EXPLORING METRICS ON THE EVALUATION OF THE BIOCLIMATIC POTENTIAL AT EARLY STAGES OF URBAN PROJECT

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ABSTRACT

Understanding and limiting the impact of buildings on their environment while seeking for optimal comfort became a matter of prime concern in urban planning. This important issue brings us to a reflection on the definition of a "bioclimatic urban planning": aiming at minimizing the energy needs while optimizing the luminous comfort on an urban project.

In this paper, we explore different metrics of luminous comfort and daylighting of the literature [1, 2] in an attempt to define an indicator appropriated to the early stages of an urban project. We choose as a case-study an office building regarding its daily occupancy and strong lighting consumptions.

Regarding urban planners practices in France, we can identify three key stages in the design of an urban project: the "*guide plan*", the "*mass plan*" and the "*block plan*". In the *guide plan,* an approximate 2D distribution of the different elements of the urban program is configured. The volumes are represented in the *mass plan*, as mass blocks corresponding to the level of detail LOD1 of the CityGML norm [3]. Finally, architectural details such as openings at windows positions, roof tilts or solar protections are defined in the *block plan*.

The *mass plan* strikes us as a key stage of an urban project regarding its "bioclimatic potential". Works on the search of an optimal geometrical configuration of the urban layout have pointed out the impact of parameters such as glazing ratios and performances or walls characteristics on the final solution [4]. Those parameters are still unknown at this stage of the project. Meanwhile, based on expert opinions, it is possible to emit consistent hypothesis for given climatic zone, use and targeted thermal performances of the building. The architectural details remain unknown but it is possible to have a precise idea of the building envelope and an indication on its interior through those three parameters.

Window positioning, solar protections or balcony are defined by the architects. Meanwhile, the urban planner may explore their impact on the performance of his project to set his architectural guidelines. Using procedural modeling to configure levels of detail may allow a refined analysis of the geometry at the early stages of the project [5].

Keywords: urban planning, bioclimatic potential, daylight penetration

INTRODUCTION

Bioclimatic architecture principles are well known since the end of the twentieth century. For a greater efficiency, those principles should be applied at the urban scale [6] and taken into account at the design phases of an urban project.

An urban project is declined in three main phases characterized by different Levels Of Details (LOD): the "*guide plan*", the "*mass plan*" and the "*block plan*". The volumes are represented in the *mass plan*, which make it a key stage of an urban project regarding its bioclimatic potential. In the present paper, we explore the metrics on the evaluation of the bioclimatic potential of an urban project and their fitting to this peculiar stage.

Bioclimatism is declined in 3 aspects: thermal loads, daylight conditions and thermal comfort in summer. In [4], the authors pointed out the impact of the buildings characteristics such as walls conduction or glazing ratios on the optimal geometric configuration of the urban environment regarding thermal loads. Based on expert opinions, it is possible to emit consistent hypothesis on those characteristics at the mass plan step knowing the climatic zone of the project, the use and targeted thermal performances of the buildings. It is however possible to estimate the heating and cooling loads in the mass plan, which should directly serve as an indicator of the first aspect of the bioclimatic potential of an urban project.

Interviewing urban planners, we identified their needs in terms of daylighting: the estimation of daylight penetration in order to seek an urban geometry which minimizes the dark spaces at the center of the buildings, where artificial lightings will be used most of the year. So, a particular attention should be put on the depth of daylight penetration in the interiors.

The Useful Daylight Indicator (UDI) [1] and the Daylight Autonomy (DA) [2] appear as prime candidates to characterize the daylight penetration in an interior. The UDI is the number of hours in which "useful" daylight conditions are achieved: when sufficient level of illuminance on the work plan is achieved avoiding discomfort due to glare. The DA is the number of hours with sufficient levels of illuminance on a horizontal plane.

Both indicators need a precise description of the interior, which is still unknown in the mass plan. The use of procedural modeling [5] provides the benefit of easily modifying modeling parameters in order to explore with changing element sizes or shapes. This advantage improves simulation application where different elements should be explored in order to analyze the impact of a given configuration.

In the next section of this paper, we present the study case and two different simulation approaches. Then, we explore the impact of the sky vault partition and time step on daylight modeling, through both approaches. In the final section, we explore the impact of architectural details such as solar protections, walls covering or window positioning on daylight penetration and justify their consideration at early stages of an urban project.

TEST CASE

We use as a test case the exact 3D model of a side-lit office space used by [1] (cf. Figure 1).

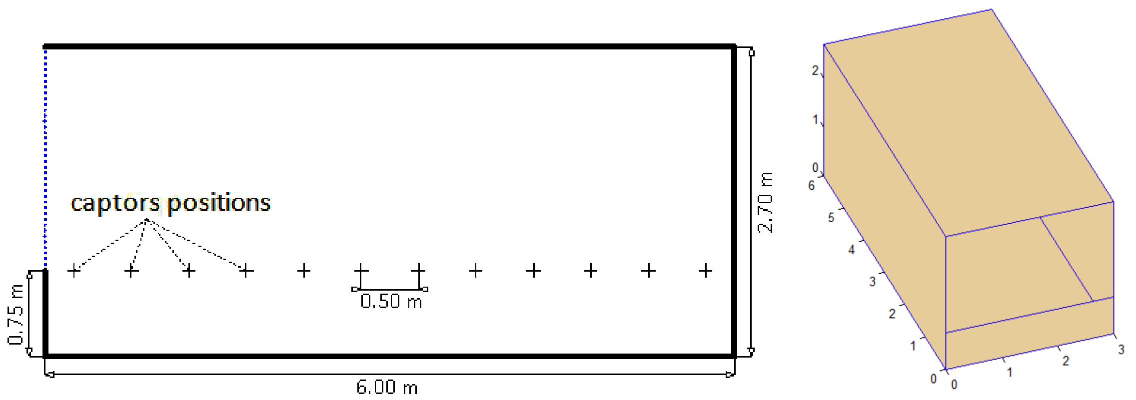

Figure 1 Office model

The same meteorological file is used with both simulation approaches for the city of London, Gatwick (latitude 51.15°) in [7]. We use the sky vault partition described in [8]. The luminance of each sky element is calculated using [9].

In a first approach, the Standard Radiosity (SR), the direct and diffuse illuminances are treated separately. Sun visibility is set for the exact position of the sun at a given time step. Sky tiles visibility is set for each calculation point though the tiles center: if the tile center is visible from one point then we consider that the entire tile is visible.

In a second approach, the incoming light that arrives to the interior spaces is treated with a pinhole model for each patch of the opening, for simplification purposes. In this work, we adapted the method presented in [10], originally intended for opening shape optimization, for daylight computation. The method is referred here as PBLI (Pinhole Based Lighting Incidence). In this case, the sky tile model includes the direct sun incidence. Another difference against the previous approach is that the visibility computed from the sky patches to all the mesh and sensors, considers the fraction of the tile that is visible.

SKYMESH AND TIME STEP

Using a sky partition of 145 elements and a time step of one hour, the SR approach shows significant differences with the reference simulation from [1] while the PBLI shows a strong correlation (cf. Figure 2). In Figure 2, we show the percent of a working year (all days from 9:00 to 18:00) with levels of illuminance inferior to the upper and lower limits of the UDI.

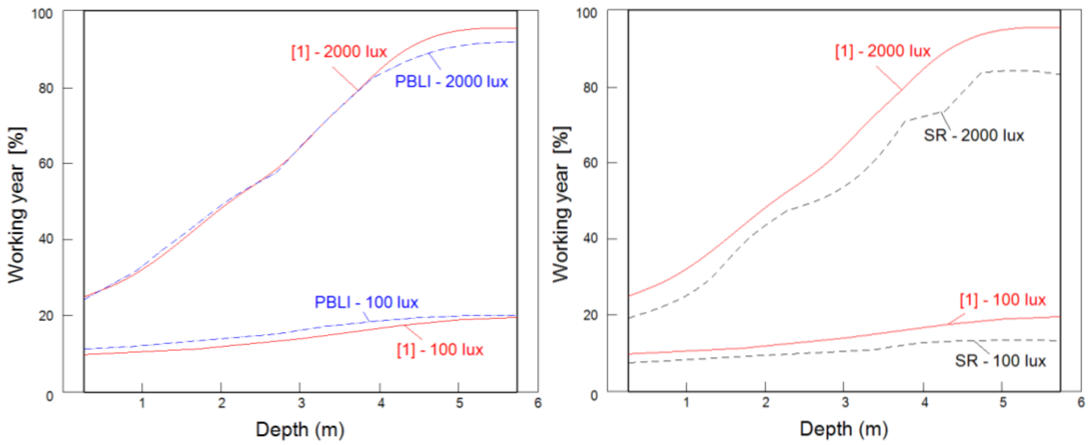

Figure 2 Distribution of Illuminance, comparison between the PBLI (left) and SR (right) methods with the reference simulation in [1]

The SR and PBLI approaches show differences both on the solar and sky direct component. The difference in the sky contribution is due to the assumption in SR that a tile is entirely visible if its center point is visible. In both [1] and the PBLI approaches, the sun luminance is distributed on the closest sky tile while in the SR approach we consider the exact position of the sun; which explains the differences in the sun contribution. As stated in [11], [1] uses a refined partition of the sky in 5010 tiles for the calculations of the direct component to minimize the angular displacement between the sun position and that of the sky tile.

The angular displacement between the sun and sky tile position is significant across a time step of one hour. To discuss its impact, we compute the number of hours with a direct illuminance exceeding 2000 lux using the SR approach. We first compare the values given by 145, 5000 and 20000 tiles with a reference simulation considering the exact position of the sun and a time step of 60 min. We then compare the values given by a time step of 60 and 15 min with the ones given by a time step of 5 min considering the exact position of the sun.

depth (m)	0,25	0,75	1,25	1,75	2,25	2,75	3,25	3,75	4,25	4,75	5,25	5,75
145 tiles	-1,6%	-1,1%	-2,0%	5,7%	13,0%	14,4%	-4,8%	16,1%	-5,0%	20,7%	-3,0%	-30,2%
5000 tiles	0,6%	0,2%	0,4%	0,4%	0,0%	0,4%	2,4%	1,3%	-2,5%	3,4%	-13,4%	3,8%
20000 tiles	0,1%	0,2%	0,7%	-1,0%	-0,6%	-0,4%	0,6%	0,0%	-2,5%	0,0%	3,0%	3,8%

Table 1 Sky vault partition impact on the solar direct contribution

depth (m)	0,25	0,75	1,25	1,75	2,25	2,75	3,25	3,75	4,25	4,75	5,25	5,75
60 / 5 min	-0,5%	1,5%	0,6%	-2,9%	1,8%	-1,9%	8,4%	-6,3%	-13,7%	-6,7%	-16,6%	-4,4%
15 / 5 min	-0,4%	0,0%	-0,3%	0,2%	-0,4%	-1,1%	-1,6%	-0,5%	-0,6%	-1,9%	-3,2%	0,7%

Table 2 Time step influence on the direct illuminance considering a 5000 tiles partition

A partition of 5000 elements appears as a good compromise regarding the precision of the results and the calculation cost, as stated in [8]. Meanwhile, although the meteorological data is set on an hourly basis, a time step higher than 15 min induces significant differences when studying the daylight conditions at the back of an interior.

In Figure 3, we compare the distribution of the illuminance using a sky partition of 5000 elements and a time step of 15 min with the SR and the PBLI approaches to the reference simulation in [1]. The results show insignificant differences and lead to the conclusion that, for this test case, a sky vault partition of 145 tiles and a time step of one hour are sufficient.

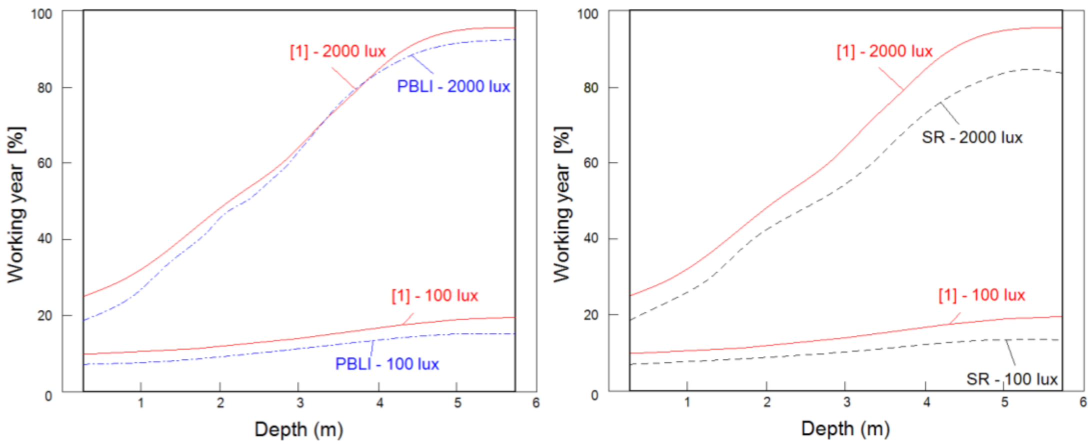

Figure 3 Comparison between the PBLI (left) and SR (right) methods with the reference simulation in [1], *using a sky partition of 5000 elements and a time step of 15 min*

ARCHITECTURAL DETAILS

Urban planners need to be able to estimate daylight penetration in the interiors when distributing the volumes of a project, in the mass plan. Daylight penetration can hardly be characterized by the incoming illuminances on the external walls of a building. In the mass plan, the glazing ratio is known for the diverse orientations and the partition index may be estimated regarding the use of the building, its target performance and the climatic zone of the project. Architectural details such as solar blinds, walls covering or window positioning come within the know-how of architects and are introduced in the block plan. In this part of the paper, we illustrate their impact on the daylight penetration and justify their consideration as soon as in the mass plan. We use the SR approach with a sky vault partition of 145 elements and a time step of one hour.

Solar blinds

Solar mobile protections are commonly used in building offices and both [2] and [1] have shown their impact on the daylight conditions in an interior. In this part of the paper, we illustrate this impact trough the following methodology. We use a “no blinds” scenario as a reference simulation to estimate the magnitude of uncertainty due to the user behavior. Such as in [2], we consider two types of user : “passive” and “active”. The passive user keeps the blinds always lowered. The active user lowers the blinds whenever the UDI upper limit is crossed on the point at 0.75 cm from the window. The blinds are modeled as filters that stop the solar direct contribution and reduces the sky direct component by 80%, as in [1]. In Figure 4, we compare the portion of the working year in which the lower limit of the UDI (100 lux) and DA (500 lux) are surpassed for the three scenarios.

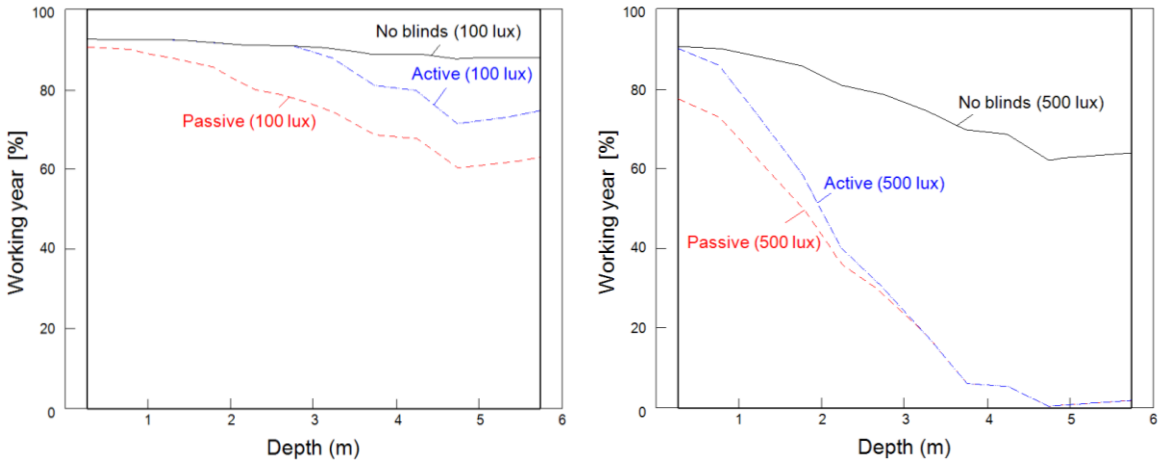

Figure 4 Solar blinds impact on the UDI (left) and DA (right)

Window positioning and wall covering

In a first example (Var1), we compute the daylight penetration in the office test case changing its window from horizontal to vertical, conserving its area. In a second example (Var2), we change the reflectivity of the ground from 0.2 to 0.5. We consider “active” solar blinds for both simulations. In Figure 5, we show the differences in the daylight penetration for both scenarios.

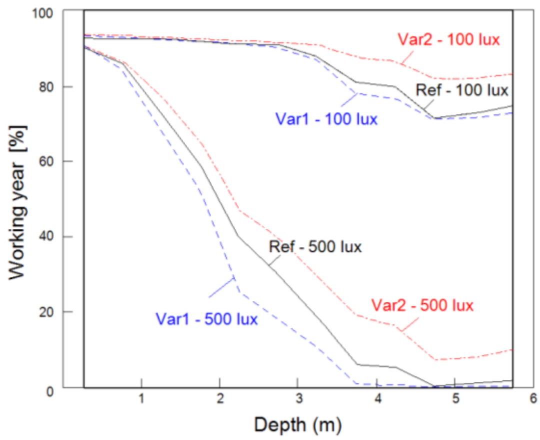

Figure 5 Window positioning (var1) and ground covering (var2) impact on the UDI and DA

CONCLUSION

In the first part of this paper, we study the impact of the time step and the sky vault partition on the UDI in order to define a criterion adapted to the points at the back of an interior, where the sky view is restrained. The results show that, although significant differences on the solar direct contribution are recorded, the impact on the UDI is negligible for this test case and a sky partition of 145 tiles appears sufficient for both the sun and sky direct contribution. The conclusion might have been different placing the office model in an urban context, were the sky view from a window is partially obstructed, and with a different orientation of the window.

In the second part, we show the strong impact of architectural details on daylight penetration and justify their consideration at early stages of an urban project. Urban planners have a good understanding of those parameters and should be able to easily explore their impact on a project as soon as in the mass plan. Perceptive thresholds and occupants behavior are the main factors impacting the criteria definition and so the final validation of a project. Urban planners can easily assimilate them and choose their optimal values according to the specificities of each singular project.

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