Relation between Proximity to Public Open Spaces and Socio-economic Level in Three Cities in the Ecuadorian Andes

María Laura Guerrero[1][a], Daniel Orellana[1,2][b], Jorge Andrade[3] and Gabriela Naranjo[4][c]

[1]*LlactaLAB – Ciudades Sustentables, Departamento de Espacio y Población, Universidad de Cuenca, Av. 12 de Abril, Cuenca, Ecuador*

[2]*Facultad de Ciencias Agropecuarias, Universidad de Cuenca, Av. 12 de Octubre, Cuenca, Ecuador*

[3]*Escuela de Arquitectura, Pontificia Universidad Católica del Ecuador sede Ibarra, Av. Jorge Guzmán, Ibarra, Ecuador*

[4]*Facultad de Arquitectura Diseño y Artes, Pontificia Universidad Católica del Ecuador, Av. 12 de Octubre, Quito, Ecuador*

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Abstract: Public Open Spaces (POSs) are necessary urban goods for satisfying personal and collective needs for physical, social and mental wellbeing. Equitable spatial access to POSs is key for guaranteeing that resources for wellbeing are democratically available for all members of the community. Environmental justice states that contemporary cities have a biased distribution of public spaces, against socially and economically more disadvantaged sectors of society. Under these premises, this paper evaluates whether there is a case of environmental imbalance in access to public spaces in three Ecuadorian cities: Quito, Cuenca and Ibarra, based on the socio-economic status of the population. A pedestrian impedance street network model was used for obtaining time to the nearest Public Open Space from each urban block, and socio-economic conditions were obtained from national census data per household and divided into quartiles. Statistical analyses included Mood's Median Test, Dunn's post-hoc test and notched boxplots for assessment. Results show that there is a significant difference in time to public spaces between quartiles, where the quartile with the lowest socio-economic conditions is also further from public spaces than the others in the three cities. These results should inform planning policies, strategies, designs and decisions for future leisure land use reserves.

1 INTRODUCTION

Urban open spaces, such as parks, forests, streams, squares and community gardens, provide critical ecosystem services and benefit physical activity, social bonding, psychological and general well-being of urban residents (Wolch, Byrne, & Newell, 2014). One important characteristic of sustainable urban development is a spatial pattern where facilities are spatially distributed in a way that they benefit as many different social groups as possible (Talen, 2010). However, studies have reported consistently that neighbourhoods with higher socioeconomic levels enjoy greater accessibility to green spaces (Talen, 2010; Wen, Zhang, Harris, Holt, & Croft, 2013). Attention must be paid to avoid racial, economic and social inequalities in access to urban goods in planning processes for creating more democratic, equitable cities.

The vast majority of studies about proximity to public spaces has been conducted in developed countries such as the United States, the United Kingdom, Australia, Europe, and some large Asian cities (Wolch et al., 2014). Only recently, researchers are studying the spatial relationship between socioeconomic conditions and proximity to urban public spaces in Latin America, and to date there are only a few cities in the region with published studies (Fernández-Álvarez, 2017; Mayorga Henao & García, 2018; Tiznado-Aitken, Muñoz, & Hurtubia, 2018).

This paper investigates whether there is a bias regarding access to public spaces due to socio-economic conditions in three Ecuadorian cities. It

[a] https://orcid.org/0000-0001-5164-1455
[b] https://orcid.org/0000-0001-8945-2035
[c] https://orcid.org/0000-0003-0570-7446

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studies the spatial distribution of public spaces in relation to the socio-economic conditions of urban dwellers, providing evidence for both future public policies and planning guidelines. It also provides a transparent and replicable methodology using available public data from official sources and Volunteered Geographic Information platforms.

The first section of the paper presents the theoretical background on public space proximity. The second section details the methodology, datasets, data processing and statistical analyses. The third section presents the results and discussion, and the last section focuses on conclusions and further research.

2 BACKGROUND

Environmental justice studies whether the distribution of urban risks and benefits is biased, disfavouring racial minorities (environmental racism) and population with lower socioeconomic status (environmental classism), based on research on absolute and relative spatial distribution of amenities, risks, and population in cities (Bolin et al., 2000; Fernández-Álvarez, 2017). For environmental justice, the term *Environment* is defined as the set of linked places "where we live, work, learn and play," a concept that challenges traditional definitions of environment and nature by including urban areas, which allows urban inhabitants to be incorporated into the environmental debate (Turner *et al.*, 2002). In most cities, the last two hundred years of urban development history have been dominated by market dynamics. These dynamics dictate the pattern of physical production of space, making product urbanism, competitive strategies, and private initiatives the major forces of social and spatial segregation in cities, leaving public spaces as residuals from private development (Mayorga Henao & García, 2018).

The definitions of Public Open Spaces (POSs) are diverse, subject to constant change and discussion, and depending on the author, sometimes it has contradictory characteristics. In a recent review of POS definitions, Andrade *et al.* (2019) elaborate on the wide range of characteristics of POSs in the international and legal literature. These authors have proposed a definition applicable to this research:

> "Unbuilt urban open space for recreational, civic, natural or cultural purposes, accessible for the whole community for free and without restriction; primarily (although not exclusively) owned by public subjects, capable of hosting a variety of uses and accommodating diverse users to enhance inclusion and social equity, suitable for protecting ecosystems and the sustainability of human settlements"

This definition is purposefully multidimensional and attempts to encompass many aspects, in accordance with Kohn (2004), who suggests a way to handle the diverse and somehow contradictory definitions of POSs. This author proposes the definition to ensure that it comprises a range of possible criteria, where a sub-selection of them would enable a space to be qualified as a POS, and not having one of the criteria wouldn't mean that the space is not a POS.

Public Open Spaces are important in terms of environmental justice for several reasons. First, they offer opportunities for physical activity that prevents the risk for chronic conditions such as obesity and heart disease (Wolch et al., 2014), and they improve the psychological health of modern communities (Mehta, 2014). Second, POSs, such as parks and other green areas, offer ecological services, including maintenance of biodiversity, regulation of urban climate, and mitigation of pollution effects and floods via water infiltration (Haq, 2015). Lastly, they provide a relevant social benefit, enriching urban life with meaning and emotions (Fernández-Álvarez, 2017). This social importance has been described by Mehta (2014) in four key roles for public spaces: as an arena for public life, as a meeting place for different social groups, as a space for displaying social symbols, and as part of the communications system between urban activities. All urban dwellers should have equal rights to access these benefits.

From the many variables that influence the use of public open spaces, such as size, quality, attractiveness (amenities within the space), proximity and accessibility, the latter two have been given more attention. For instance, Pasaogullari (2004) explored visibility, physical structure, sidewalks, dispersion, and proximity, finding that variables like proximity, dispersed location, travel time and characteristics of the transport environment affect accessibility to public spaces directly in Famagusta, Cyprus. Lotfi & Koohsari (2009) analysed proximity to various urban services, including POSs, in relation to deprivation levels of the population, finding, surprisingly, that for the case of Tehran, neighbourhoods with higher deprivation have better access to public spaces. Tiznado-Aitken et al. (2018) focused on analysing both proximity to public transport stops and urban walking environment together to understand the accessibility to POSs in Santiago, Chile, in relation to the socio-economic situation of the population, finding a correlation between low income and poor access and urban space quality. Bancroft et al. (2015) in a systematic review found a variation in the association between access to parks and physical activity, possibly due to the heterogeneity of exposure measurements (variables related to parks like proximity, density, amenities); therefore, they recommended improvements in study design and sampling to clarify the relationship between access to parks and physical activity. The authors mention that in the current study designs, perceived park environment characteristics and smaller (vs. larger) buffer sizes seemed to be more predictive of physical activity.

It is worth making a distinction between proximity and accessibility. Proximity refers to the direct physical distance between two things. Accessibility, on the other hand, is a far more complex definition than just a spatial mismatch. It involves influential factors such as user characteristics, social and physical barriers, attributes of the facility, and interaction with other facilities in the system (Wang et al., 2013). Furthermore, accessibility to public spaces also has been defined as a measure of the spatial distribution of facilities adjusted for the desire and the ability of people to overcome distance or travel time to access a POS (Giles-Corti et al., 2005). In this sense, this paper focuses on proximity, where distance is a component of a wider concept that determines how reachable urban services are for different groups. The wider concept, accessibility, can be tackled in further research.

Accessibility is closely related to the urban form, which makes it possible for citizens to participate in activities, obtain resources, and benefit from services and information (Lynch, 1960). Moreover, accessibility is affected by zoning policies and sprawl patterns in cities, which tend to make distances increase for working purposes; therefore, they should decrease for the satisfaction of other needs, like leisure in POSs. In terms of democratic access, assessing proximity makes sense where transport means are available for the entire population, making walking the most suitable form of transport, since it can be used without income, race or gender distinctions (Mayorga Henao & García García, 2018). There is a trend in the literature to use 400m as a distance to estimate the potential 'walk-on' or 'walk-off' threshold to urban services (Koohsari, Badland, & Giles-Corti, 2013); other studies indicate that it is a good starting point, but a person's willingness to walk is also influenced by weather conditions, total travel time, walking distance to the destination, footpath access to traffic being negotiated, and the attractiveness of the route (Daniels & Mulley, 2013; Ker & Ginn, 2003).

In this paper, we investigate the accessibility to public open spaces in three cities in terms of proximity to the place of residence of urban dwellers for three cities in the Ecuadorian Andes (Quito, Cuenca and Ibarra). Moreover, we evaluate if there is a relation between the socio-economic level and the proximity to POSs.

3 METHODOLOGY

We assessed population's proximity to POSs by evaluating walking time to the nearest POS from each city block. Individual dwellers were categorised according to their socio-economic conditions to appraise whether there is a bias in accessibility for different socio-economic levels.

3.1 Study Area

The three cities were chosen due to their different sizes (metropolitan, intermediate and small cities), which allows evaluating the existence of patterns regarding public space distribution and conditions in the region that are not dependant on city size.

Quito is the capital of the country and also of Pichincha province, with an urban population of 1,021,474 million and a surface of 266.75Km2. The surface for public spaces is 24.37Km2 (7.09%). According to this data, the green urban index is 23.86m2/inhabitant. It is located at 2,850 m.a.s.l. at the base of the Pichincha volcano (west) and limited by the geologic fault EC-31 to the east. Both geographic landmarks highly determine its morphological development in a longitudinal way, hence challenging mobility and distribution of services.

Cuenca is the capital of Azuay province, with 323,000 urban inhabitants; it covers 73Km2. From this, 2.43Km2 (3.3%) are dedicated to POSs. The green urban index is 7.52m2/inhabitant. It is located in an inter-Andean valley at 2,500 m.a.s.l. Hydrology is very important in Cuenca, with 4 main rivers and 11 secondary water courses, like creeks, crossing the city. The city shape is strongly influenced by a terraced geomorphology and several rivers and streams, which makes connectivity one of the main challenges for urban development.

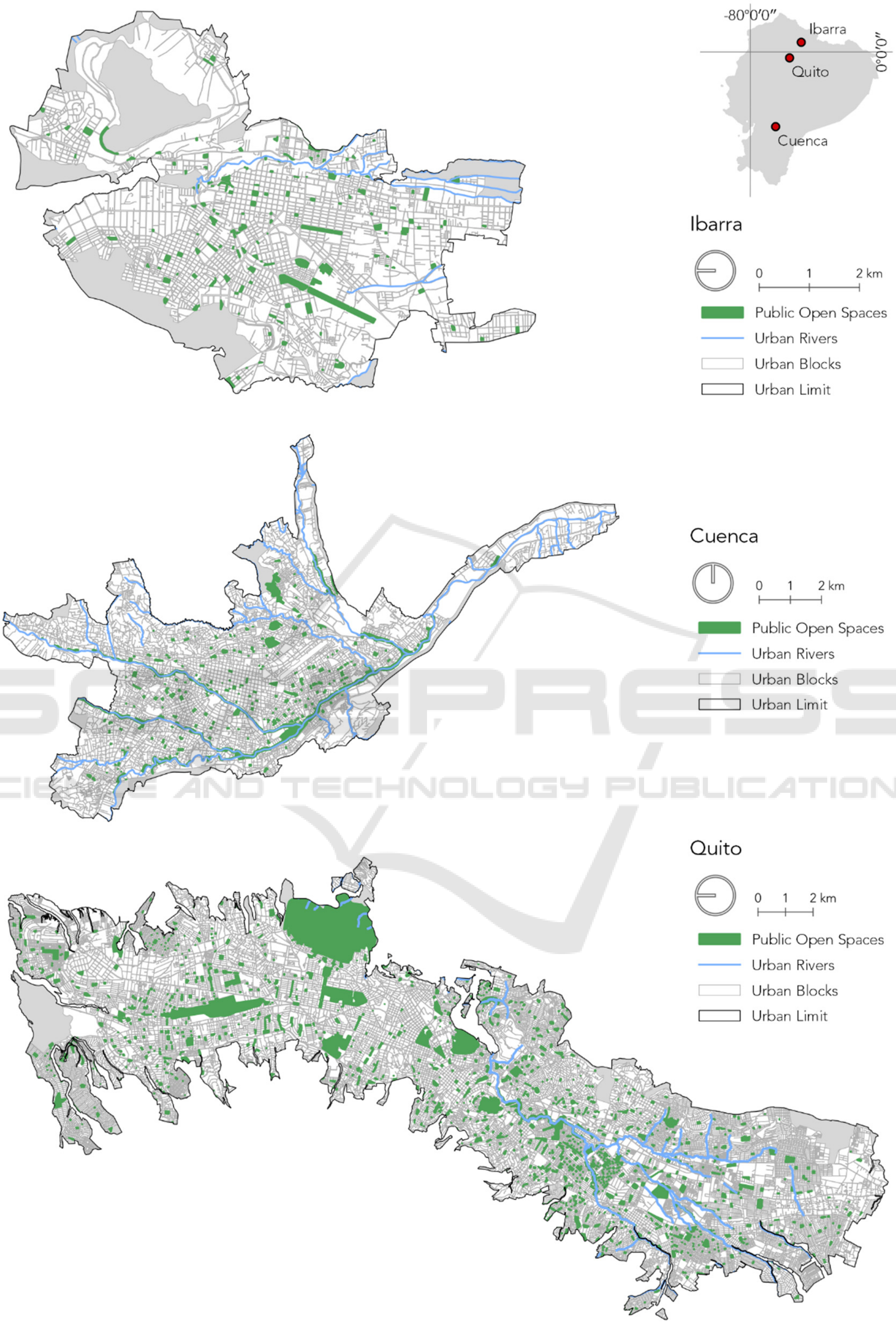

Figure 1: Distribution of Public Open Spaces in Ibarra, Cuenca and Quito.

Ibarra is the capital of Imbabura province and has an urban population of 129,305 and a 43.45Km2 extension. Public spaces occupy 1.36Km2 (3.13% of the total surface). The green urban index is 10.52m2/inhabitant. It is located at the base of the Imbabura volcano at 2,225 m.a.s.l. and limits with the Yaguarcocha Lake to the northeast. The closeness to both the volcano and the lake are to be considered; however, being a small city, it has not yet reached a problematic limit regarding natural conditions, which makes planning decisions timely.

For this analysis only the area inside the official urban boundary was analysed. The distribution of POSs in each city is represented in Figure 1.

3.2 Datasets

The unit of analysis is each person in the urban areas of the three cities. The socio economic condition of each person was represented by the Living Condition Index (LCI) (Orellana & Osorio, 2014) of their corresponding household. The LCI was computed using official data from the 2010 census (INEC, 2011), which included an identification code of the city block where the household is located. This code was used to geo-reference each individual at the block level. There are no data protection constraints, given that although the index is calculated per household, the household's precise location is unknown, because census cartography is released up to city block as the most disaggregated geographical level.

A second dataset contained the public spaces in each city. First, local authority databases were obtained. Then, a team in each city revised the databases, confirming that they corresponded to existing public sites and updating them to only public open spaces (leaving aside roofed playing courts, for example) using aerial imagery and on-site verification.

Finally, the third dataset comprised the urban street network of each city obtained from OpenStreetMap (OpenStreetMap, 2019). The dataset was revised and corrected for topological consistency and connectivity.

3.3 Process

First, a pedestrian impedance model was built to calculate network walking time in minutes for each street segment and intersection using Network Analyst in ArcGIS 10.3.. The impedance model was computed based on the street hierarchy, the existence of pedestrian infrastructure such as sidewalks and footways, and the existence of facilities at intersections, like pedestrian traffic lights or zebra crossings.

Second, the Living Conditions Index (Orellana & Osorio, 2014) socio-economic conditions of each individual was computed in IBM SPSS Statistics 25.0 at the household level. The LCI takes into account physical household characteristics (flooring, walls and roofing materials, and overcrowding), access to basic services (water, electricity, sewage and communications), level of education of household dwellers and access to health insurance (public or private). The spatial location of each individual was represented as the centroid of the block the household belongs to. The mean LCI was assigned to each city block for visual exploratory purposes.

Third, the walking time to the closest POS was obtained for each individual using the "closest facility" algorithm in ArcGIS's Network Analyst. Usually, origins and destinations are represented by centroids of polygons (city blocks and POSs). However, since the algorithm will automatically snap the centroid to the nearest network edge, centroids of large POSs (larger than 10000m2) may not be a useful representation of destinations, because origins at the other side of the POS will have artificially large values of network distances and times (the algorithm will compute the distance as if they must walk all around the POS to where the centroid was snapped). Therefore, destinations were represented as points at the perimeter of each POS each 100m. To select the perimeter lines that actually have street fronts, a 10-meter buffer from road centre line was computed, based on the average width of streets in the three cities. Then points were generated along the selected lines each 100m. Finally, large fenced POSs and those with designated entrances or limited by topography were individually analysed to determine their connections to the street network. This approach implied a considerable pre-processing effort compared with the traditional method of centroids.

3.4 Statistical Analyses

To assess the potential bias on accessibility to POSs for different socio-economic levels, the population was classified into quartiles according their LCI. Then, the Mood's Median Test was used to identify if there were significant differences on the walking time to the nearest point for different LCI quartiles. Moreover, Dunn's post-hoc test with Bonferroni correction was used for pairwise comparisons. Boxplots were also used for visual exploration of the differences. Statistical analyses were conducted in R.

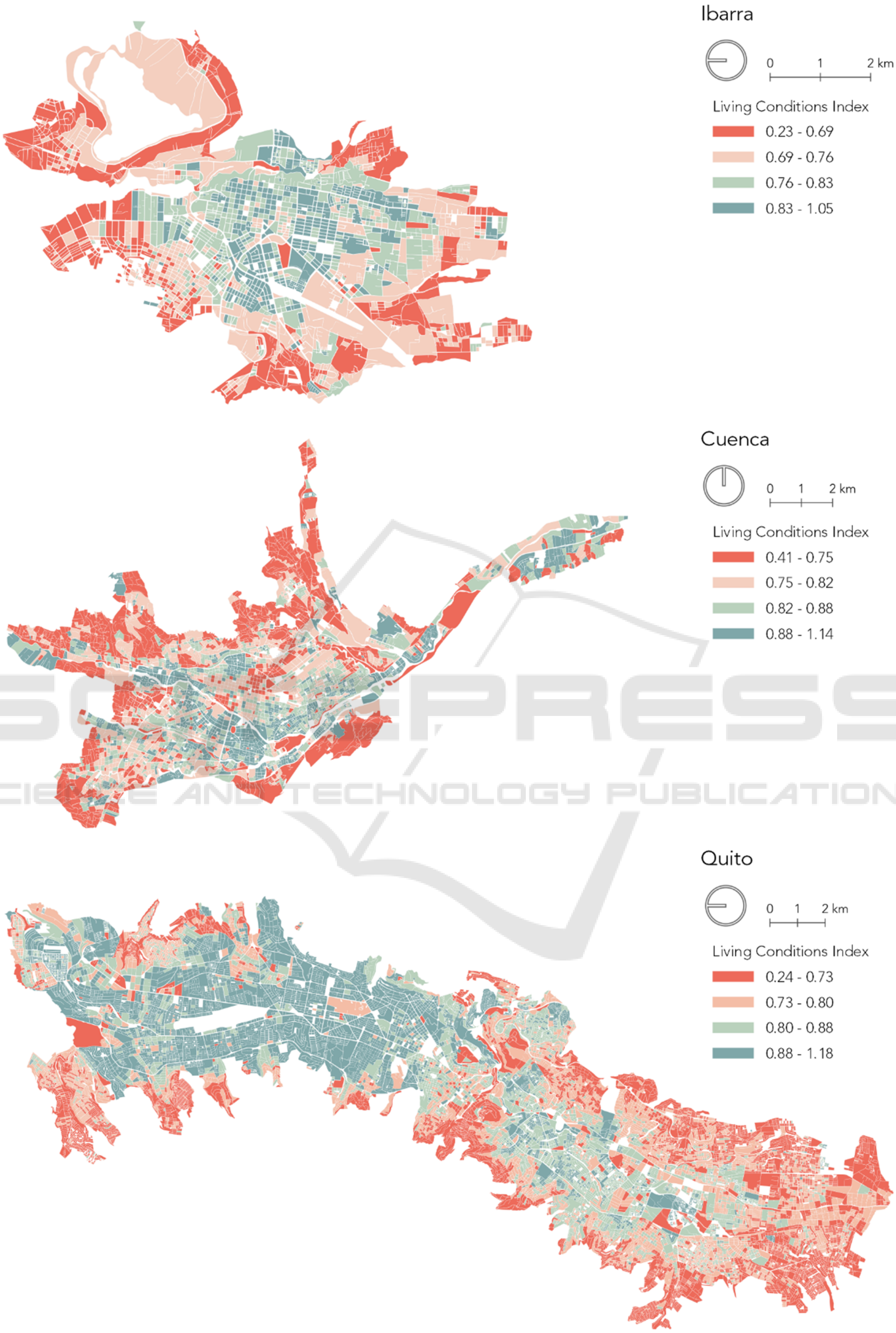

Figure 2: Socio-economic conditions for Ibarra, Cuenca and Quito.

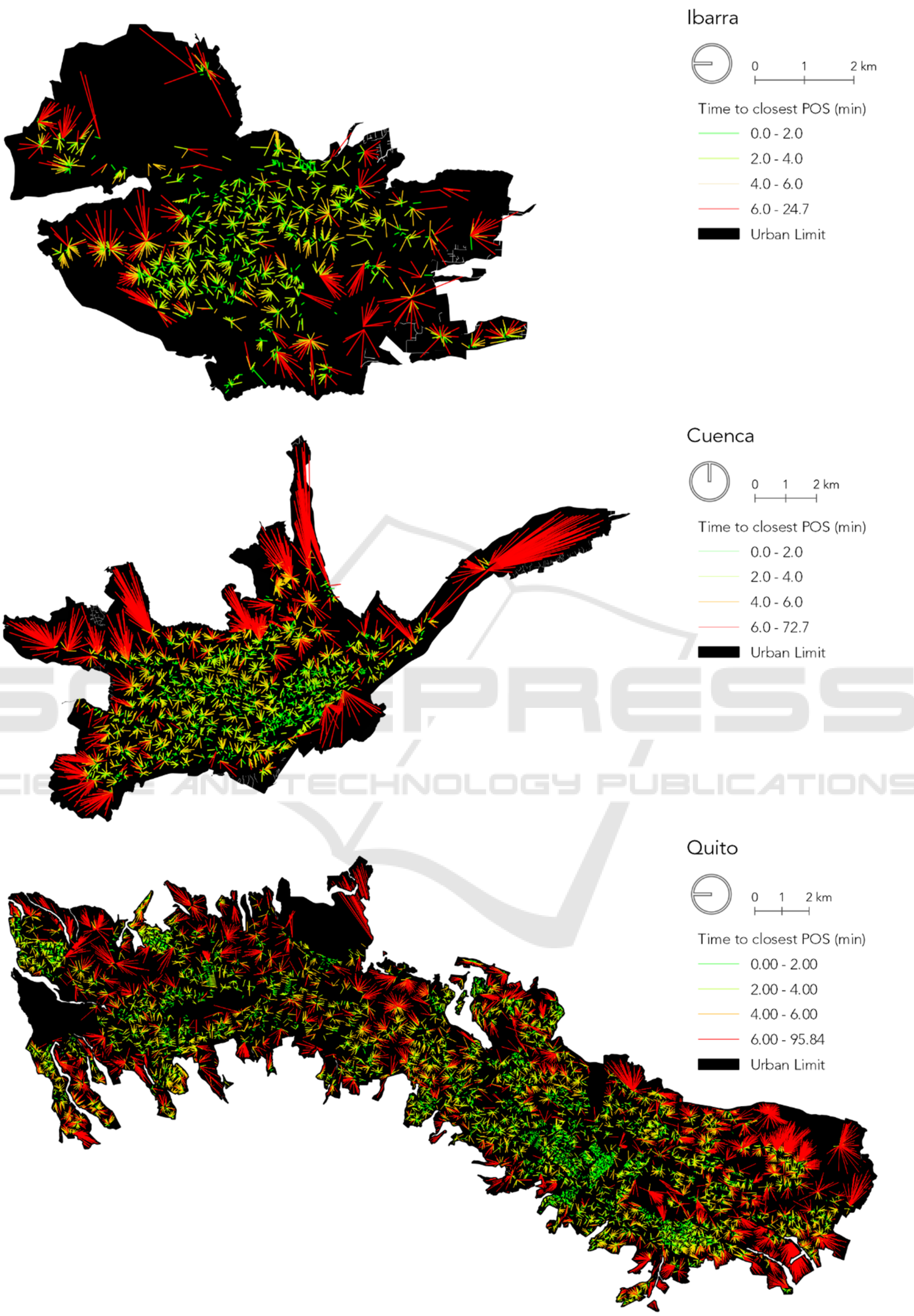

Figure 3: Time to access POS in Ibarra, Cuenca and Quito from each city block.

4 RESULTS AND DISCUSSION

4.1 Descriptive Statistics of Proximity to Public Open Spaces

The mean time in minutes to reach a POS was 4.7 in Quito, 6.6 in Cuenca and 3.8 in Ibarra. The median for the three cities was approximately 3 minutes. Also in all three cities the value for the third quartile is less than 6 minutes, which means that 75% of people are about 6 minutes away from a POS. This might seem encouraging, but as we will discuss further along, what matters in terms of environmental justice is the socio-economic profile of those who are further away and the differences they might have with the rest of the population. There are some possible causes for that distribution of POS in each city. In Quito, planning became important from the 1950s onwards, under the tradition of the Modern Movement, which promoted big and small public space reserves before most Ecuadorian cities experimented rapid growth (Cifuentes, 2016). The downside of this initial planning process is that the model was polarized, segregating (both geographically and economically) and served the interests of landlords (Carrión & Erazo, 2012), which planted the seed for the evident socio-economic divide between the north and the south that is currently experimented. In Cuenca, planning also played an important role around the same time that in Quito, by keeping river banks in a natural state to be converted into formal POSs later on (Hermida, Hermida, Cabrera, & Calle, 2015). As rivers transversally cross the city, mainly from west to east, the banks became crucial for the POS distribution. Ibarra, a smaller and younger city, has experimented horizontal sprawl from the 1980s onwards, but without replacing previously existing public spaces for other land uses. Even though the average time might be encouraging, the longest time to the nearest POS in Quito is 95.8 minutes, 72.7 minutes in Cuenca, and 24.7 minutes in Ibarra.

Table 1: Descriptive statistics of time (minutes) from city block centroids to the closest POS.

	Ibarra	*Cuenca*	*Quito*
Minimum	0.000	0.000	0.000
Maximum	24.679	72.743	95.841
Mean	3.838	6.620	4.712
Median	3.110	3.046	3.224
Standard deviation	3.103	10.264	5.661
Coeff. of Variation	0.808	1.551	1.201
First quartile	1.851	1.579	1.639
Third quartile	4.863	5.982	5.919

4.2 Socio-economic Spatial Distribution

A spatial pattern of socio-economic conditions becomes evident: higher levels tend to gather in or around the city centres, while lower LCI values were located mainly in the periphery. This pattern is clearer for Cuenca and Ibarra. Quito, on the other hand, shows a very strong division by socio-economic status between the north and the south of the city, the south being the most disadvantaged one. Blocks with the lowest LCI are located on the extreme south and the extreme north of the urban area. See Figure 2 for details.

Besides this global pattern, there are also small clusters of high LCI values on peripheral areas. These are usually modern residential developments where families with high socio-economic conditions move to the suburban areas looking for larger parcels and houses with private gardens or inside gated communities. There are also clusters and single blocks of low LCI values near the city centres where some impoverished neighbours are located.

4.3 Relation between Socio-economic Distribution and Proximity to Public Open Spaces

Visual analysis showed that there seems to be a perceivable bias regarding access to public open spaces in all three cities, with longer travel times towards the periphery where blocks with the lowest socio-economic conditions are usually located. Figure 3 shows the spatial assignment of each city block to the closest POS. Although the analysis was conducted using network distance and walking time, the assignment of blocks to POSs was represented using straight lines for the sake of visual interpretation.

Results of Mood's median test (Table 2) evidenced that there are significant differences between the medians of travel times to POS for different LCI quartiles in all three cities (alpha = 0,05).

Table 2: Mood's Median Test Results.

	Ibarra	*Cuenca*	*Quito*
X squared	1353.3	6958.7	7541.6
P value	<0.0001	<0.0001	<0.0001

Table 3: Dunn's Test Results.

		Ibarra			*Cuenca*			*Quito*		
Value		*q1*	*q2*	*q3*	*q1*	*q2*	*q3*	*q1*	*q2*	*q3*
z	*q2*	13.519			11.258			44.870		
p-value		0.000*			0.000*			0.000*		
z	*q3*	20.780	7.270		20.557	9.304		58.843	9.922	
p-value		0.000*	0.000*		0.000*	0.000*		0.000*	0.000*	
z	*q4*	17.882	4.357	2.920	20.928	9.674	0.370	7.459	36.443	49.191
p-value		0.000*	0.000*	0105*	0.000*	0.000*	1.000	0.000*	0.000*	0.000*

The boxplots showed that, for all cities, people in the first LCI quartile were further away from a POS than the people in Q2 and in turn, they were further compared to people in Q3. These differences were statistically significant as revealed by Dunn's test with Bonferroni's correction. Quartile Q4, however, behaved in a different way. Median travel time for Q4 was not significantly different from Q1 in Quito and from Q3 in Cuenca. In the case of Ibarra, was significantly higher than for Q3. A possible explanation might be that dwellers in the best socio-economic conditions (Q4) don't prioritize living near a POS and tend to look for more remote locations with the possibility of private green space. This might be due to self-segregation by acquisitive capacity (Table 3 and Figures 4-5).

5 CONCLUSIONS

In this paper we explored the relation between public space distribution and socio-economic status of the population in three Ecuadorian cities in the Andes region. For this purpose, we used a pedestrian impedance street network model to calculate the walking time from city blocks centroids to the entrances to public spaces for different socio-economic levels. Although people may access to POS using different transportation means, walking time to POS will better reflect accessibility for different socio-economic groups.

There results were consistent on the three cities, independently of their size and particular historical or physical conditions. First, although the walking time to the nearest public space was relatively low from most city blocks, there was a statistically significant difference among socio-economic levels. This means that there is a case of environmental injustice in the studied cities, regardless of their surface, population size or particular geographies, a condition that should be addressed through detailed spatial planning and

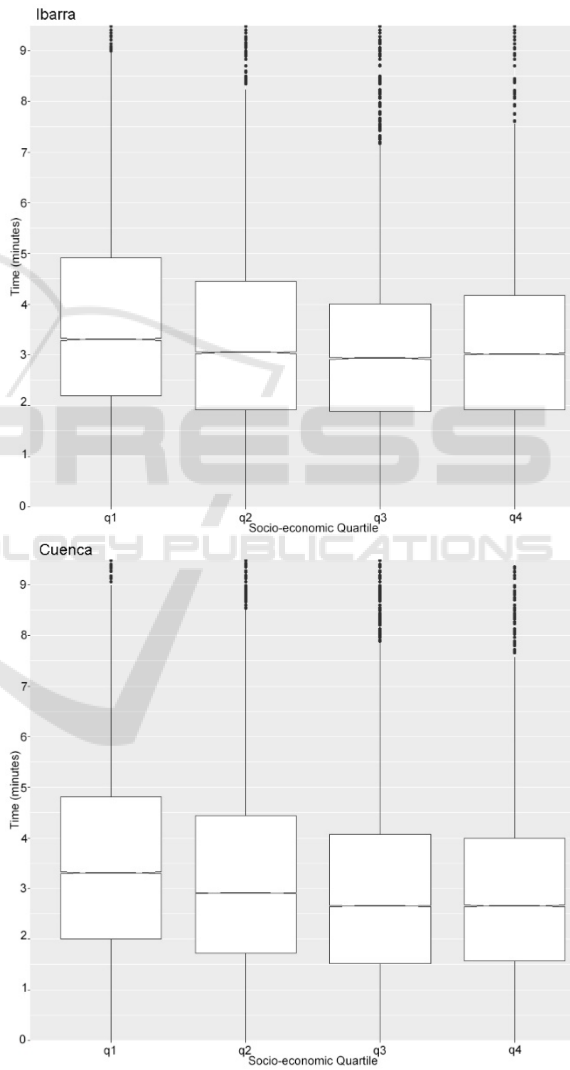

Figure 4: Boxplots of time for each socio-economic quartile (Ibarra-Cuenca).

land use public policy. For example, parcels should be reserved for public spaces in areas that are in process of consolidation, with special care for those where the inhabitants have vulnerable socio-economic conditions. Also, in already consolidated areas where the need of public space is identified, some publically owned parcels could be partially or totally to POSs. Finally, some work can be done with the community to form public-private alliances for the provision of POSs and collective spaces.

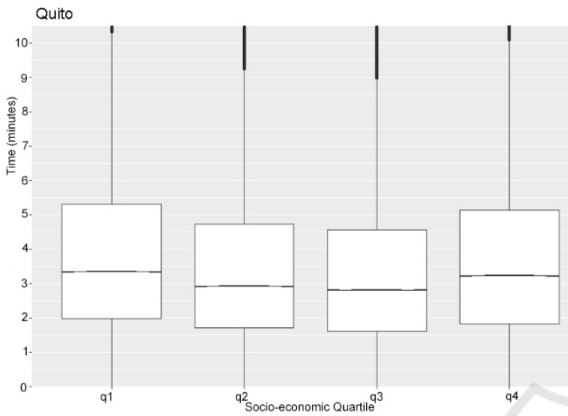

Figure 5: Boxplots of time for each socio-economic quartile (Quito).

Second, there is a trend in the three cities in which walking time to the nearest POS diminishes from the first to the third LCI quartile. This is, as the socio-economic condition improves, there are more accessibility to POSs. However, this trend is disrupted for the fourth LCI quartile, where the walking time to the nearest POS increases again or is not different from Q3, and therefore accessibility to POSs drops again. Given that their economic status is not an impediment, it is assumed that distancing from urban services, like POSs, is intentional which indicates a trend with an impact on urban growth that should be properly analysed and addressed. Authors like Talen (2010) support this affirmation, indicating that public parks can substitute for private open space for apartment dwellers, but not for owners of single-family detached homes, who are likely to have their own private outdoor space. This pattern is consistent with the urban sprawl process characterising Ecuadorian and Latin American cities, where urban planning is usually weak, producing low-quality urban neighbourhoods in new expansion areas where even wealthier families are located. Overall, we were able to confirm a bias on spatial proximity to POSs regarding the socio-economic level of population in the three studied cities.

In methodological terms, one improvement of this work is that the spatial and statistical analysis was based on high-detailed datasets. We were able to assess walking time to nearest POS for each person in the three cities. Moreover, the representation of destination as points at the border of the POS instead of centroids is a more accurate representation for modelling routes to the closest facility in network analysis.

Further research could take proximity to POSs to a deeper level, by analysing accessibility as it was defined in the Background section of the paper, taking into account the attractiveness of public spaces and their relation to space use. At the same time other accessibility metrics should be explored beyond time-based proximity (e.g. different transportation modes).

Also, from a planning perspective, potential sites for public space should be identified in the areas where the deprived population is, to decrease the bias against the more vulnerable sectors. Finally, the methodology could be reproduced to more cities in the country, and also to other urban services, to inform public policy.

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