Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 198 (2017) 467 – 481

Procedia Engineering

www.elsevier.com/locate/procedia

Urban Transitions Conference, Shanghai, September 2016

Resilience in Latin American cities: behaviour vs. space quality in the riverbanks of the Tomebamba River

M. Augusta Hermida[a,b]*, Mateo Neira[a], Natasha Cabrera-Jara[a,b], Pablo Osorio[a]

[a]Universidad de Cuenca, Departamento de Espacio y Población
[b]Universidad de Cuenca, Facultad de Arquitectura
Av. 12 de Abril s/n, Cuenca 010150, Ecuador

Abstract

Design and city planning should integrate the treatment of rivers and riverbanks as main elements of the green network and the resilience of cities. It is urgent to understand not only their role in the generation of urban biodiversity and their potential as green corridors but also as a public space layer that strengthens the public dimension of the city. It is essential to know the type of activities and behaviour on the riverbanks so as to meet the needs of the population and create urban identities. However, there is relatively little knowledge about the use and preferences of green spaces in developing countries. New techniques that offer more reliable ways of predicting and understanding the use of the space can be valuable tools for designing resilient cities. The proposed methodology aims to generate a spatially explicit empirical basis about the behaviour of the population in different areas of the Tomebamba River in Cuenca-Ecuador -based on systematic observation, behaviour mapping using mobile data collection and spatial analysis techniques-, seeking for correlations with the connectivity, the spatial quality and the physical characteristics of the riverbanks. The results show differences in the spaces men and women use, and the type of activities for each group, especially near peri-urban areas where spatial quality is lower. There is a bigger difference in age groups more pronounced in areas lacking infrastructure and those with access barriers. Significant differences where observed in types of activities related to the characteristics and quality of the surrounding built environment and to the connectivity of the riverbanks. Building the empirical evidence in a spatially explicit way will provide the knowledge base needed for urban designers and policy-makers, in Latin American contexts, so as to build open space systems that integrate natural resources and at the same time promote social resilience.

© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of the Urban Transitions Conference

Keywords: Resilient Cities; Social Interaction; Urban Green Space; Urban Waterfonts.

1877-7058 © 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of the Urban Transitions Conference
doi:10.1016/j.proeng.2017.07.101

1. Introduction

In designing sustainable cities emphasis should be put on creating and maintaining urban resilience –the capacity of a system to adjust to internal and external shocks and to diverse interruptions while maintaining its fundamental structure, processes and identity [1, 2]. What underlies a truly resilient city is not how stable it seems, but its ability to face an unexpected shock that would alter its form, structure, and even its identity in a significant way. For cities to be sustainable, urban design must take into account the influence of internal and external changes now and in the future [3].

It is necessary to examine the urban design strategies that would drive cities towards sustainability and resilience so that they are better adapted to their environment, more resilient in the way they operate, and more creative in generating resources and civic life [4].

Several authors like Teh [5], Woltjer [6] and Novotny [7], point out the importance of incorporating the treatment of rivers and its banks in the design and planning of today's cities, understanding them as the articulating system of public space. Teh shows, in his study of London, the relationship between social practices and the state of public space around bodies of water. Woltjer highlights the importance of urban uses linked to rivers, proposing special planning. Meanwhile, Novotny includes reflections on the potential of the river and its banks in terms of urban landscape, and along with other researchers highlights their role in generating more resilient cities [8]. River recovery projects have proven to be catalyst for urban renewal, stimulating the creation of functional and attractive communities [9].

Furthermore, the design of public space also allows the incorporation of new perspectives that reinforce the public dimension of the contemporary city. As Gehl and Svarre [10] point out, public space is part of the built environment and public life is everything that happens outside of buildings; therefore life in cities is the complex and versatile activities taking place in public space, nevertheless, life in public space has been forgotten, displaced by cars, by the large scale, and the specialization of functions. Designing public space and building a public sphere are the horizons that actors responsible for transforming the city should seek [11]. The needs of people across different cultures and political systems are extremely similar: contact with nature and with other people, an attractive environment, places for recreation and play, greater participation in the design process, privacy, and a sense of community identity; thus the importance of urban landscape design, universal in many cases and influential in the quality of life and behaviour of its users and nearby residents [12].

For years, some researchers have collected information regarding the interactions of people and spaces in the city, this material can provide a higher understanding of life in cities that allows the prediction of what will happen in a given space [10]. In psychology it has been shown that there is a need to differentiate between objective and subjective attributes of the environment and take into account processes that attend perception and evaluation in the way humans interact with their environment. It seems appropriate then to take an even broader approach and study the interactions between individuals and their built environment [13]. We understand that the quality of a place is not an inherent attribute solely to the built environment, but is strongly linked to the types of uses present in that space, in a dialectical relationship between the environment and people, so studies have to include both physical space as well as the perception of its users [14].

The methodology used in this paper aims to understand the spatial factors that influence the use of the Tomebamba riverbanks in Cuenca, Ecuador. The methods aim to collect data on daily use patterns of the riverbanks and quantify the physical characteristics of the immediate environment to determine the relationship between use and spatial configurations. A combination of behaviour mapping, space syntax, spatial quality assessment by experts, and quantitative indicators of physical characteristics of space are used.

The results show there are differences in the spaces men and women use, and the type of activities observed for each group, especially near peri-urban areas where spatial quality is low. There is a bigger difference in age groups; almost no children or elders were observed in all areas, these differences are more pronounced in areas lacking infrastructure and those with access barriers. Significant differences where observed in types of activities that take place in different parts of the riverbanks, these differences seem to relate to the characteristics and quality of the surrounding built environment, especially the presence and types of urban furniture, and to the connectivity of the river banks to the city

2. Methodology

2.1. The city of Cuenca as a case study

The city of Cuenca and its predecessor settlements, Guapondelig and Tomebamba, have always maintained a close relationship with the water. The Spanish foundation took place on the Inca and Cañari city, in a fluvial terrace on the northern banks of the Tomebamba River. Cuenca has grown since then marked by the relationship with the river. In 1947 it expanded into the southern bank, and thereafter experienced expansive growth determined by road corridors, which in turn were marked by the geographic corridors: rivers and streams. Currently the urban area of Cuenca has 133Km of water networks made up of four rivers: Tomebamba, Yanuncay, Tarqui, and Machángara (Fig. 1.); and a considerable number of streams and brooks, among which Milchichig and El Salado stand out.

If we recognize that the banks of rivers and streams constitute the backbone component of the green network and public space of cities [15], we can say that Cuenca has a significant potential in this area. However, several problems associated with these spaces, including: the lack of continuity related to the pedestrian network; the deterioration of spatial and environmental quality in certain areas; low biodiversity; lack of quality urban design; little or no attention to natural hazards, predominantly floods and landslides; abandonment and insecurity, among others, affect the relationship between the river, the city and its citizens; triggering processes of abandonment, privatization, urban decay and segregation. Extrapolating these results to the entire city it can be observed that the water network, one of the most significant features of Cuenca, poses serious problems related to its function as an articulator and generator of public space, urban biodiversity, and public life.

In 1982 through the Urban Development Plan of Cuenca the local government showed interest in the riverbanks [16] situation that led, years later, in the creation and improvement of linear parks; however these spaces have not been thought out as part of a comprehensive network. More recent plans include the gradual intervention on the banks of the rivers of Cuenca, but are solved as isolated elements and the rupture zones of the network are not studied in depth. Added to this fact is the information gap, in the municipal cadaster, on the use and occupation of the riverbanks, activities, frequency and number of users, conflict, security, soil permeability or biodiversity. The existing information focuses on the river as a water resource but not on the possibilities of their banks as public spaces, namely as a mechanism of inclusion and democratization of social life, as a place to meet others, as an area where values and habits are socialized, as a territory of contact, co-presence and peaceful, civilized and even egalitarian interaction between different social groups [17].

It is also unknown whether there are patterns of behaviour related to certain types of user and whether these patterns are related to the spatial connectivity of the riverbanks. Nor has the potential of urban and landscape design as a tool for building resilient and sustainable cities been explored in depth. In this sense, this work aims to fill knowledge gaps and provide significant methodological responses in the relationship of space and population.

2.2. Study area selection

As a first step in the selection of the study areas, a statistical cluster analysis was used to define five different sections -named A through E (Fig. 1)- along the river in terms of population density, land use, and vegetation percentage. The latest census data available, the 2010 population and housing census [18], was used to calculate population density, whereas municipal cadastral data, updated in 2012, was used to calculate land use and vegetation percentage. Sections A and E are characterized by lower population density and land use, and high percentage of vegetation, whereas central sections B, C and D have higher population density and land use, and lower vegetation percentage.

Once the five sections of the Tomebamba River were differentiated, points of rupture and areas of emblematic uses were recorded. Rupture points included the places where movement continuity is lost due to privatization or presence of high traffic road infrastructure. Areas of emblematic uses included all those clearly recognizable by the presence of traditional uses such as washing clothes, urban infrastructure, natural protected areas, and harmful uses, such as medium scale industry. Under these considerations 13 points (Fig. 1) where identified, which were used for the final delimitation of the study zones. The most representative points were chosen, considering the magnitude of the ruptures and emblematic uses, and were grouped forming single zones. A total of five different study zones, one for each section, were identified (Fig. 2).

After identifying the study zones a unit of analysis was defined, so as to be able to measure, aggregate and compare the different variables. Voronoi polygons were generated in order to get equidistant lines perpendicular to the river and a buffer around the river was defined to regulate the area of each polygon. Each unit of analysis has a 100m length along the river and 100m across the river, this allowed the units of analysis to be large enough so as to measure all the variables; and small enough so as to capture variability within each zone. All the polygons were then divided by the axis of the river to differentiate the northern and southern riverbanks. A total of 106 units of analysis were obtained covering all the study zones (Fig. 3). All the results are presented in function of these units of analysis and maintain the same scale. The relationship between spatial variables and users is explored using exploratory visual analysis and Pearson's linear correlations.

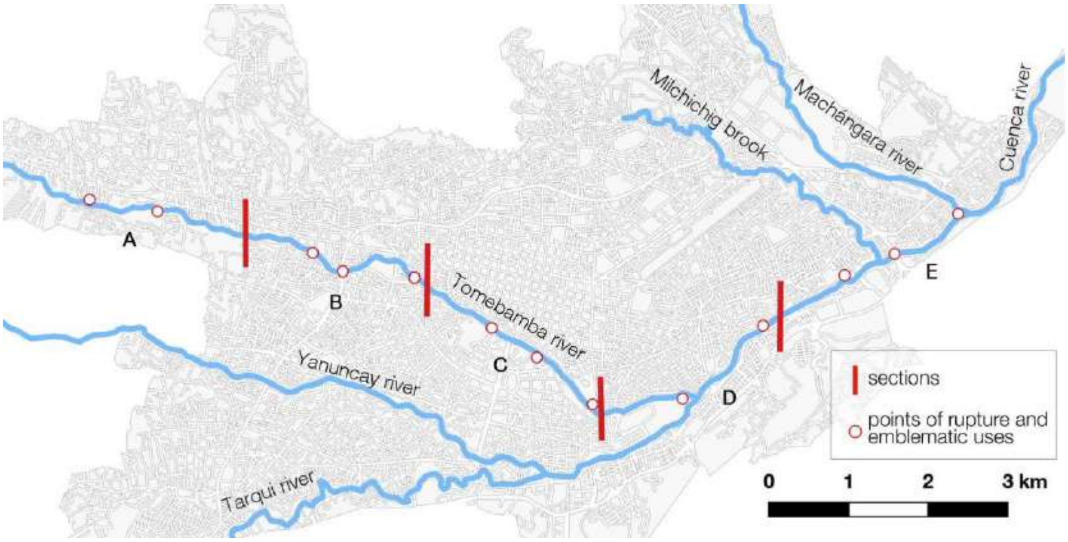

Fig. 1. Sections of the Tomebamba River.

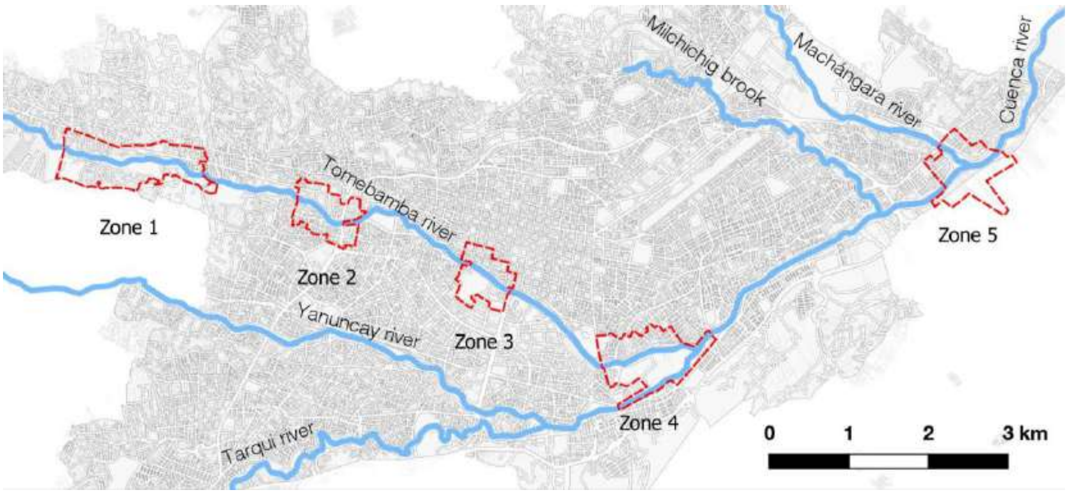

Fig. 2. Study zones.

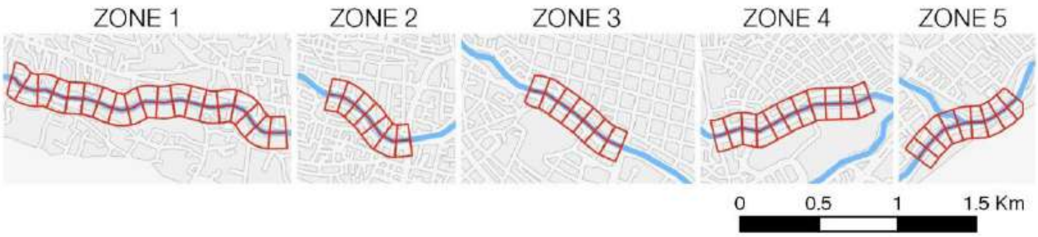

Fig. 3. Units of analysis.

2.3. Behaviour mapping

Most methodologies that measure, record, and analyze the behaviour in public space are based on systematic observations of behaviour and uses of space, within a matrix for each area [19, 20]. This facilitates the collection of large amounts of data for quantitative analysis. However, individuals are not registered in their exact location and time; therefore the data does not allow more precise studies about user behaviour related to physical and spatial configurations of places and time. Other researchers have used mapping behaviour that records the exact location of users, but the type of activities registered are categorized as sedentary and active [21, 22], so the resulting database lacks relevant information on the relationship between use and space.

To overcome these limitations Golicnik [23] proposed a methodology that combines behaviour mapping and spatial annotation techniques supported by GIS visualization. The proposed methodology generates a spatially explicit empirical database that allows a rigorous and accurate study of the human-environment relationships. However, spatial annotation can only register a limited amount of information, so only a single use or behaviour can be registered, when in real life a person may be doing more than one. This methodology also requires considerable time for digitization, since all the observations are made by hand.

In this paper, for the study of behaviour and uses in public space, a methodology adapted from the work of Golicnik [23] is proposed. Behaviour mapping and spatial annotation is complemented with digital forms that allow the gathering of more information on behaviour and relationships, and creates a spatially explicit database with greater detail on types of uses and spatial relations. Open Data Kit (ODK), an open source tool that can generate and manage mobile data collection solutions, was used. ODK has a number of advantages compared with other data collection methods, associated with the fact that smartphones are quickly becoming the preferred platform for the delivery of data collection services and information, more independence from energy infrastructure, the ability to connect to the internet through cellular networks, and the faculty to have interfaces that allow application with well-defined objectives for a variety of domains [24].

Table 1. Data dictionary.

Entity	Size	Data Type	Description
Unit of analysis	2	Character	Id of the unit of analysis
Date	8	Character	Date of the observation (DD/MM/YY)
ID	5	Character	Unique ID number of registered user
Sex	10	Character	Sex of registered user
Age group	10	Character	Age range of registered user (children, adults, elders)
Spatial relation	15	Character	Spatial position of registered user (standing, sitting, laying)
Element relation	15	Character	Spatial element used by registered user (sidewalk, grass, tree, bench)
Activity	80	Character	Activities done by registered user separated by comas

The detailed data collection consisted of observations on each unit of analysis during November and December of 2015 in three times of day: 9h00, 12h00, and 17h00, for a total of six weekdays and two weekends. Time, frequency, and duration of observations were designed in order to capture possible differences in usage patterns at different time of day and different days of the week.

The observation protocol consisted of systematic walks through each unit of analysis, performing a visual scan of ten minutes to record stationary activities that were marked as a data point in a detailed paper map along with a unique ID number, and a form was filled with relevant information for each registered data point using ODK. The resulting database was verified for possible errors. The final database contained georeferenced data for each person observed in the riverbanks within the days and hours established by the protocol, and a corresponding data table with information about sex, age group, spatial relationship, and activities (Table 1).

2.4. Connectivity of Cuenca and the Tomebamba River

Space Syntax was applied to measure the connectivity of the city and its relationship with the Tomebamba River. Space Syntax can be described as a family of theories and techniques developed to study the relationship between human societies and space, from a general theory of the structure of built space in all of its forms: buildings, settlements, cities, and landscapes [25]. The central idea of Space Syntax is that social structure is inherently spatial, and that the configuration of the built environment has a fundamental social logic [26]. In the context of this paper the goal of space syntax analysis is to measure the street network connectivity of the city and its relation to the river, in order to study its relationship with the use of space. Segment analysis is used in which, in contrast to axial analysis, all road lines are segmented in their intersections and all calculations are made weighting topological steps with angle of intersections. One of the advantages of segment maps is that they can be created from a road-centerline map, which reduces subjectivity in the analysis [27].

The measures used were: 1) syntactic *integration*, a measure of mathematical *closeness* with the normalizations set out in Hiller and Hanson [26], which measure how close each segment is to all other segments in the network; and 2) syntactic *choice,* a measure of mathematical *betweenness,* which measures how many shortest paths between every pair of segments passes through each segment for all segments in the network. We can think of i*ntegration* as a measure of to-movement potential (its potential as a destination), and *choice* as a measure of through-movement potential (its potential as a route) [28].

The street network used has all the roads, streets, and trails of the city, taking into account not only the segments that can be traveled by car, but also all pedestrian and cyclist paths and trails. The network was created from OpenStreetMap (OSM) after applying topological corrections. A .tsv file was made containing all the segments that do not intersect, such as overpasses. The street network along with the .tsv file were imported into depthmapX were angular segment analysis were run. The analysis included global and local measures, where local measure was performed with a radius of 500m. The results were exported to MapInfo format to be processes along with all other variables in GIS. To aggregate the results to the units of analysis and zones of study a kernel density analysis was used to create a continuous surface that contained street network density weighted by the space syntax measures.

2.5. Spatial quality assessment by experts

Space quality criteria have been developed over decades, many of which have been collected, sorted and categorized in a tool called 'the twelve quality criteria' [10]. Apparently these criteria affect the use of public space, since their compliance encourages people to use and stay in these spaces, and has been developed in close dialogue with practice, so that it can give useful insight into the places assessed. This space quality criteria tool is formulated in function of human needs and senses and is grouped into three categories: protection, comfort, and enjoyment.

To assess the space quality of the Tomebamba riverbanks, an ODK form was developed in which experts assessed the different spaces on a 1-3 scale that allows the comparison between all units of analysis and can give a clearer picture on the different aspects of space that can make people feel comfortable and stay in a particular place. The form was designed according to the criteria described in Table 2. Assessment results were aggregated into each of the categories mentioned above.

Table 2. Spatial quality measurements.

Category	Measurement
Protection	Protection against traffic and accidents
	Protection against crime and violence
	Protection against negative sensorial experiences
Comfort	Possibilities for walking
	Possibilities for standing
	Possibilities for sitting
	Possibilities for see
	Possibilities for hearing and talking
	Possibilities for play
Enjoyment	Small scale services
	Designing for enjoyment of positive climate elements
	Designing for positive sense-experiences

2.6. Physical characteristics of the riverbanks

Physical attributes of public space determine their environmental quality; they provide necessary conditions for social activity and generate public space perceptions [29]. Although the physical characteristics are diverse, authors such as Borja and Muxí [30], Talen [31] and Pascual and Peña [32], emphasize over the importance of accessibility and variety of uses. Borja and Muxí note that a public space is physically characterized by the accessibility and adaptability of its facilities to different uses, Talen relates accessibility with the sense of ownership and use frequency of a space, while Pascual and Peña emphasize over the importance of diversity of public space activities.

Under these reflections and based on the CIPAR index developed by Che, Yang, Chen y Xu [33], which assess riverbanks accessibility, the present study uses three quantitative indicators: the first two are related to spatial accessibility, and consider the banks width and the possibility of mobility that is offered by paths and sidewalks, whereas the third indicator measures the diversity of uses of urban facilities (Table 3). These indicators are addressed as basic conditions to understand the riverbanks as public spaces, though there are many more that determine its spatial quality.

To obtain the required information for the calculation of indicators, the municipal cadaster from Cuenca, updated on 2012, was used. Data not available from the cadaster was collected in field, georeferencing its location with GPS and systematizing it by using SIG. Subsequently, the necessary calculations were developed to obtain the results of the indicators for each of the 106 units of analysis.

Table 3. Quantitative indicators of physical characteristics of space.

Indicator	Description	Required information	Sources	Calculation
Walking accessibility	Evaluates the pedestrian road accessibility (sidewalks and pedestrian paths) in terms of slope and width. It is considered that both limit the movement of citizens with reduced mobility [34]	Pedestrian path width Pedestrian path slope	Field survey, 2016 Municipal cadaster, 2012	Accessible pedestrian road percentage (absence of physical barriers, wider than 90cm and a slope < 5%)
Riverbank width	Measures the area of analysis average width, synthesizing the possibility of occupying the shore with stationary activities	Area of analysis length Area of analysis surface	Municipal cadaster, 2012 Municipal cadaster, 2012	Average width (riverbanks total surface divided by its length)
Urban furniture diversity	Values diversity and mix of urban furniture for stationary activities	Facilities classified by activity type (play, sports, cooking, eating, contemplation)	Field survey, 2016	H index (diversity and mix of furniture)

3. Results

3.1. Users behaviour

The final database has 1253 people observed. A series of comparative analysis were performed between different study zones. The activities recorded were classified into three groups, recreational, productive and daily activities, in order to facilitate comparisons and analysis. Density maps were also made to visually explore zones with greater number of users and comparative maps were elaborated to compare different age groups where differences are substantial (Fig. 4).

The study zones closer to the city center have a greater influx of users, measured by the number of people recorded doing stationary activities. Zone 3 has the largest number of registered users, followed by Zone 4. In general the relationship between observed men and women on the riverbanks is 62%-38% (Table 5) respectively. However, there are differences in the percentage of men and women observed within each zone. Zone 1 has the biggest difference between these two groups of users, with an approximate ratio of 80%-20%. The area with the smallest difference between the two user groups is Zone 2, with a ratio of approximately 50%-50%.

In general, all areas have few children and elders. The various zones have similar patterns; however the areas that present higher number of children and elders are Zones 2 and 4, which are closer to residential zones. The different zones also differ in types of activity. Zone 4 and 5 have predominately recreational and leisure activities. In Zone 1 productive activities, such as wood chopping, were more common, and explains the higher presence of men. Zone 3 has mostly daily activities such as waiting for a bus.

In relation to the spatial relationships, most users in all zones were found standing up (63.80%), reflecting a lack of urban furniture, such as benches, along the riverbanks. Depending on the zone, different physical elements were used more than others. In the case of Zone 1 most people were registered near trees (50.24%), mainly related to productive uses. In Zone 2 most users were using the riverbanks, sitting, standing or laying on grass areas (43.39%) or near or in the water (43.80%), mainly for recreational activities, or for traditional productive uses like clothes washing. People in Zone 3 were mainly waiting in bus stops (40.38%) or standing in the pedestrian bridges (20.33%). In zone 4 and 5 most people were in grass areas 34.24% and 73.83% respectively, showing the importance of riverbanks as places of leisure and recreation.

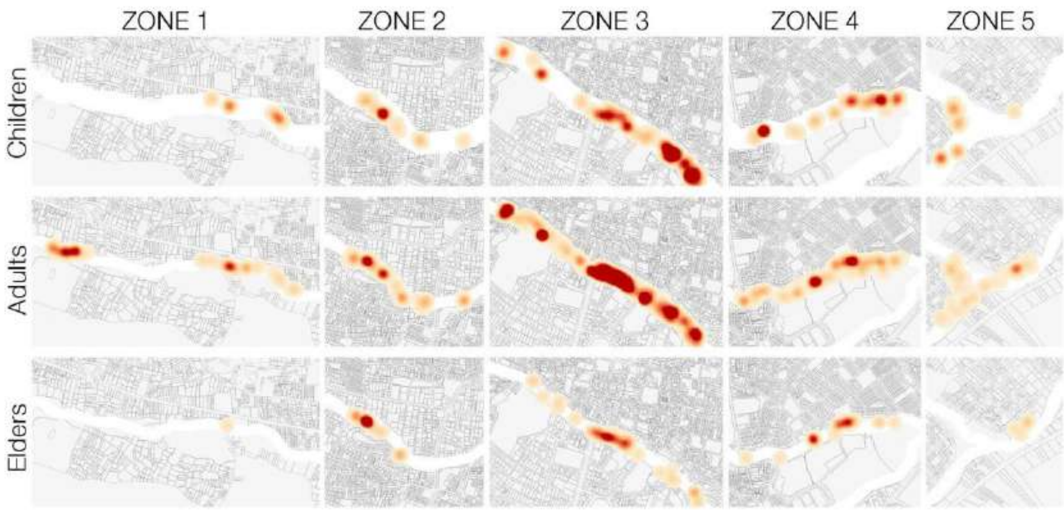

Fig. 4. Heatmap of people observed in all study zones.

Table 5. Percentage of people registered in all the zones by age and sex groups.

Study Zone	Men				Women			
	Children	Adults	Elders	Total	Children	Adults	Elders	Total
Zone 1	3.86%	78.26%	0.48%	82.60%	4.83%	12.57%	0.00%	17.40%
Zone 2	6.61%	32.64%	7.02%	46.27%	5.37%	35.95%	12.41%	53.73%
Zone 3	3.57%	48.90%	2.20%	54.67%	2.47%	42.31%	0.55%	45.33%
Zone 4	11.58%	48.52%	4.68%	64.78%	7.39%	22.66%	5.17%	35.22%
Zone 5	13.08%	48.60%	1.87%	63.55%	8.41%	25.23%	2.81%	36.45%

Fig. 5. Number of people found in each unit of analysis.

In Figure 5 the number of people observed in each unit of analysis is shown represented by a color gradient, were higher presence of people is shown in more intense color. In Zone 1 most people were found in the northern bank, but in general not too many users were registered, except for the western part where productive uses took place. Zone 2 has a high percentage of people on the southern bank, this zone is characterized by residential use, and as was shown above, has fewer differences between age groups. Zone 3 and 4 both have registered users distributed evenly around all areas, while Zone 5 has most users on its northern bank.

3.2. Connectivity

In identifying the overall structure of Cuenca, a regionalized urban pattern with a highly integrated center can be seen (Fig. 6. (A)), visualizing street segments from red for high values to blue for low. The mean normalized global integration for the city is 0.63, indicating that overall the urban area is shallow, with most spaces a few angular steps from the rest of the system.

Through the integration values we can detect that the northeastern part of the city is segregated from the rest of the system, as well as other peripheral areas. In the central zone, consisting of El Ejido and the Historic Center, we can see the formation of a deformed wheel structure, a hub of integrated lines towards the center with strong integrators that connect the hub to the edges. Most integrators that join the central hub are made up of the main avenues of the city.

The choice value allows us to visualize the streets and segments with the most potential of being a route between two destinations (Fig. 6. (B)). A peripheral ring can be detected, made up of two main avenues that bypass the city. Most avenues in the city have high choice values, highlighting their importance as connectors. By having four rivers that cross the city, bridges also become important structural elements within the urban network and tend to have high *choice* values. These results confirm some intuitive notions of the city and the importance of the avenues and bridges in shaping the urban structure.

The Tomebamba River crosses the city from east to west, passing along one of the avenues with high *choice* value and through part of the integration core (area with the top 10% of *integration* values). The mean values within each unit of analysis are visualized in Fig. 7 and Fig. 8 using a green, yellow, red color scheme, representing high, medium, and low values accordingly, and the averages for each study zone are shown in Table 4.

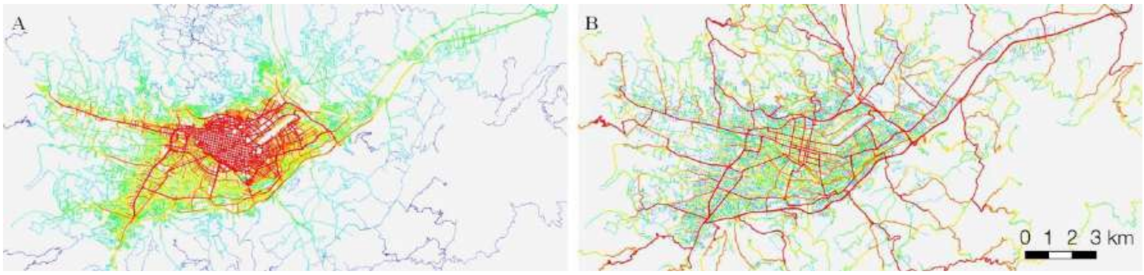

Fig. 6. (A) *Integration* values, (B) *choice* values.

Within each study zone we can observe similar trends, with little variability in the units of analysis. We can see that the peripheral areas tend to have low *integration* values (Zone 1 and 5) while the central areas have higher ones (Fig. 7). Areas with higher street density and bridges in general have higher values. In the case of Zone 3 proximity to a university campus, with several pedestrian paths, and to the Historic Centre, with its regular grid, tend to have the highest *integration.* Regarding *choice*, we can observe a similar pattern, with a marked tendency in the local analysis (Fig. 8). The bridges linking the city center with the south tend to be segments with high *choice values* so areas near bridges tend to have high *choice* as well. Zone 3 has units of analysis with similar local and global values, while in other zone they vary.

Fig. 7. *Integration* values by unit of analysis.

Fig. 8. *Choice* values by unit of analysis.

Table 4. Mean values of *integration* and *choice* for each study zone.

Study Zone	Integration r=n	Integration r=500m	Choice r=n	Choice r=500m
Zone 1	0.09	0.02	0.05	0.01
Zone 2	0.45	0.24	0.09	0.16
Zone 3	0.50	0.32	0.17	0.24
Zone 4	0.48	0.32	0.03	0.22
Zone 5	0.16	0.07	0.10	0.00

3.3. Spatial Quality

In relation to the spatial quality, Figure 9 shows the aggregated values of protection, comfort, and enjoyment. The values are represented by a green, yellow or red color scheme, representing high, medium, and low values accordingly. The lowest values are displayed in Zone 1, especially in the area near a ceramic factory. The highest values are in Zone 2, especially towards the southern bank, closer to residential areas.

The presence of vegetation in the different areas was an important element in the assessment of protection and comfort, having areas with higher percentage of vegetation resulted in a better score on these two categories. However, Zone 1 where there is a high percentage of vegetation and biodiversity rank low on all three categories due to the lack of other facilities. Other elements such as trashcans, benches, and other facilities were important in defining values of enjoyment and comfort. All though different spatial characteristics and urban elements overlap in defining the values of the three categories, each one defines a different experience within all spaces.

Zones 2, 3 and 4 have an overall higher score along all three categories; these coincide with areas that have had urban interventions and in general are perceived as having better quality by the whole of the population. But, although this is true for these three zones, units of analysis near high traffic street have lower values compared to those in the same area but in close proximity to pedestrian roads or residential streets.

Fig. 9. Indicators of spatial quality for each unit of analysis.

3.4. Physical characteristics

Figure 10 shows the results for each zone, with the same representation as shown in the previous section. Each area has specific physical attributes that match their urban condition. Zone 1, being in the edge of the urban area of

Cuenca has not gone through processes of effective planning and presents privatization of the riverbanks by a ceramic factory, gated communities of families with high purchasing power and, at the same time, some precarious settlements; which, reduces accessibility and the possibility of urban furniture. Zone 2 is inserted on a consolidated urban fabric; however, its riverbanks have not had a comprehensive treatment and lacks accessible pedestrian paths and urban furniture, except for the southern shore in the west where there is a linear park with facilities designed for various activities and the treatment of sidewalks and trails. Zone 3 corresponds to the most emblematic areas of the river, as it is part of the historic center. Despite having multiple interventions and treatment of pedestrian and cyclist paths, has the lowest score on the three indicators, and has suffered the greatest alterations throughout its history. Its banks have been significantly reduced; in fact it is embanked along an extension greater than 60m. The narrowness makes it difficult to install urban furniture other than benches, so its score is low in this regard. Moreover, the presence of physical obstacles in pedestrian paths prevents easy movement of people with limited mobility. The southern bank of Zone 4 is located on one of the most significant urban parks in the city; however it has no accessible trails and no urban furniture, because all activities usually take place within the park. The northern bank sits on a residential area, which has preserved a considerable width of the riverbank, devoting this space to different recreational activities and providing accessible sidewalk. Zone 5 is located in at the junction of Tomebamba River with another major river of the city, the Machángara, and its banks have considerable widths and native vegetation. However, there is no treatment of public space that could allow its use; it does not have trails, paths or urban facilities, such as benches.

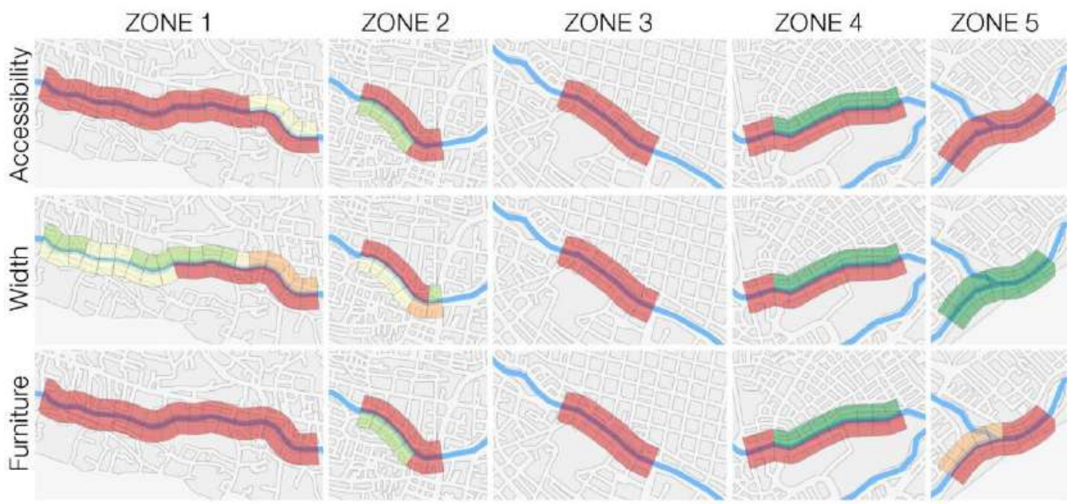

Fig. 10. Indicators of physical characteristics.

4. Discussion

Research identifies those elements that are associated with presence of people, and therefore with increased use of the river as public space. These elements give criteria that can guide interventions on the banks of the rivers of Cuenca and can be generalized for intervention in urban rivers of Andean cities. The research offers evidence of three elements –connectivity, spatial quality and physical characteristics- that are related to greater use of spaces, and that can serve as criteria for urban interventions. An exploratory visual analysis was applied to explore, and find spatial patterns, on the results shown above. The goal was to identify spatial characteristics that have relation to the frequency of use of the various spaces of the riverbanks. Once we found possible influential variables, the results were further explored using Pearson's linear correlation.

The first element is connectivity of the area, understood at multiple scales. On a broader scale it refers to the connection of each area with the street network of the city. Measures of integration and choice have allowed the identification of this relation. More integrated spaces to the city have a greater presence of people. On a local scale, pedestrian accessibility to an area and the continuity of the riverbank are especially important for various activities related to movement: walking, running, and fishing are activities that require different forms of connectivity. More connected areas embrace many uses of this type of activities that require different forms of connectivity. In terms of connectivity, the number of people using a specific space is correlated with global and local integration, and to a lesser extent with local choice. This agrees with research on space syntax on the measure of local integration being a measure of space as a potential destination. Although local choice is less correlated with use, it still has some relation to space use, possibly because of the importance of pedestrian bridges in defining place. These results are more pronounced in the case of women then in men, showing a stronger influence of connectivity on the presence of women along the riverbanks.

The second element that promotes greater space use has to do with particular spatial quality of each area, especially those that are related to experiences of comfort, enjoyment and aesthetic quality. These are aspects that depend on the subjectivity of each person, and in the case of Cuenca are linked elements of identity and belonging. In this regard it is important to ensure the quality of urban design of riverbanks without removing elements of physical and intangible heritage. The correlation of spatial quality indicators with the use of space had special significance in the correlation between comfort and enjoyment. In the case of the presence of men in space, enjoyment has a higher value, while in the case of women comfort seems to play a more important role. The results show that there are differences in the use of space by men and women, especially near peripheral urban areas where spatial quality is low and there is little accessibility for pedestrians. There is also a great difference in age groups, adults use most of the riverbanks, and almost no children and elders were observed, these differences in age groups were more pronounced in areas with access barriers and lacking urban facilities.

The third element, related to the physical characteristics of space, accessibility, diversity and percentage of urban furniture have a relatively high correlation with presence of people, and as noted in the study, depend not only on the amount but also on its diversity. Diversity helps broaden the heterogeneity of age, gender and interest in public space, which facilitates the consolidation of a meeting place that allows the presence of different social groups, promoting social resilience. Again we see differences between the presence of men and women, mainly accessibility seems to be much more correlated with the presence of women in space. The presences of urban furniture, such as exercise machines, benches, and children's games have a positive effect on the use of space, especially in the presence of elders, children and women. These play an important role in the types of activities that take place on the banks and the spatial relationships that users establish with places. Women, children and elders in general seem to have a greater sensibility towards spatial characteristics of the riverbanks.

Table 6. Correlations between connectivity values, space quality, physical characteristics and space usage.

Study Zone	Indicators	Pearson r with total usage	Pearson r with presence of man	Pearson r with presence of women
Connectivity	Global integration	0.38***	0.31**	0.42***
	Local integration	0.36***	0.28**	0.40***
	Global choice	0.03	0.01	0.06
	Local choice	0.28**	0.21*	0.33***
Space quality	Protection	0.1	0.11	0.1
	Comfort	0.26**	0.19	0.31**
	Enjoyment	0.24*	0.31**	0.42***
Physical characteristics	Accessibility	0.38***	0.31**	0.42***
	Width	-0.05	-0.02	-0.08
	Furniture	0.30**	0.24*	0.32***

*p<0.05,
**p<0.01,
***p<0.001

In contrast, other elements, such as the width of the riverbank and the configuration of public space to provide protection against traffic, insecurity or negative sensory experiences, are not related to the presence of people. These elements should not be the priority criteria to guide the implementation of public spaces in urban riverbanks, although they should still be considered in planning and design.

The linear correlation between behaviour, connectivity, spatial quality and physical characteristics of the riverbanks are shown in Table 6. Correlations were made only for general use of space, and divided by men and women's use. Age groups were not explored using statistical analysis due to the fact that in most of the spaces most users were adults, making children and elder groups too small to make meaningful statistical analysis.

5. Conclusions

The rivers that cross the city of Cuenca are an interesting case because of the multiple functions they offer. Water streams, riverbanks, and the surrounding built environment have articulated the public life of the city from the earliest human settlements; they have emerged as an iconic landmark in the imagination of city dwellers and constitute a green network with the potential for strengthening urban biodiversity.

Despite the recognition that rivers and their surrounding have as part of the public life of Cuenca, problems have been identified for their functioning as public spaces: lack of continuity related to the pedestrian network, the deterioration of spatial and environmental quality, low biodiversity, lack of quality in urban design, little attention paid to natural hazards, abandonment and insecurity. These problems affect the relationship between the river, the city and its citizens, triggering processes of abandonment, privatization, urban decay and segregation. These problems separate us from the idea of the river as quality public space, in which the inclusion and democratization of social life, as a place to meet others, as an area where values and habits are socialized, as a territory of contact, co-presence and peaceful, civilized and even egalitarian interaction between different social groups [17] is possible. To achieve this vision, we must begin by promoting the presence and use of these spaces.

This research is a contribution to the search on human-environment relationships in public space related to urban rivers and their use. However, more research is needed on the issue, and after this work we can suggest some important characteristics to be considered in the design and implementation of these public spaces. After analyzing all the results, and as a consequence of the observations made in field, we consider necessary to expand the research, not only considering the immediate environment of the riverbank but its urban context. In this regard we suggest some important additional characteristics that should be considered in the design and implementation of these public spaces.

First, it is necessary to assess with more precision and detail the urban context of the study areas. Elements associated with the first built line could affect the use and enjoyment of the riverbanks, such as: the diversity of uses and accessibility (vehicular or pedestrian) of the buildings facing the banks, which determine the physical relations and the mix of uses that mediate public and private space. Likewise, aesthetics aspects of the first built line may affect the appreciation and enjoyment of the banks: the height of buildings impacts on the visual fields of users, and the visual porosity of buildings can affect users' appreciation of the public space. In addition to the physical aspects, the urban context around a river has socioeconomic characteristics that deserve attention. The existence of segregation can influence use and activities that take place in a public space.

Secondly, we consider that the study of public space in urban rivers should include aspects of urban resilience, as the use and enjoyment of public space cannot be dissociated from the relationship of these spaces with nature, in the sense of facilitating the formation of green networks that allow the adjustment of variability that rivers have in the Andean region and maintain their fundamental structure, public life, and identity. The resilience is expressed in the quality of green areas and the configuration of the riverbanks. Plant and animal diversity, for example, can affect the use and enjoyment of the banks, particularly in user perceptions. Complementarily, it is important to consider the soil permeability to sustain the natural cycle of the ground and ecosystem development in urban areas, and lastly, to consider the flooding areas of the riverbanks would allow including in the analysis the vulnerability of the different areas to flooding, a key aspect in Andean cities.

Finally, it is necessary to analyze the use of rivers and their banks not only through spatial comparisons, but also temporal analysis. Hours of the day with more or less use can provide information about public space that has not been considered, such as lighting, which affects the use of space in the evenings. Public space can show a variety of uses throughout the day, on different days of the week, and even through the year.

References

[1] L. H. Gunderson, C. S. Holling, L. Pritchard, and G. D. Peterson, "Resilience of large-scale resource systems," in Resilience and the behaviour of large-scale systems, Washington, D.C.: Island Press, 2002.
[2] L. H. Gunderson and C. S. Holling, Panarcy. Understanding Transformations in Human and Natural Systems. Washington, D.C.: Island Press, 2002.
[3] J. Wu and T. Wu, "Ecological resilience as a foundation for urban design and sustainability" in Resilience in Urban Ecology and Design: Linking Theory and Practice for Sustainable Cities, 2013, pp. 211–230.
[4] A. Washburn, The Nature of Urban Design. A New York perspective on resilience, vol. 1. Washington, D.C.: IslandPress, 2013.
[5] T. Teh, "Historic water-cycle infrastructure and its influence on urban form in London," in Water and Urban Development Paradigms: Towards an Integration of Engineering, Design and Management Approaches, J. Feyen, K. Shannon, and M. Neville, Eds. CRC Press, 2009.
[6] J. Woltjer, "How water flows in strategic spacial planning: The strategic role of water in Dutch regional planning projects," in Water and Urban Development Paradigms: Towards an Integration of Engineering, Design and Management Approaches, J. Feyen, K. Shannon, and M. Neville, Eds. CRC Press, 2009.
[7] V. Novotny, "Sustainable urban water management," in Water and Urban Development Paradigms: Towards an Integration of Engineering, Design and Management Approaches, J. Feyen, K. Shannon, and M. Neville, Eds. CRC Press, 2009.
[8] V. Novotny, J. Ahern, and P. Brown, Water Centric Sustainable Communities. John Wiley & Sons, Inc., 2010.
[9] H. Jinnai, "The Waterfront as a Public Place in Tokyo," in Public Places in Asia Pacific Cities SE - 2, vol. 60, P. Miao, Ed. Springer Netherlands, 2001, pp. 49–70.
[10] J. Gehl and B. Svarre, How to study public life. Island Press, 2013.
[11] E. Cicalò, "Designing Public Spaces and Constructing Public Spheres: A Manifesto," in City Project and Public Space, 2013, pp. 221–235.
[12] R. H. Matsuoka and R. Kaplan, "People needs in the urban landscape: Analysis of Landscape and Urban Planning contributions," Landsc. Urban Plan., vol. 84, no. 1, pp. 7–19, 2008.
[13] E. Van Der Meer, M. Brucks, A. Husemann, M. Hofmann, J. Honold, and R. Beyer, "Perspectives in Urban Ecology," J. Chem. Inf. Model., vol. 53, no. 9, pp. 1689–1699, 2013.
[14] M. Adams, "Quality of Urban Spaces and Wellbeing," Wellbeing, vol. II, pp. 1–21, 2013.
[15] A. Zajac and Y. Deckmyn, "Ghent: Water as a structuring element of urbanity," Water Urban Development Paradigms., pp. 144–150, 2009.
[16] C. Jaramillo, "Evolución histórica de la ciudad de Cuenca," Rev. del Inst. Geográfico Mil., no. 26, pp. 117–137, 1982.
[17] E. Duhau and A. Giglia, Las reglas del desorden: habitar la metrópoli. México, 2008.
[18] GAD Municipal de Cuenca, "Catastro Municipal," 2012.
[19] Project for Public Spaces, "How to Turn a Place Around: A Handbook for Creating Successful Public Spaces," New York, 2005.
[20] H. E. Wright Wendel, R. K. Zarger, and J. R. Mihelcic, "Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America," Landsc. Urban Plan., vol. 107, no. 3, pp. 272–282, 2012.
[21] A. Cheshmehzangi and T. Heat, "Urban Identities: Influences on Socio-Environmental Values and Spatial Inter-Relations," Procedia - Soc. Behav. Sci., vol. 36, no. June 2011, pp. 253–264, 2012.
[22] M. R. Ngesan, H. A. Karim, and S. S. Zubir, "Image of Urban Public Park during Nighttime in Relation to Place Identity," Procedia -Social Behav. Sci., vol. 101, pp. 328–337, 2013.
[23] B. Golicnik and C. Ward Thompson, "Emerging relationships between design and use of urban park spaces," Landsc. Urban Plan., vol. 94, no. 1, pp. 38–53, 2010.
[24] W. Brunette, M. Sundt, and N. Dell, "Open data kit 2.0: expanding and refining information services for developing regions," Proc. 14th …, 2013.
[25] S. Bafna, "Space Syntax: A Brief Introduction to Its Logic and Analytical Techniques," Environ. Behav., vol. 35, no. 1, pp. 17–29, 2003.
[26] B. Hillier and J. Hanson, The Social Logic of Space. 1984.
[27] A. Turner, "Could A Road-centre Line Be An Axial Line In Disguise?," Proc. 5th Int. Sp. Syntax Symp., pp. 145–159, 2005.
[28] B. Hillier, "The Genetic Code for Cities: Is it simpler than we think?," in Complexity Theories of Cities Have Come of Age, J. Portugali, Ed. Springer-Verlag Berlin Heidelberg, 2012, pp. 129–152.
[29] K. Lloyd and C. Auld, "Leisure, public space and quality of life in the urban environment," Urban Policy Res., vol. 21, no. 4, pp. 339–356, 2003.
[30] J. Borja and Z. Muxí, El espacio público, ciudad y ciudadanía. 2000.
[31] E. Talen, "Measuring the public realm: a preliminary assessment of the link between public space and sense of community" J. Archit. Plann. Res., vol. 17, no. 4, pp. 344–360, 2000.
[32] A. Pascual and J. Peña, "Espacios abiertos de uso público," Arquitectura y Urbanismo, vol. 33, no. 1, pp. 25–42, 2012.
[33] Y. Che, K. Yang, T. Chen, and Q. Xu, "Assessing a riverfront rehabilitation project using the comprehensive index of public accessibility," Ecol. Eng., vol. 40, pp. 80–87, 2012.
[34] A. Hermida, D. Orellana, N. Cabrera, P. Osorio and C. Calle, La ciudad es Esto. Medición y representación espacial para ciudades compactas y sustentables, Cuenca: Universidad de Cuenca, 2015.