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Characterization of library lighting design: A study of dynamic and static space

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ABSTRACT: *The use of space is a fundamental variable in the creative process, so it is included in the lighting design. This paper presents a key to characterize the lighting space, to be used in the initial stages of architectural design. It aims to highlight the role of quantitative and qualitative lighting values of space. To carry on this study, two very different libraries have been analysed in Barcelona. The first case study corresponds to a university library whose function is reading and mainly individual study. The second case study, the community library, has a more participatory character with society, i.e. it includes reading spaces, meeting spaces, learning spaces for children and a conference hall. This research compares two library lighting design in terms of spatial configuration. Analysing false colour images reveals that there are different lighting intentions. The first case study shows that the difference between the luminance of the work area and the general environment is ten times greater. The second case study shows that the luminance in the work area is ten times less than the background. Therefore, it is suggested that the lighting design of those two libraries corresponds to the static and dynamic use of space.*

KEYWORDS: *Lighting design, library lighting, luminance value, false-colour image.*

1. INTRODUCTION

Today, libraries have transformed the use of studying space [1,2,3,4,5]. In the past, the architectural typology was configured to keep the knowledge acquired by civilizations. Subsequently, the function of the library included elite education, among which were religious groups. Monasteries, in particular, were characterized by introspection and self-learning. Throughout history, studies have been developed to analyse the impact of lighting in reading activities. Among them, the research of Arnau, Muñoz, and Gibson stand out due to the depth of their conclusions and the relevance to the subject of this study.

According to Arnau [6], colour and light play a primary role in the creation of space for worship. The binomial, subject-object, sustains its relationship in the inhabited space. Muñoz [7] shares Arnau's point of view, the sacredness of religious spaces is associated with libraries through light and silence. The user of libraries has multiple lighting needs. Lighting to focus on the main activity and environmental lighting to visualize the space limits [8]. Directional lighting tends to exclude distractions from reading. Meanwhile, diffuse lighting leans towards including another type of activities such as spatial orientation, social interaction and more. Artificial directional lighting enables concentration in user activity so long as there is light directed to work plane and there is less light reflected

in other surfaces. Natural diffuse lighting allows different activities at the same time in the libraries.

Thus, the primary activity in the old libraries was concentrated solely on reading; while, at present, the flexibility in the use of this type of space allows greater participation of society with culture. Finally, regarding visual perception, Gibson [9] clarifies the difference between the visual field (static use of space) and the visual world (dynamic use of space). Despite the differences in approach, the authors reach similar conclusions regarding the undeniable role of lighting in the construction of spaces dedicated to learning activities. Libraries spaces are therefore fundamentally concerned with the creation of an environment between the subject, the activity, and the light.

2. METHODOLOGY

The libraries chosen are typologically different, both stand out for their light qualities in terms of visual comfort [10]. It seeks to examine the relationship between the activities of the subject and the type of lighting of the objects. For this study, it has been chosen to analyse the libraries with digital pictures in High Dynamic Range (HDR). Each image corresponds to different scenes subjected to software that reveals luminance (L) value. To generate HDR images and false colour images, the website <https://www.jaloxa.eu> has been used in 2015, which is currently not in service. The

quantitative information of the scenes allows us to evaluate the luminance contrast in the visual field [11].

3. CASE STUDIES

The first case, owned by the Pompeu Fabra University since 1992, is the Dipòsit d'Aigües library. It is located opposite the Ciutadella park, in the Sant Martí district of Barcelona. Constructed in 1874 by Josep Fontserè as a water tank to feed the waterfall fountain inside the park, the old water tank was later refurbished as a library by Lluís Clotet and Ignacio Paricio [12]. The library is formed by eleven parallel arches of 14 meters high, which intersect by another eleven arches rows and extend along 65 meters. This generates that inside we find passages modified by a forest of high red brick columns on a grey carpeted floor, natural wood furniture and white metal luminaires.

Naturally lit from an overhead opening in the centre of the building and vertical windows in the perimeter. All photographs were taken on the same day, on June 16th, but at different hours. Three pictures were selected, as mentioned before, because is relevant to focus on reading activity and search book activity. At 14:00h the sky was partially clear. The library was illuminated by diffuse natural light through windows. Due to the distance of high-level windows from work plane, the artificial light plays a central role in the scenes studied. The lamp model used was fluorescents Philips Master TL5 HE 21W/830 SLV/40 on the furniture.

Because users are related to university studies, the lighting intention focuses on the reading activity. The floor plan (Fig. 1) shows three analysis scenes: collective reading, individual reading and corridors (Fig. 2-3-4).

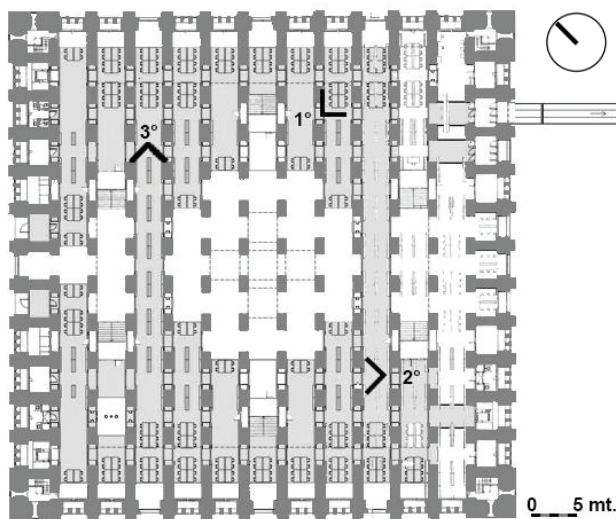


Figure 1: First floor plan Pompeu Fabra Library.



Figure 2: First HDR photo of group reading place.

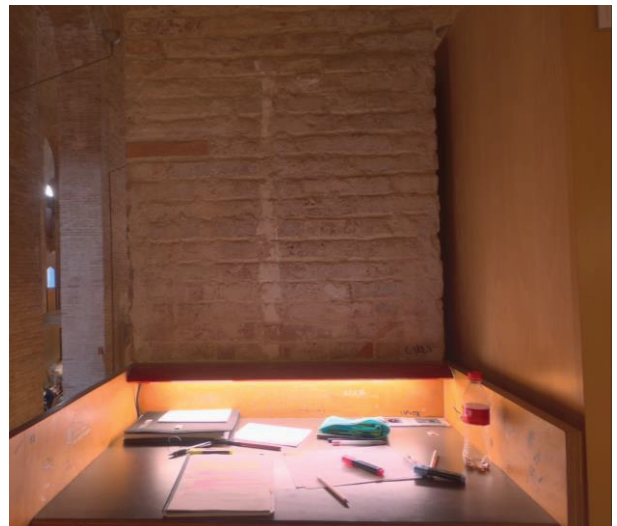


Figure 3: Second HDR photo of individual reading place.



Figure 4: Third HDR photo of corridors facing window.

The second case is the Agustí Centelles library, which opened in 2010. It is located in the Eixample district of Barcelona. The architects Rahola and Vidal had to group different uses and users in one building: a civic centre, an auditorium, a nursery school and a library [13].

The library starts from the third floor and occupies 4 levels, the double heights allow good views to the outside and diffuse light into the interiors (Fig. 5-6). The vertical surfaces are mostly white and are made up of the columns, the perimeter walls, the metal profiles that support the glazed facade and the shelves that delimit the reading areas of the circulation area. The horizontal surfaces are basically white for the ceiling of acoustic tiles and gray for the floor. As for the tables they are white except those of black color that are in front of the north-east glazed façade.

The interiors are illuminated by natural light through the north-east and south-west facing facade. These photographs were completed at 11:00h, on June 22nd, when the sky was partially clear. The artificial light comes from fluorescents Philips Master TL-D 58W/840 on the ceiling and Philips Tornado T2 8W WW E14 220-240V 1PF/6 on the table lamp.

The lighting design seeks to place the major activities next to the facades to allow the greatest entry of light from the outside. The choice of each HDR photo follows the same criteria as before: a place of shared reading, individual reading, and corridors (Fig. 7-8-9).

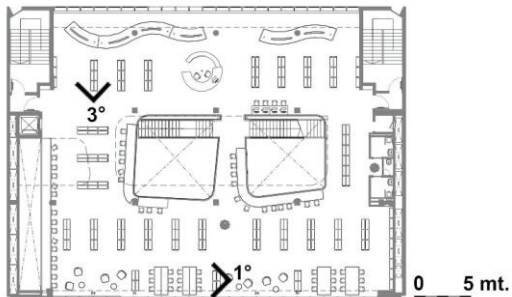


Figure 5: Fifth floor plan Agustí Centelles Library.

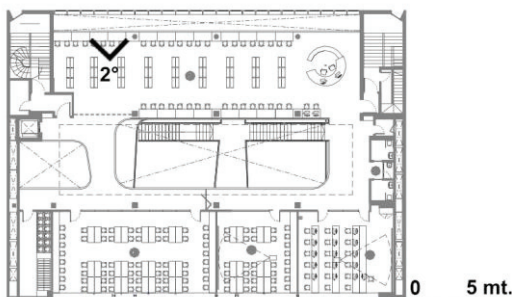


Figure 6: Sixth floor plan Agustí Centelles Library.



Figure 7: First HDR photo of group reading place.



Figure 8: Second HDR photo of individual reading place.



Figure 9: Third HDR photo of individual reading place.

4. RESULTS

The results in the university library (Figure 10-11), show that the luminance levels at the work plane are greater than the luminance levels in the environment. Also, in Figure 12, the luminance level on the bookshelves is higher than luminance level in other surfaces. The luminance values on the desk of group and individual reading place are between 10 cd/m² to 317 cd/m², but primarily near 100 cd/m², while the luminance values in the surrounding surfaces are mainly 10 cd/m². The luminance ratio of the environment and the work plane in this university library is near 1:10.

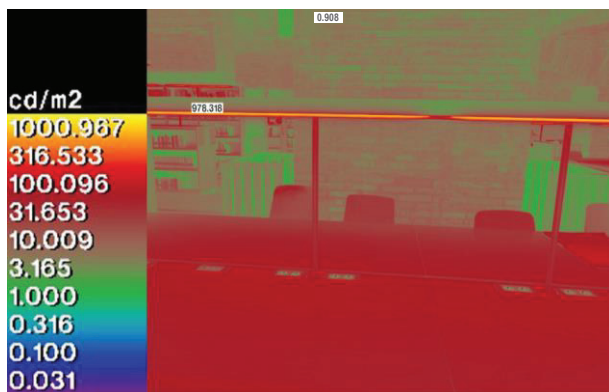


Figure 10: False colour photo of group reading place.

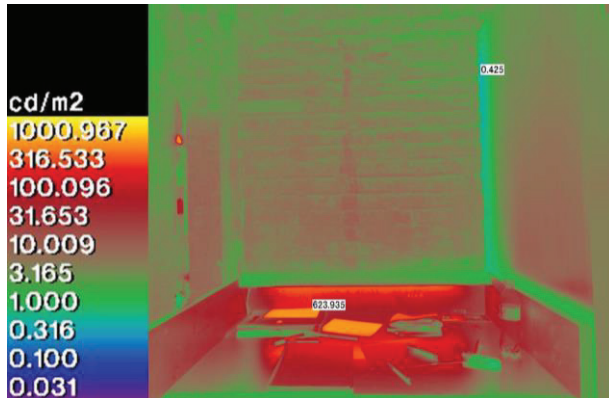


Figure 11: False colour photo of individual reading place.

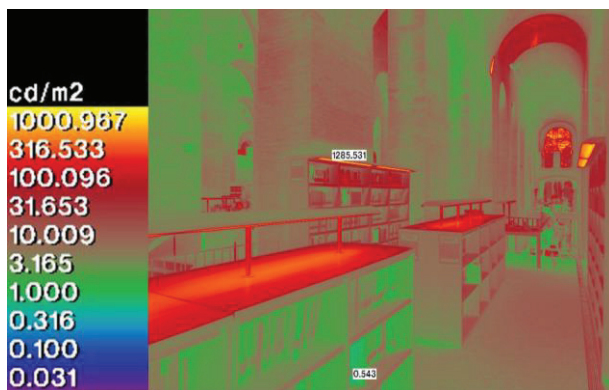


Figure 12: False colour photo of corridors facing window.

The false-colour photos in the community library (Figure 13-14), reveal that the luminance levels in the work plane of reading zone are lower than the luminance levels that surroundings. Figure 15 shows that luminance level in the interior is lower than the exterior, except from the artificial light source. The luminance values on the work plane are between 10 cd/m² and 317 cd/m², but mostly 100 cd/m². The luminance levels of surfaces from the exterior is between 317 cd/m² and 1000 cd/m², but primarily 1000 cd/m² when is facing window. The luminance ratio of the environment and the work plane in this community library is near 10:1.

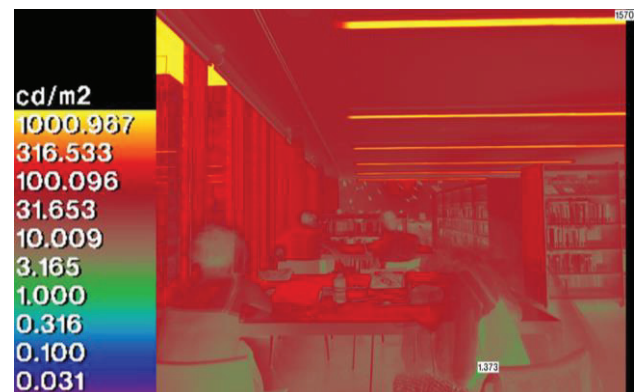


Figure 13: False colour photo of group reading place.

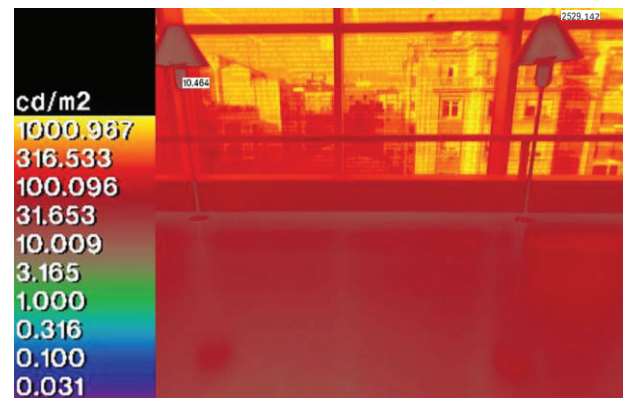


Figure 14: False colour photo of individual reading place.

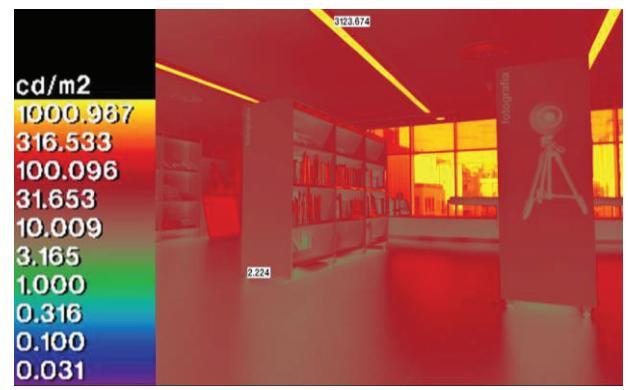


Figure 15: False colour photo of corridors facing window.

5. DISCUSSION

The analysis of false colour images mainly reveals that current library lighting regulations focus on the level of illumination on the work plane [14-15-16]. In both libraries, it was found that the work plane is sufficiently illuminated to carry out the reading activity, according to the UNE-EN 12464-1 standard [17]. The luminance value on the work plane is approximately 100 cd/m², which corresponds to an illuminance of approximately 500 lux depending on the reflection coefficient of the materials. Although it was not found a recommendation of specific luminance ratio for libraries, this work has adopted the proposed by the IRAM- AADL STANDARD J-20-06 [18], applicable to work areas or visual task, which are summarized in table 1.

Table 1: Maximum ratio between the Background Luminance (BL) and the Visual task (Vt).

Visual Field	Ratio BL:Vt
Central vision (30° cone opening)	3:1
Peripheral vision (90° cone opening)	10:1
Maximum L point of the visual field	40:1

It should be noted that all cases studied are under the ranges proposed in the table above. Considering any point of the work plane (100 cd/m²) and the maximum luminance point of the visual field, both cases studies are under the ratio of 40:1. In the first case, the university library, the maximum luminance point is 1285 cd/m², so the ratio is 13:1. In the second case, the community library, the maximum luminance point is 3123 cd/m², so the ratio is 31:1. The results obtained in this analysis show that these values are taken into account so as not to exceed the recommendations in the regulations.

However, we observed a great difference in the luminance contrast between the environment that surrounds the user of both libraries and the work plane. In the first case study, the ratio is shown to be 1:10, where the average luminance of the space limits is 10 cd/m² and the luminance on the reading activity is 100 cd/m². In the second case study, the ratio of the luminance contrast is reversed, with the ratio of 10:1, where the average luminance of the surfaces outside the building is 1000 cd/m² and the luminance of the work plane remains as 100 cd/m². The inversely proportional change between both libraries is the most noticeable light factor that the user experiences through the two buildings. The change of ratio corresponds to the change of the use of the space in each library. The first one is exclusively to reading activity while the second one has spaces for another activities besides reading books, such as children's area

to play and learn, meeting spaces to read newspapers, living rooms to play music with earphones and a conference hall. The luminance contrast in the university library is strongly ruled by the use of artificial source light, while the influence of natural light through windows in the community library is undeniable.

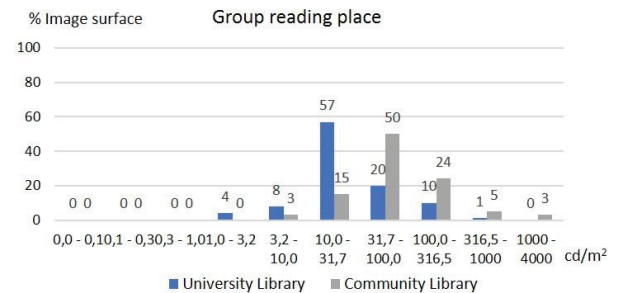


Figure 16: Luminance distribution of group reading

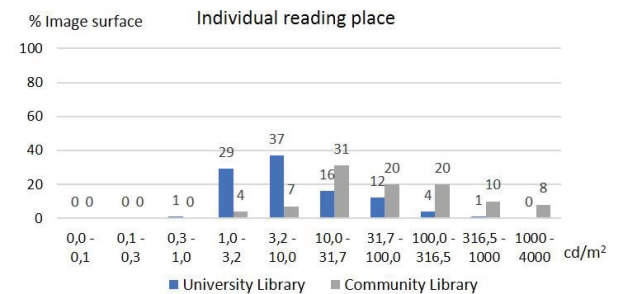


Figure 17: Luminance distribution of individual reading

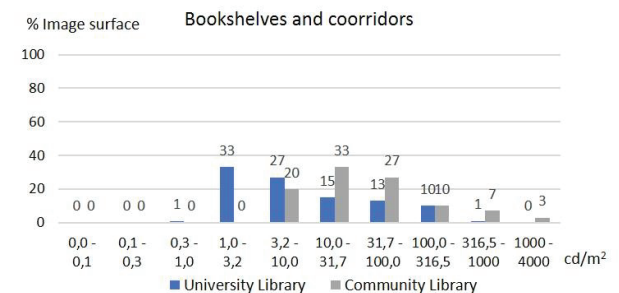


Figure 18: Luminance distribution of corridors and bookshelves

We can see (Fig 16-17-18) that the light distribution is more uniform in the community library than the university library. Also, the graphics show the percentage of light distribution is higher in the group reading place than the individual reading place. The luminance predominant in group reading place in the university library has 57% of luminance between 10 cd/m² and 32 cd/m², while the luminance predominant in individual reading place in the community library has 50% of luminance between 32 cd/m² and 100 cd/m². The comparison of each scene study between both libraries serves to conclude that the light distribution tends to be more uniform in a group reading place than an individual reading place.

6. CONCLUSION

The evaluation of the lighting design of these two libraries allows us to quantify the luminance in spaces with different lighting intentions. Group and individual reading spaces have been examined, as well as corridors with bookshelves. Due to the differences in the average illuminance in each library, an analysis of the luminance contrast between the work plane and the background has been carried out [19]. Both case studies present the same luminance in the task level, but the luminance of the surrounding surfaces is completely different. Current normative likely specify to lighting designer the illuminance in the work plane, however, the regulations are more flexible on how to illuminate other surfaces [20]. The chance is left to the lighting designer to choose how to light the rest of the surfaces taking into account the user's activities [21].

In the university library, the ratio between the luminance of the background and the work plane is 1:10, while in the community library the ratio is 10: 1. This inversely proportional change is perhaps due to the change in space usage of both libraries. In the first case study, it was found that all the spaces are conditioned solely for the study of university students. The university library, has directional lighting which helps to focus on reading activity, so it has mainly a static use of space. In the second case study, it was observed that there are a wide variety of activities in addition to reading, such as learning for children, meeting people for reading newspapers, searching for videos and music, among others. The community library, has diffuse lighting connecting the interior with the exterior visually, so it has mainly a dynamic use of space.

According to the results obtained, it seems that for spaces intended solely for reading, it is preferred to focus the highest luminosity on the work plane. In spaces that require multiple activities, there is a preference for putting more light intensity on the surfaces that define the space. Although it is evident that each activity requires a different lighting design, the present work reveals that the uniform light distribution allows the development of a greater number of activities simultaneously. The opportunity to carry out evaluations of different lighting environments could improve the specificity of the current regulation.

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