Impact of urban design on daylight availability

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ABSTRACT: The knowledge of the daylight availability in the urban environment is characterized as an essential input data for design. The form of control of this daylight access is basically done, in the case of Brazilian cities, through the legislation of urban land use. This legislation establishes, among other aspects, rules and limits of height and easements among buildings.
However, the criteria used for the establishment of these rules are not clear and it is supposed that the total occupation of the urban land, using the maximum plot ratio allowed, can lead to poor daylight availability in the urban environment.
The present work analyzes a real situation in the city of Florianópolis, Southern Brazil. Using computer simulation, different scenarios of maximum use of the urban land were generated. These scenarios resulted from the application of the urban land use, as defined in the city master plan. The software used for the scenarios generation were CityZoom and Apolux, for the simulation of the master plan and for the daylight performance simulations, respectively. In the analysis of the daylight availability the percentage of visible sky, the sunlight duration and the illuminances on the facades and on the sidewalks were correlated. The results have shown that the exhaustion of urban land, using the maximum plot ratio allowed by the legislation, affects significantly the daylight availability, parameter that should be more adequately considered.

Keywords: Daylight availability, urban environment, computer simulation

1. INTRODUCTION

The sun and daylight planning is essential for the exploitation of the benefits of solar energy. The first step is that the sunlight and skylight should be present in the exterior and interior of the buildings [1]. The variables related with the daylighting in the internal environment can be divided in two groups: the external and the built environment. Variable of the external environment are: the solar radiation and the level of illumination. While the variable of the built environment are divided in: external obstruction, building design and internal environment [2].

The configuration of the obstructions, tall buildings and other nearby obstructions, can affect the solar and daylight reception. The definition of these variables can significantly improve, or turn worse, the conditions of the internal daylighting environment [3, 4].

For Assis [5] it has been a consensus among the researchers about the impact of the built environment in the climate. Some variables of the urban form are directly involved on local climatic changes. The author suggests a systematic analysis of urban realities, the use of climatic simulation models and the interaction between these two processes to assist in definition of new criteria and conception methods. Buildings height variation to improve the ventilation local conditions, the adjusted solar orientation and buildings arrangement are lines of direction established for the World Meteorological Organization for the planning and climatic responsible urban design [5].

One conclusion from the studies developed by Ng [6, 7] in Hong Kong is that better performances for illumination and ventilation were obtained when it varied the skylines, that is, for the same density the variation in the urban design can lead to different conditions of daylight availability.

For Ratti, Baker and Steemers [8] urban geometry is presented as one of the main associated variables to the building energy performance, influencing the solar energy and daylight availability on the building façade. An extremely obstructed urban environment reduces the daylight and solar energy exploitation.

2. THE STUDY

The main objective of this work is to analyze the impact of urban land exhaustion on solar and daylight availability, using the maximum plot ratio allowed by legislation. For that, a real situation in the city of Florianópolis was chosen and reproduced in digital media. The main urban variables are: street width, urban blocks and land plots. Two urban scenarios were simulated: the current situation and the maximum plot ratio allowed by legislation. These scenarios were used for the daylight simulation.

In the analysis of the daylight availability the percentage of visible sky, the sunlight duration and the illuminances on the street, sidewalks and façades were correlated.

Regarding the sunlight duration, a recommended value of one to 2,5 hours in winter is found elsewhere in the literature [1, 3]. The sky visible percentage and the illuminances were analised against a reference condition of no obstruction.

The main stages of the study are presented as follows:

2.2 The place - Florianópolis city

Florianópolis, 27°30 latitude South and 48°36 longitude West, being an island, presents a limited possibility of expansion (see figure 1). This limitation generates a building market trend in exploring the maximum urban land use, disrespecting in many cases aspects associated to the environmental quality.

Figure 1: The case study: Brazil, Santa Catarina State, Florianópolis Island and the city center location

The chosen area is situated in a central city area, in the neighborhoods of the Hercílio Luz Avenue (see figure 1 and 2). It is a downtown location with services, commerce, offices and dwelling use. The base area presents a surface of approximately 38,961 m2, with about 925 m length and 600 m width, including 17 blocks. Two sets of constructions, nominated of Set 2 and 3, were analyzed in this work, as shown in figure 2.

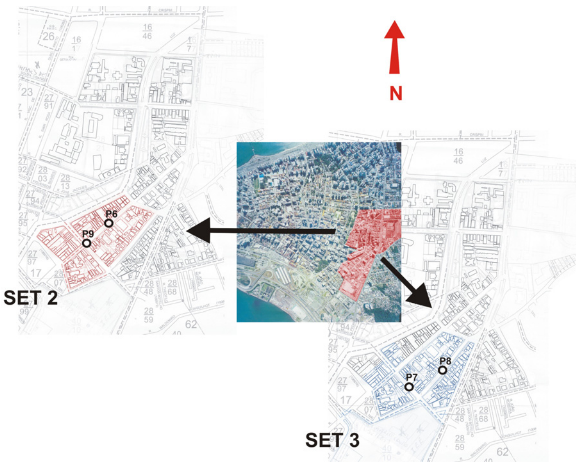

Figure 2: Set groups 2 and 3, points 6,7,8 and 9

In each set, two groups of points were analyzed. The points nominated 6 and 9 are located in Set 2 and the points 7 and 8 are located in Set 3. Each group (see figure 3) has a point of measurement in the middle of street (S), two points in the middle of the sidewalk (Swa and Swb) an four points on building façades (Ffa/b, Fbacka/b, Frightside a/b, Fleftside a/b). The points are lined up perpendicularly to the street axle (see figure 3). Points 6, 8 and 9 are in Southwest-Northeast direction and point 7 in Northeast-Southwest orientation.

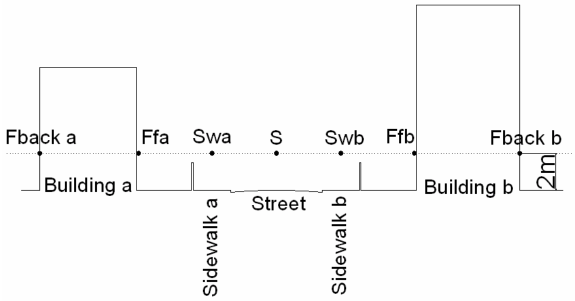

Figure 3: Section of street axle showing analysed points

In the study survey of the area, in order to reproduce the existing situation, maps and data were obtained in the Florianópolis Urban Planning Institute – IPUF [9], as well as several visits to the place to take photographs (figure 4) and measurements, in order to identify aspects not available in IPUF.

Figure 4: Fish-eye lenses image from one of the studied places

2.2 Scenarios

For the scenarios construction the Cityzoom computer program was used (www.cityzoom.net). This program was developed by Professor Benamy Turkienicz in the Laboratory for Simulation and Modeling in Architecture and Urbanism (SimLab) of the Federal University of Rio Grande do Sul (UFRGS). Cityzoom has the objective of assisting the urban planning process. Through the insertion of real data, as the urban legislation and street pattern (see figure 5), the program can generate different scenarios, that is, a three-dimensional urban space simulation.

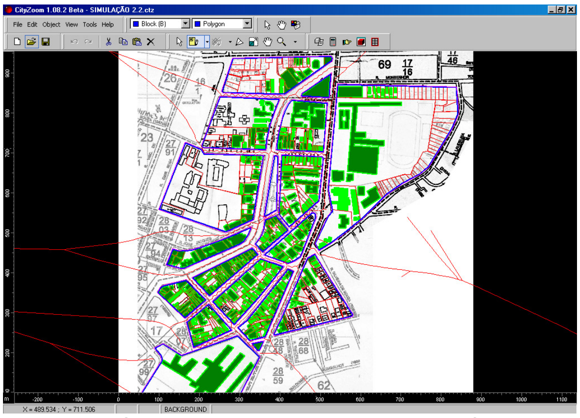

Figure 5: Cityzoom screenshot: view from the Florianópolis urban area

The simulation results can be analyzed under qualitative and quantitative aspects. It can be estimated, for example, population of a building or city block, hours of insolation and solar envelope and urban morphology [10]. Being a program conceived for an urban approach, it can quickly reproduce the existing situation and, from the insertion of the legislation requirements (building code and master plan), establish different scenarios of occupation (figure 6).

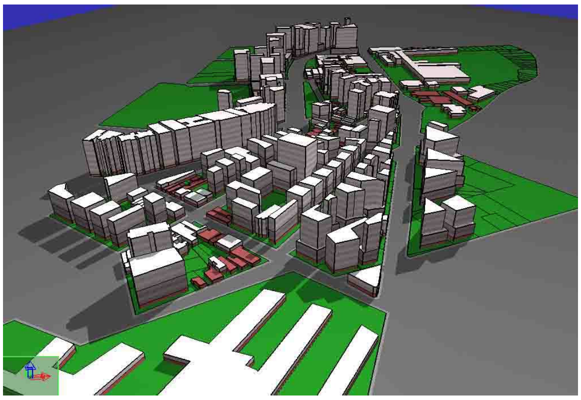

Figure 6: Maximum legislation occupation scenarios from Cityzoom

For the study development, the simulated scenarios were divided in: current scenarios (CS) and maximum legislation occupation scenarios (LS). As a reference for comparisons, a non-obstructed façades condition was also simulated.

In the scenario of maximum occupation, a solution for merging the lots was used. The lots smaller than 15 meters wide were merged, a threshold of 15 to 30 meters was used as a reference. The short buildings that can be distinguished from the set are protected by law because they are considered having historical interest, therefore, must be preserved.

2.4 Daylight simulation

The daylight performance simulations were carried out with the Apolux program. The program is based on the spherical vectorial model concept, developed by Claro [11, 12], researcher at the Laboratory of Environmental Comfort (LabCon), Federal University of Santa Catarina. The code uses the radiosity algorithm for the daylight calculation and the IES models for Sky Luminance Distribution.

The scenarios from Cityzoom program were exported to the Apolux for daylight performance simulation. The parameters of analysis were: the illuminances, the sunshine hours and the sky factor (figures 7 and 8). The model description used was: reflectance of 0.20 for streets, sidewalks and lots; and 0.40 for the façades. Clear and cloudy sky condition, winter and summer, schedules of 9:00, 12:00 and 15:00 hours were used as simulation variables. Points of analysis were on 2 meters height. It is worth mentioning that illuminances and the sky factor correlation were performed only for cloudy sky condition.

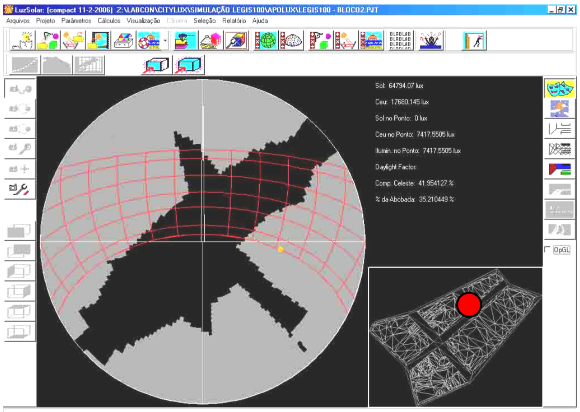

Figure 7: Apolux screenshot: view of the obstruction mask, the right image shows the point of analysis location

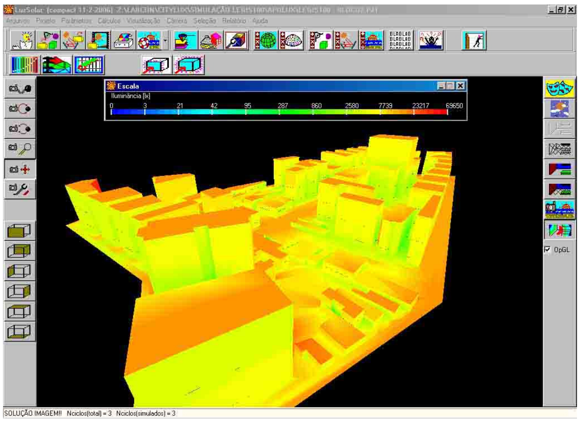

Figure 8: Apolux screenshot: the 3D scenario illuminance view

3. RESULTS AND ANALYSIS

3.1 Sky factor

The percentage of sky seen from a certain point is called the sky factor. In the analysis of this parameter (figure 9) one can observe that the current scenario presents higher percentages of sky factor, around 80% for points 7, 8 and 9, and values between 45 and 60% for point 6. In the legislation scenario, point P9 presents the greatest sky factor percentage, what it justifies in its corner location (see figure 9 and 10).

The points P6 and P8 presents lower sky factor, since they are situated in the middle of the square, situation of greater sky obstruction.

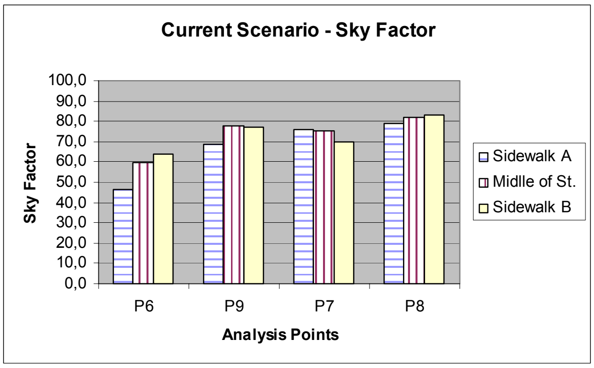

Figure 9: Sky factor CS scenario

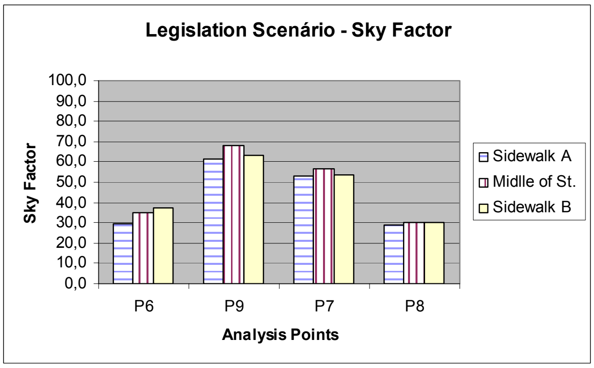

Figure 10: Sky factor LS scenario

3.2 Sunshine hours

In the sunshine hours analysis (figures 11 to 14) a relatively obvious correlation with the sky factor can be observed: the higher is the sky obstruction, the lower is the sunshine hours at the point. The sunshine hour's reduction, however, is more significant in the winter, with low angles of sun altitude. With a value of 30% sky factor, it is perceived that the sunshine hour's value is about one hour only, value that can be considered critical for the winter conditions.

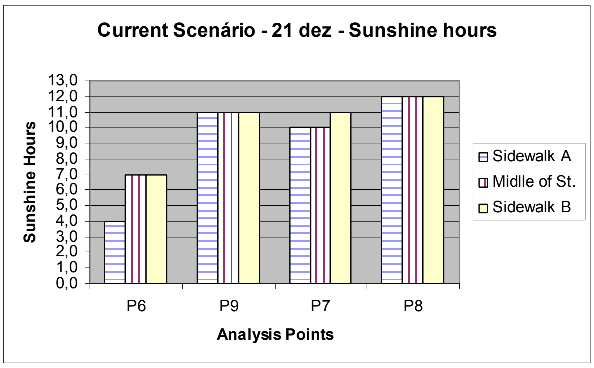

Figure 11: Summer sunshine hours CS scenario

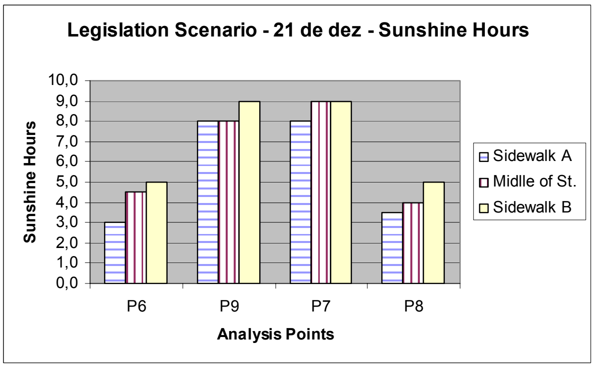

Figure 12: Summer sunshine hours LS scenario

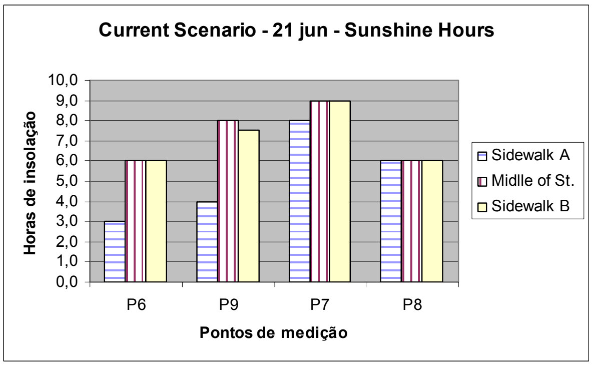

Figure 13: Winter sunshine hours CS scenario

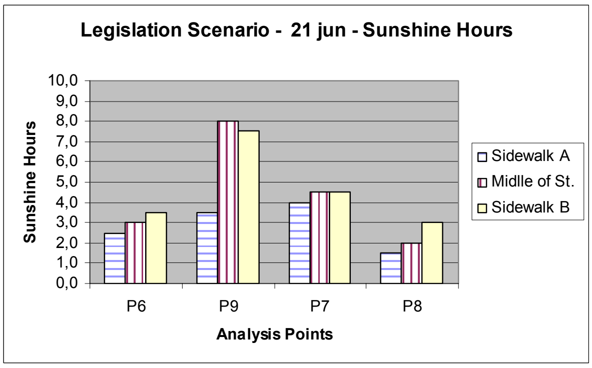

Figure 14: Winter Sunshine hours LS scenario

3.3 Illuminance levels

One can observe that the illuminance levels (figures 15 to 16) show a direct relation with the sky factor percentages. For the points with higher sky factor, around 80%, higher illuminances are also observed. The highest illuminances occurred at point 9, located at a corner, as well as the highest sky factor. In the situations of higher obstruction, with the sky factor around 30%, a reduction of 50% on the illuminance levels, with cloudy sky condition, were found.

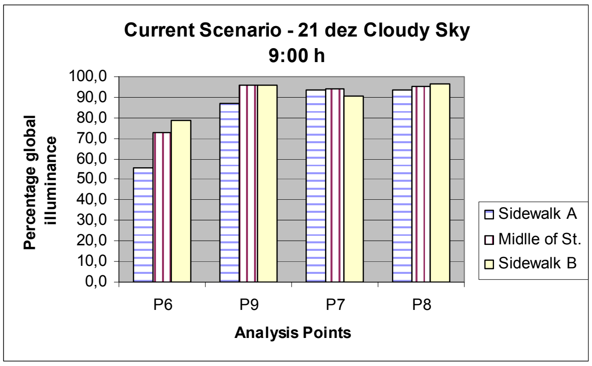

Figure 15: Summer illuminance percentage Current scenario

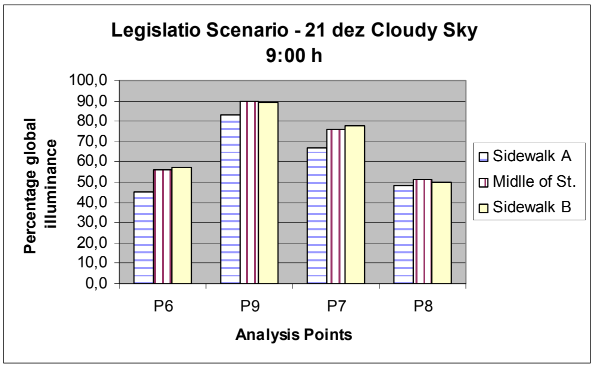

Figure 16: Summer illuminance percentage Legislation scenario

3.4 Façades exposition conditions

In the façade analysis, points located in the front façade, right and left sides were observed. The values found for the current scenarios and for the legislation ones were compared with the values found for the same façades in a totally non-obstructed condition. An illuminance percentage which represents a ratio of the scenario façade illuminance to the illuminance in a non-obstructed condition is presented in the graphs shown in figures 17 to 22.

Figures 17 and 18 present the results from points 9 and 8, and as seen previously, point 9 (less obstructed) it is situated at a corner and point 8 at the middle of the block (more obstructed). One can note that the difference between the illuminance values found in the CS scenario and the LS scenario were more significant at the point 8 (the most obstructed), showing proportions as low as 40%.

The already observed correlation between the sky factor and the illuminance levels can be identified again. The smaller the sky factor the lower the iluminances (figures 17 to 20).

The sunshine hour's analysis pointed out critical situations with no sunshine on the façades. This situation occurred in the LS scenario where the law allows for a high plot occupation in the lower building floors from ground to 3rd ones (figures 21 and 22).

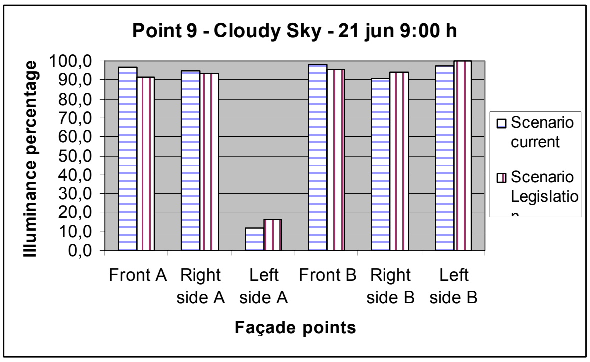

Figure 17: Point 9 - Façades illuminance levels

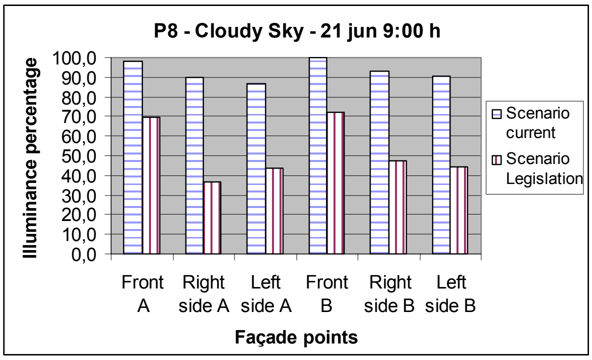

Figure 18: Point 8 - Façades illuminance levels

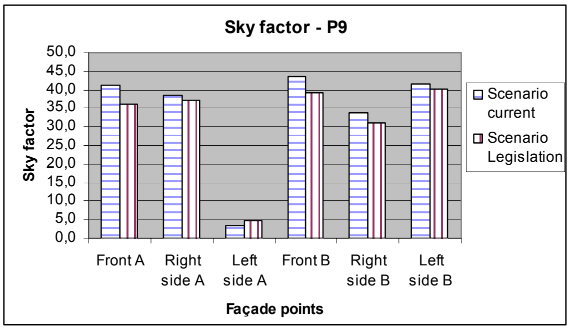

Figure 19: Point 9 – Façades Sky factor

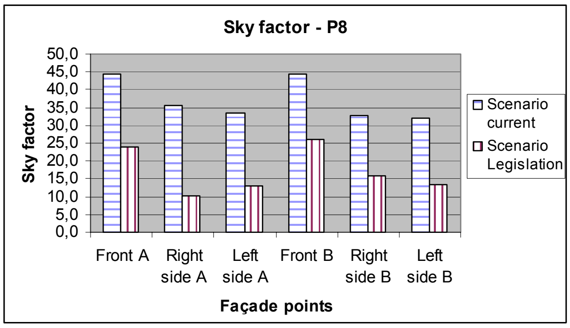

Figure 20: Point 8 – Façades Sky factor

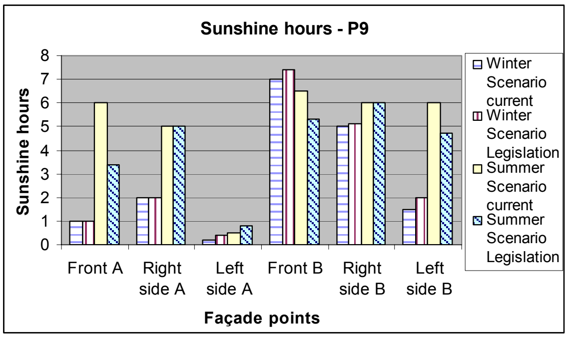

Figure 21: P9 – Sunshine hours

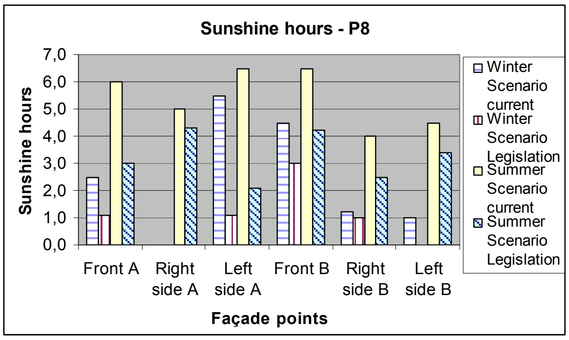

Figure 22: P8 – Sunshine hours

5. CONCLUSION

Besides establishing limits of occupation and exploitation of the urban ground, the land use legislation is also responsible for the daylight access in the urban environment. Using computer simulation and working in a central area of the Florianópolis downtown, a land use exhaustion scenario was generated from the application of the current legislation.

The methodology proposed in this study consisted of the generation of different urban scenarios, representing different options of urban area occupation. This scenario generation consisted of producing 3D models of the maximum building density for each set of generation rules.

Daylight conditions were than computed for the different scenarios and analyzed through the following parameters: percentage of visible sky, sunshine hours and illuminance levels. The objective of the study was to analyze the impact of the maximum limits of land occupation allowed by the legislation, in the sunshine and daylight availability in the urban environment.

One could observe that the percentage of visible sky is a parameter that can be associated to the urban legislation, so that the land occupation control can ensure conditions of daylight availability; critical values of sunshine hours, below 2 hours in the winter, and low illuminance values were observed associated to percentages of visible sky as low as 30%.

It was also observed that the point in the middle of the blocks presented the lowest visible sky percentage, resulting accordingly in low illuminance levels and reduced sunshine hours.

The whole methodology was very effective, promising and capable of dealing with large urban areas, also allowing the use of real urban settlements.

The present study is part of a larger proposal to analyze the impact of constructed surroundings on daylighting in buildings.

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