

# Sustainable Recommendations for the Faculty of technology of the University of Brasilia – Brazil

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**ABSTRACT:** The present paper describes the beginning of a sustainable requalification program devised for some buildings of the University of Brasilia, located in the city of Brasilia (latitude 15° south). The requalification comprehends actions for implementing of old functions with reutilization of the existing building and landscape patrimony, a change in the patterns of consumption, an improvement in energy efficiency and a concern with the alternatives for optimum use of the spaces. In order to achieve environments that are both energetically efficient and adequate to the comfort of the users, the strategies were thought of considering Brazilian Bioclimatic zoning for the region of Brasilia.

Key-words: sustainable requalification, thermal and luminous comfort.

## 1. INTRODUCTION

The city of Brasilia is located at latitude 15°52' south with 1200m altitude and almost 1000 km distant from the sea.

It's climate can be classified as Tropical of Altitude where two very distinct seasons can be identified: hot and humid (October to April) and dry (May to September). Within the dry season a third period can be pointed out classified as hot and dry, which lasts from August to September.

The average air temperature is 21,6°C. The daily averages are relatively low varying between 14,6°C, in July, and 21,1°C in October, characterizing, thus, a predominance of mild temperatures.

The average relative humidity is 70%. The driest month is August, with 56%. The absolute minimum relative humidity registered is 8% in September.

The main wind is coming from the East during almost all year long with average speed between 2 and 3 m/s.

The solar radiation is of 2600 hours annually. During the summer (21/12 at 12am), the levels of illuminance in the horizontal plan are of 98.000 lux, while in Autumn (21/3 at 12am) they are 101.000lux, both with partially cloudy sky. In winter (21/06 at 12am) with clear sky, we have 96.000 lux.

Table 1 summarizes the bioclimatic analyses of Brasilia's climate and the indicated strategies. The hygro-thermal conditions remain within comfortable limits during 41% of the hours of the year. The percentage of discomfort caused by cold is higher than that caused by heat due to night conditions.

The main bioclimatic strategies indicated for the heat are ventilation, thermal mass and evaporative

cooling. The use of air conditioning is necessary only in 0,08% hours of the year. (Table 1)

**Table 1:** Recommended bioclimatic strategies

Comfort	Discomfort	BIOCLIMÁTIC STRATEGIES [%]	
		Strategy	Percentage
41,2 %	COLD 36,6 %	Thermal mass	31,3
		Solar passive heating	4,37
		Artificial heating	0,99
	HEAT 22,2 %	Ventilation	21,2
		Evaporative chillness	8,38
		Thermal mass	8,29
		Air conditioning	0,08
		OBS.: The percentage of discomfort by heat or by cold doesn't correspond a total of strategies, as the perceptual of these consider also overlaid zones.	

Source: Adapted from [1]

The building from the Faculty of Technology (FT) of the University of Brasilia, built in the seventies, is composed of three similar blocks situated in different levels and connected by covered pathways, which result in a set of pleasant spaces. (Fig. 1, 2)

Each block is composed of two stories. On the ground floor the administration, the teacher's rooms, the classrooms and the auditorium are located. On the top floor, which covers the ground floor only partially, are the remaining professor's rooms. The biggest part of the roof is plane, made of concrete slab covered with metal plate.

A program of sustainable requalification was proposed for this building. The concept of sustainable requalification is directly linked to the

recovery of degraded areas and damaged elements, and the improvement of the environment quality, creating, therefore, a renewed interest in the collective space and the use of open areas.



**Figure 1:** Faculty of Technology, University of Brasilia, aerial view



**Figure 2:** Faculty of Technology

It was proposed the beginning of a sustainable requalification program for the building. The concept of requalification is less linked to the idea of old loss of vitality and makes clearer the idea of increasing generated activities of economic profits, recovery of degraded areas and damaged elements, and improvement of environment quality. A new interest for a collective space of conviviality, use of open spaces, development and use of passive and eco-compatible technologies are required.

## 2. METHOD

The evaluation was developed, at first instance, through a sensorial analysis organized as a checklist, containing categories and subcategories of performance such as thermal, luminous and acoustic comfort. Later, the building's spatial attributes were related to the environmental performance conditions, to which adequateness values were credited.

Thus, indicators for the constructed environment were defined (directly related to the environmental performance results) according to its use, the needs, the local climatic conditions and the characteristics of the architectural project - given its great morphologic diversity.

In the study's final phase, the indicators were evaluated aiming the sustainability.

For the **Stage of Planning** four environments were selected. Two on the ground floor: classroom (east orientated, Fig. 3) and professor's room (west orientated, Fig. 4). And two on the top floor: professor's room (east orientated, Fig. 5) and professor's room (west orientated, Fig. 6).



**Figure 3:** Classroom located on the ground floor with openings directed towards east.



**Figure 4:** Professor's room on the ground floor – west orientated

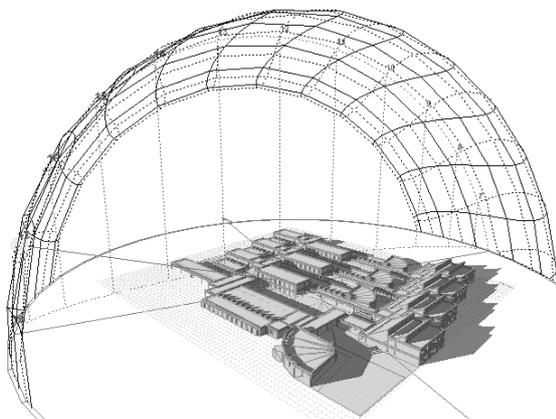


**Figure 5:** Professor's room on the top floor (east)



**Figure 6:** Professor's room top floor (west)

The selection aimed to embrace the main facades of the building. (Fig. 7)



**Figure 7:** The sun path during the year and the shadows on 23<sup>rd</sup> of September at 5 pm. (Ecotect)

In the **Stage of Verification**, the sensorial analysis with the above mentioned indicators and the analysis of the ventilation (according to prevailing winds) were included. Also, measurements and simulation of selected environments of the building were performed. The survey, the evaluation and the definition of indicators were developed by checklist of the covering materials (considering each selected space as a typical space of the building) and a sensorial appreciation of the thermal, acoustic and luminous comfort of the environment in question.

The checklist of *the Components and Materials of the Typical Spaces* [2] identifies the main external walls (and its orientation), types of covering, lining and floor, as well as the equipment and furniture found there, taking into account its characteristics according to surface material, window frames, doors, colors and types and size of the openings.

Simultaneously, a checklist called *Sensorial Analysis of the Environment Comfort* [2] was applied to the chosen spaces, divided according to the thermal, luminous and acoustic comfort with the corresponding index (from 1 and 5) to establish indicators of environmental performance.

Thermal comfort was analyzed using information about the temperature, the ventilation, the humidity, solar radiation and heat gains through walls, ceilings, equipment and occupation.

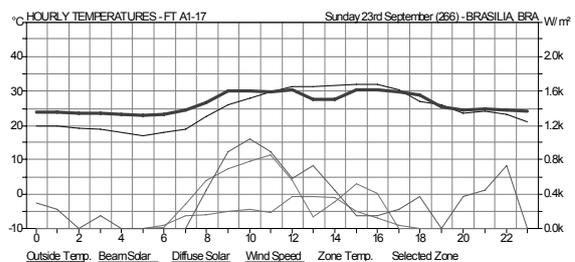
The luminous comfort was assessed according to the intensity and distribution of illuminance and luminance of natural light as well as the existence and quality of the external visibility.

The acoustic comfort was evaluated by the type and localization of the noise (external and internal) and the reverberation.

The measurements of thermal variables were performed with measures of temperature (external and internal), humidity, and superficial temperatures throughout two days (one with clear sky and other cloudy), at 9 am, 12 am, 2 pm and 5 pm.

The internal and external measurements of the natural illumination were performed simultaneously, always registering the conditions of the sky.

For the simulations two softwares were used: ECOTECT for analysis of thermal performance and RAYFRONT for analysis of the natural illumination (Fig. 8, 9).



**Figure 8:** Example of the simulations made with ECOTECT. Temperatures in the classroom on 23<sup>rd</sup> of September.



**Figure 9:** Example of the simulations with Rayfront. Natural illumination in the classroom.

The results of the simulations were the basis for corroborating the data obtained both in the Planning (solar incidence analysis) and Verification (sensorial evaluation and measurements) Stages.

In the final stage, called **Recommendations**, diagnosis and recommendations were elaborated to solve the environmental performance problems in a sustainable way.

The beginning of a requalification process points towards the aspects to be worked. Thus, the evaluation of environmental performance of the

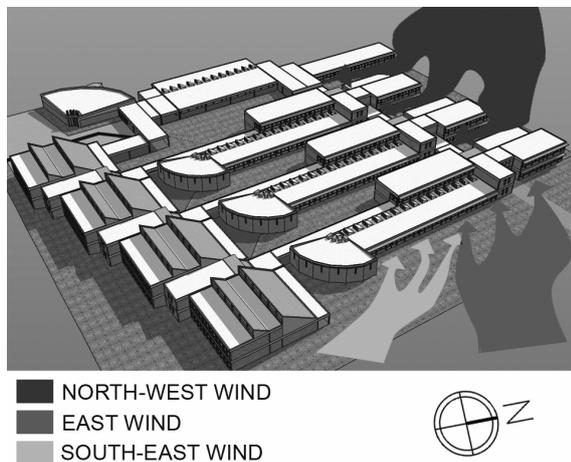
Faculty of Technology (by sampling) answers to the needs of initiating this process.

However, in order to elaborate the Architectonical Project, it's necessary to apply the method fully – to a significant number of environments, taking into account the technical aspects of the materials which compose the building, the sensorial appreciation and the measurements and simulations of the physical and environmental conditions of the building.

### 3. ANALYSIS OF THE RESULTS

#### 3.1 Ventilation performance

The predominant wind all year long is the East wind. In the dry period (winter), there is a secondary direction, although less frequent: the Southeast wind. In this period the predominant speed of the wind varies between 2 and 4 m/s. (Fig. 10)



**Figure 10:** The building and the prevailing winds

In the humid period (summer) the secondary winds are Northwest and the Northeast with speeds varying from 2 to 5 m/s. The absence of wind takes 33% of the year, which is more often in hot and humid months. During the analysis, three prevailing winds were considered: east, southeast and northwest. (Fig. 6)

##### 3.1.1 Classroom, ground floor, east (Fig. 3)

It receives the East and Southeast wind directly, and does not receive the Northwest wind. The crossed ventilation is possible through zenithal window. When the door is open, the East and Southeast wind cross the whole room. However, the windowpanes for ventilation are placed at 1,60m above the ground, so the sitting person does not feel so much the effects of the breeze.

##### 3.1.2 Professor's room, ground floor, west (Fig. 4)

This facade doesn't receive any of the analyzed wind directly because the building itself works as a barrier. The Northwest wind is canalized by the corridor formed by the outside walls of the building, making the direct entrance of air into internal spaces

all the more difficult. This is considered more serious due to the angle of the window, which is opposite to the direction of the wind.

##### 3.1.3 Professor's room, top floor, east (Fig.5)

It receives the East wind directly, but the crossed ventilation is only possible with the door open. However, the type of window with a fixed windowpane at the bottom and a ventilation flap at the top, hinders the incoming wind.

##### 3.1.4 Professor's room, top floor, west (Fig. 6)

The Southeast and the East winds come indirectly in this room when the door is open. If the door is closed, this room doesn't receive ventilation. The room's narrow window, partly with a fixed windowpane and partly with a ventilation flap, has an orientation which doesn't correspond to the direction of the prevailing winds, thus allowing only a modest air renovation.

The best orientation for the windows according to solar radiation, hardly ever coincides with the best orientation according to winds direction. In the case of Brasilia, the prevailing wind comes from the East, but placing the openings according to such orientation would strongly affect the thermal and luminous comfort.

#### 3.2. Natural illumination performance

The small distance between the neighboring blocks of the building project shadows in the rooms. West orientated rooms (Fig. 4 and 6) have tall and narrow windows with azimuth of 200° that prejudice even more the entrance of natural light.

The shape of the openings doesn't contribute to a uniform and efficient distribution of the natural light, once they are located only in one end of the room. This ends up bringing direct sunlight into the room, which dazzles people. In order to solve this situation, we propose extending the window (horizontally) to reach all the extension of the wall, and create the parapet higher than the work surface.

In the east side, the openings are larger (Fig 3 and 5), promoting high incidence of solar radiation in the morning, which provokes excessive and dazzle strong contrasts on the work surfaces.

In other periods the levels of illuminance are constant, however, with average values under the 300 lux, value established for the classrooms by the NBR 5413 [3].

The existence of a Zenithal opening (shed) in the classroom, at the top opposite to the side opening, don't not raise considerably the levels of illuminance throughout the period in which the measurements were made. Nevertheless, the measurements taken after 2pm showed the presence of some direct light coming through these openings, which can cause dazzling.

The east orientated openings receive all the solar radiation directly in the morning having high levels of illuminance, which ends up creating dazzling in some points. The situation is not worse because the worktables are located in the opposite side of this light.

With clear sky the improvement in the distribution

of illuminance throughout the room can be easily noticed, however the levels of homogeneity are low (specially deeper in the rooms).

The west orientated rooms (Fig. 4 and 6) present smaller levels of illuminance in the morning and the display of the side openings hinders a greater distribution of the lighting. Another factor that interferes negatively with the optimal natural light distribution in this room is the color of the surfaces and the furniture, which are mostly dark. Through the light level measurements it was possible to verify that the uniformity of light is extremely low, which makes artificial illumination necessary all day long.

### 3.3 Thermal performance

The sensorial analysis and measurements took place only in November. Therefore, computer simulations for the equinox and the solstice were made in order to verify thermal performance in other seasons. Thanks to the computer simulations it was possible to obtain thermal behavior diagnosis of the building during the entire year.

#### 3.3.1 Classroom, ground floor, east (Fig. 3)

The classroom has window with 60% WWR and the external horizontal shading device of 90 cm. The sensorial analysis detected the room had adequate temperature during the morning and low ventilation. In the afternoon there is more ventilation and humidity sensation.

The measures demonstrated that the internal temperatures are within the limits of thermal comfort in the early morning. In the afternoon, however, it reaches 30°C, which is still lower than the outside temperatures. The surface temperatures were within the limits of thermal comfort.

Simulations indicated that the shading device is not large enough, allowing heat gains related to the direct solar radiation of approximately 2.000 W/h between May and September (during 8 and 9 am). However, the highest thermal gains (reaching 18 Watts/m<sup>2</sup>) result from the room's occupancy (40 people + artificial illumination). The temperatures may increase 4,5°C due to such factors. Heat gains from conduction reach 1.200 W/h in the hot and sunny days.

#### 3.3.2 Professor's room, ground floor, west (Fig. 4)

This room has a high and narrow window with azimuth of 200°, which allows little or no direct solar radiation in the room. The sensorial analysis demonstrates that the room has a pleasant temperature during the morning.

The temperature levels remained within the limits of thermal comfort (18-29°C) during the morning and above this limit in the afternoon, but still lower than the outside temperatures. The surface temperatures (ceiling, floor and the walls) also remained within the limits.

The simulations demonstrate that temperature gains related to the conduction are low. According to the simulations, the temperatures inside the room would be within the limits all year long if it were not for the internal temperature gains of 44 Watts/m<sup>2</sup> (2 persons, 2 computers and artificial light) that elevate

the internal temperature in approximately 6°C.

#### 3.3.3 Professor's room, top floor, east (Fig.5)

This room has three surfaces exposed to solar radiation: two walls and the ceiling. The east orientated window occupies 65% of external wall. The horizontal shading device of 90 cm is inefficient, as the simulations demonstrated high thermal gains related to the direct solar radiation.

When the room is occupied, the internal heat gains reach up to 57 Watts/m<sup>2</sup>, elevating internal temperatures by 4°C. The gains related to the conduction of the opaque surfaces are relatively low.

#### 3.3.4 Professor's room, top floor, west (Fig. 6)

In the early morning, the thermal sensation is pleasant, but in the afternoon the room is too hot and badly ventilated.

The temperature measurements confirmed the sensorial analysis, detecting temperatures within the limits of thermal comfort in the morning but higher in the afternoon.

The simulations demonstrated that there is no direct sunlight in the room during the months of May, June, July and August. The main temperature gain is internal and reaches 55 Watts/m<sup>2</sup> when the room is fully occupied. The gains related to the conduction are relatively low, showing that external opaque surfaces have a reasonable thermal inertia. Internal temperatures exceed the limits of thermal comfort during the hottest and sunniest days.

The analysis demonstrated that the building has temperatures above the limits of thermal comfort, especially in the beginning of the afternoon. This is valid for both: the rooms facing east and the ones facing west. The main reason is the sum of heat gains coming from solar radiation, the equipments and human presence. The poor ventilation in the rooms also increases the sensation of discomfort.

## 4. RECOMMENDATIONS FOR SUSTAINABLE REQUALIFICATION

In order to achieve energetically efficient environments that are also adequate to the comfort of the users, a series of recommendations were elaborated based on the results of the sensorial analysis, the measurements and the computer simulations. The recommendations are in accord with the existing Brazilian regulations regarding thermal and luminous comfort. [3] [4]

The recommendations presented herein should be contemplated in specific studies that would result in executive and detailed projects. The recommendations comprehend promotion of thermal comfort, general efficiency, sustainability and acoustic comfort, and natural light optimization. Aid

### 4.1 Improvement of thermal comfort

The building possesses a relatively good thermal mass which improves its thermal performance. The horizontal shading device is insufficient, principally for the windows facing east. Most of the time, the

windowpanes do not allow the desired openings to provide ventilation. The internal loads are significant in most rooms.

Thus, it is recommended to change the opening systems of the windows, enlarge the shading devices and diminish the building's thermal load whenever possible (for instance, exchanging old lamps for new and more efficient ones). The installation of cooling devices based on evaporation and micro-sprinklers can also be recommended. In order to diminish the ceiling's thermal load we propose the installation of a low weight double-cover, overlaid on the original roof (Fig. 11).



**Figure 11:** Lightweight cover overlaid to original cover.

On some parts of the roof, the use of green roof can be recommended. The green roofs improve the micro-climate of the building and its surroundings due to the higher air humidity levels (created by the evapotranspiration of the plants) and significant thermal mass. During the rainy season, it also decreases the overload on the rainwater collective system for it holds a great amount of water that only reaches the drains once the critical stage has passed. It is also possible to stock the rainwater to reuse it on coolers and for flushing toilets.

One of the green roofs, which can be implemented on the existing concrete slabs of the building in question are the Ecotelhas (Ecotiles) made of lightweight concrete. In the specific case of FT, the rainwater collected by the green roof could be used for flushing and cooling. The cooling system would use sprinklers located next to windows and classroom corridors - approximately 3 meters high.

The cooling system by sprinklers is a technique that combines the evaporation of water with the space's natural or forced air renewal. The water is distributed at high pressures, and gets to the vaporizer peaks with outer wholes of 0.2mm. These transform the water into thin particles, which evaporate quickly without reaching the floor and getting it wet.

#### 4.2 Promotion of the efficiency and sustainability

The promotions of efficiency and sustainability would be achieved in various fronts:

- Water efficiency: collect and reuse rainwater
- Energy efficiency: diminish the artificial air conditioning and lighting and introduce a system of independent light controls and efficient lights;

- Accessibility improvement: use anti-sliding materials on ramps and stairs.
- Identity of campus: re-design the communication and visual identity, introducing light colors on surfaces and furniture and improving the common grounds and meeting places.

#### 4.3 Promotion of the acoustic comfort

The acoustic comfort can be promoted by using absorbing materials and acoustically adequate linings to inhibit long periods of reverberation, which make the understanding of the spoken word difficult.

#### 4.3 Optimal use of natural light

The optimal use of natural light can be achieved with elements to redirect the direct solar light and the efficient distribution of diffuse light. [5]

Another suggestion is the replacement of the ordinary glass present in the openings by more advanced systems in terms of technology. These systems could be fixed or mobile elements, and can provide the same solar protection normally achieved by using external shading devices, thus reducing the building's internal temperatures. Besides, such systems can reduce the occurrence of dazzling caused by direct light.

It's necessary, however, that the use of such systems be planned alongside with the artificial illumination to obtain a greater energetic economy.

Among these advanced systems we can name: light shelf, prismatic panels and laser cut panel.

For the specific case presented in the study, we recommend the use of light shelf because of its low initial investment and facility to implement.

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