Assessment of Visual Comfort in the UII Library

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Abstract: *Libraries are common communal areas for students, especially in higher education. Not only to read, the space tends to also be used as a place of co-working. Unfortunately, the unoptimized infrastructure of libraries became one of the factors of the country's low literacy rate. To encourage people to visit libraries in order to also increase the country's literacy rate, we need to make sure to accommodate the needs of the visitors, which is the visual comfort. This research assesses the existing condition of the main library of Universitas Islam Indonesia to see whether or not the building had fulfilled all the criterias of visual comfort. The research was conducted with a quantitative method with direct data collection by light intensity measurement and user's perception's questionnaires as well as doing simulation to modify the existing performance with DIALux software. The result showed that most of the lighting performance was up to standard only during the day, which implies the lack of sufficiency of the artificial lighting intensity performance.*

Keywords: Library, Lighting intensity, User Perception, Visual Comfort

INTRODUCTION

1. Background

In higher education institutions, libraries are one of the main hubs as the space to find all kinds of information and resources. Libraries are common for communal areas where people work in groups or by themselves to study or read. Hence, these activities require visual comfort. Visual comfort itself is the sufficiency of lighting components in the matters of quantity affecting the comfort of the users (Sok, 2020). Therefore, it is important to maintain the users' visual comfort in the library.

Literacy rate in Indonesia can still be classified as relatively low, one of the main factors was due to the unoptimized infrastructure of reading facilities or library as reading and study center in most study institutions (Tahmidaten & Krismanto, 2020). Contrary to this belief, *Universitas Islam Indonesia* (UII) managed to design and developed a fairly successful library building, seen from the amount of students visiting and studying there. The building's success in encouraging students to study and read in the library became the main motivation to conduct research about the building's performance. On account of that, the building was also used as a research object of previous lighting research in UII. The previous research focuses on the existing lighting condition in bare rooms in the building relating to lighting standards. This study analyzed the building's lighting condition as blank rooms and only through comparing measurements and simulation to standard. Hence, the result of the previous study shows that UII Main Library lighting on the floor where reading and studying was conducted have fulfilled the standard requirements for the activities, with minimum needs of lighting modification (Anshori et al., 2022). However, the previous study of the UII Main Library was only conducted through simulation which did not take into account the surrounding buildings and the existing condition which includes the existing openings as well as the user's actual perception of the actual condition.

To differ from the previous study, although the main topic was similar, this research will enrich the data on the users' comfort based on their direct perception of the building condition during their activities. Not only that, this study will also take into account the arrangement of furnishing and how it may affect the distribution of lighting inside the rooms as well as doing simulation in order to do modification to better the quality of lighting throughout the building.

2. Problem Statement

Several of the existing research focuses on the quality of the lighting in the study case and in the scope of standard, natural, and artificial lighting. There are two main questions that drive the research:

1. Does the result of lighting measurement in the UII Main Library fulfill the visual comfort standard of lighting?
2. How does the existing quality and distribution of lighting in UII Main Library affect the visual comfort of the users?

3. Research Objective

1. To measure if the lighting quality is up to standard for visual comfort
2. To analyze if the current state of lighting is comfortable for the users based on their direct perception
3. To understand the factors of how the lighting qualities affect the user's comfort.

4. Limitation

1. This research will only apply to UII Main Library which located in Sleman
2. The building will only be limited to the UII Main Library building
3. The sampled area in the UII Main Library will be the level with most visitor that functions as reading and coworking spaces which is the Upper Ground level
4. Time of the day to take into consideration in this research was during the day and during the night to differentiate between the performance of daylighting and artificial lighting in the building
5. The sky condition to be measured was during the average clear day
6. Furnishing to include in the simulation will be furniture which have higher chance in disrupting daylight distribution such as bookshelves

LITERATURE REVIEW

Visual comfort is the result of an adequate visual environment on the well-being of the user's visual condition which shows the direct correlation between lighting quality and the visual sense (Michael & Heracleous, 2017). The quality in question consists of the lighting intensity, glare, and user's perception which will be the main variables to be focused on which can branch to other impacting factors such as the distribution of light as well as the furniture arrangement.

Intensity

Lighting is one of the most crucial components in education buildings (Wu & Ng, 2003). It was found that better lighting conditions results in better performance of the occupance where productivity increases by 20% in a pleasant lighting atmosphere. However, the type of artificial lighting commonly has little to no effect on visual performance (Odemis et al., 2004). According to Michael & Heracleous (2017), visual comfort is mainly dependent on (i) Human eye physiology, (ii) Quantity and distribution of light, and (iii) Spectral emission of luminaires. As mentioned before, visual comfort relates to the quantity and quality of lighting components which affects the performance and comfort of the users' visual (Sok, 2020). Visual comfort perception is higher than room atmosphere perception where the lighting techniques, illumination levels, light colors, room reflection factors, and daylighting contribution are the factors that most affect the room quality (Mandala, 2019). Based on the research from Kurniasih & Saputra (2019), The standard average illumination level for library lighting to achieve visual comfort is 300 Lx, when that has been fulfilled, we still need to avoid glare to maintain the users' visual comfort. These theories show that the physical qualities of lighting, such as the sufficient lighting intensity can be one of the factors of visual comfort as well as improving the activities' performance.

Glare

According to *Badan Standarisasi Nasional* (2001), glare can be categorized into disability glare and discomfort glare. Disability glare happens in the area with luminance beyond the capacity of visible objects' luminance which results in the decline of contrast, making details not clearly visible. The source of disability glares are commonly direct sunlight or window openings with visible sky. On the other hand, discomfort glare happens when several interior elements have a significantly higher luminance than the surrounding interior elements. Discomfort glare will increase if the luminance is high with wide area, dim background luminance, and positioned on eye level. Because of this, *Badan Standarisasi Nasional* in SNI 03-6575-2001 established the maximum glare index depending on the visual activity types and control necessity. Library's maximum glare index is 19 which can be categorized as critical for glare control. Therefore, by looking at the theories as well as the standard, it is evident that glare should be one of the most important factors to be maintained as low as possible in order to not cause visual disturbance.

Perception

User's perception relies on the subjective experience of the people themselves, therefore some papers found that user's comfort might not always be dependent on standards. Where before it was stated that glare has high effects on visual comfort, it was also found in some cases that grid-based glare does not result strongly in user's response, however illuminance and spatial daylight autonomy does (Shafavi et al., 2020). Based on this theory, the most crucial points which affect the result of the user's perception was illuminance and spatial daylight autonomy.

In some other cases it was also found that despite the below standard lighting quality of a room, the occupants still perceive the room as eligible for their activities (Mandala, 2019). It was evident that most of the time, people do prefer a sufficiently lit environment, especially while doing visual activities (Anshori et al., 2022). However, it does not hinder the prospect of them feeling comfortable in dimmer environments, although in most cases, this phenomenon happens in environments in which activities are less to non visual such as hostels (Dahlan et al., 2009). There are three factors relating to user's comfort and their lighting environment, which are (i) Quantity of light, (ii) Light source color rendering capacity, and (iii) Risk of glare (Michael & Heracleous, 2017). Based on these theories, sufficiently lit environments do tend to be preferred, however, this does not limit the possibility of user's feeling comfortable in dimly lit environments which shows that the user's perception is more subjective instead of solely standard-based.

METHOD

This research will be conducted using the quantitative method with direct measurement with lux meter (*figure 1*) as shown in the sample placement (*figure 2*) as well as questionnaire based survey as the primary data collection tools. Whereas DIALux software will be used for simulation, analysis and further solution or suggestions. The data analysis will be conducted by comparing qualitative data. The respondents for the survey were picked to fulfill the response based on where they were located in the designated zones (A-G) to see if the different lighting conditions in each zone have significant effects towards the user's comfort.

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A
(Source: Author, 2023)

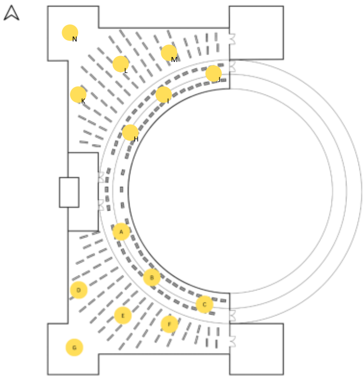
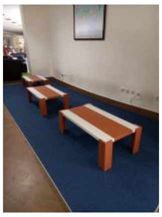


Figure 1. *Sample Placement*
(Source: Author, 2023)

E
(Source: Author, 2023)



B
(Source: Author, 2023)

F
(Source: Author, 2023)

D
(Source: Author, 2023)

C
(Source: Author, 2023)

G
(Source: Author, 2023)

Table 1. Questionnaire

Question	Scale 1 2 3 4 5	Question
Dim task area		Bright task area
Inappropriate light color		Appropriate light color
There is visual distraction		There is no visual distraction
Visual exhaustion		No visual exhaustion
Detailed object not focused		Detailed object looks focused
Hard to differentiate color		Clear color differences
Disturbing glare		Minimum to no glare

RESULT AND DISCUSSION

1. Intensity

The findings is based on the South and North wing during the day and during the night time that compared to the minimum standard of requirement where the 300 Lx was used as the standard for areas with visual activities such as reading and working areas, while 100 Lx was used as the standard of areas with little to no visual activities such as circulations.

Based on the direct observation, the result shows during the day, the sofa table, sofa seat, floor seating with windows, and the west table already meet the standard. However, only circulation areas (circulation and in between bookshelves) with lower lighting standar had fulfilled the standard during the night which indicate the lack of sufficient intensity of the artificial lighting. Otherwise, some areas did not fulfill the lighting requirements, which were the regular floor seating and individual stalls for both of the wings, as well as the sofa seat and west table in the north wing, withheld visual activities such as reading and working. This increases the urgency to resolve the lack of lighting intensity.

Table 2. South Wing Lux Meter Direct Measurement Findings

Area	Standard	Day Average (12:00 PM)	Night Average (18:00 PM)	Fulfilling Standards
Sofa Table	300 Lx	820,4 Lx	151 Lx	Day
Sofa Seat	300 Lx	634 Lx	159,7 Lx	Day
Between Bookshelves	100 Lx	142,75 Lx	227,4 Lx	Both
Circulation	100 Lx	159 Lx	128 Lx	Both
Floor Seating	300 Lx	87,5 Lx	190,4 Lx	None
Floor Seating (With windows)	300 Lx	3154,5 Lx	152,3 Lx	Day
West Table	300 Lx	308,2 Lx	159,7 Lx	Day
Individual Stall	300 Lx	70,5 Lx	26,4 Lx	None

Table 3. North Wing Lux Meter Direct Measurement Findings

Area	Standard	Day Average (12:00 PM)	Night Average (18:00 PM)	Fulfilling Standards
Sofa Table	300 Lx	325,34 Lx	107,75 Lx	Day
Sofa Seat	300 Lx	250,67 Lx	101,75 Lx	None
Between Bookshelves	100 Lx	178,75 Lx	144 Lx	Both
Circulation	100 Lx	196,25 Lx	163 Lx	Both
Floor Seating	300 Lx	212 Lx	125,67 Lx	None
Floor Seating (With windows)	300 Lx	529 Lx	87 Lx	Day
West Table	300 Lx	214 Lx	159,7 Lx	None
Individual Stall	300 Lx	71,25 Lx	57,50 Lx	None

The simulation (*figure 2*) shows differences in the daylighting intensity between the simulation and direct measurements, which overall had lower intensity. This could possibly be due to the lack of surrounding context in the simulation to take into account. In the real life condition, the lighting could be less intense as the simulation due to the shadowing of the neighboring faculty building, indoor shading, as well as the type of glass. The glasses on the east side are tinted and have grids, unlike the singular glass panel in the software. The west area was neighboring another faculty building and the windows had blinds that sometimes were closed. However, the quality of the simulation had similar results of the fulfillment of the standard with the direct measurement.

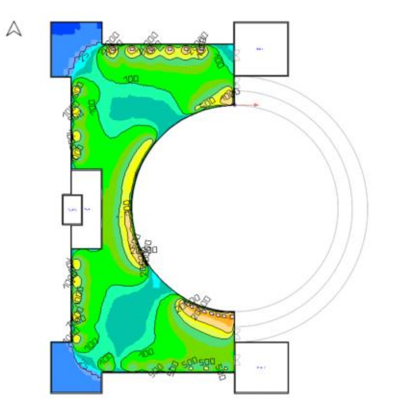


Figure 2. DIALux Daylighting Simulation

Table 4. Direct Measurements and Simulation Comparisons

Area	Standard	Direct Measurement	Simulation Result	Difference Percentage
Sofa Table	300 Lx	820,4 Lx	700 Lx	17,2%
Sofa Seat	300 Lx	634 Lx	600 Lx	5,7%
Between Bookshelves	100 Lx	142,75 Lx	100 Lx	42,75%
Circulation	100 Lx	159 Lx	100Lx	59%
Floor Seating	300 Lx	87,5 Lx	100 Lx	12,5%
Floor Seating (With windows)	300 Lx	3154,5 Lx	1000 Lx	215,45%
West Table	300 Lx	308,2 Lx	1000 Lx	69,18%
Individual Stall	300 Lx	70,5 Lx	25 Lx	182%

As we can see in *table 4*, the results have various differences. The area with the closest difference between the simulation and direct measurement was the sofa seat area with only 5,7% difference. On the other hand, the area with the most difference between the two methods of measurement was the floor seating with windows with 215,45% difference. All of the simulation results were lower than the direct measurement, except for the floor seating.

2. User Perception

The result of the survey of the user's perception shows a variety of ratings as seen in *Table 4.* Zone A, the sofa area, had mainly higher ratings with 4 and 5 score for each question, except for the visual focus which according to the second respondent had a score of 1, meaning that they think the visual focus in that zone was not good. Zone B, which is the no-window floor seating, falls more in the lower range of the rating scale, ranging from 2 to 4. Zone C, which was the floor seating with window showed higher rating than the floor seating with no window, ranging from 3-5, the score falls in a moderate to higher rating. Zone D, the west table, was the area with the most responses. As seen in *table 5*, this zone had a wider range from 2-5 where the lowest score was also for the visual focus. Zone E, the in-between bookshelves, was the most consistent between the two respondents as they gave the same scores for each point asked, ranging from 2-5. Zone F, the circulation, was almost as consistent as zone E, ranging from 3-5. Zone F appeared to have the smallest gap of score range compared to other zones. Zone G, the individual stalls were the last zone surveyed. The zone has the smallest score for lighting brightness, but highest score for visual focus. Zone E, F, and G are the only zones with high rating of visual focus where out of the three, only zone G was the one used for reading activities.

Table 5. Questionnaire Accumulated Rating

Zone	Dim-Bright	Light Color	Visual Focus	Visual Vigor	Detail Rendering	Color Rendering	Glare
a	4	5	5	4	4	4	4
	5	4	1	5	4	4	4
b	3	4	2	2	4	3	4
c	4	4	3	4	3	3	5
d	5	5	2	4	4	5	4
	4	4	3	4	3	4	5
	5	4	3	4	3	4	4
e	3	4	4	2	2	3	5
	3	4	4	2	2	3	5
f	4	4	4	3	3	3	5
	3	4	4	3	3	3	5
g	2	4	5	4	4	4	5
	3	5	5	4	3	4	4

From the data that was gathered by both direct measurements and user's perception questionnaires, we can start to see correlations between the two. The areas which were used as reading areas and had fulfilled the standard (*Table 2*), had more higher points. The areas that have not fulfilled the standard, such as the floor seating and the individual stalls, or the areas that are not used for reading activities, such as the circulations and in between bookshelves, have consistently scored lower points. This confirmed the research by Kurniasih & Saputra (2019), that the requirement standard of lighting intensity does affect the comfort of the people. The results, correlated with the zones, were also confirming the statement from Anshori et al., (2022), that people prefer a well lit area for visual activities. The result also contradicts with the theory from Dahlan et al. (2009) that people would be willing to enjoy the dim area when they're not doing visual activities since the result showed the lower score for the dimmer, non-visual areas.

The responses for the dimmer area showed that the respondents felt visual or eye fatigue which also affected their visual focus, not allowing them to render better details. The area also affected the ability to render colors accurately. Correlated with the user's comfort theory by Michael & Heracleous (2017), the result had already obliterated two out of three points needed to be comfortably fulfilling.

DESIGN RECOMMENDATION

Based on the findings, the crucial part of the object was the artificial lighting intensity where the most urgent area to modify was the individual stall on the south-west and north-west corner of the plan. Hence, the modification was made by adding light fixtures on those areas which can be seen in *figure 4* was accumulated to 300 lux, fulfilling the standard of lighting for visual activities. The lights for the reading areas were all arranged using LED lights (Philips RC461B PSD W60L60 PSD W60L60 VPC PIP LED34S/- NO), hence increasing the intensity both for the added artificial lighting and the existing. Other than that we can also use the crucial variables in the questionnaire so that the object will fulfill the user's visual comfort not only in lighting intensity but also other aspects relating to it.

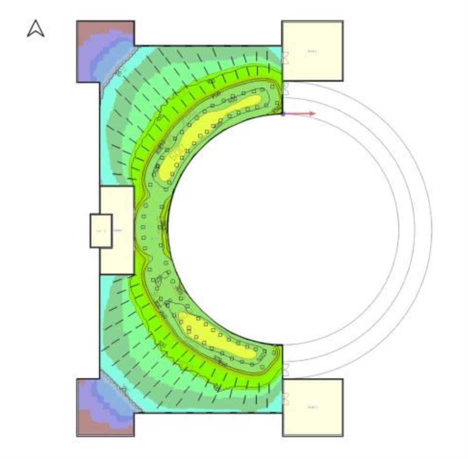


Figure 3. Existing Artificial Lighting

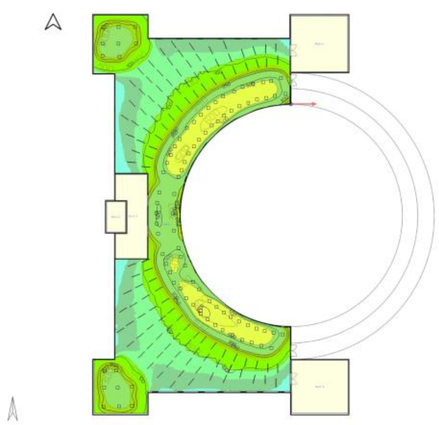


Figure 4. Modified Artificial Lighting

CONCLUSION

The findings showed three categories of lighting intensity conditions in the library: below the standard, fulfilled the standard, and exceeding the standard. The zones that fell below the standard were the regular floor seating and individual stalls in both the north and south wing of the library, as well as the north wing west table and sofa table. The zones that have achieved the standard requirements were the bookshelves area and circulation, which both were not used for reading activities, as well as the south wing sofa seat and west table, and the sofa table and floor seating with windows in both of the wings of the library. The fulfilling zone that functioned to accommodate reading and visual activities, only achieved the standard during the day, while the zones that didn't, achieved the standards during both times since the standard of requirements were lower. The only zone that exceeded the standard greatly was the floor seating with windows during daytime, showing the amount of natural daylight was close to direct sunlight. Based on the response and relating it to the lighting condition of the zones, the areas with dimmer lighting qualities (B, E, and G) result in lower visual vigor, while the zones which were brighter (D and A) have issues in visual focus instead. However, despite having issues with visual focus, the areas that are brighter seem to be more preferred looking at the higher number of respondents from the brighter zones. From that, we can see the main issue of the library lighting was in the artificial lighting which raises the urgency of lighting fixture modifications. Therefore, several additions of light points were made which increased the light intensity in the needed areas to fulfill the standard requirements. The variables and responses obtained from the results of the questionnaire can also be used as a benchmark for further research about visual comfort not only relating to lighting intensity.

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