Research Note

Study of the Potential of Natural Light in Low and High Density Urban Environments in the Oasis City of Mendoza, in Summer

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ABSTRACT

In urban geometries, the heights of building facades and the components of public spaces may constitute surfaces that modify the natural light proper to the sunny climate of the region. This study assesses the lighting potential of two urban canyons located in high and low building density areas of the oasis city of Mendoza, taking into consideration the same street orientation axis and tree species in summer. The study is conducted according to a Protocol for Natural Lighting Measurement in urban environments. As the results show, the contribution of the reflected component is reduced in the case of 30-meter wide urban canyons as the facades in the high building density area are influenced by the significant width of the streets. Furthermore, the view of the sky vault is obstructed by the trees, experiencing their maximum foliar growth in that season. On the contrary, the influence of the diffused component is, in both cases, increased.

KEYWORDS: natural light, urban environments, urban forest

1. Introduction

An open space is often associated with a positive human visual experience. In the urban context, different factors may contribute to make this experience satisfactory. Visual discomfort, for instance, is linked to the correlation between the general lighting conditions of the environment and the set of expectations, motivations and attitudes of the users. In this context, visual comfort implies obtaining quality lighting as a result of the design of a space suitable for the specific lighting conditions of each site and capable of meeting the expectations of the users[1)-4)].

In the built space, visual comfort decreases as glare is experienced within the visual field. More specifically, discomfort glare and visual impairment take place as a result of very high contrasts or luminance values in the visual field[5)].

As stated in previous works, the city of Mendoza, located in the center-west of the Argentine Republic, has the sunny climate proper to arid regions, with values above 100000lx in summer. When looking into the city structure, it can be noticed that, contrary to the usual forms adopted by arid regions, there is seasonal control by means of the urban forest acting as an environmental protection element. Because of this, Mendoza can be said to be an oasis city. The distribution of the trees creates, along the day, varying light levels in public spaces and its potential quantitative and qualitative contribution to visual comfort is not always maximized[6)].

In addition to this determining factor, the high levels of land use translate into a completely tight and compact urban fabric, but its spatial and volumetric distribution displays a heterogenous three-dimensional bumpy texture due to the lack of consolidation and uniformity regarding heights. The pyramid spatial structure concentrates the greatest building mass and heights in the area where the founding of the city took place, in downtown Mendoza. It gradually decreases towards the outskirts of the urban stain corresponding to the metropolitan area, reaching the lowest densities in residential areas. In this respect, the urban space is structured according to three distinctive building densities (high, medium and low). For assessment and comparison purposes, the most important densities are the high building density corresponding to the sector identified as the founding area (downtown) and the low density proper to the outskirts.

All these special features characterizing the open environments of the city explain why the lighting of the urban settings is influenced by the presence of this organic filter and by the morphological characteristics of the environments such as the width and height of the canyons.

In view of this, and as part of an approach to natural lighting in the built space in the region, we present a comparative study of the potential of the incident light in two cases representative of the urban fabric: two urban canyons located in areas with contrasting building densities[7]. The first canyon corresponds to a high density area of tall buildings, while the second one is located in a low density sector with one or two-storey buildings. In both cases, the tree species and the street width are the same. The study was conducted in accordance with a measurement protocol specially designed to quantify the resource. The purpose of this work is to assess and compare the lighting impact of urban canyons with different features as regards urban morphology, taking into consideration the urban landscape variables under the influence of light incidence. These variables have an impact on the visual comfort of people in the open urban environment as well as on the overall availability of the resource. Some of the variables are the light permeability values of the canyons and the light distribution on horizontal surfaces.

2. Methodology

2.1 Description of study cases

The cases under study are two urban settings sharing the same street width (30 meters) and tree species (Mulberry). Both are east-west oriented canyons with most of the surface of the frontages facing north.

The pedestrian street Sarmiento located to lat: 32° 53' 37"S and long: 68° 50' 20"W, in downtown Mendoza, was selected for the high building density area. The spatial configuration of this urban environment is uniform and has full spaces, with blocks of buildings of about 9 storeys. In the low density area, for the other part, we selected Roque Sáenz Peña Street, an environment with one or two-storey buildings; its coordinates are: latitude 32° 52' 49"S and longitude 68° 51' 30"W.

Figures 1 and 2 show the planimetries of the cases under study, with the same orientation on an east-west axis located at 12° in relation to the north-south perpendicular, and the corresponding hemispherical image (recorded at 10am) showing the sun path in summer. These graphics were processed using the software

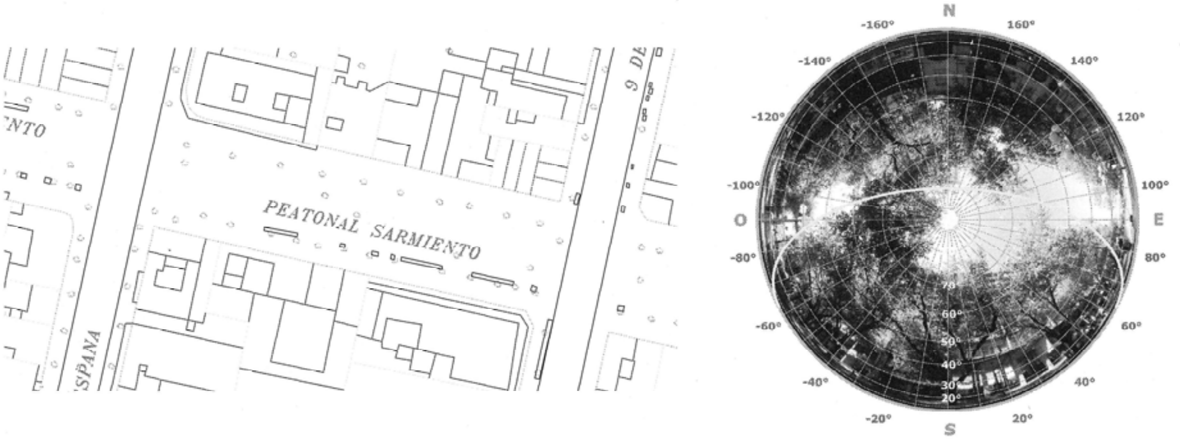

Figure 1 Plan of the canyon in the high building density area and fish-eye image of the scene

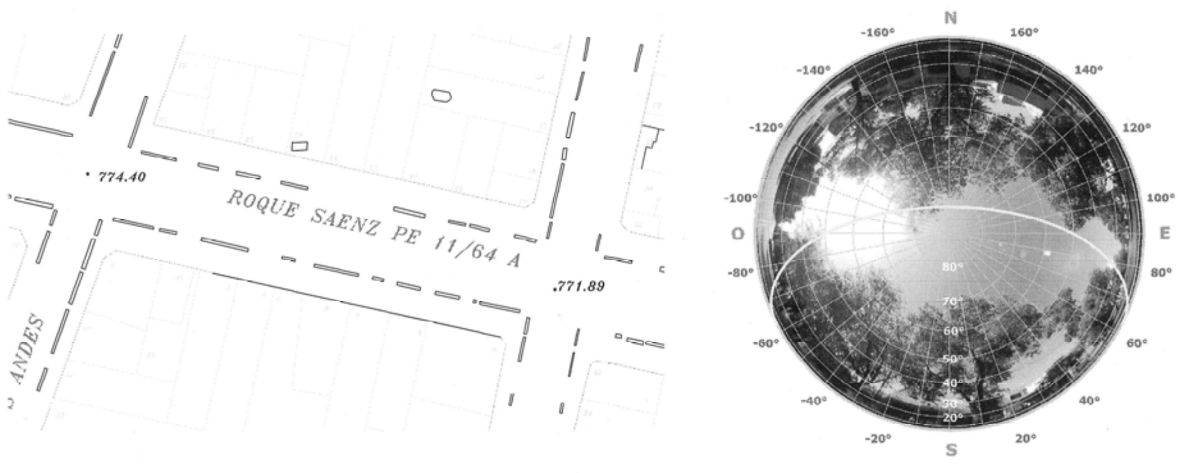

Figure 2 Plan of the canyon in the low building density area and fish-eye image of the scene

Figure 3 High density case: pedestrian street Sarmiento (left),
Low density case: R. S. Peña Street (right)

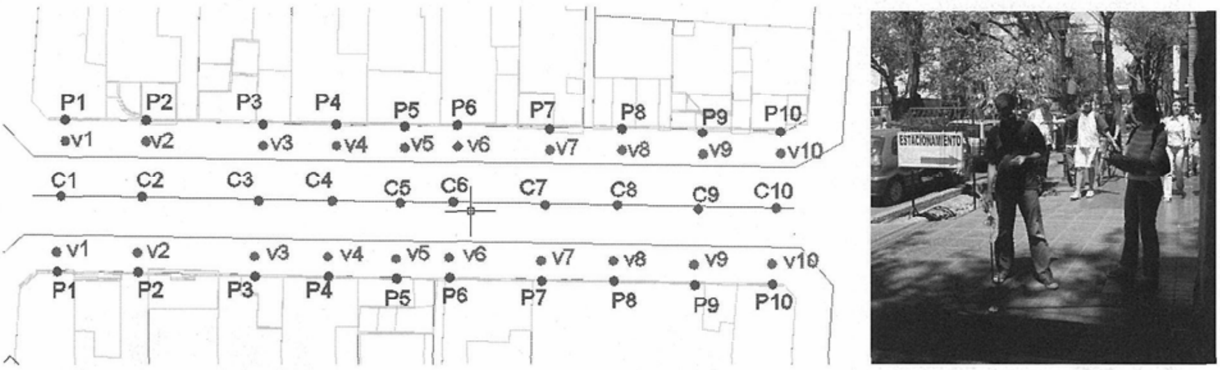

Figure 4 Measurement grid for roads and sidewalks and on-site survey photo

called Geosol.

In the following photographs (Figure 3), the densities of both urban settings are compared.

2.2 Processing of sky view factor (SVF) images

The first stage of the study comprised the assessment of the light permeabilities of each site using the application PIXEL DE CIELO, a tool used for obtaining the sky view factor (SVF) from the analysis of digital images of the same points[8]. It shows the relation between the unobstructed sky view and that part of the sky vault masked by the different components of the urban environment (building configuration, trees, luminaries, urban furnishings, etc.). The photographic survey was carried out with a Nikon Coolpix 5400 camera, equipped with a fish-eye lens with the use of equiangular projection.

For the purpose of this work, we put forward the analysis of building configurations in real scenes, comparing two points with the same location in both cases. Three types of images are processed for each setting. The processing involves identifying and separating different layers according to the most important space variables: first, the processing of the whole image, then the tree morphology factor and, finally, the urban morphology profile. In this way, we can assess the impact of the selected variables under the influence of natural light.

2.3 On-site measurement

In order to study the physical and objective parameters of the lighting comfort in the environments, measurements were taken uninterruptedly along a summer day (December 8, 2006). In this case, we consider those taken at noon. We assessed the horizontal illuminance on the road (at ground level) and on the sidewalks (at ground level).

The equipment used for the collection of data comprised a LI-COR 189 luxmeter with an LI-210 photometric sensor and a 2003S leveling fixture, and a Tenmars DL 201 luxmeter, both with cosine correction.

In order to carry out the measurement, a series of points were equidistantly distributed along the roads and sidewalks, indicating the places at which illuminance data were later collected at ground level (Figure 4).

3. Analysis of results

3.1 Comparison taking into consideration the sky view factor

The analysis of the first group of photographs, taking into consideration only the permeability of the tree crowns, shows that the values are very similar in both cases. This is due to the growth and structure of the foliage leading to a similar configuration. Although the trees do not form a uniform green vaulted structure, they do present different permeabilities. Regarding the blockage due to the built space, it can be noticed that the impact of the high building density (50% of sky view) is greater than that of the low density (92% of sky view). Finally, the comparison of the current situation in both cases shows that the high building density has a value of 28%, compared to the 41% allowed by the low density. The difference arises from the characteristics of the urban geometry, mainly from the contrasting heights and building densities (Figures 5 and 6).

Furthermore, it can be added that, for this type of comparison between contrasting densities, the variable with the greatest impact on the availability of natural light is the built morphology, since the trees, which share the same features in both cases, create a blockage of 28% in the high building density area, and of 41% in the low density one. This fact should be taken into consideration in future urban planning. In Mendoza, the tree serves as an element for light incidence control.

3.2 Lighting assessment

The graphics of the isolux curves, made with the Surfer software, in high and low density areas show substantial differences regarding the distribution of light on the surfaces. This is due to the impact exerted mainly by the features of the surrounding morphology; mostly by the height profiles and the contrasting building densities.

After looking at the first case in more detail, it can be concluded that the curves show heterogeneous light levels and surfaces in the high density area. Shadows are cast on the sidewalks by the buildings lining the canyon. Regarding the road axis, for the other part, the differences arise from the openings created by the trees (Figure 7). When looking at the urban road channel as a whole, it may be said that the space corresponds to a shade situation. The location of the trees is not an im-

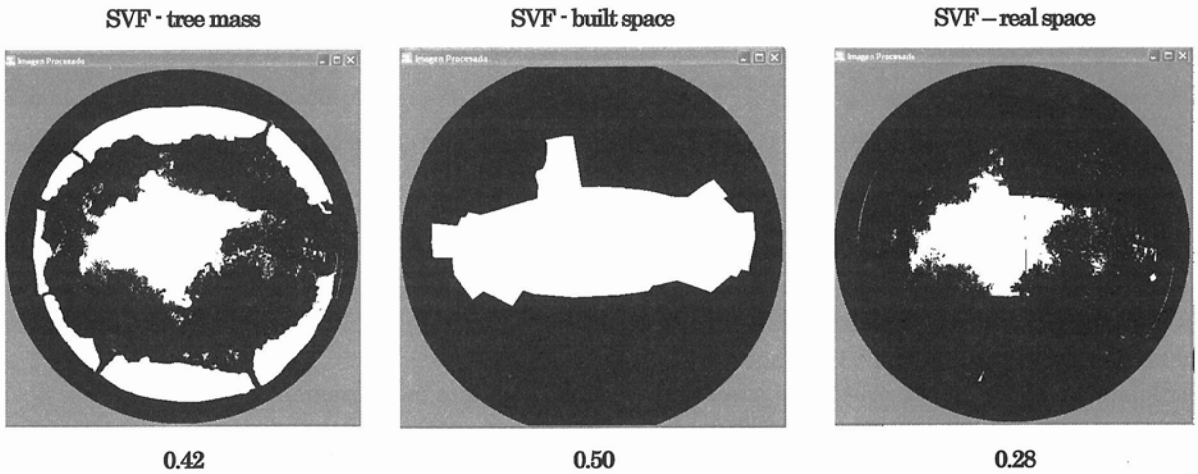

Figure 5 Separation of layers of SVF corresponding to the high building density

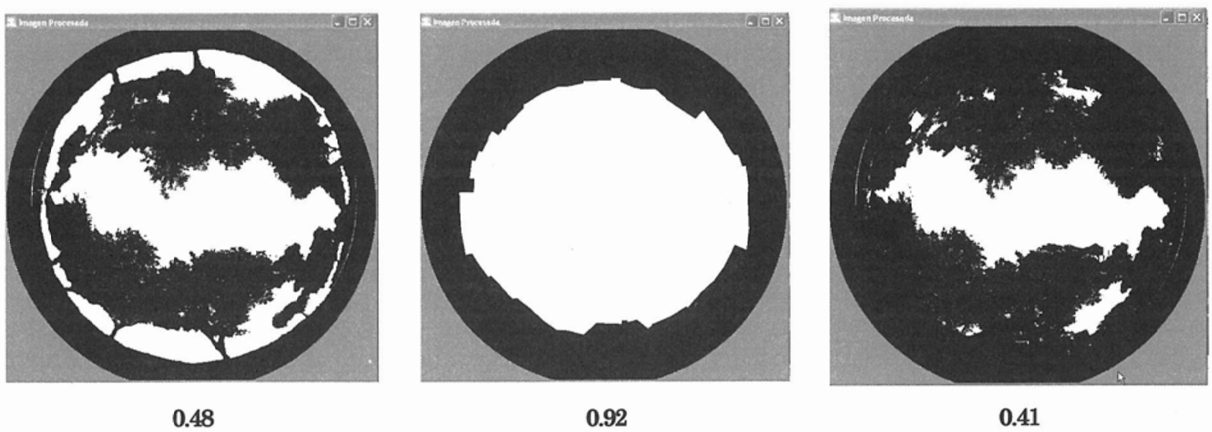

Figure 6 Separation of layers of SVF corresponding to the low building density

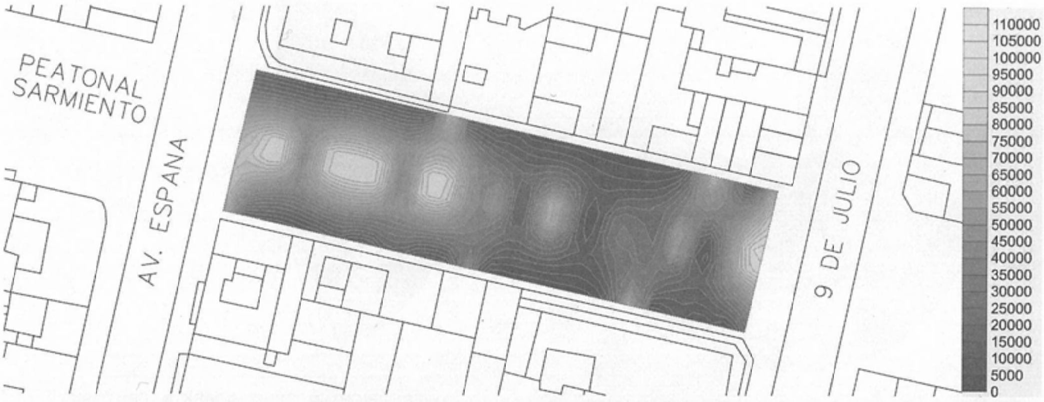

Figure 7 Iluminances at ground level corresponding to the whole urban canyon in the high density area

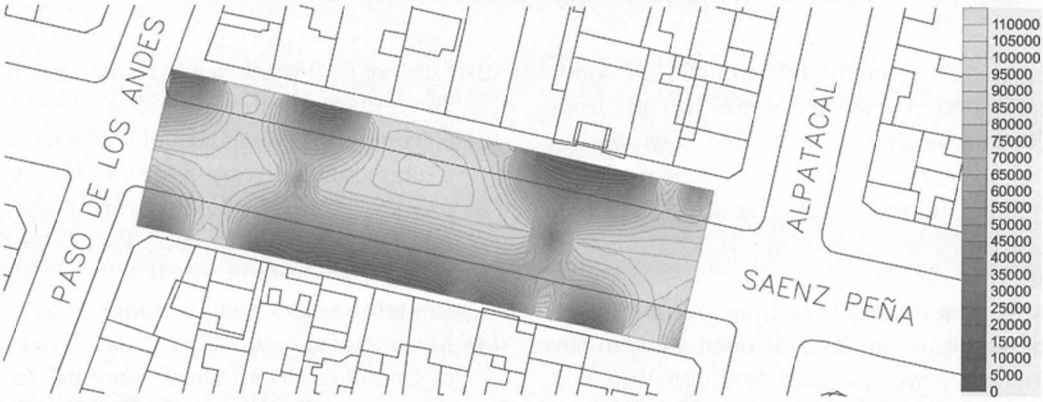

Figure 8 Iluminances at ground level corresponding to the whole urban canyon in the low density area

Table 1 Comparative values for high and low density

	High density - Sarmiento Street			Low density - Roque Sáenz Peña Street		
	South sidewalk	Road	North sidewalk	South sidewalk	Road	North sidewalk
Eh med	12582	61317	13206	36511	96547	53040
Eh max	97400	101560	97750	103970	101840	102040
Eh min	1089	2006	1150	2393	7049	1558

portant variable as they share a similar configuration. Although the trees do not form a uniform green vaulted structure, they do display some different distinctive features regarding permeability, mostly on the sidewalks.

In the low density area, on the contrary, the distribution of light changes radically taking into consideration the contrasting points and number of storeys with direct light incidence. The horizontal surfaces are highly light reflecting. These lighting conditions are created by the low building heights and the openness of the sky (Figure 8).

It is worth noticing that, in the situations under study, the width of the urban road channel proves to be an important factor influencing the lighting conditions created in the environments.

The values in Table 1 are indicators of the impact of the specific surrounding morphology. On the road, and as shown by the medium illuminance (Eh), the average value in the high density area is around 61300 lx, while the great exposure to daylight in the low density area accounts for the average value of 96547 lx along the street axis. The availability of natural light in each environment amounts to 30% in the pedestrian street Sarmiento and 60% in Roque Sáenz Peña Street. The Horizontal Global Illuminance during the measurement was of 104070 lx.

Finally, the daylight conditions of all the points in the grids were analyzed so as to compare both cases. The values were classified into four groups ranging from 0

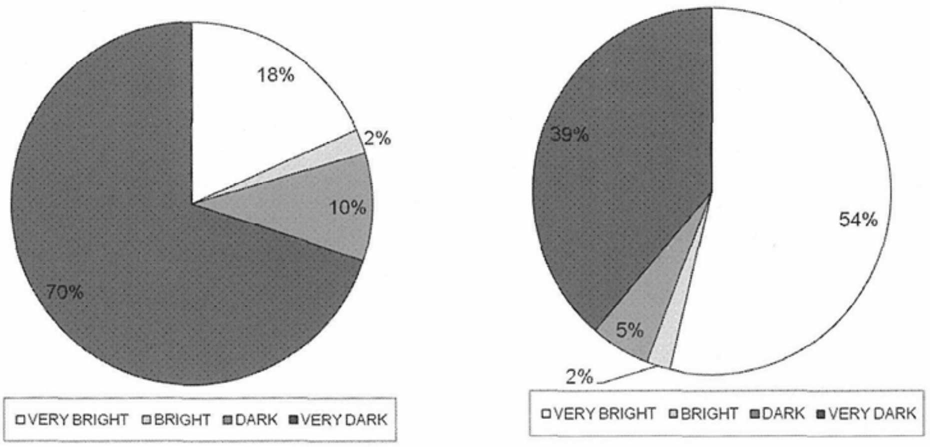

Figure 9 Percentages of the light conditions for high and low densities

to 30000lx ("darkness"), from 30000 to 60000lx ("semi-darkness"), from 60000 to 90000lx ("dimness") and from 90000 to 120000lx ("brightness"). In this way, we determined and compared the percentages and performance of all the points surveyed in each setting (Figure 9).

4. Conclusions

From the assessment of the distribution of light in the selected environments, it can be concluded that, in the case of comparisons between contrasting densities and regarding urban road channels of great width, the variable with the greatest impact on the availability of natural light is the built morphology. The constrasting building heights account for the varying levels. This is made evident in the percentages of availability in the high density (60%) and low density (30%) areas. The differences can be further observed in the illuminance curves corresponding to the sidewalks of the urban geometry, mostly conditioned by the building heights.

In addition, it is worth pointing out that exposure to 100000lx on a summer day, in public spaces, in the city of Mendoza results in experiencing not only glare, but also thermal discomfort. It is in this scenario that trees may contribute as an environmental filter.

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