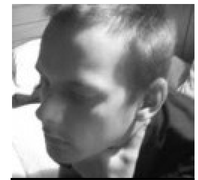
Urban canyons morphology, thermal comfort and urban design in Concepcion's city center, Chile



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Introduction

This study was developed within the project FONDECYT No. 1130305
"Study and modeling of urban climate on a local scale, as a basis for proposing guidelines for adaptation to climate change in a network of Chilean cities."

The study of the relationship between climate and city is part of "... two of the most serious environmental issues of the twentieth century: population growth and climate change ..." (Stewart and Oke, 2012). So the geography and urban design are key players to build a better quality of life in the city.

Abstract

This study is part of understanding the urban microclimate at scale of the urban canyon and its relationship with thermal comfort and urban design. It were selected 9 urban canyons located in the metropolitan center of the city of Concepcion, Chile. For morphology analysis, Local Climate Zone classification system (Stewart and Oke, 2012) was applied. Fish eye photographs (sky view factor), height of buildings using LIDAR data, air temperature and wind speed obtained from field measurements, and solar radiation data and shadowing by Ecotect software, were studied. All these inputs are integrated in the Actual Sensation Vote (ASV) thermal comfort index (Nikolopoulou et al. 2004).These results were compared with thermal comfort survey passers, and then were interpreted considering urban design factors that have a significant impact on the thermal comfort of the public space during the summer.
Finally it is noted that as there are covered canyons, corresponding to "Tulipas" project, having higher degree of discomfort. On the other hand, the canyon of the diagonal street Pedro Aguirre Cerda regarding the urban net due to its characteristics of orientation and morphology is the one with the best rates of thermal comfort in relation to the physical aspects. While generally the metropolitan center of Concepcion is a comfortable place in summer it is expected that the future effects of climate change shift this condition. It is concluded that urban regulatory plans play a relevant role in adaptation measures.

Keywords: Actual Sensation Vote, Thermal Comfort, Sky View Factor, Climate adaptation, Urban Street Canyon.

Methodology

The methodology is built on a structure consisting of three concepts, the city, the climate, and the men. Each item is coded with an indicator in order to be able to use simple statistical process, which is correlation of the variables and the representation of 2D mapping results.

These indicators are: physical thermal confort (ASV), perceptual thermal comfort (surveys), Shadow factor (%) and Sky View Factor (SVF).

For the city concept, the goal is to determine and model in 3D, different urban canyons. Urban density plays an essential role in the design, planning and management of modern cities (Gonzalez-Aguilera et al, 2013). The three-dimensional understanding of urban roughness is achieved with the use of LIDAR data (Light Detection and Ranging) that can be described as a cloud of points in space, each with a coordinate x, y, z. (Hunt and Royal, 2013).

For the concept of climate, the objective is to physical modeling the thermal comfort by atmospheric data records required by the ASV formula (Nikolopoulou et al, 2004). Obtained with mobile stations and numerical modeling in Ecotect Analysis.

$$ASV = (0{,}049\ T^{o}\ air) + (0{,}001\ Rad) - (0{,}051\ Vel\ v.) + (0{,}014\ HR) - 2{,}079$$

Where: (Tº air) = air tº in ºC, (Rad) = solar radiation in watt/sqm, (Vel v.) = wind speed in meters per second and (HR) = relative humidity in percentage.

In the case of man, the purpose of perceptually model the thermal comfort in urban canyons, is translated into a measurement through surveys, authors like Cheng (2008), Nikolopoulou et al (2004) and Mayer et al (2008), mention the importance of human thermal comfort for studies of urban micro climate.

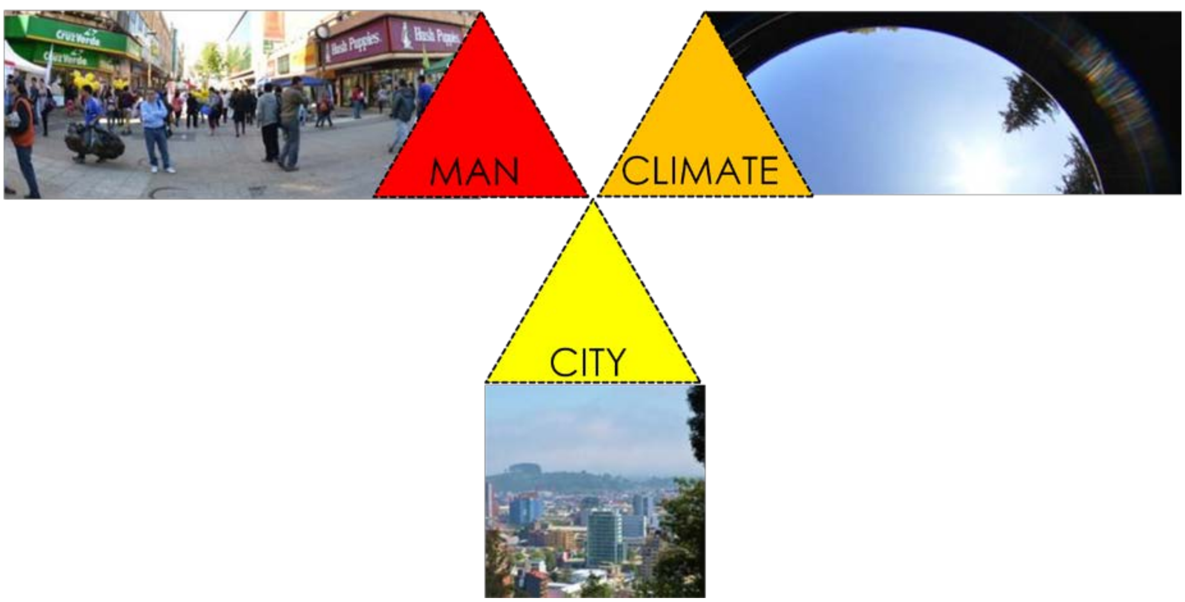

Figure 1: diagram of the general purpose. Source: author

Results

For the concepts of urban indicators, SVF and shading factor, were obtained. The results of SVF values were obtained for each control point for each canyon and then averaged.
For obtaining shading factor was necessary a 3D simplification process from the original cloud points (LiDAR).
Once imported the simplified model to Ecotect Analysis, it is generated the shadow factor mapping on January 14th at 14:00hrs. and their respective table for each canyon, the resulting figure can be seen that the transverse canyons (NW-SE) are shadier than longitudinal canyons (SW-NE).

Results associated with thermal comfort through atmospheric climate data, results represent physical thermal comfort (quantitative). From the resulting mapping, it can be seen that the longitudinal canyons (SO-NE) have higher values of discomfort with respect to the transverse canyons (NE-SW).

In perceptual thermal comfort (through surveys), the mapping emphasizes that only one canyon can be categorized as comfortable (the diagonal Nº9) The mapping shows in first instance, the values represent more discomfort about physical comfort values, and secondly that the longitudinal canyons (SW-NE) show higher values of discomfort with respect to the transverse canyons (NE-SW).

Crossing the indicators obtained from SVF, shading coefficient, physical thermal comfort (ASV) and perceptual thermal comfort (surveys) on scales from 0-1, the correlation matrix is generated indicating that there is inverse correlation mainly to a higher SVF lower is the surface shaded and there is no correlation between physical modeling method comfort and perceptual modeling method comfort, demonstrating that thermal comfort models generated based only on numerical models do not necessarily reflect reality.

Comparing and overlaying maps both physical comfort and perceptual, it is determined that the two models tend to receive greater thermal comfort in the transverse canyons (NW-SE) and the canyon with the better thermal comfort index in both cases is the canyon Nº9 called Diagonal Pedro Aguirre Cerda.

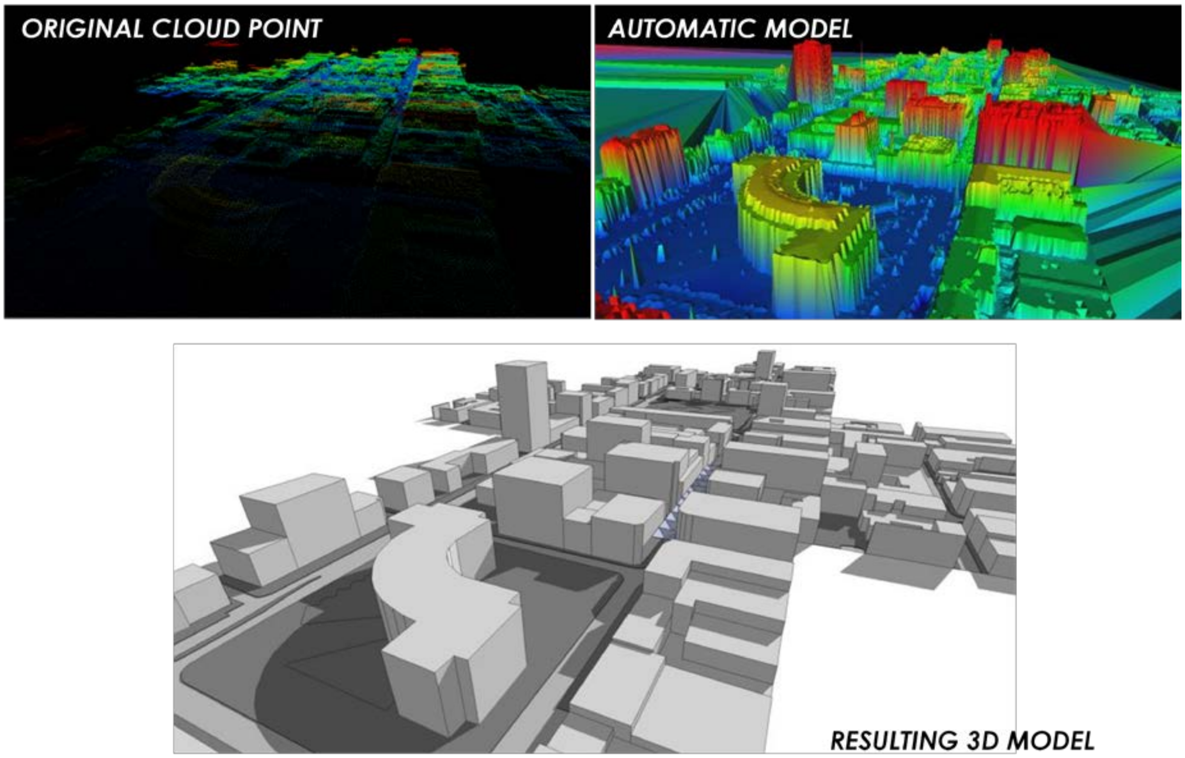

Figure 2: resulting 3D model from the LIDAR data. Source: Author.

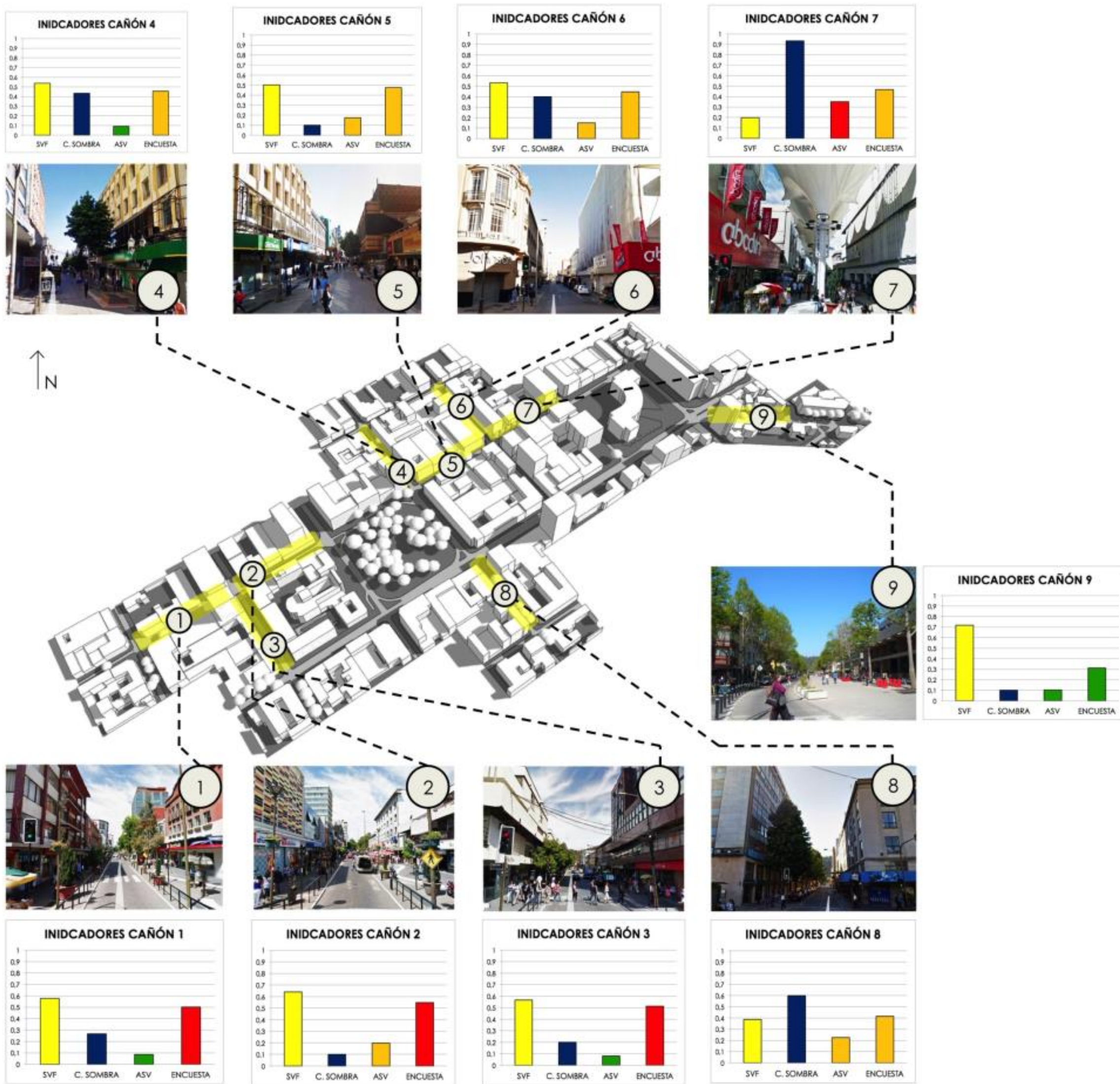

Figure 3: mixed results, urban, physical and perceptual indicators. Source: author.

Final considerations

"This type of results is useful for urban designers because proper planning and careful microclimate design in urban areas can provide protection against the negative and exposure to positive aspects of climate, therefore, increase the use of outdoor space throughout the year "(Nikolopoulou et al, 2004).

The center of Concepcion was modeled in three dimensions from the lidar data, these are accurate and contain the information necessary to generate a model of simple faces that can be processed in Ecotect, but its high cost of acquisition makes this tool hard to access.

The correlation matrix worked well, significant correlations between the three-dimensional models of canyons and physical comfort were obtained, but low correlation results were obtained with models of perceptual comfort.

It is advisable to replicate the study in the winter season in order to protect the public spaces of the negative variables of extreme weather indicators and exhibit spaces to positive atmospheric variables depending on the thermal comfort.

In order to be able to deliver some of the possible results in winter, the three-dimensional model was used to draw the cones of shadow generated during a day in summer (January 14) and one day in winter (July 8).
As stated above the canyons in transverse direction (NW-SE) have better thermal comfort in summer and are also more exposed to solar radiation during the winter, due to blockage of sun exposure for buildings for the canyons in the direction SW-NE.

It is recommended to generate more canyons with features of canyon No. 9; with streets proportions in which the width of the street is twice the height of buildings in each side a lateral row of deciduous trees.

Instead, the more discomfortable canyon in both cases corresponds to the covered canyon Barros Arana Street. In general it can be concluded that this type of urban design has no positive impact on the livability of the city, reducing energy consumption and particularly thermal comfort.

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References

Cheng, V. (2008). Urban Climatic Map and Standards for Wind Environment Feasibility Study. *Methodologies and Findings of User's Wind Comfort Level Survey* .

González-Aguilera, D., Crespo-Matellán, E., Hernández-López, D., & Rodríguez-Gonzálvez, P. (2013). Automated Urban Analysis Based on LiDAR-Derived Building Models. *IEEE Transactions on geoscience and remote sensing* , 1844 - 1851.

Hunt, K., & Royall, D. (2013). A LiDAR-Based Analysis of Stream Channel Cross Section Change Across an Urban-Rural Land-Use Boundary. *The Professional Geographer , 65* (2), 296-311.

Mayer, H., Holst, J., Dostal, P., Imbery, F., & Schindler, D. (2008). Human thermal comfort in summer within an urban street canyon in Central Europe. *Meteorologische Zeitschrift , 17* (3), 241 - 250.

Nikolopoulou, M., Lykoudis, S., & Kikira, M. (2004). Thermal Confort in outdoor spaces: Fiel studies in Greece. *Centre for Renewable Energy Source (C.R.E.S)* .

Stewart, D. y Oke, T.R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society*, Vol. 93 Issue 12, p1879-1900.