Parametric Lighting Studies

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ABSTRACT: The paper investigates various projects variables namely geometry, window size, quantity and distribution of artificial light. The ECOTECT software is the analytical tool, which permits space adequacy studies and optimization of the energy used on artificial lightings due to its parametrical capacity. This investigation is carried out in a 36m² office environment, where only one facade provides daylight. The obtained illumination qualities are results of varying the sizes of the void, room's width and length. As a starting point demanded by the NBR 5413[1] for workstations and circulations, lighting levels were calculated. These values allow energy consumption analysis in relation to daylight availability and energy demand by artificial lighting. A table shows the geometry consumption relation featuring evaluation levels to space related to geometry, activity and energy consumption. This table also established the necessary proportions limits of sufficiency and adequacy of daylighting levels. From this study, it is possible to evaluate the best relation between geometry, lighting and energy.

Keywords: energy, lighting, parametric studies

1. INTRODUCTION

The aim of this work is to investigate the energy consumption of office environments in contemporary buildings.

The ECOTECT software engenders analysis simulations and testes acoustic, lighting and thermal analyses of environment comfort evaluation. It allows various degrees of daylight simulations, which involves reparations of a 3-dimensional model room with respective window openings and skylights. This analysis also requests the CIE standard sky values indicating sunny or overcast, etc. to allow light calculations. [3]

The presented analyses are parametric studies referred to a constructed environment, which analyzed space geometry, natural lighting through a modified void size, artificial lighting localization.

The quality evaluations, of both natural and artificial lighting, were based on the maximum and minimum values established by the NBR 5413 [5]. These values were explored in order to limit the use of artificial lighting when natural light is available and to avoid the glare caused by oversized openings.

However, a logical consequence of added use of natural light will increase window surface. This will mean glare due to excessive lighting and increase in thermal load. The later will result in thermal discomfort or larger energy consumption by the air-conditioning system. [4]

The human eye adjusts more easily to natural light rather than artificial due to the facts that artificial light produces a different spectrum of colors that contrast the natural light. Moreover, artificial light does not vary during the day and reduces the object colors and contrast richness. [4]

Another focus point of this study is the call for air-conditioning system caused by significant increase in the lighting void. In most situations, it is easier to deal with temperature rise due to artificial lightings rather than to by solar radiation. According to Ghisi e Tinker [1], building energy consumption is significant often because of air-conditioning and artificial lighting. It is, therefore, essential to optimize the performance of these systems in order to achieve energy savings.

Accounting all observations mentioned, this paper concludes with a table that relates geometry to energy consumption, which shows the energy used in office buildings. Hence, a reference to reduce artificial lighting and save energy consumption for mechanic systems and cooling loads.

Conclusions also take into account circulations, activities, designs and furniture positions in the analyzed environment.

2. OBJECTIVE

The objective of this work is to evaluate the lighting needed in relation to activity and losses resulting from inappropriate geometry. The lighting levels evaluation was based on the values established by NBR 5413.

By establishing a table relating geometry and energy consumption, the objective is to evaluate spaces, which are classified as *appropriate*, especially when the natural lighting is sufficient; or *inappropriate*, when it consumes unnecessary energy during the day.

3. METHODOLOGY

The local sky luminosity and the project parameters - such as geometry and room size, kind of window glass, room colors and external surface reflectance - allow daylight quality calculations in order to verify the necessity of supplementary daylight, or to modify parameters according to required lighting level. This lighting level, regardless of natural or artificial lighting, depends on the type of tasks and the user's age. [4]

To develop these parametric analyses, we chose a 36.0m² offices area, from which width and length are varied in order to analyze the variation of lighting in respective varied environment.

The 2.70m ceiling height is constant; window void corresponds to variation in room width (a) and length (b). Other dimensions correspond to figure 1.

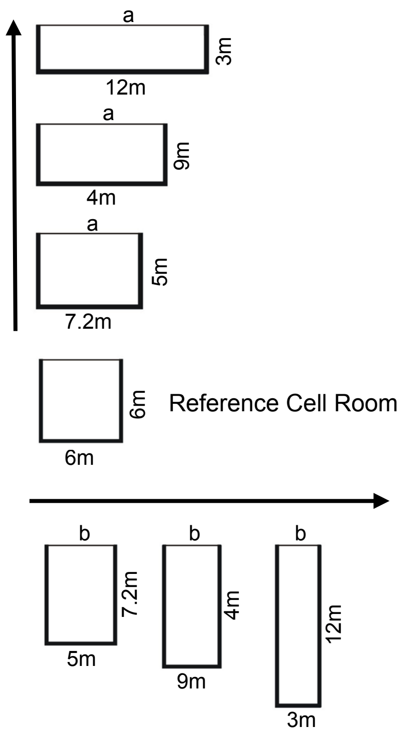


Figure1: Varied widths and lengths of the analyzed environments

A series of simulations was developed to access daylighting behavior and complement it with artificial light so as to obtain an evaluation in energy consumption.

In order to determine precise energy consumption related to the geometry, experiment was carried out in intermediate rooms with different dimensions (4.75x7.6m; 4.5x8.0m; 4.23x8.5m; 3.75x9.6m; 3.6x10.0m 3.27x11.0m), which allow observations the point where artificial lights were required.

These simulations enable a geometry vs consumption table to be established which classifies the environments as *appropriate* and *inappropriate*. (See section 4).

3.1. Parameters

The following factors were used for various simulations:

- working plane height 0.75m (according to NBR 5413);
- white internal walls;
- lighting void composed by simple glass with aluminum frame;
- brown wooden floor;
- white ceiling.

The calculations were based on the CIE data, with external 8500lux. The simulations were a north facing environment, located in Porto Alegre (latitude 30°S), at 12:00pm, June 21st. In Porto Alegre, there is sufficient lighting in summer; therefore, no added artificial lighting is necessary. The sky type used by the software is the CIE Overcast one.

The NBR 5413 suggests that 1/10 of the value adapted to the working plane should be used in all the remaining area of the environment. It also recommends that the luminosity at any point of the workstation should not be less than 70% of the average luminosity NBR 5382[2] recommendation [6].

In cases when the void size increases with width, depending on the environment characteristics, light may cause glare.

3.2. Simulations

Images of all cases presented were adjusted to be legible in grayscale. Figures 2, 3 and 4 present the 6.0x6.0m reference cell room and the extreme cases: 12.0m width and 3.0m length and 3.0 width and 12.0m length, respectively.

The contours used to perform all simulations were 250 and the scale varies from minimum 0 to maximum 4000lux. By using these values, images shown below can be compared by means of colors, where white represents 4000lux and black represents 0lux.

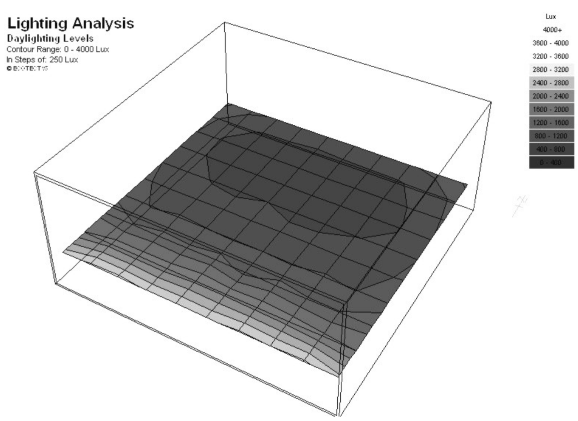


Figure 2: Reference cell room – 6.0x6.0m²

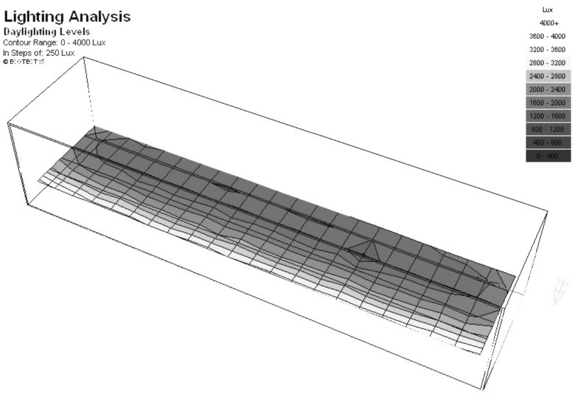


Figure 3: 12.0x3.0m²

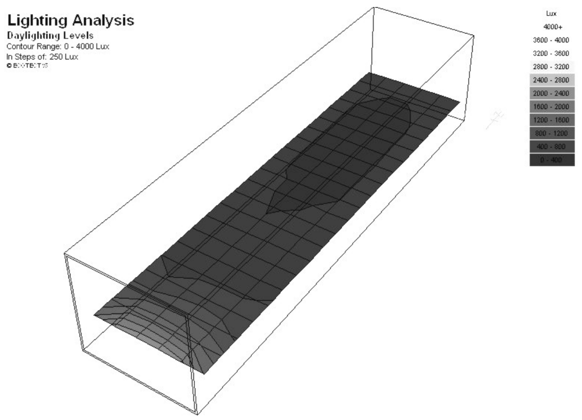


Figure 4: 3.0x12.0m²

4. RESULTS DISCUSSION

Table1 clearly shows that the reference cell room has the least illuminated point corresponding to 658lux. This observation demonstrates that by enlarging the daylighting void, the interior daylight availability increased; hence, when the room width increases, the day-lighting void increases. Experiment concludes that, when room's length decreased, the day-lighting availability increased.

These observations lead to other conclusions: room with 3.0m width and 12.0m length (figure 3), the lighting levels would be higher, varying from 3374lux in the most illuminated point to 1211lux in the least illuminated point.

Changing the size of the room to 4.0x9.0m, as shown in Table1, the minimum lighting point is 388lux. In the environments shown in Figure 1, this is the case where daylight system does not meet 500lux light level as required by NBR 5413 [5]. It would be, therefore, necessary to use artificial lighting in these rooms even during the day.

In the 5.0x7.0m room, 488lux was met. However this lighting level is not representative because it has just one point with less than the 500lux recommended illumination. So, rooms with geometry between 4.0x9.0m and 5.0x7.2m are critical because lighting levels can be lower than the NBR 5413 500lux requirement. Intermediate room geometry with dimensions as follow: 4.75x7.5m; 4.5x8.0m; 4.23x8.5m; 3.75x9.6m; 3.6x10.0m and 3.27x11.0m were tested.

Table1 shows maximum and minimum values encountered in the simulated rooms.

Dimensions (m)		Maximum (lux)	Minimum (lux)	Floor area with less than 500lux (%)
Width	Depth			
12.0	3.0	3374	1211	0
9.0	4.0	3179	978	0
7.2	5.0	2895	808	0
6.0	**6.0**	**2819**	**658**	**0**
5.0	7.2	2795	488	0
4.75*	7.6*	2681	461	12.41%
4.5*	8.0	2653	453	16.86%
4.23*	8.5*	2639	414	25.86%
4.0	9.0	2530	388	35.83%
3.75*	9.6*	2592	369	43.86%
3.6*	10.0*	2576	347	49.27%
3.27*	11.0*	2354	289	62.24%
3.0	12.0	2223	211	74.11%

* Intermediate rooms
The bold line – Reference cell room

Table 1 - Values encountered in the simulated rooms.

According to local regulations, the area with lower lighting levels than the recommended must not be bigger than 2/3 of the floor area (66,66%), which, in this case, corresponds to 24.00m². From this, it can be concluded that, among the analyzed rooms, just the 3.0m length and 12.0m width geometry is not appropriate.

Another important point to be observed is the uniformity of lighting distribution. A uniformly lit room allows more spatial possibilities to furniture distribution. Hence, the furniture distribution area is restricted when area sufficiently illuminated is small. According to Corbella [4], the daylight distribution in a room is directly correlated to the colors of the surfaces.

According to Hopkinson (1966), the conditions that create the glare sensation are also applicable to these study cases. The glaring grade increases in sunny days; however, when the surrounding elements are as bright help reduce the glaring grade. Porto Alegre has > 12000lux external luminosity, ideally, natural light system should be used to illuminate rooms, at the same time, using shading devices to protected from direct solar radiation.

4.1 Artificial light

A complementary study was carried out on artificial light using luminaries and lamps manufactured by a known Brazilian company. The aim is to characterize the possibilities of lighting system and the inserted photometric characteristics.

The luminary chosen is a Lumini[3], model FE-1560/232. It uses two 32W light bulbs and a starter to each lamp.

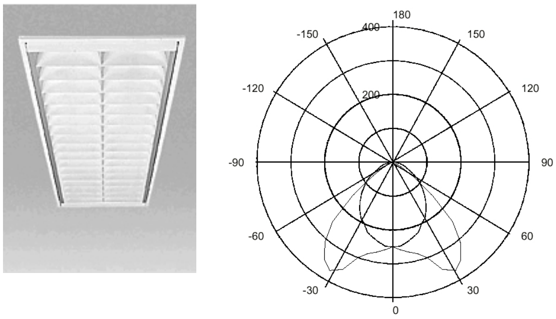
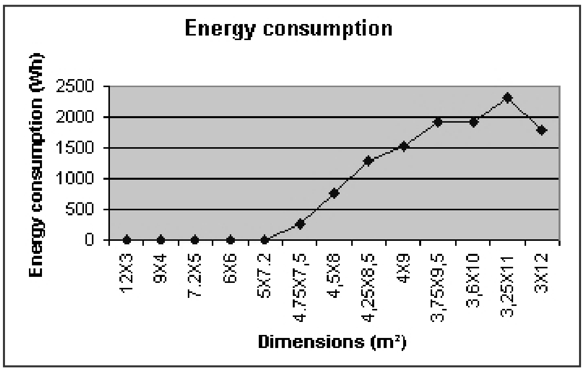


Figure 5 Artificial lighting system

Study shows complementary artificial light is needed during the day to achieve a uniformity of the established 500lux in the whole room. This includes the period without daylight. However, in some points, the luminosity exceeds the minimum recommended by NBR 5413 when all the lights turned on during the day. In order to control excess, it is possible to incorporate a command device that divides lights into groups within the luminary. As such, allow turning on the luminaries located in points where daylight does not reach 500lux standard.

Graph 1 shows the energy consumption of all analyzed geometries, taking into account the number of luminaries and the numbers must be turned on in each case during the day.

The consumption calculation refers to Figure 5 luminary example, which consumes 128W.



Graph 1 – Energy consumption

Graph 1 points out the room of 3.0mx12.0m width and length is considered geometrically less appropriate, which allows > 2/3 floor area luminosity less than the standard required. Nonetheless, the room of 3.27mx11.0m width and length has the least appropriate energy efficiency configuration than the former room. Even with increased length, the 3.0x12.0m room consumes less energy due to diminished room's width that facilitates the lighting uniformity just by using two luminary lines. The colors of room place an important part on the scale of reflection. In these experiments, walls and ceiling are white, but the brown floor could be replaced by other lighter colors.

Figures 6 and 7 show two cases described earlier. To perform these simulations, walls are white in order to achieve high reflection grade. Rooms were simulated to evaluate the minimum lighting level available according to exterior daylighting availability. This is to observe in cases a high glare grade; a diminishing interior control can create the contrasts. [2]

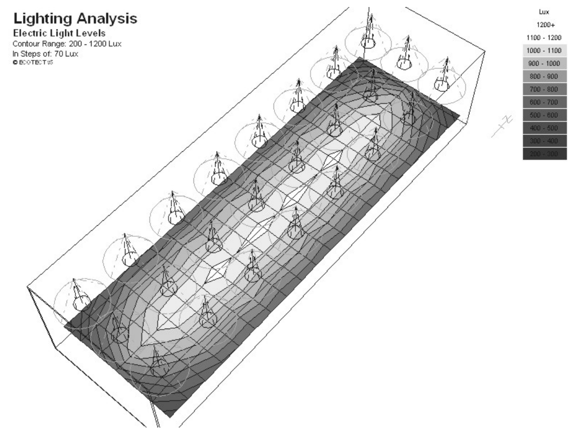


Figure6 – 3.27x11.0m² room artificial light distribution

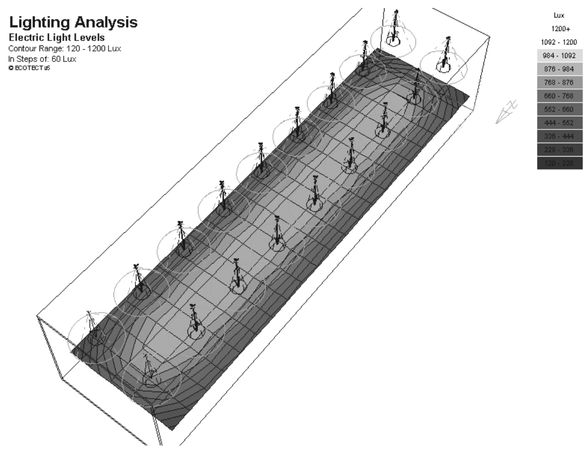


Figure7 – 3.0x12.0m² room artificial light distribution

The outline used to perform all simulations was 60 and the analysis scale varies from minimum 120lux to maximum 1200lux.

In 3.27x11.0m room (figure6) the minimum lighting level found was 523lux and the maximum was 1123lux; in the 3.0x12.0m room the minimum value reached was 516lux and the maximum was 916lux.

As described in figures 2, 3 and 4, the images were adjusted to be legible in grayscale.

Table 2 relates geometry to energy consumption. It identifies which geometries are energy efficient and those correspond to *appropriate* do not need artificial lighting during the day while those correspond to *inappropriate* do.

geometry (m)	width	length	appropriate	inappropriate
	12.0	3.0		
	9.0	4.0		
	7.2	5.0		
	6.0	6.0		
	5.0	7.2		
	4.75*	7.6*		
	4.5*	8.0		
	4.23*	8.5*		
	4.0	9.0		
	3.75*	9.6*		
	3.6*	10.0*		
	3.27*	11.0*		
	3.0	12.0		

Table 2 – Geometry assessment

5. CONCLUSION

This parametric study is still in the course of development. The parameters analyzed in this work are geometry, day-lighting void size, environment colors and energy.

Artificial lighting system (luminary + light bulb) was used in all cases for the energy consumption analyses. Noted that the artificial lighting system can vary according to the situation, which certainly would generate less energy consumption in some cases, e.g., in some cases, same number of luminaries were used, but, in others, two 16W bulbs were used instead of two 32W. In these cases the lighting levels is around 800lux divided into three luminary lines and in case two lines were used, 500lux NBR5413 standard cannot be achieved. The solution for this situation would be the use of these three lines but using the 16W lamps only.

The parameters used in these simulations can cause glare in rooms due to white walls with high reflection index. These data were taken to evaluate situations where daylight distribution is best in rooms due to reflections. On the contrary, rooms with darker walls need more light to achieve uniformity. Therefore, the day-lighting availability represents a minor value in required lighting level needed to perform the simulations.

A uniform lighting distribution provides possibilities of a plan layout. Lighter-colored spaces usually avoid residual areas.

Experiment studies carried out in Porto Alegre at latitude 30°S was due to its exterior lighting levels that can reach 30000lux, and in a clear day, > 100000lux. 1% exterior light admission in a building give lighting level of 300lux in overcast days and up to 1000lux in clear days [4], which is sufficient to any office activity. Though these levels are rarely accessible, there is no need big glass areas but in other less luminous regions as shown in figure3, where an interior lighting level is higher than 1000lux in all floor area.

Whereas, evenings, dawns, late afternoons and dense cloudy days, artificial lighting is necessary. Nevertheless, these projects basis should be complementary and not natural lighting substitution.

In conclusion, there are some basic rules of daylighting planning:

- The shapes of a room (not size/area) determine the utilization and mean daylight factors.
- Various smaller daylight openings are more favorable (especially with regard to uniformity) than one large opening.
- Similarly, it is more efficient to install a larger number of low intensity artificial light than one with high in capacity.

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1 NBR 5314 is a regulation that establishes minimum values for artificial interior lighting, where commercial, industrial, studies, sports and others activities are mentioned.

2 NBR 5382 is a regulation that establishes the way interior illuminance should be veryfied to rectangular areas.

3 Available on Lumini's website:
http://www.lumini.com.br/