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PROARQ 18

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Office lighting: presentation of lighting design for IBGE and discussion about the use of LEDs

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ABSTRACT

The article focuses on lighting in the corporate environment. Features lighting design for offices of IBGE, proposed on dissertation work by Moura (2008), which not used LED technology in artificial lighting. Discusses the LED on its positive and negative aspects, mentioned in the literature, and its use in lighting projects. Ponders about the shock between the use of conventional technologies and new technologies such as LED in artificial lighting in corporate environments and opts for the possibility of using both, substantiated on the lighting design of Corporate Intelligence Center (CIC) of IBGE, completed in 2010.

Keywords: Lighting in corporate environment. Lighting design of IBGE's office. Using LEDs. Combination of conventional technology and new lighting technologies.

Introduction

The headquarter offices of the Brazilian Institute of Geography and Statistics (IBGE) are located in Rio de Janeiro, in two adjacent buildings, the number 146 and 166 in the same street, in the neighborhood of Castelo in the city center.

These units were the subject of a case study developed by Moura (2008) in a dissertation paper on corporate architecture which focused on artificial lighting in offices and was presented to the Graduate Program in Architecture (PROARQ) from the Architecture and Planning College of the Universidade Federal do Rio de Janeiro, in 2008.

The main motivation for the study was the existence of a plan that had begun in 2006 for refurbishing the buildings, which despite encompassing steps to modify the windows, change the air conditioners, floors and the layout of offices, did not foresee any change with regards to the lighting.

The case study developed in the dissertation is briefly recapitulated in this article. Using a Post-Occupancy Evaluation (POE) as an architecture methodology capable of indicating how a building works and influencing the rules, standards and design decisions, we proposed a refurbishing of the lighting in the offices of the institution, based on a combined system of natural and artificial lighting, in order to improve the execution of tasks routinely developed there.

The proposed lighting project took into account specific technical and conceptual guidelines such as, functionality, energy efficiency, minimizing operating costs and environmental and visual comfort, combined with the notion of well-being in order to meet the physical and psychological needs of the people who perform their professional activities at the IBGE offices.

The project also adopted a mix of solutions in artificial lighting that combined the use of fluorescent and incandescent bulbs, without the use of LED devices - *Light Emitting Diode*.

A summary of the proposed project which has now been executed, intends, at first, to reinforce the importance of this type of research in architectural design - in that it provides, at the same time, data and information for future work in this specific segment as well as the fundamentals for the commencement of a cycle of studies and the implementation of new lighting projects in the IBGE institution.

Secondly, it discusses its validity today, against the increasingly frequent use of LED technology, which also refers to indications of total replacement of conventional bulbs.

The paper therefore presents the lighting project proposed for the offices of IBGE and reflects on the positive and negative aspects of LED technology through a literature perspective. It presents a point of view regarding the use

of traditional technologies and new technologies in lighting projects, consubstantiated on the lighting project implemented at the Centro de Inteligência Corporativa (Corporate Intelligence Center - CIC) of IBGE, which will be presented in sequence. The paper concludes with recommendations and a list of reference sources.

The research scenario

The IBGE buildings have an architectural design dating from the 1930s, featuring a common and distinctive style to most buildings located in the vicinity. They are public buildings that have not undergone any great change in recent years, only small and limited renovations, such as space adaptations and maintenance.

The building number 166 has construction details that favor the incidence of natural light and ventilation of the floors. The number 146, on the other hand, has narrow aisles and poor air circulation and natural lighting. This is the building on which the study focused.

More precisely, the model offices being analyzed are located on the eighth floor; the floor presents a standard distribution of rooms and fixtures similar to all floors in both buildings.

The offices have a traditional layout, functioning as closed work offices. The individual offices have either masonry walls or plywood partitions, moreover, places that have undergone adaptations are quite similar to *office landscape*'s typology.

The internal space distribution presents simultaneously traditional workspace's characteristics, which prioritizes hard cores and enclosed areas, as well as, paradoxically, the idea of *office landscapes*, which by using plywood partitions, allows for the standardization and individualization of workspaces. The elevator hall works as the main circulation area, and the internal circulation uses passages trough workspaces composed of two or three rooms. The plan below shows the workspaces [1].

PICTURE 1

Standard floor plant

Source: MOURA (2008, p. 110).

The tenth floor of the building number 166, where the Executive Board and Presidency of the Institute are located was also considered as a reference for the development of the study, not only because the lighting at that floor was poor and badly distributed but also due to the use of the fixtures not being the best.

Methodology and assessment tools used in the research

Among the types of research around the built environment[11], the methodology provided by the APO, Avaliação Pós-Ocupação (POE, Post-Occupation Evaluation) was chosen, an evaluation model of interactive performance, which detects pathologies and determines therapies throughout the course of the production process and the use of built environments. (ORNSTEIN et al, 1995).

Elali e Veloso (2004, p. 35) state that the POE differs from other methods of research on the built environment "due to its seeking practical and applicable results in pragmatic terms and pinpointing short, medium or long term changes".

The correct development of the POE requires detailed technical analysis procedures, with measurements, diagnostics and recommendations. It also requires sensibility to the space that is being assessed because it includes understanding its sociocultural context (whether through a historical perspective or through an analysis of the current situation as an essential factor for the evaluation of the current environment) as well as observing the cognitive aspects of the sub-

1. Elali and Veloso (2004) cite amount the assessment forms of the built environment, the Environmental Assessment (EA), the Environmental Impact Assessment (EIA) Environmental Impact Report (EIR); Social Environmental Assessment (SEA); Social Evaluation of Constructions (SEC); and Pre-Project Assessment (PPA).

jects inserted therein, subjects which cooperate to the knowledge of the space through the viewpoint of its occupants (hence the need for their participation), especially in areas or buildings that have been used for some time, and that are or will be subjected to renovation and refurbishing, as was the case of the IBGE buildings (CHIMENTI, RHEINGANTZ e BARONCINI, 2000).

With this perspective, two operational instruments recognized by the POE methodology were used in the study: *Walkthrough* Analysis and Behavioral Assessment which was done through a structured questionnaire given to twenty employees from the floor that was being studied. The questionnaire was composed of eighteen multiple-choice questions guided by the variables "lighting or no lighting for reading and writing activities" and "glare or no-glare when working with the computer."

The *Walkthrough* Analysis (or Preliminary Analysis) is the recognition of the built environment and the descriptive identification of its problems and positive aspects, observing physical and functional characteristics and the activities of its users (CASTRO, 2004). The questionnaire, on the other hand, is one of the techniques for data collection. When composed of well-written questions and closely connected to the formulation of the research problem, it is a procedure considered capable of generating the data needed to achieve specific proposed objectives (GIL, 2008).

A mapping of the luminance in the offices was also done in order to verify the suitability of the type of artificial lighting used in the different environments. Lighting levels were analyzed according to the NBR 5413/92 which lays down recommended values for indoor lighting (ABNT NBR 5413, 1992).

Main results obtained with the methodology used

The rooms on the eighth floor of the building number 146 are generally 25m^2 size in average. They present common project's details. The spaces have wood-color laminated flooring or beige 30mmX30mm vinyl flooring. The walls are beige and the ceilings are painted white. It is common to find plywood partitions working as walls, commonly colored in icy white or dark wood paneling. The workstations have an 'L' format, usually with no dividing elements between the tables.

The protective films of the windows were removed during the renovations that had been started in 2006, period when the model of the windows was changed (from window sash to jalousie ones) and new standardized blinds were placed in all the rooms.

Artificial lighting Inside most rooms, is provided with Recessed & Ceiling Mount Indirect Fluorescent lighting Fixtures, that uses 20W to 40W, varying the number of lamps. Nevertheless, different models were found in some rooms. It was noted that the model of the lamps used were old and outdated and that their layout did not follow any standard pattern, possibly due to the constant changes made to the layout of these spaces.

Other important points that were noted were: the poor condition of the lampss, the fact that many of the bulbs are at the end of their useful life (which resulted in the replacement not always obeying the same color scheme) and the lamps used are not always energy or light efficient.

The images below [2] provide an overview of these findings.

PICTURE 2
Artificial lighting used in most of the IBGE rooms

Source: MOURA (2008, p. 117, 118, 123).

During the first part of the *Walkthrough* Analysis, it became evident that the type of lighting used in the floor that was being studied (certainly the same type used in all of the floors in the two buildings) is poor and does not fit the setting of the offices, nor the visual needs of the employees of the institution.

The second part of the *Walkthrough* methodology consisted in the measurement of the light in the workstations with the use of a digital lux meter, taking into account the value determined by NBR 5413 of 500 lux for office lighting, in order to know if the standards determined by this regulatory norm were being met. It was discovered, during this measurement, that the distribution of the lamps was uneven. The measurements taken were either much lower or much higher than those suggested by the NBR 5413, which represented a lack of lighting balance in the work area.

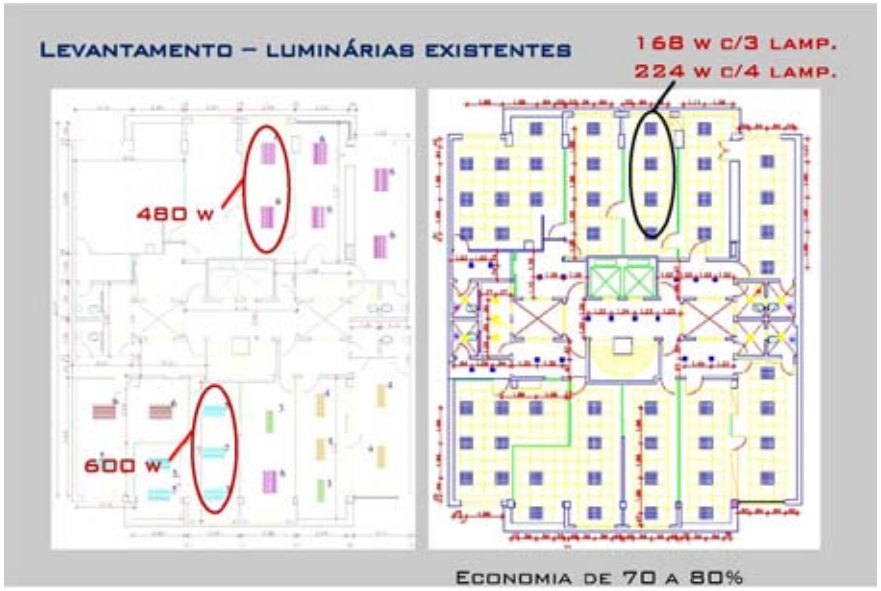
One can obtain optimal performance by correctly positioning the lamps, over the space that the illuminance is intended to reach by replacing the existing lamp for a more efficient one, as suggested in the project proposal, with great savings in power, measured in Watts, as demonstrated by the picture [3] below.

PICTURE 3

Artificial lighting used in most of the IBGE offices.

Picture subtitles: (in blue: MAPPING – LAMPS CURRENTLY USED / in black: 70% to 80% Economy)

Source: IBGE (2010).



Regarding the results of the questionnaires, we highlight the following: (i) the age range of the majority of the employees varied between 40 and 55, which highlights a greater need for lighting on the work surface, (ii) the users did not have a clear knowledge about the average level of illumination required for the performance of their tasks, with a predominant need among them for comfort in their own workstations, (iii) according to 81% of the participants, the bulbs should remain lit at all times in the workplace, despite the incidence of natural light, (iv) 63% of the participants said that the general lighting at their desks was not enough; (v) in the case of computer use, 75% of the participants confirmed that the lamps currently used caused glare.

These results reinforced the need for a lighting design that could solve or at least mitigate the deficiencies found in the offices of the institution

The proposed project and considerations on office lighting projects

The main objective of the proposed project was to suggest an artificial lighting system that combined energy efficiency with visual comfort, using lamps that are more efficient and present an even ceiling's reflection and lighting distribution. Therefore representing the opposite of the current situation, in which there is no norm or project that justifies their actual location. The project also sought an efficient lighting system that would be easy to maintain and that would have an initial moderate cost, due to this being a public institution which is not always able to carry out sophisticated projects with the available budget.

The main problem found was concerning different ceiling heights. It forced the project to provide consistency to the ceiling lining lighting. The initial step was to develop the ceiling layout that would allow future adjustments and divisions in the rooms. Therefore, a specific lighting fixture was chosen to allow future adaptations to the 60x60cm acoustic plate layout.

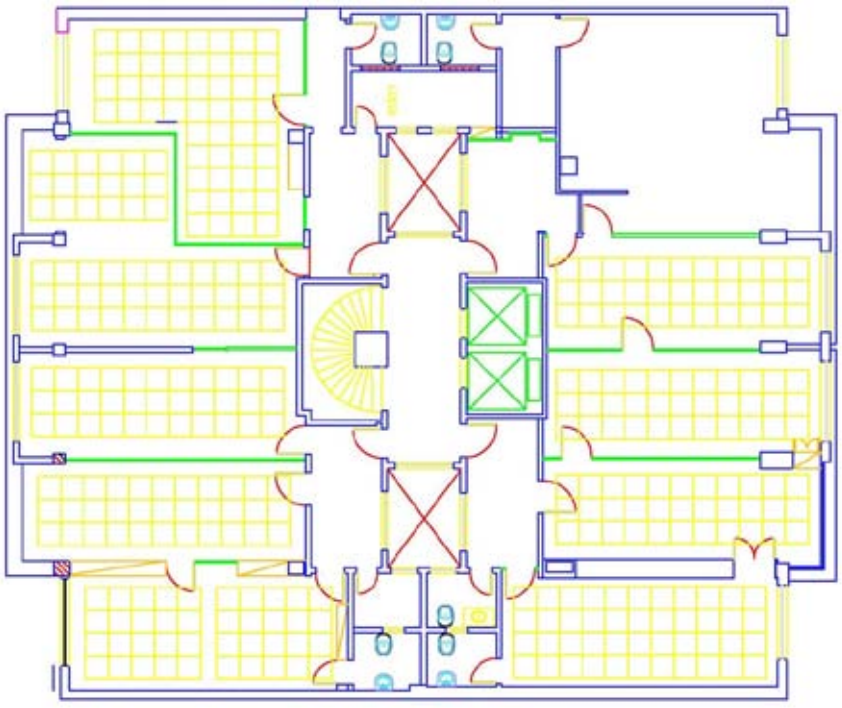
The solution was designing a ceiling array containing the acoustic plates creating drawings related to the original room sizes. The room perimeter was fulfilled with plaster ceiling lining around the room's edges, allowing for future plywood wall partitions removal without interfering with ceilings' pagination of lamps, or even worse, the subsequent redistribution of the new room's layout. This can be seen in Picture [4] below, which illustrates the ceiling layout.

Ceilings layouts were the base to define lamps position and fixture concerning their placement on the modulation design adopted as well as the aesthetics

PICTURE 4

Floor plan of the ceiling layout

Source: MOURA (2008, p. 137).



aspects. The calculation used to determine the amount of lamps needed to meet the 500 lux standard for the work surface was officially set and done with the use of General Electric (GE) Aladan software which assists lighting technique calculations.

The lamps chosen for the workspaces were T5 - 14W, with working temperature of 3000K. This lamp corresponds to FE 1779/414 built-in model, from Lumini, but it showed higher efficiency. Its technical characteristics are: high efficiency

with 03 or 04 lamps of 14W, inside a steel body treated and painted in white using electrostatic process, parabolic reflector and fins in anodized aluminum, with high gloss, built-in reactor in the upper part of the lamp and attached to the ceiling using tie rods.

In the halls, the model chosen followed the modern lighting concept, whereby it is possible to have light, feel the light, but not see the light source (a lamp is built in as a light box embedded in the room elements). The lamp chosen was the 'no *frame* 226', which is frameless, built-in the plaster lining. The layout is extremely clean since it uses screws to provide fixture. The internal bulb selected was Dulux / D 26W/827, Osram - 2x26W.

For the bathrooms and kitchens, the option was for a simpler model, with matte diffusers. The model selected was E4433/226 with two compact florescent lamps. It uses a steel body treated and painted in white using an electrostatic process, a translucent acrylic display, built-in reactor in the upper part of the lamp and the attached to the ceiling uses stainless steel springs. The bulb used inside this lamp was Dulux / D 26W/827, Osram - 2x26W.

The project proposed an efficient functional lighting for the administrative sectors, with some differences for the areas of the presidency, the board and the meeting rooms. In order to achieve this goal, we used a variety of elements such as special light fixtures and quad-parabolic models for T5 bulbs. The proposal not only aimed at functional and differential lighting, but also at efficiency, low thermal load and visual impact

In the operational areas, the lamps proposed were the double-parabolic type, with T5, with low thermal loads. In the wider spaces, the models chosen were square, with a bulbs capacity of four 14 watts using 3000 kelvin (K).

In the hallways, the focus was on diffused light; for the waiting areas dim lighting with a concentration of light on the performance of functions, eliminating possible decorative sources and spotlights, prioritizing visual comfort.

On the floor of the Presidency, the same type of lighting used in the workrooms was proposed, but with the difference of using lighting to highlight some walls. In the room of the President of the institute, the emphasis was on the main back wall. In the assistant's room, the spotlight was on both walls (one on each side of the entrance to each room), and in the lobby and waiting room, the same *'no frame' model* used in all the other passageways. But since this was an important room, which served as the access to the Presidency and where the main IBGE auditorium is located, special sized light boxes with 28W bulbs with a color temperature of 3000K were selected.

Every lighting project must meet objective aspects, such as the amount of lighting, the cost for the installation of the equipment, easy maintenance, replacement of the equipment, as well as the working life of the lamps, energy consumption and equipment safety. On the other hand, it must take into ac-

count subjective factors such as the sensations and emotions caused by the ambient lighting which provide qualitative expectations in people in relation to their workplace.

There is no standard format to be chosen in a lighting project to achieve these ends. There are resources - equipment, fixtures and lamps - from different manufacturers, which must be analyzed, based on their features and performance and integrated into each environment in order to meet the needs of its users.

With this in mind, it was proposed, according to the criteria and parameters recommended by the technical norms, different solutions using fluorescent tube lamps (14W, 16W, 28W and 32W) and compact fluorescent bulb lamps (26W) and, also, mixed equipment operating with fluorescent and incandescent bulbs, combining general lighting with direct lighting on the workstations, which solved several problems that were appraised with the use of the POE methodology instruments, and the measurements taken.

The use of LED

New technologies are being employed in order to obtain satisfactory levels of artificial lighting. The LED - *Light Emitting Diode* - is one of them. Emerging in the 1960s, it had major repercussions 30 years later, including in Brazil, where, since the 90s, depending on the evolution of the research, it was able to be applied in various situations.

In Brazil, the Latin American country most receptive to new technologies, the solutions offered by the use of LEDs are being widely adopted, mainly in projects done by professional architects and *lighting designers*. It is estimated that the LED market in the country is currently in the order of 250 000 units / year and there will be a 100% growth by the end of 2012 (FREITAS, 2011).

The light-emitting diodes (LEDs in English) are electronic components (chips) based on solid-state semiconductor materials that, when energized, emit visible light. The emission occurs by quantum effect (LIMA et al, 2009).

By introducing new paradigms and lighting possibilities, LEDs represent a break with the traditional artificial lighting and are seen as harbingers of a new era in the lighting design (which includes light sources, lamps and controls), thanks to the many benefits and advantages offered when compared to traditional lighting sources (GOIS, 2008).

It is said, that in the near future, the lighting market will see the complete replacement of conventional technologies for LEDs. Market studies indicate that the penetration of LEDs in the world market currently hovers around 15%, and that it will reach 50% by 2015 (FREITAS, 2010; FREITAS, 2011). This is due to the tendency for LEDs, which are evolving in luminous efficiency, to outrival

these technologies, such as fluorescent tubes, which are still widely used in corporate spaces.

The literature highlights the benefits and advantages of the LED. Among which:

- Innovative Technology;
- Varied application and flexible use due to reduced shape and size;
- Instant Activation;
- Durability and long working life, enabling lower replacement costs;
- Quality color and white light tonal versatility;
- High luminous efficiency, since they are specific light sources, with smaller loss than traditional bulbs. It is even said that an LED lamp can surpass the efficiency of an incandescent bulb up to about 40W;
- Variety and color control;
- Color temperature variation;
- Low heat dissipation;
- Increased robustness and better performance in relation to conventional lighting (BRAGA, 2008; LIMA et al, 2009; FREITAS, 2010; FREITAS, 2011).

As for environmental sustainability (which is now a requirement to be considered in all phases of the built environment, from idealization, concept, design, construction, use and maintenance to the end of the useful life of the building), the LEDs are compatible with this concept because they do not emit toxic substances to the environment, they are energy-efficient and provide low power consumption, saving up to 80% when compared to other technologies (MOTTA e AGUILAR, 2009; BRAGA, 2008; LIMA et al, 2009; FREITAS, 2010; FREITAS, 2011).

The cost factor, still high when it comes to the purchase and implementation of the LED technology, which in principle could restrict its adoption, is not seen as a problem, because the benefits of the LED, particularly the high performance and long working life, would create a compensation mechanism.

As far as prices go, they are decreasing, even though the LEDs are still undergoing development and improvement which so far, does not allow for large scale production. In the United States, in 2004, the kilo-lumen of the white LEDs cost around $ 250 and in 2006 it was down to $ 50 (FREITAS, 2010; MENEZES, 2011; FREITAS, 2011; E-CONSERVATION, 2006).

In other words, the LEDs would meet all the requirements needed to replace traditional light bulbs in all types of environments. However, in contrast to the benefits and advantages mentioned, the literature also notes the negative aspects of the LED technology.

The quality of the light emitted by the LEDs is questioned because it tends to be diffuse and does not provide focused lighting, which results in the loss of luminous flux. Góis (2008) notes that, currently, good quality LEDs have a specification from 20,000 to 50,000 hours with lumen loss of 30%, the same parameter used by manufacturers of traditional light bulbs in the definition of working life.

Braga (2008) states that, in setups that require constant illumination (which is the case of workplaces); the LED brightness degrades over time, reducing its useful working life by half. It is also said that the characteristics of the LEDs (both in terms of brightness over time as well as regarding temperature variations) are not so great as to assure us that they may be used without complications in any setup.

Indeed, Gois (2008) states that the LED chip produces heat and, according to Freitas (2011), steady electric current consumption, one of the main LEDs characteristics, generates a lot of heat making thermal dissipation a technical barrier to its improvement. This aspect influences its durability, which is only possible through the use of heat sinks, mostly in aluminum, considered a good thermal conductor, which causes the robustness of the product and its cost to be higher than of glass, for example.

According to *lighting designer* Umberto Boggian (cited by FREITAS, 2011), with a sink that is a bit smaller than recommended, the LED life can be affected, causing it to not last as long as in ideal conditions of application, where the dissipation system is correctly applied to the product.

Speaking of the application, by producing vibrant colors in differentiated aspects, LEDs have been mostly used in stage or observation lighting, drawing special attention in outdoor and urban equipment. (GOIS, 2008).

Another point raised in the literature concerns the fact that, on one side, alone and individually, the LED offers low power consumption, presenting efficiency from the energy point of view; on the other, with lamps where there are several of these components; energy efficiency is reduced, just as it occurs with other traditional lighting sources. (GOIS, 2008).

Thus, despite benefits and advantages, there are factors that objectively limit the widespread and indiscriminate adoption of LEDs in lighting technique projects. As stated by Freitas (2011, p. 49-50):

> ***The LED benefits are undeniable; however, LED isn't always the best choice as a light source, and, in many cases, despite its application, the environment may also require another more traditional light source. Factors such as luminous flux, CRI [Color Rendering Index], thermal and color temperature, among others, should be considered when deciding on the application of LED lighting, because a project cannot and should not be guided exclusively by the appeal of energy savings.***

It is also evident that the application of LEDs is often incorrect because many professionals still have not assimilated all of the information and technical expertise needed in order to use it (FREITAS, 2011).

Therefore, one must ponder the exclusive use of LEDs and the possibility of using them consistently and properly, especially in offices and corporate environments, where there are specific lighting requirements, particularly because this technology is ideal for highlighting details or creating lighting effects.

These ideas were gathered in the lighting project for the IBGE Corporate Intelligence Center (CIC), presented below.

The lighting project for the IBGE CIC

In 2009 the *retrofit* project in the 10th floor of the building number 126 in Franklin Roosevelt Avenue, in the center of Rio de Janeiro began. The building was ceded to the IBGE by the former SUDAM (Superintendence for the Development of the Amazon) for the implementation of an excellence development center by the Executive Board of the Institute. The space, which corresponds to approximately 350m^2, was designed to be flexible in the inner areas, allowing different compositions and allowing for different arrangements to be implemented in seven planned rooms, according to the needs for training, meetings, seminars and video conferences proposed for all the IBGE units in Brazil. Simultaneously, a lighting design for the space was developed.

The lighting proposal basically followed the one idealized for the IBGE offices in Moura's (2008)work, which was implemented in specific sectors that needed renovation and emergency adaptation, such as the Computer Management offices, the Office of the President and the Executive Board. These sectors needed a layout change in order to better accommodate the work that would be developed there.

The lighting project for the CIC followed the same concept adopted for the ceiling array layout, allowing flexibility in the rooms and a more appropriate format for their use, since the occupation of spaces was designed to be used in different types of arrangements with retractable partitions type. It took into account energy efficiency, and environmental and visual comfort in the ambiences. The calculation followed the standards established by NBR 5413 of 500lux luminance on the work surface.

In the circulation Lumincenter supplier lamps were used. They are similar to those specified in the IBGE lighting project. The model selected was Lumini E4433/226, built-in lighting fixtures with a frosted glass diffuser frame 228, from Lumini, with T5 2x28W bulbs and color temperature of 3000K to make the places' sense warmer

PICTURE 5

CIC lighting technique Project.

Source: IBGE (2010).

The CIC was inaugurated in October 2010. The lighting of the space was guided by the use of LED technology in combination with traditional technologies. LEDs were used for spot lighting in the reception (in combination with conventional bulbs), in order to save energy due to the greater number of lamps that remained on, in addition to natural light, which is intense throughout the day. The space of the cyber café received the same lighting design.

The lighting chosen for those ambiences enables lamps with LED bulbs to stay on almost full time during the time the spaces are being used because they have proven to have a durable working life and allow the 'ON and OFF' movement without suffering great impact.

Another solution was to use ceiling's indirect *tears* employing T5 bulbs, 28W (3000 K), used together with the solution adopted at the reception to bring indirect light which substitute the natural light on cloudy days or at nighttime lighting.

These solutions can be seen in the set of pictures below [5], illustrating how the rooms, cyber cafe and reception of CIC look with LED lighting placed in specific corners.

Final Considerations

This article was about corporate lighting, more specifically lighting in offices, showing that lighting in these spaces has significance, given the need for efficient and constant lighting for the optimal performance of professional tasks.

Briefly presented was the lighting project proposed in 2008 for the IBGE offices in Rio de Janeiro which did not use LED technology exclusively, opting for solutions that combined natural light and artificial lighting with the use of incandescent and fluorescent lamps.

Due to the recognized increase in the use of LEDs in lighting technique projects, the technology was presented, contrasting its benefits and advantages with its negative aspects, both of which are mentioned in the literature.

It should be considered that the exclusive adoption of LEDs may entail unique problems and may not always result in the best technical option in certain

situations, such as the work environments in office buildings, in which more efficient lighting systems, both from the energy as well as visual comfort viewpoint, could strategically combine the use of LED technology with conventional technology, because the former does not override the latter. This approach was applied in the lighting project for the IBGE CIC, presented here, which combined, in the artificial lighting system, conventional lighting technique resources with more recent ones.

On the other hand, however, one cannot disregard the impressive progress that LED technology has achieved since then, mainly thanks to large investments made by companies from this area on new research. This advance could mean the possibility of the exclusive use of LEDs in all environments and situations, as the prediction from experts who advocate the undisputed LED technology leadership.

This work aims at adding state-of-the-art knowledge to the field of study relating to lighting in corporate environments. It is expected that the contents worked and analyzed here will contribute to the development of new research in this area, an area considered lacking in research.

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