Calculation of Areas of Permanence in Public Spaces, According to Solar Radiation Simulated Conditions

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Abstract. Permanence of people in public spaces is conditioned to several environmental factors, such as solar insolation. This specific factor is of particular interest in tropical countries, since it determines the comfort levels of people staying in public places for a length of time.

This paper contains the analysis of people´s *Areas of Permanence* in public spaces, taking into account solar radiation. The solar radiation data was obtained through simulations developed with a LISP routine named Torres 15.0 [1] executed in AutoCAD, which registers the number of hours that each point is affected by direct solar radiation.

Resulting solar data were transformed to data of *Areas of Permanence* by creating *Tolerance Ranges* to sun exposure. The ranges were divided into five types of areas: *Long* and *Short Permanence*, *Pause, Slow* and *Fast Traffic*. These areas correspond to the time that people are willing to tolerate sun in different activities.

The objective of this analysis is to collect data of environmental influence on the human body and its response, allowing the creation of principles for enhanced design.

Keywords: Public Spaces, Solar Insolation, Areas of Permanence, Tolerance Ranges.

1 Introduction

Colombia is located in the world's tropical zone. In this zone, environmental factors such as insolation and temperature remain stable during the year, due to the lack of extreme seasonal variability.

These steady conditions given by the particular geographical zone encourage the continuous use of outdoor spaces. Therefore, it is of particular interest within urban design to maximize the various functions served by the available public spaces. Consequently, it is important then to provide open air areas that can be used for leisure or for work, to exercise or simply to rest [2]. The previous should provide sound foundations on which to build adequate guidelines of urban design [3].

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Within this context, the use of public spaces is highly conditioned by the availability of solar radiation. The time of permanence of a person in a specific part of the public space, *i.e. a bench*, is directly related to the amount of solar radiation falling on that bench. As a result, the furniture and areas designed for *Long Permanence* in the public spaces should provide certain amount of sheltering from direct solar radiation, in order to guarantee activities to remain in those spaces.

Nowadays, solar radiation simulation is available from different software routines. These programmes allow the identification of the impact of solar radiation over surfaces, calculating the solar exposure in a determined period of time [4]. In this research, data from Torres 15.0 LISP routine was used in order to classify and analyse the results [1].

The solar phenomenon is an important area of research: the sun is part of the influential environmental factors that modify the behavior of people under different activities [5]. The software tools used in this research, allowed the development of accurate calculations based on solar exposure, making it possible to convert Solar Radiation Areas into *Areas of Permanence* of people in certain spaces, taking into account the *Tolerance Ranges*. This paper presents the analysis of such results, classifying and evaluating the data obtained from insolation values, in order to predict the areas of public spaces where people will be more likely to stay for different periods of time.

2 Methodology

2.1 Insolation Simulation

The impact of solar radiation upon the built environment can be accurately predicted through simulation software. These results are mainly used to provide guidance on how to improve energy consumption and reduce carbon emissions [4].

Torres 15.0 is a LISP routine executed in AutoCAD® [6], this software tool simulates the average hours of direct solar radiation exposure of a certain point in a given period of time, within a 3D building model [1].

The routine is designed to register the solar impact in a grid of dots spread over the evaluated zone. Each dot changes its position in the Z axis, every time it receives direct solar radiation. Figure 1 shows a theoretical example of the evaluation process performed in Torres 15.0 to obtain solar radiation results.

This simulation was developed with the Latitude of Bogota - Colombia 4.35N. It was configured to evaluate a solar year and to collect data every 15 days, every half hour, from 7:00 h to 17:00 h.

The image above (Fig. 1) shows an evaluation of solar radiation over a building and its surroundings where are located various trees. The grid observed in the model corresponds to several dots with a numeric value that represents the amount of solar exposure received in the simulation.

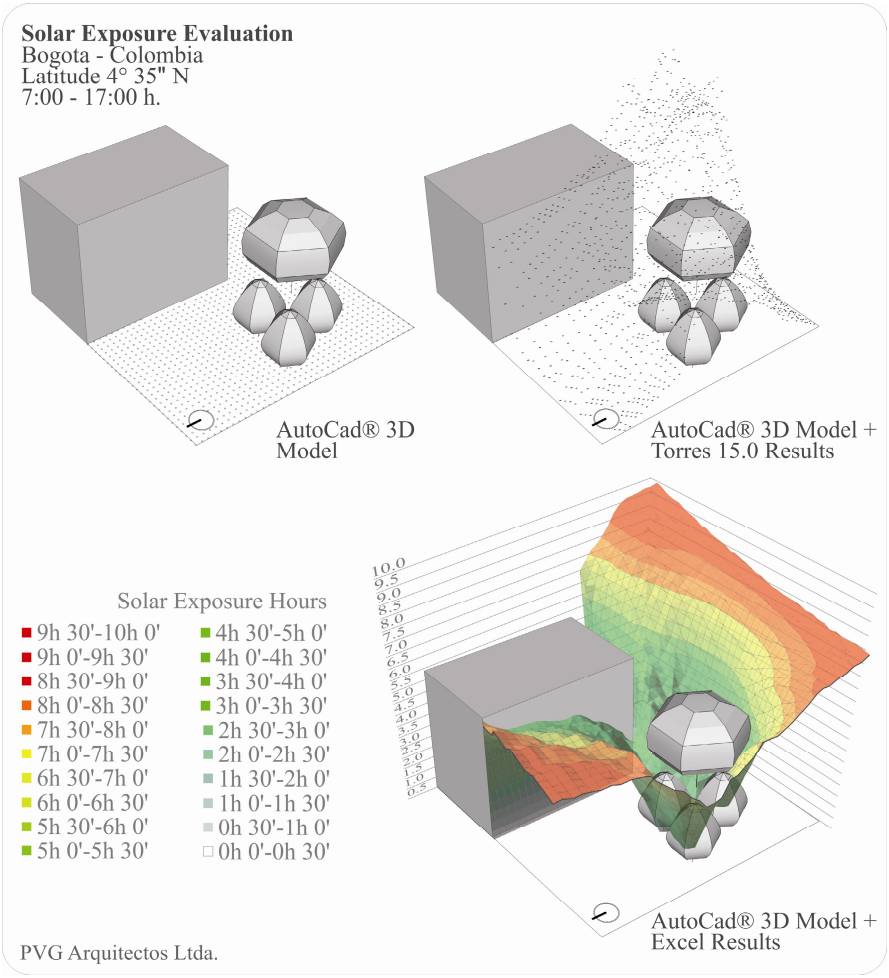

Fig. 1. Solar Exposure Evaluation applied to a theoretical case of a building and a group of trees located in Bogota – Colombia. The upper images indicate the process in 3D modeling and the bottom image contains the mapped results. The colour scale indicates the average of solar exposure hours, where the red areas are the maximum insolation and grey colours contain the areas with the minimum exposure.

After the simulation has finished, the resulting data was processed through an Excel® [7] Sheet, to reassign the interpretation of the values, which will no longer indicate solar exposure but permanence of people in the space, mapping it into a graph and assigning different colours for the resulting areas. The bottom image in Figure 1 contains an overlapped view of the Excel® results and the 3D model. The different colours represent the average of solar exposure received, red being the maximum exposure to solar radiation and grey being the least: 10 hours and 1 hour a day per year respectively.

2.2 Areas of Permanence

This is a classification of the areas depending on solar radiation exposure received. According to the solar exposure time, every area allows to perform specific activities and, therefore, postures. More solar protection in an area, allows a wider range of activities to perform and postures to assume.

There are five categories of areas, according to the amount of time pedestrians stay, which is determined by their *Tolerance Ranges*. These categories are: *Long Permanence Area, Short Permanence Area*, *Pause*, *Slow Traffic* and *Fast Traffic Area*.

The *Tolerance Ranges* of insolation for the classification in each category was established according to observational behavior of people in public spaces in Colombia [3].

The data conversion was developed taking the insolation Excel® data and classifying it in *Tolerance Ranges*. This classification was developed through an Excel® calculation sheet which contains the specified percentages of tolerance.

2.3 Areas of Permanence According to Tolerance Ranges

1. *Long Permanence:* Shaded areas to stay for long periods of the day. Maximum Insolation Average of 25%.
2. *Short Permanence:* Shaded areas to remain for different periods of the day. Maximum Insolation Average of 50%.
3. *Pause:* Unprotected Shaded Areas which will eventually provide shadow to stay for short periods of time. Maximum Insolation Average of 75%.
4. *Slow Traffic:* Insolated Areas with eventual sun protection. Maximum Insolation Average of 87%.
5. *Fast Traffic:* Insolated Areas with a minimum or null shadow presence. Maximum Insolation Average of 100%.

In Figure 2, Solar Exposure Evaluation is converted to Areas of Permanence using the *Tolerance Ranges* percentages.

2.4 Body Postures and Activities

The categories mentioned above were defined to predict human behaviour and postures according to solar availability in the *Areas of Permanence*.

Taking into account solar radiation data and *Tolerance Ranges*, a list of Body Postures was built classifying them by their movement or stillness. The postures are conditioned by the activities, furniture and environmental conditions, because of: physiological necessities, objects/space options and comfort perception in terms of temperature.

Figure 3 describes the standard positions of the body from movement to stillness. These positions are categorised according to the *Tolerance Ranges* and the demand of sun protection, to determine which postures are more likely to be used in every zone.

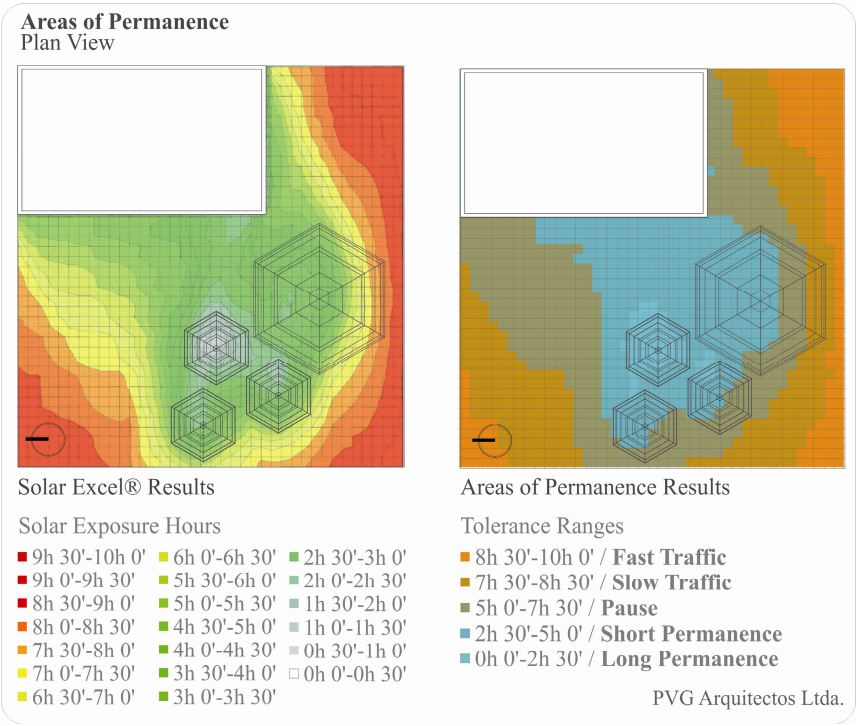

Fig. 2. Areas *of Permanence*. The left image corresponds to the insolation evaluation from plan view; the colour scale indicates the average of solar exposure during the year. The right figure corresponds to the insolation data converted to *Areas of Permanence*; the colour scale indicates the *Tolerance Rages*.

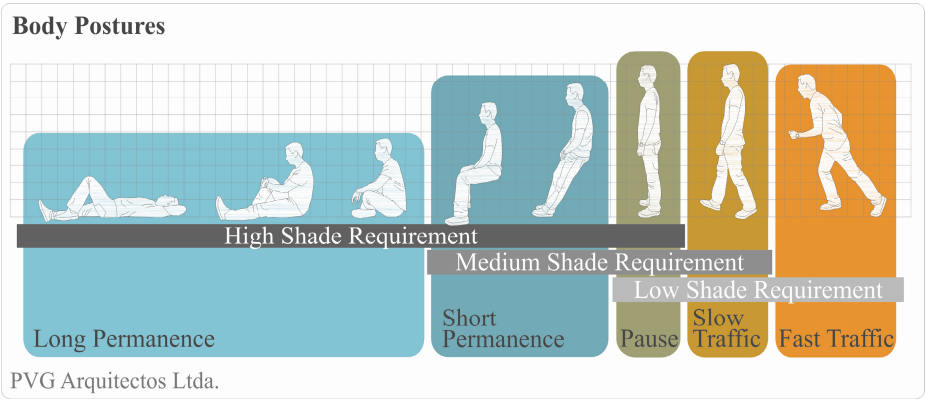

Fig. 3. Standard Postures adopted in public spaces with colours in accordance to the *Tolerance Ranges*. From the left to the right side of the figure, the postures are: Lay, Sitting, Lotus, Sitting Standard, Ischiatic Support, Standing Standard, Walking and Jogging. The mentioned body positions are a simplified group of postures which includes suspended positions and movement positions.

The postures *Lay Position* to *Standing Standard Positions* corresponds to High Shade Requirement area, *Sitting Standard* to *Slow Traffic Positions* as Medium Shade Requirement area and *Standing Standard* to *Jogging Postures* corresponds to the minimum or null sun protection requirement area.

3 Application and Results

The method described was used to evaluate "Plaza de la Concepción", the main square of the Historical City of Mompox, Colombia. Mompox is a Municipality located in Bolívar, Colombia, with 31°C average temperature [8] and 9° 14´ N of Latitude. The purpose of PVG Arquitectos was to assess the design to recover of the square, performed in 2012 by the Architecture Office OPUS Oficina de Proyectos Urbanos from Colombia. The project proposal integrated the analysis of Areas of Permanence according to solar radiation availability.

Figure 4 corresponds to the plan view of Solar and Permanence results obtained from "Plaza de la Concepción" analysis. The simulation was executed in two periods to compare early morning with midday results. The selected periods were: from 6:00 hrs to 10:00 hrs and from 10:00 hrs to 14:00 hrs.

The upper images of Figure 4 contain the sun exposure evaluation. It can be observed that the areas near buildings and vegetation are always protected against solar radiation, contrary to what happens with the areas located at the middle, that is, far from the surrounding buildings or vegetation.

At the bottom of Figure 4, there is an analysis of *Areas of Permanence*, performed with insolation exposure results. The shades resulting from the evaluation showed a possible path to connect the buildings that may be extended by artificial means. This strategy will also promote remaining activities in this area.

"Plaza de la Concepción" / Analysis of Results and Development of Design Principles.

Simulation from 6:00 hrs. ***to 10:00 hrs***.
This evaluation indicates that almost the entire square is suitable for *Long* and *Short Permanence*, excluding the west zone. The furniture recommended for this area should serve for meeting and staying purposes, and be flexible to be re-arranged as required. Furthermore, floor surfaces should be constructed in soft materials, to encourage lay position and sitting lotus postures. This may persuade users to adopt the suggested body posture, according to the respective *Area of Permanence*.

Pause and *Slow Traffic* A*reas* are located at the middle and west side of the square. The furniture should serve for short term postures because high solar exposure will create the need to seek for *Longer Permanence Areas*. These areas are recommended for transitory activities, such as waiting for somebody. On the other hand, the furniture should have low thermal conductivity in order to prevent high temperature gained by the surfaces, which will be exposed to direct solar radiation.

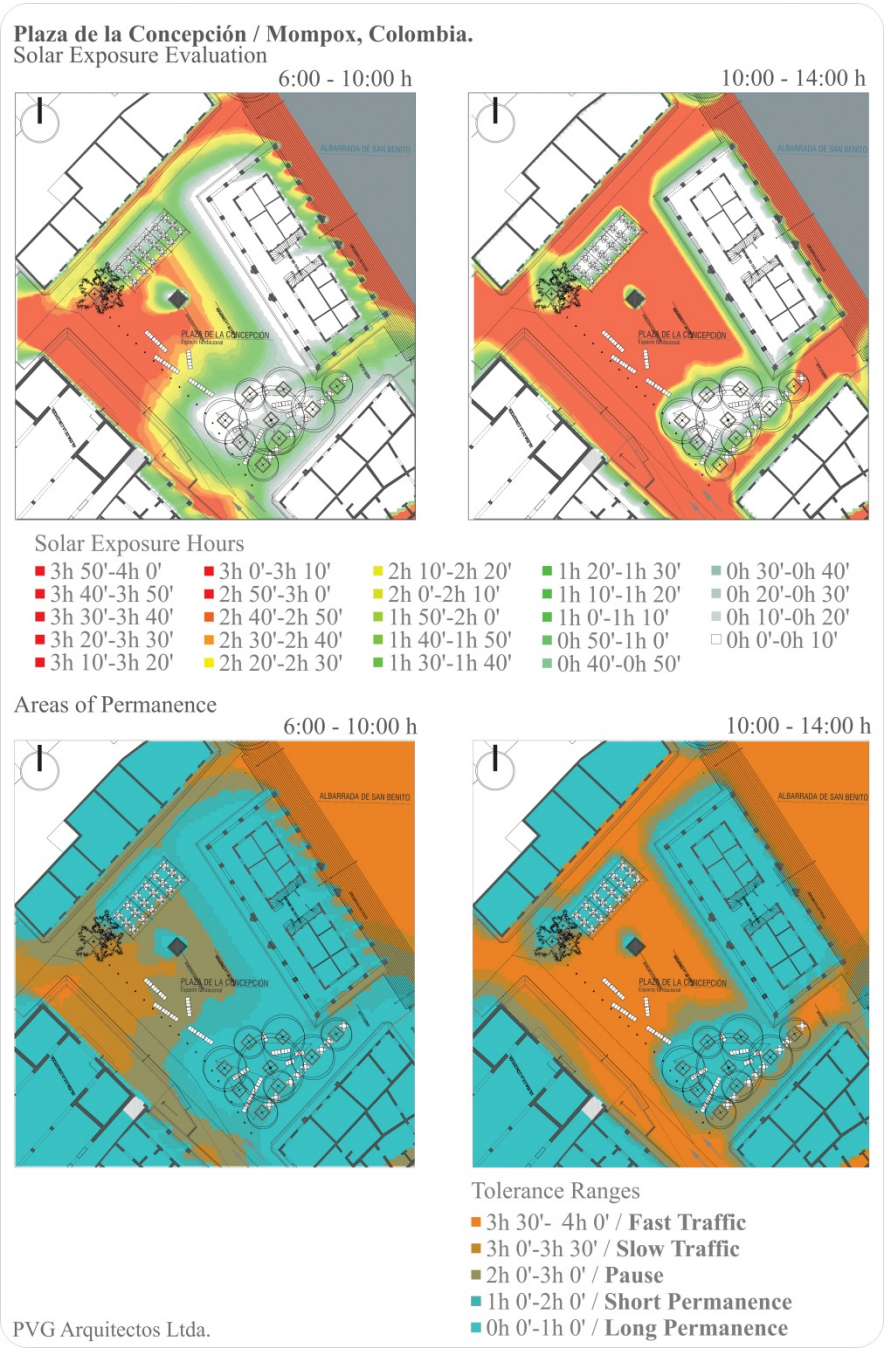

Fig. 4. Solar Exposure and *Areas of Permanence* Evaluation applied to "Plaza de la Concepción" Mompox – Colombia

Fast Traffic Areas are located far from the facades. The size of this area shrinks in the morning and grows at midday, increasing or decreasing the remaining areas.

Midday Simulation 10:00 hrs. ***to 14:00 hrs***.
At Midday, *Long* and *Short Permanence Areas* were reduced to a small zone near the buildings and trees. In order to promote long permanence outdoor activities in this period of the day, it is necessary to provide shading devices or tall vegetation to reduce solar radiation exposure.

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However, according to the simulation, *Fast Traffic* category is the largest area in this period of the day, which means that at midday the place is suitable for in-movement activities. In this circumstances, the materials used for the urban equipment, should meet specific qualities of colour and finishing. For instance, traffic activities require surfaces with friction and uniformity in order to avoid slipping or stumbling of pedestrians. It is also necessary to prevent the glare caused by the reflection of the sun falling on bright or glossy surfaces.

The benches used as urban furniture belong to different permanence areas depending on the time of the day: in the mornings to *Pause* and *Short Permanence Areas*, and in the midday to *Fast Traffic Area*.

To sum up, the use of the public space in Plaza de la Concepcion will be different according to the hour of the day. Under the previous considerations, the design of the square and its furniture should consider a schedule of uses of the public space throughout the year, and across the day.

4 Conclusions

Technical evaluation tools of the environment, such as solar radiation software simulators can enhance the design of spaces, particularly if appropriate analysis is developed by converting environmental data to human behavior data. This prediction of human behavior is a powerful tool to define the possible uses of spaces at the design stage of the project.

Defining the *Tolerance Ranges* is important, since they are used to measure the length of permanence that a person is willing to endure, based on specific solar exposure. These ranges apply to a particular location since they are conditioned by: relative humidity, rainfall, sunshine hours, physiological characteristics of user (age, gender, origin, health conditions, clothing, amongst other).

There are unexplored paths regarding *Tolerance Ranges* as a tool to define *Areas of Permanence* in a space, which must be objects of further investigations. It is necessary to define *Tolerance Ranges* according to solar exposure of the human body in different environmental conditions.

The main aim of this research has been to acknowledge the sun as a significant factor in the design process of outdoor spaces, moreover if it takes into account the human factors.

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