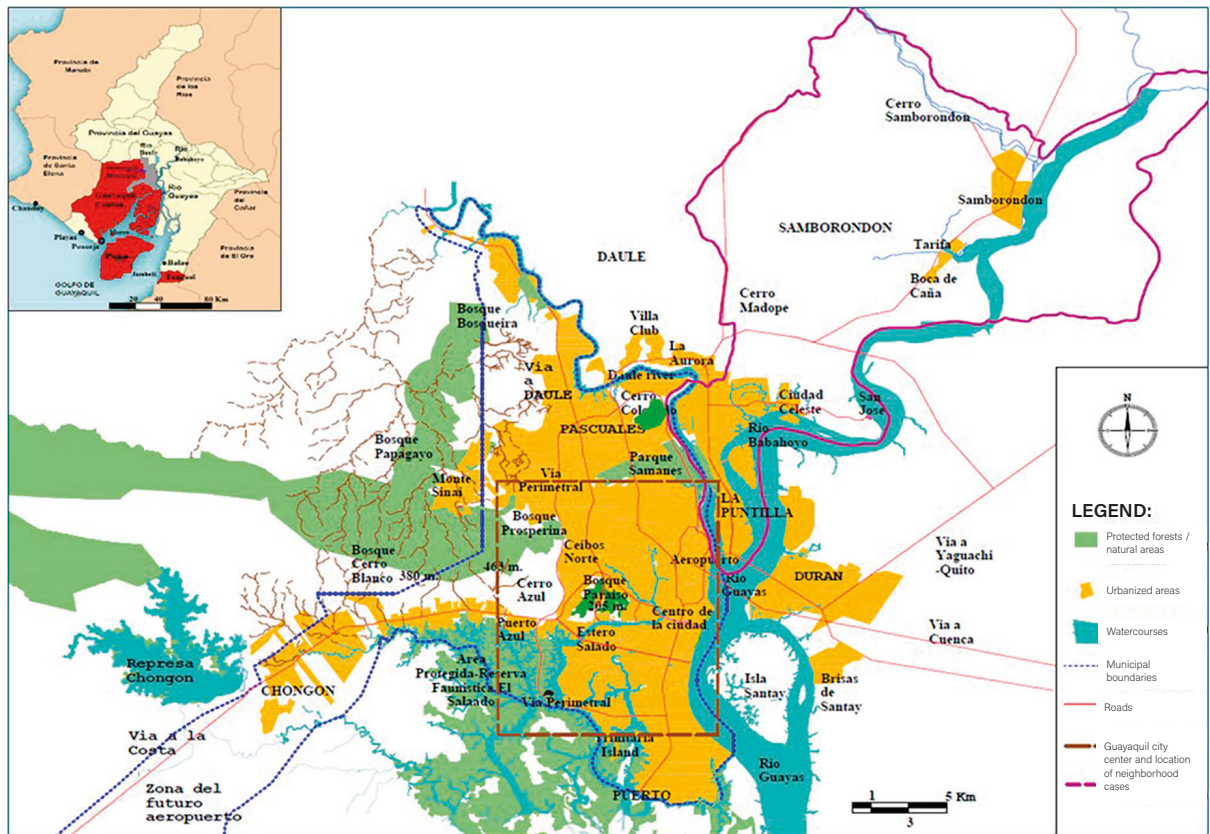


Figure 1: Guayaquil Municipal Area and quadrant showing the location of neighborhood cases. (2025)

Nevertheless, it is undeniable that social and territorial sustainability problems persist. The mobility plan is insufficient, and the city continues to expand toward the periphery, through both informal and formal settlements. Studies such as the one proposed in this research are therefore necessary and provide a starting point for future research.

1.2. Theoretical foundations

The sustainability of the urban form has been widely discussed by various authors in relation to its impact on ecosystems and urban quality of life (Higuera, 2006), as well as in the search for diverse urban models (Breheny et al., 1996). In this context, the neighborhood unit emerges as a more manageable unit of analysis for understanding the urban context and achieving a human scale—the relationship between the housing unit and the built environment—thereby fostering social control and social connections (Jacobs, 1961).

1.2.1. Urban form and its elements

Based on extensive literature review, six elements that are essential components of urban form and its influence are analyzed for this study:

a) Scale

Scale is one of the most relevant elements in the debate on sustainable urban form. Some authors define it as the different levels of complexity within an internal structure that together form a whole—such as a district or region—ranging from the district or region down to the city, the neighborhood unit, streets, blocks, and buildings (Zumelzu, 2016; Ehlers, 2011). These levels define urban form and how it is analyzed, measured, and understood, and are expressed at the microstructural level of the city, in the “neighborhood” as the primary unit for the relationship between the individual and the city (Dempsey et al., 2010; Weissner et al., 2022; Ungureanu and Soimosan, 2023; Maqsood and Zumelzu, 2021; Moreno and Hinostroza, 2019). In turn, the Guayaquil Canton Land Use Plan [PDOT] (2025) defines the neighborhood as the basic unit of social organization and human settlement in a city.

b) Density-Compactness

Density is an indicator frequently used in urban studies to determine the provision of facilities and services to an area. It complements the compact city model, which advocates the concentration of services

and a reduction in mobility needs (Bosetti, 2016), based on factors such as connectivity, urban patterns, land uses, and architectural typologies (Moreno and Hinostroza, 2019). It is therefore necessary to complement this indicator with others, such as those mentioned, in order to provide a better understanding of the urban form of neighborhoods within the urban context (Bosetti, 2016; Talen, 2011).

c) Connectivity-Mobility

Connectivity plays an essential role in the development of a sustainable urban form (Moroke et al., 2020). Just as with Density, there are interrelated elements involved, such as access to various public transportation systems, distance to bus stops, bike lanes, and urban patterns. Furthermore, connectivity leads to universal accessibility, understood as the provision of streets and sidewalks that are accessible to all users—free of obstacles, comfortable, and safe to navigate (Sternberg, 2000).

d) Accessibility—Green Spaces

At the neighborhood level, accessibility is also defined as access within walking distance to various services, urban facilities, and recreational green spaces, at a maximum distance of 400 m (Tiago et al., 2024), considering accessibility a fundamental element of good urban design, by reducing the tendency to use cars, lowering the carbon footprint, improving

residents' quality of life, and even increasing the economic value of their properties (Sui and Zhu, 2024; Ewing et al., 2008). The latter must be complemented by land-use management measures to prevent potential phenomena such as gentrification (Gorey, 2025). Regarding public amenities, proximity to green spaces is of fundamental importance, as it helps improve residents' quality of life and their physical and mental health (Nieuwenhuijsen et al., 2022).

e) Environmental Quality

Two elements are considered: air quality and noise pollution. The first relates to the scarcity of green spaces in Guayaquil's urban area, the high level of CO₂ in the urban environment, and the carbon footprint, with Air Quality Index (AQI) levels ranging from 250 to 360. The second factor, based on the daytime and nighttime noise map prepared by the Municipality of Guayaquil (Guayaquil Canton Land Use Plan [PDOT], 2025), shows levels ranging from 50 to 70 dB.

1.3. Integration of sustainability elements, selection of indicators and indices

Assessing sustainability through the use of indicators as units of measurement allows for a quantitative approach to the complex phenomenon of sustainability (Dizdaroglu, 2015), taking into account various studies (Khodakarami et al., 2023; Segnestam,

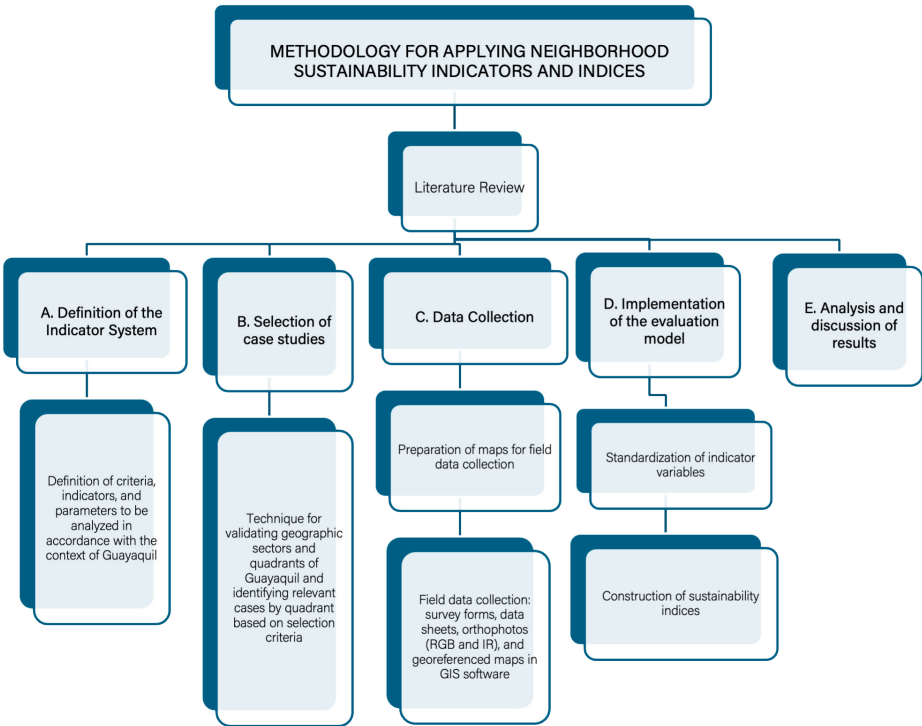


Figure 2: Methodological flowchart of the research. (2025)

Component	Indicator	Formula/Methodology
Compactness	Density (inhabitants/ha)	Number of inhabitants / total area of the Neighborhood Unit (UB)
	Housing density (units/ha)	Number of of housing units/Total UB area
	Percentage of land occupied (%)	Total area/Total area UB lots
	Absolute Density (m)	Built-up volume per unit of UB area = (Built-up (m ²) * height (m) / total lot area (m ²))
Connectivity	Percentage of the population living near amenities (%). Distance to Basic Social Facilities (ISB) (Health, Education, Sports, Markets, Recreation)	Percentage of the population near facilities: Education 500 m, Basic healthcare 500 m, Hospitals 1 km, Sports 500 m, Mini-markets 500 m, Recreation 300 m.
	Proximity—walking distance (m) to public transportation stops	Walking distance from a central point in the neighborhood to at least one bus stop within a radius of 300–500 and 1,000 m.
	Proximity—distance to bike paths (m)	Distance from a central point in the neighborhood to at least one bike path within a radius of 300–500 and 1,000 m. If none exist, it is assumed they are more than 1,000 m away.
	Proportion of public pedestrian space (%)	Percentage of pedestrian-only road area relative to vehicular road area within the UB
Green spaces	Accessibility and continuity of public pedestrian routes (%)	Percentage of the length of accessible and continuous routes (obstacle-free travel corridor) in the UB
	Percentage of green spaces (%)	Percentage of green space / Total UB area
	Distance to green and recreational areas (m)	Distance to a green space (<1,000 m ²) within a radius of 200–500 m. Distance to a green space (>1,000 m ²) within a radius of 500–2,000 m.
	Percentage of Permeable Soil (%)	Percentage of natural soil area/total green area (excluding circulation areas and paved areas)
Environmental quality	Air quality (AQI)	Air quality sensors—CO (ppm), between 250 and 360 AQI.
	Acoustic comfort (dB)	NEC 11—Ecuadorian Building Code, between 50 and 70 dB.

Table 1: Components, indicators, and formula/methodology for their application. (2025)

2023; Zulaica and Tomadoni, 2021; Hernández, 2009) and, in particular, the “Agenda 21 Plan” (Barcelona Urban Ecology Agency, 2009). This methodology has been widely used but rarely applied in Latin America. However, notable studies in this context include those by Jofre (2009) and Escobar (2006), as well as, in Ecuador, Hermida et al. (2015) in Cuenca; Vélez et al. (2023) in Loja; and Delgado et al. (2024) in Guayaquil. Thus, the integration of sustainability elements includes conceptual aspects related to the selection of indicators, as well as technical aspects such as the standardization of variables for the construction of indices that enable comparative analysis (Huang et al., 2015; Dizdaroglu, 2015), while acknowledging the multiple phenomena involved, multicausality, interdependence, and the multiscale reality of territories (Hilley and Sim, 2020; Kennedy et al., 2014; Jofre, 2009).

2. Methodology

The research was based on the initial study by Delgado et al. (2024), “Urban Sustainability—Analysis at the Neighborhood Level,” expanding the scope of the conceptual review, the parameters for measuring indicators, and the number of neighborhood units to be analyzed, to obtain a sample that, while not intended to cover the entire neighborhood universe of Guayaquil, is representative of the city as a whole. This process was structured into five phases (Figure 2).

2.1. Definition of the indicator system

In the first phase, the indicator system was defined based on the sustainability criteria set forth in the *System of Indicators and Constraints for Large and Medium-Sized Cities* (Barcelona Urban Ecology Agency, 2009), and a review of various sources (García and Seguel, 2019; Moreno and Hinostroza, 2019; Huang et al., 2015; Petrov et al., 2013; Hernández, 2009; Jofre, 2009; Escobar, 2006; Segnestam, 2003), four main sustainability criteria—compactness, connectivity, green spaces, and environmental quality—were defined. Based on these, 14 indicators (UB) were selected (Table 1).

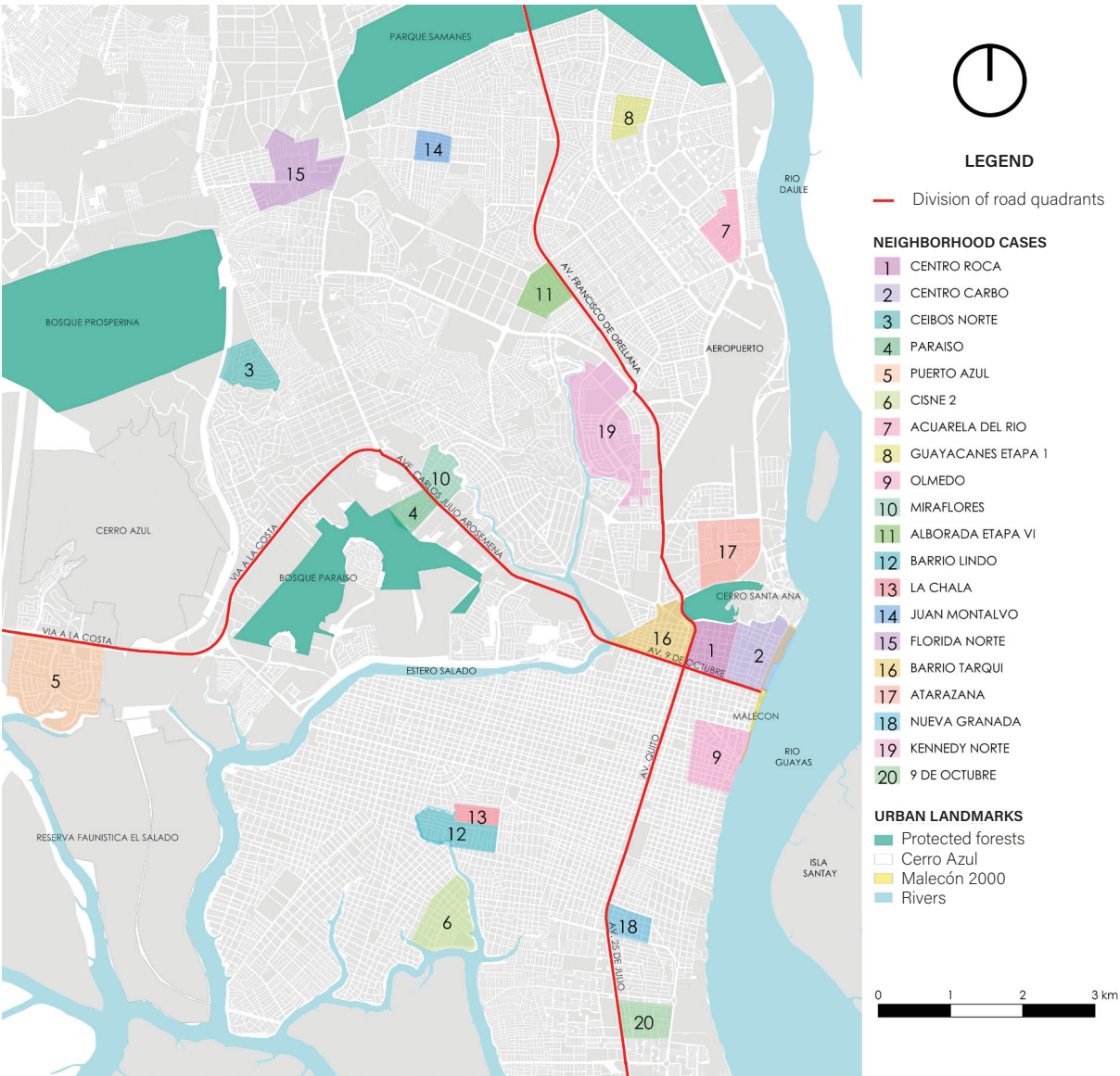


Figure 3: Location of neighborhood unit cases in quadrants defined by Guayaquil's road network. (2025)

2.2. Selection of case studies

The cases to be used for the study were selected based on criteria such as: location (distributed across the city's four geographic quadrants), size (within a 500-meter radius), historical period (selected from four historical periods representative of the city: 1821–1929; 1954–1961; 1970–1984; 1984–1990), morphological (grid, radial, linear, and organic patterns), social (upper-middle, middle, and lower classes), architectural typology (single-story, two-story, and multi-story residential buildings, with or without arcades), and in accordance with morphological-administrative characteristics; thus, in the city center, the neighborhood unit is defined by the urban parishes.

Regarding the location of the cases, the city was divided into four quadrants along major thoroughfares, running north to south and east to west. Thus, the north-south axis runs along Francisco de Orellana Avenue, enters the city center, and continues south along Quito Avenue. The east-west axis runs from the city's Malecón along 9 de Octubre Avenue, crosses the bridge over the Estero Salado, and continues along Carlos Julio Avenue toward Del Bombero Avenue, which leads to the coast.

Seven neighborhoods were selected in the northwest quadrant (Barrio Tarqui, Miraflores, Kennedy Norte, Alborada VI, Juan Montalvo, Florida Norte, Ceibos Norte), five in the southwest (Paraíso, Puerto Azul, La Chala, Barrio Lindo, Cisne 2), 5 in the northeast (Centro Roca, Centro Carbo, Atarazana, Acuarela del Río, Guayacanes Phase 1), and 3 in the southeast (Olmedo, Nueva Granada, 9 de Octubre), for a total of 20 cases (Figure 3).

2.3. Data collection

In this phase, plans for field data collection were prepared based on publicly available information from the Municipality of Guayaquil and a review of the ordinances of the Guayaquil Canton Land Use Plan [PDOT] (2025). The following tools were selected for data collection: survey and data forms, orthophotos (RGB and IR), georeferenced maps, and GIS software. A total of 120 students enrolled in the Sustainable Urban Development and Pre-Professional Practicum courses participated, and 12 base maps were developed for each neighborhood unit.

2.4. Implementation of the evaluation model

To define the parameter ranges for the indicators, a literature review was conducted, and international references (García and Seguel, 2019; Barcelona Urban Ecology Agency, 2009) and national references (Guayaquil Canton Land Use Plan [PDOT], 2025; Vélez Alvear et al., 2023; Hermida et al., 2015). To validate the estimates, high, low, and medium values were defined (Table 2).

In turn, to develop a Neighborhood Urban Sustainability Index (ISUB), variables were normalized by assigning a rating scale to each indicator on a normalized scale (EsN) ranging from 1 to 0, where 1 represents the maximum value of the parameter range assigned per indicator and 0 represents the minimum value (Pollesh and Dale, 2016; Pinar et al., 2014), using the Min-Max method, as described by Gursoy Haksevenler et al. (2025) (Table 2).

Consequently, neighborhood sustainability indices were developed based on four components—compactness (*Com*), connectivity (*Con*), green spaces (*Av*), and environmental quality (*Ca*)—and the fourteen indicators distributed across these components. This was done by summing the parameterized indices for each neighborhood unit and dividing by the total number of normalized indicators. The ISUB was calculated using the formula:

$$ISUB = \frac{Com + Con + Av + Ca}{No. of Indicators (14)}$$

The variables were aggregated by assigning the same weight to each one. This approach was chosen because this is an exploratory study and there is no local empirical evidence to prioritize the components; it is the option that introduces the least subjective bias and serves as a valid starting point for indices in the exploratory stage (Nardo et al., 2005) and for the Multidimensional Poverty Index (Alkire and Foster, 2011).

Subsequently, to review the results regarding sustainability levels, we drew on international references (Zulaica and Tomadoni, 2021) and local references (Hermida et al., 2015; Vélez Alvear et al., 2023). However, these studies differ from the present study in terms of methodology and indicator selection; therefore, they were used only as contextual references. The following ranges were used: 0.16–0.20; 0.21–0.30; 0.31–0.40; 0.41–0.50; 0.51–0.60, which indicate neighborhood sustainability levels.

Maximum and minimum values				
High	Upper-middle	Medium	Medium-Low	Low
1	0.75	0.5	0.25	0

Table 2: Rating scale for standardizing indicators based on the range of parameters that influence the definition of the Neighborhood Sustainability Index. (2025)

No. Casos	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Roca-Centro	Carbo-Centro	Ceibos Norte	Paraíso	Puerto Azul	Cisne 2	Acuarela	9 de octubre	Guayacanes-Etapa 1	Olmedo	Miraflores	Alborada	Barrio Lindo	La Chala	Juan Montalvo	Florida Norte	Barrio Tarqui	Atarazana	Granada	Kennedy Norte
1 INDICADORES																				
1 Densidad (Hab/ha)	90	44	124	247	99	224	85.51	140.28	159	186	207	187	324	124	246	125	96	172.18	91.95	88.41
Escala Normalizada EsN	0.2	0	0.37	0.98	0.24	0.88	0.18	0.45	0.55	0.69	0.79	0.68	1	0.37	0.97	0.38	0.23	0.62	0.22	0.18
2 Densidad (Viv/ha)	10	5	25	29	17	32	30.8	21.3	30	17	19	57	54	48	49	25	19	23	18.39	8.78
EsN	0.01	0	0.35	0.49	0.23	0.6	0.55	0.26	0.5	0.23	0.24	0.96	0.9	0.8	0.85	0.3	0.24	0.28	0.24	0
3 Porcentaje de suelo ocupado (%)	40	45	63.7	72.8	65	71	88	78	34	62	59	74	55	57	84	86	76.1	87	52.75	74.7
EsN	0.23	0.25	0.68	1	0.75	1	1	1	0.12	0.6	0.45	1	0.45	0.48	1	1	1	1	0.40	1
4 Compacidad (m)	8.13	7.24	3.32	1.92	2.5	1.09	3.77	4.4	1.65	2.65	3.46	3.91	3.02	3.45	2.36	5.02	1.08	3.02	1.94	4.01
EsN	1	1	0.5	0.2	0.3	0.01	0.65	0.80	0.12	0.27	0.60	0.70	0.50	0.65	0.30	1	0.10	0.50	0.24	0.75
Subtotal EsN	1.44	1.25	1.90	267	1.52	2.49	2.38	2.51	1.29	1.79	2.08	3.34	2.85	2.30	3.12	2.68	157	2.40	1.10	1.93

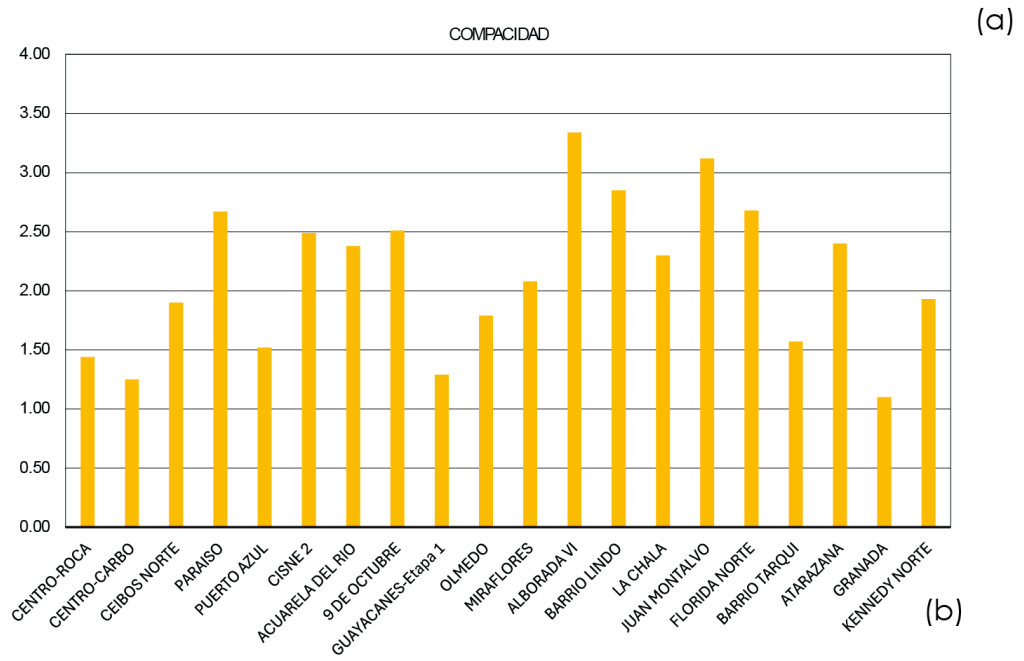


Figure 4: Results of the Compactness component. a) Indicator normalization; b) bar chart; c) urban morphology (A: Alborada, B: Juan Montalvo, C: Barrio Lindo). FCI Project (2024)

3. Results

3.1. Components: mean and indicator parameters

The results are presented in Table 3, which shows the mean for each indicator across the 20 neighborhood units and includes the parameter ranges defined for each indicator.

3.2. Compactness component

Urban density per inhabitant is low to moderate in 80% of cases, corresponding to an average of 153 (inhabitants/ha). There is only one case with a density higher than 324 (inhabitants/ha), corresponding to the Barrio Lindo neighborhood unit, which originated as an informal settlement. In terms of housing density per hectare, 80% of cases have a low-to-medium density, below 30 dwellings per hectare. Regarding the percentage of land occupied, most cases show a moderate level. With respect to the compactness indicator, the cases in the city center and the Carbo and Roca parishes stand out with a high level, due to the presence of high-rise buildings. In the overall results for this component, the highest levels are found in the Alborada and Juan Montalvo cases to the north and the Barrio Lindo case to the south of the city (Figure 4).

3.3. Connectivity component

Regarding distance to amenities, 60% of cases show a high level; however, this changes in the case of gated communities such as Ceibos Norte and Puerto Azul, due to the lack of educational or healthcare institutions within them, even though they do have commercial or recreational facilities, resulting in a medium-low level.

Regarding distance to bus stops, a medium-high value is observed in 60% of cases, with a maximum distance of 300 meters; in contrast, gated communities show a medium-low value. Regarding distance to bike lanes, the majority of cases (85%) fall into the low category; only in downtown areas such as Carbo and Roca, as well as in Tarqui and Kennedy Norte, is the level medium, due to the presence of partial bike lanes within these areas or along their perimeter. For this indicator, distance ranges were established as 300–500 meters and over 1,000 meters to at least one bike path. Additionally, the ratio of pedestrian to vehicular road space is low in all cases.

Universal accessibility and pedestrian continuity also rank among the lowest indicators. Thus, on sidewalks in most cases, continuity is interrupted by obstacles such as garage entrances, street signs, planters, trash cans, and unstable sidewalk surfaces,

Component	Indicator	Mean value obtained from case studies	Parameters		
			*High (AUS)	*Medium	*Low
Compactness	Density (inhabitants/ha)	153.00	>250 people/ha	150 people/ha	<50 people/ha
	Density (inhabitants/ha)	26.91	>60 live/ha	30 live/ha	< 10 individuals/ha
	Percentage of land occupied (%)	66.25	>70%	60%	<30%
	Compactness (m)	3.34	>5 m	>3 m	<1 m
Connectivity	Percentage of the population living near facilities (%). Radii: 300, 500, 1,000 m	47.25	>50%	40%	<30%
	Proximity—walking distance (m) to public transit stops—radii of 300, 500, and 1,000 m.	364.75	<=300 m	500 m	>1,000 m
	Proximity—distance to bike paths (m)—radii of 300, 500, and 1,000 m.	1225	<=300 m	500 m	>1000 m
	Share of public pedestrian space (%)	17.43	>50%	30%	<7%
	Accessibility and continuity of public pedestrian networks (%)	18.75	>40%	30%	<10%
Green spaces	Percentage of green spaces (%)	3.84	>30%	12	<1%
	Distance to green and recreational areas (m)—radii of 200, 500, and 2,000 m	647.05	<200 m	500 m	>2000 m
	Percentage of permeable soil (%)	2.62	>30%	15%	<2%
Environmental quality	Air Quality (AQI)	338	<250	330	>360
	Noise comfort (dB)	69.2	<50	55	>70

Note: Theoretical and empirical basis for defining ranges:
*Density (inhabitants/ha) and (residents/ha)—Range determined based on Guayaquil's population projection for 2030, assuming that the current urban footprint will remain unchanged [PDOT], (2025).

*Percentage of land occupied (%)—Based on the FCI Project (2024) and Hermida et al. (2015).

* Compactness (m)—Based on studies by the Urban Ecology Agency (2009).

* Percentage of population near public facilities (%)—Based on the FCI Project (2024), Moreno and Hinojosa (2019), and Hermida et al. (2015).

* Distance to public transportation stops and bike lanes (m)—Based on Moreno and Hinojosa (2019).

* Continuity of public pedestrian networks (%)—Based on the FCI Project (2024).

* Percentage of green spaces (%)—Based on Konijnendijk (2022) and the FCI Project (2024).

* Distance to green and recreational areas (m)—Based on [PDOT], (2025).

* Percentage of permeable soil (%)—Based on Hermida et al. (2015).

* Air quality and acoustic comfort—Based on Calero et al. (2017) and the FCI Project (2024).

Table 3: Results: average indicators and range of parameters. (2025)

No. Casos	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Roca-Centro	Carbo-Centro	Ceibos Norte	Paraiso	Puerto Azul	Cisne 2	Acuarela	9 de octubre	Guayacanes-Etapa 1	Olmedo	Miraflores	Alborada	Barrio Lindo	La Chala	Juan Montalvo	Florida Norte	Barrio Tarqui	Atarazana	Granada	Kennedy Norte
2	INDICADORES																			
1	Porcentaje acceso a equipamientos (%)	50	50	40	45	40	45	45	40	50	45	40	45	50	50	50	50	50	50	50
	EsN	1	1	0.5	0.75	0.5	0.75	0.75	0.5	1	0.75	0.5	0.75	1	1	1	1	1	1	1
2	Distancia a paradas de buses (m)	300	300	750	500	750	300	480	503	350	80	90	500	300	300	225	267	260	500	240
	EsN	1	1	0.25	0.5	0.25	1	0.55	0.6	0.87	1	1	0.5	1	1	1	1	0.5	1	1
3	Distancia a ciclovías (m)	750	750	1000	1000	1000	1000	1000	1500	1500	1500	1500	1500	1500	1500	1500	1500	750	1500	1500
	EsN	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0.5
4	Porcentaje peatonal/vehicular (%)	9	8	21	24	21	24	18	26.51	25	25	22	21	9	8	7	9	22	15	11
	EsN	0.1	0.1	0.25	0.28	0.25	0.28	0.24	0.4	0.3	0.3	0.25	0.25	0.1	0.1	0.1	0.1	0.25	0.18	0.5
5	Continuidad-accesibilidad universal (%)	25	26	20	20	20	15	15	15	25	25	20	25	15	10	15	15	15	25	10
	EsN	0.25	0.25	0.1	0.1	0.1	0.06	0.06	0.06	0.25	0.25	0.1	0.25	0.06	0.01	0.06	0.06	0.06	0.25	0.01
	Subtotal EsN	2.6	2.6	1.1	1.63	1.1	2.09	1.6	1.56	2.42	2.3	2.35	1.75	2.16	2.11	2.16	2.16	2.56	1.93	2.51

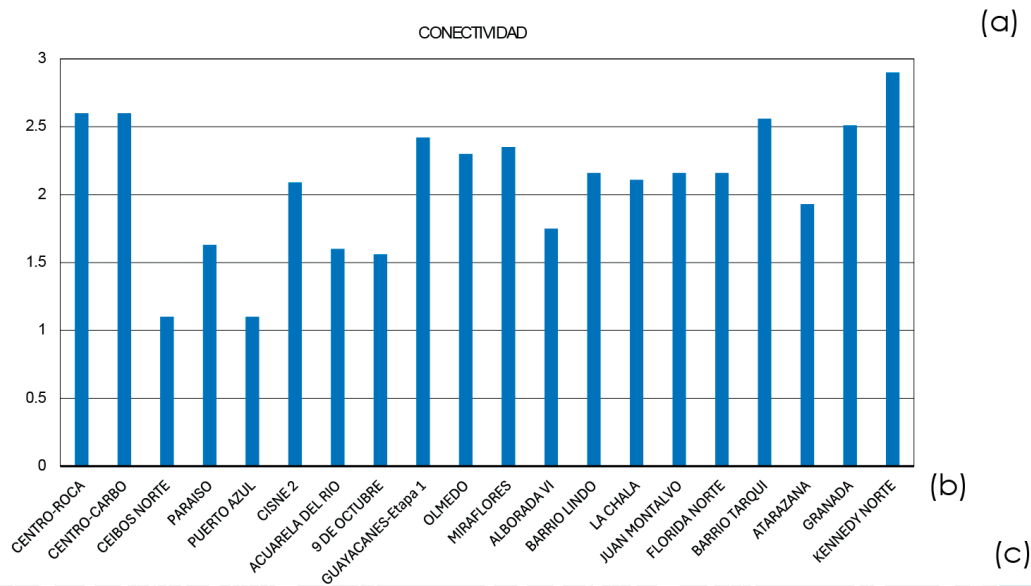
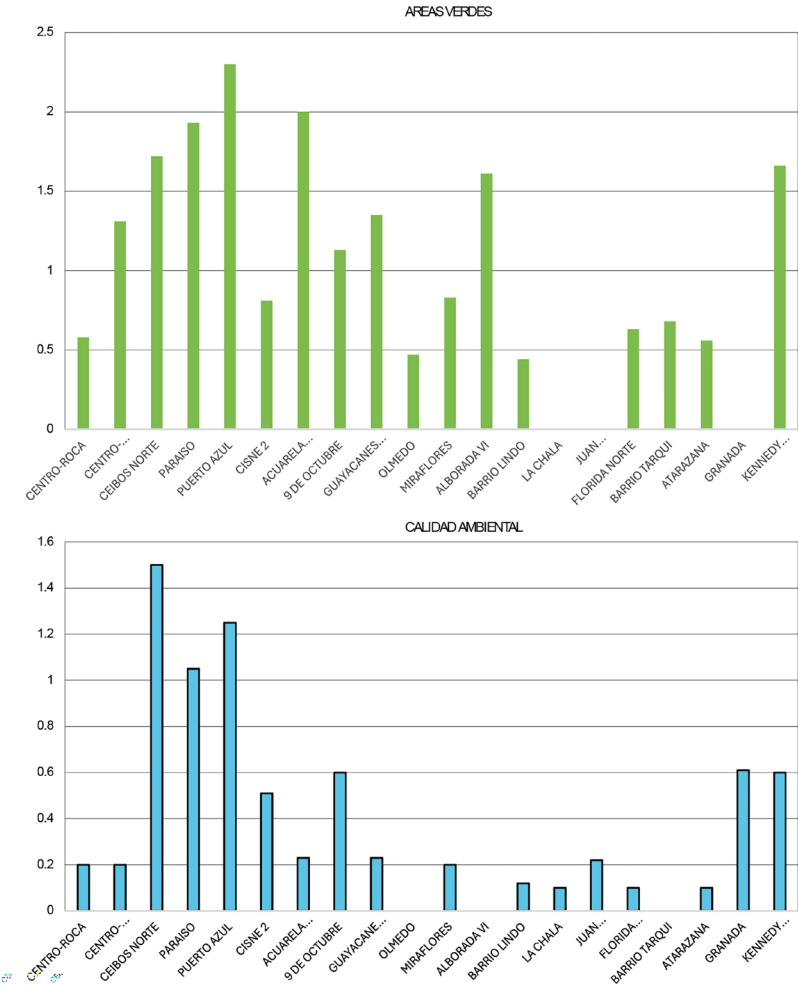


Figure 5: Results of the Connectivity component. a) Evaluative normalization of indicators; b) bar chart; c) urban morphology (A: Kennedy Norte; B: Tarqui; C: Centro parishes: Roca and Carbo). FCI Project (2024)

No. Casos	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Roca-Centro	Carbo-Centro	Ceibos Norte	Paraíso	Puerto Azul	Cisne 2	Acuarela	9 de octubre	Guayaquines -Etapa 1	Olmedo	Miraflores	Alborada	Barrio Lindo	La Chala	Juan Montalvo	Florida Norte	Barrio Tarquí	Atarazana	Granada	Kennedy Norte
INDICADORES																				
3 AREAS VERDES																				
1 Porcentaje áreas verdes (%)	2	11	8.1	1.3	11.2	2	8	4	8.4	0.57	0.09	5.6	0.078	0	0	0.25	0.66	2.26	0	11.2
EsN	0.08	0.48	0.34	0.7	0.47	0.08	0.45	0.18	0.35	0	0	0.23	0	0	0	0	0	0.13	0	0.46
2 Distancia a áreas verdes (m)	500	300	300	300	300	1000	60	300	65	600	300	150	640	2000	2000	431	400	750	2000	545
EsN	0.5	0.83	0.83	0.83	0.83	0.33	1	0.83	1	0.46	0.83	1	0.44	0	0	0.63	0.68	0.43	0	0.6
3 Porcentaje suelo permeable (%)	1.72	1.74	5.49	4.2	12.45	4.2	5.4	1.86	0.3	0.4	1.73	3.97	0.11	0	0.9	0.13	0.4	1.21	0.1	6.0
EsN	0	0	0.55	0.4	1	0.4	0.55	0.12	0	0	0	0.38	0	0	0	0	0	0	0	0.6
Subtotal EsN	0.58	1.31	1.72	1.93	2.3	0.81	2.0	1.13	1.35	0.47	0.83	1.61	0.44	0	0	0.63	0.68	0.56	0	1.66
4 CALIDAD AMBIENTAL																				...
1 Calidad del aire (CO2-PPM)	360	360	250	300	220	330	350	330	350	370	360	370	350	360	350	360	370	360	330	330
EsN	0.1	0.1	1	0.75	1	0.5	0.12	0.5	0.12	0	0.1	0	0.12	0.1	0.12	0.1	0	0.1	0.5	0.5
2 Confort acústico (Db)	70	70	55	56	57	75	65	70	65	75	70	75	73	75	70	75	77	76	65	70
EsN	0.1	0.1	0.5	0.3	0.25	0.01	0.11	0.1	0.11	0	0.1	0	0	0	0.1	0	0	0	0.11	0.1
Subtotal EsN	0.20	0.20	1.5	1.05	1.25	0.51	0.23	0.6	0.23	0	0.2	0	0.12	0.1	0.22	0.1	0	0.1	0.61	0.6



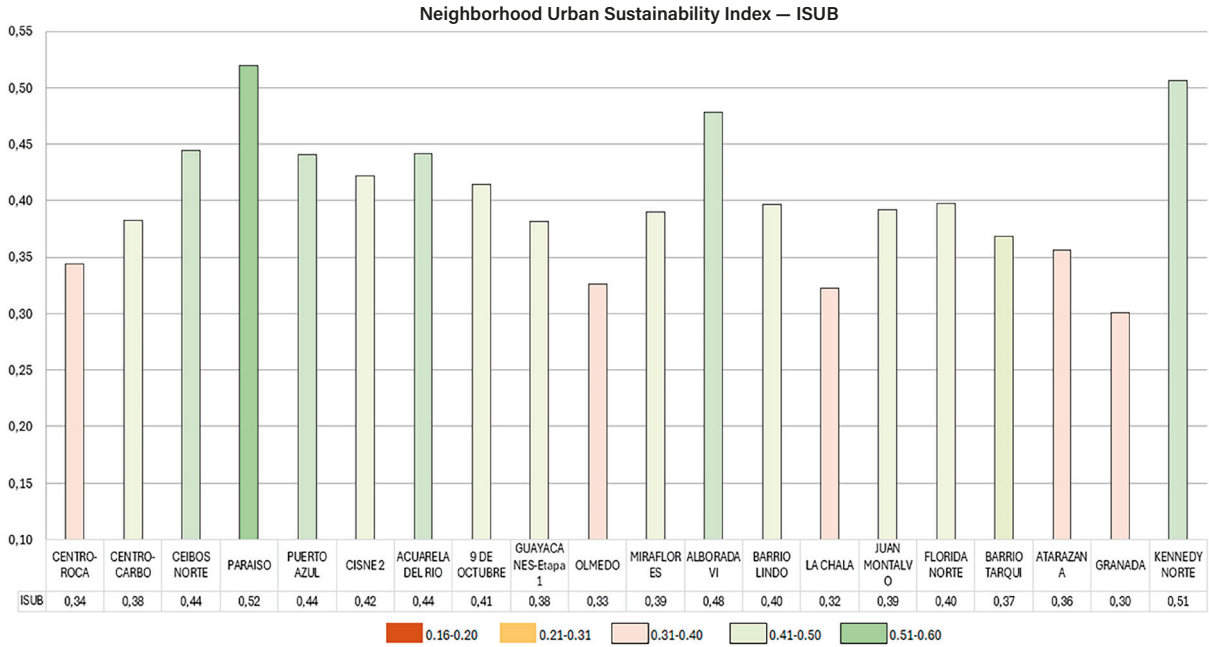


Figure 7: Overall results of sustainability indices by neighborhood units. (2025)



Figure 8: Urban patterns and photographs of neighborhood cases with the highest ISUB values obtained, including the city-center case. (A: Paraíso, B: Kennedy Norte, C: Ceibos Norte, D: Acuarela, E: Puerto Azul, F: Alborada VI Etapa, G: Centro Roca y Carbo). FCI Project (2025)

Cases	Cases							
	Case 1	Case 2	Case3	Case 4	Case 5	Case 6	Case 7	Case 8
	Paraíso	Kennedy norte	Ceibos norte	Acuarela del río	Puerto azul	Alborada VI	Centro-roca	Centro-carbo
Area (HA)	21	66,96	37,3		80,08	31,6	42,48	65,25
Housing typologies	The dwellings are 1- to 3-story houses, with varying heights; some are terraced due to the irregularity of the terrain.	Single-family homes and apartments.	The dwellings are 1- to 2-story houses, some terraced due to the irregularity of the terrain; therefore, their heights vary up to 4 stories.	Single-family homes, apartments, hotels, and collective housing.	The dwellings are 1- to 3-story houses, with varying heights, and 20% are apartments.	Single-family homes, apartments, hotels, and collective housing.	Most dwellings are apartments in high-rise buildings, collective housing, and single-family homes.	Most dwellings are apartments in high-rise buildings, collective housing, and single-family homes.
								

Figure 9: Neighborhood unit area and housing types in neighborhoods with the highest ISUB scores. (2025)

and there are no ramps for people with disabilities; which are only present in the Roca and Carbo downtown areas, in the tourist and business district—though even these have shortcomings; for example, they end at a gap caused by the difference in level between the street and the sidewalk, making it difficult for wheelchair users to navigate them independently (Torres and Delgado, 2023).

Overall, within the connectivity component, the highest scores are found in Kennedy Norte and Tarqui, followed by Roca and Carbo (Figure 5). The latter two areas are served by several bus lines, the Metrovía (a north-south bus transit system), and the Aerovía (an aerial transit system connecting to Durán, an urban parish on the other side of the Guayas River).

3.4. Green spaces component

Regarding this component, the indicator for the percentage of green spaces is one of the most critical: 45% of cases fall within the 0–1% range for green spaces, and 55% are at a medium level, with a maximum of 11.2% green spaces. No case reaches the high level of 30% green spaces.

Regarding distance to green spaces, only 15% of cases achieve optimal values of less than 300 meters on foot; with regard to permeable surfaces, this indicator is low in all cases (Figure 6).

3.5. Environmental quality component

Regarding environmental quality, air quality measurement data obtained through sensors and mobile applications were used (Patiño et al., 2024; Burbano, 2022). Optimal results were observed for Ceibos Norte and Paraíso, with average CO₂-PPM concentrations of 250–220. Regarding acoustic comfort, only the Puerto Azul, Ceibos Norte, and Paraíso cases had low-to-moderate levels, while the remaining cases had high noise levels. Thus, in the city center, levels can range from 70 to 80 dB. In other cases, this measurement corresponds to 60–70 dB (Calero et al., 2017) (Figure 6).

3.6. Neighborhood Urban Sustainability Indices (ISUB)

The indices were estimated to obtain a relative measure of sustainability. These show low levels in most of the neighborhoods analyzed, as 70% fall within the range of 0.31 to 0.40, considered an average value; 20% fall between 0.41 and 0.50, corresponding to a medium-high value; and only 10% exceed 0.51, an optimal-high value. The median is 0.39, which is considered an average level within the established ranges (Figure 7).

The urban patterns and photographs of the neighborhoods with the highest ISUB values, as well as the downtown area, are presented in Figure 8. Meanwhile, the areas of the neighborhood units and the housing types in the neighborhoods with the highest ISUB levels are shown in Figure 9.

4. Discussion

The main findings regarding the overall sustainability indices place most cases at a medium-to-low level (0.40), using local and international cases as references. However, these cases differ in methodology, indicator selection, and weighting; therefore, these references were used only qualitatively and contextually.

Taking this into account, the ranges obtained in other studies in Cuenca and Loja (Vélez Alvear et al., 2023; Hermida et al., 2015) indicate average levels between 0.31 and 0.40. Although these are quite low compared to other studies (Zulaica and Tomadoni, 2021), which classify 0.58 to 0.67 as very low and 0.71 to 0.75 as average, and other studies with even higher levels (Gursoy Haksevenler et al., 2025), with average levels ranging from 40 to 60 out of 100. In turn, compared to other studies in Latin American cities, such as Temuco, Chile (García and Seguel, 2019), this study shows low scores on mobility indicators, such as bike lanes, pedestrianization, universal accessibility, and the allocation of public pedestrian space (Moreno and Hinostroza, 2019; Weissner et al., 2022).

The highest levels of sustainability are found in neighborhoods near natural protected areas and major connecting roads, such as Paraíso and Kennedy Norte, on the edge of the Paraíso tropical dry forest and the Estero Salado, and at the foot of V3 connecting roads, according to Guayaquil's road classification ordinance [PDOT] (2025). In the case of Paraíso, it is at the foot of Carlos Julio Avenue; in the case of Kennedy Norte, it is crossed by Francisco de Orellana Avenue. Additionally, neighborhoods such as Alborada, Ceibos Norte, Acuarela del Río, and Puerto Azul have an average level of on-site amenities and road connectivity. However, these results must be interpreted with an awareness of the shortcomings affecting these neighborhoods, such as poor pedestrian accessibility, a lack of bike lanes, and environmental quality. Puerto Azul is also located on the edge of a natural protection area, such as the Estero Salado.

About compactness, the parishes in the city center, such as Carbo and Roca, while exhibiting a high level of compactness due to high-rise buildings ranging from 3 to 35 stories with an average height of 22 meters, have low residential Density. This suggests a low occupancy rate in these downtown buildings, which affects their quality as urban public spaces, resulting in limited activity and a sense of insecurity, especially at night.

Additionally, downtown parishes have high levels of connectivity, as they are home to various public transportation lines, the aerial tram system, and partial bike lanes, even though there are shortcomings in the continuity of public space on sidewalks and in green spaces and environmental quality. These shortcomings highlight the lack of a clear local land-use policy for the city center. Although there are some initiatives and regulations established by the Municipality of Guayaquil, such as the Ordinance on Downtown Buildings (2019), they do not include instruments for the comprehensive planning and implementation of housing in the city center—and, in particular, social housing—but only for the city's outskirts, through the Special Zones of Social Interest [ZEIS].

About connectivity, while indicators of distance to public facilities and bus stops are high in most cases (60%), indicators of distance to bike lanes, the distribution of public pedestrian infrastructure, and universal accessibility are low in the majority of cases. Only 20% of cases feature partial and discontinuous bike lanes; universal accessibility is absent in most cases and is only partially present in downtown areas. Furthermore, the low levels of pedestrian-friendly public road infrastructure point to one of the main shortcomings of Guayaquil's neighborhoods in mobility: the prioritization of vehicles over pedestrians and cyclists. A walkable city leads to reduced pollution levels, improved health for its residents, and a higher quality of urban life (Torres and Delgado, 2023). This implies that planning policies at both the neighborhood and city levels should be shifted toward more sustainable mobility.

Regarding green spaces, the percentage of green areas and permeable surfaces is low in most cases (15%) and even nonexistent in some. This is vital, given that Guayaquil is a city with a high UV index and an average temperature of 30 degrees, which is rising due to the effects of climate change—highlighting the urgency of providing neighborhoods with green spaces and incorporating nature-based solutions (Salmon et al., 2023; Manual on Urban Green Infrastructure, [MUVH], 2022) in urban and architectural improvement or new development projects. The indicator of distance from a neighborhood's central point to these green spaces is also low to moderate, highlighting the need to improve the equitable distribution of these areas within the neighborhood's urban fabric (Konijnendijk, 2022). At the same time, environmental quality—in terms of air quality and acoustic comfort—is low, which translates into a low quality of life and the potential incidence of respiratory diseases, as well as noise-induced stress and reduced environmental comfort when using public and private spaces.

5. Conclusions

This study highlights urban shortcomings and imbalances at the neighborhood level regarding sustainability and the provision of sustainable, inclusive, and accessible infrastructure. Low levels of indicators related to walkability—such as the distribution of public pedestrian ways and continuity in universal accessibility design—suggest the need to develop policies for a more walkable city, with access to comfortable public transportation and improvements in the quality of public spaces. This would reduce urban environmental pollution and improve the population's health and quality of life. Similarly, the low percentages of green spaces highlight the need to provide neighborhoods with such spaces within walking distance, in order to positively influence not only the physical and mental health of their residents but also the social integration and cohesion of the neighborhoods.

The neighborhood urban sustainability index has been proposed as a composite measure that integrates the most representative indicators to measure and identify the levels of each component. One limitation of the study is that all variables carry equal weight in the index, implying they contribute equally to neighborhood sustainability. This decision is justified as an exploratory baseline approach and as a valid starting point for indices at this stage. As a next step, future research should refine the model by validating the weights using the Delphi method with local experts or through statistical or multi-criteria analysis.

Additionally, one of the main limitations of the study was the field data collection and the validation of available bibliographic information on the city, which had to be cross-checked and verified on-site. This process required extensive data processing, map-making, and fieldwork.

Identifying low levels in indicators for neighborhood units will enable the formulation of urban policies that promote more sustainable development, guiding investment plans and improving residents' quality of life. Thus, neighborhood-level policies should include incentives and ordinances that promote sustainable development, utilizing green infrastructure, increasing permeable surfaces, improving the design of streets and public spaces, design standards, infrastructure provision, and signage for sidewalk use—all of which enable the reservation of an unobstructed pedestrian walkway, thereby contributing to improved universal accessibility and environmental quality.

In short, it is necessary to strengthen local governance focused on sustainability through plans and ordinances that include standards and implementation mechanisms for established areas and those undergoing development. Furthermore, urban control and regulation must be strengthened through land-use management tools and technical and operational

measures to advance sustainable development goals. Finally, it is necessary to consider the importance of the local context in sustainability assessments, as well as the unique characteristics of each city in terms of its morphology, history, culture, location, climate, and social conditions, as a starting point for developing neighborhood sustainability policies and plans that improve quality of life and enable cities to address the challenges of climate change.

Conflict of Interests. The authors declare no conflict of interests.

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