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The impact of artificial lighting on improving the visual experience of museum visitors: A case study of Sharjah Museum of Islamic Civilization

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Abstract
Lighting is a crucial element in museum design, directly influencing visitors' psychological responses, visual experience, and overall satisfaction. Despite its significance, limited research exists on artificial lighting in museums within the United Arab Emirates. This study addresses that gap by examining the impact of artificial lighting on visitor experience at the Sharjah Museum of Islamic Civilization, focusing on Gallery 4. A descriptive analytical approach was used, employing two surveys for data collection. The first survey, assessing satisfaction with ambient lighting, received 223 responses and was analyzed using SPSS. The second, evaluating the influence of lighting on the visual experience, gathered 74 responses. Findings revealed that 91.0% of visitors were negatively affected by inadequate lighting, such as glare or uneven distribution, which impaired exhibit engagement. Additionally, 90.6% indicated that appropriate lighting enhanced their comfort and satisfaction. In response, a lighting simulation for Gallery 4 was developed using Rendering AI and PromeAI to optimize distribution and visibility. The study recommends selecting lighting types that balance warm and cool tones, minimizing visual strain through established standards, using simulation tools to refine lighting design, and expanding research to include varied museum types, fostering more context-sensitive lighting strategies.

Keywords: Museum, Artificial lighting, Visual experience, Museum display, Museum visitor

1. Introduction

Museums are among the most significant institutions that embody the historical and living memory of people's lives, serving as lasting and tangible cultural reservoirs. It transfers to us through a time journey into the realms of history, art, and knowledge. In addition, museums are cultural oases where heritage and creativity converge to create unforgettable experiences. It highlights and preserves national identity by reflecting and communicating the culture of a nation shaped by past civilizations and continuing into the present [1]. Indeed, it serves as expansive spaces that embrace the light of the ancients and the remnants of time. The museum display acts as a mirror through which visitors engage with the exhibited artifacts, serving as the vital link between the museum and its audience [2].

UAE's museum sector is characterized by dynamic activity, with approximately 102 diverse museums showcasing a wide range of art, history, and culture. Around 65 are public museums, and 137 are private institutions, distributed across the various emirates in the country [3]. Moreover, specialized departments in the UAE that are dedicated to museum studies and design have emerged because of the growing significance of museums in the modern era. To showcase its artistic and cultural legacy, the country has made significant investments in developing unique museums. Even though museum lighting is essential to the success of the entire operation and the visitor experience, more research and improved integration with modern design and visitor psychology are still needed [4].

The strategic design of museums to highlight visual details plays a pivotal role in attracting and engaging visitors. Within this context, lighting serves as a fundamental component in shaping a unique visual experience that transforms each museum visit into an exceptional journey. It enhances the visual scene and amplifies the impact of the exhibited elements. The importance of the visual experience in museum visits lies in its profound effect on how visitors interact with the displays [5]. This experience is not merely about viewing artworks; it is an exploratory journey that merges aesthetic and educational dimensions to deepen visitors' understanding and enrich their knowledge. This experience is rooted in visual comfort, which shapes the visitor's perception and engagement within the museum environment. Visual comfort refers to an individual's response to the quantity and quality of lighting in a space. It is assessed using two approaches: the "discomfort approach," which focuses on minimizing visual disturbances, and the "well-being approach," which evaluates the positive effects on satisfaction and comfort. According to the International Commission on Illumination, lighting environment standards define factors related to visual comfort, including color temperature, color rendering index, glare, illumination levels, uniformity, etc. [6].

"Museum lighting" refers to the lighting of museums and exhibitions, as well as the techniques and fixtures used in displaying artworks, artifacts, and other objects. Unlike lighting in commercial environments, museum lighting focuses on creating an atmosphere that enhances the beauty of exhibits and improves the visitor's experience. The primary goal of museum lighting is to make the displayed item the center of attention, as proper lighting helps in revealing the object's natural beauty [7]. Lighting creates a sense of anticipation for the visitors upon arrival and continues to guide them toward moments of drama or contemplation within the exhibition space. It can be used to alter the mood or ambiance of the gallery, to draw the visitor's attention to specific artworks and sculptures, or to employ the subtle play of light and shadow to guide their journey from entrance to exit. In this way, lighting becomes a main character in the narrative, inspiring visitors and shaping their steps throughout this unique artistic and cultural journey [8]. Managing the preservation of cultural heritage poses a significant challenge in our time. Appropriate and evenly distributed lighting is a key aspect of heritage conservation, as it plays a prominent role in preserving cultural landmarks and museum collections [9].

The importance of this study lies in shedding light on the impact of artificial lighting in enhancing visitor satisfaction in museums. It explores how lighting shapes the visual scene, adding an element of contemplation. Understanding the effect of artificial lighting on museum visitors will contribute to improving their experience, enhancing their engagement, reflection, and achieving visual comfort. Moreover, effective museum lighting distribution highlights key elements, improving educational focus and attention, which in turn enhances visitors' understanding and supports the museum's educational goals. This research also helps bridge the knowledge gap by providing essential information for designers and museum managers to understand the role artificial lighting plays in influencing visitors. Furthermore, the findings and conclusions derived from this study will aid in improving museum designs and exhibition arrangements, enhancing visitors' responses and overall experience.

The lack of research and references on artificial lighting in UAE museums and how it affects visitor satisfaction is the root of the study. Addressing this gap is critical for museum design, as lighting has a significant impact on how visitors experience the space and their emotional reactions. Due to growing national and international awareness of mental health, the UAE is now creating policies that support improving the well-being in public spaces like museums. Therefore, the main objectives of this research are the following :

1. Studying the standards related to the functional and aesthetic roles of artificial lighting in museums.
2. Exploring artificial lighting in the level of visitor satisfaction with ambient lighting in museums.
3. Analyzing the artificial lighting readings that achieve visual comfort for museum visitors.

2. Literature review

In recent years, numerous studies have begun to shed light on the impact of lighting and its importance in museums [10]. The study emphasized that lighting is a fundamental element in the storytelling process within museums. He noted that lighting plays a prominent role in engaging visitors and providing them with an immersive experience of their surroundings. The study also pointed out that poorly designed lighting may cause side effects that negatively impact artifacts and other museum objects. Lighting is an essential component for sustainable museum planning [11]. They argued that the quality of lighting should be taken seriously into consideration, as it is a critical factor alongside other elements that influence museum exhibition design. They explained that exhibition lighting design supports scenographic elements, such as text, sound, color, and materials. Lighting serves as an expressive tool, a language with a unique structure, capable of enhancing narratives or conveying specific ideas within space. The results concluded that providing sufficient and high-quality lighting for all museum activities significantly enhances the communication and experience of visitors, achieving what is referred to as "visual comfort".

Researchers [12] determined the vital role of lighting in defining the purpose and function, as well as in showcasing the architectural style that distinguishes historical objects. The study recommendations aim to ensure lighting suitability without causing negative effects, and the importance of consulting lighting design experts to fulfil their role effectively. Moreover, [13] highlighted the role of artificial lighting in enhancing the functional and aesthetic values of interior spaces as a fundamental element. They emphasized that both natural and artificial lighting have psychological effects on humans. The study proposed the necessity of considering light color and its quality, as it significantly impacts light intensity. His findings indicated that the design and configuration of lighting impacts, when aligned with the conceptual design of a space, contribute to creating a visually captivating environment. Conversely, using inappropriate lighting negatively affects the visitor experience within the space.

Similarly, in [14] it asserted that lighting makes art visible in museums. He argued that appropriate lighting design can create an aesthetic connection between the viewer and the artwork. The study analyzed the extent to which lighting choices influence the perception of how an artwork was created by the artist. Schielke outlined three criteria that should guide lighting design decisions: the content of the artwork, the formal aspects of the visual medium, and the spatial-temporal context in which the artwork was produced. Furthermore, [15] discussed the impact of artificial lighting on visitors' emotional responses in museums. They identified that the optimal correlated color temperature (CCT) for visual comfort ranges between 2500K and 3500K, as it is generally perceived as the most comfortable range, to evaluate comfort levels, visual clarity, and the warmth perceived in the environment. The study highlighted key lighting parameters, including uniformity, contrast, color rendering, glare, and three-dimensional impression. Table 1 summarizes the elements and criteria derived from relevant literature published since 2019, which were used as the basis for formulating the questionnaire.

Table 1. Summary of elements identified in the literature relevant to the research topic

Elements	Researcher	Number of Studies
Visual Comfort	[11,14,12]	3
Color Rendering Index (CRI)	[11,14,12]	3
Color Temperature	[11,15,14,12	4
Museum Visitors' Psychology	[10,12,13,15,14]	5
Warmth Evaluation	[15]	1
Visual Perception Evaluation	[13,15]	2
Comfort Evaluation	[15]	1
Glare	[15,13]	2
Shadows	[15,13]	2

2.1. Case study

Sharjah Museum of Islamic Civilization (Figure 1) is one of the most prominent historical and cultural landmarks in the city of Sharjah and the UAE. It is a cultural monument that reflects the brilliance of Islamic architecture and the beauty of Arabic ornamentation. The museum offers a comprehensive view of Islamic civilization throughout the ages, highlighting the contributions of the Islamic world to the fields of art, science, and culture [16].

Figure 1. The Sharjah Museum of Islamic Civilization

The museum houses over 5,000 artifacts that demonstrate the artistic and scientific innovations contributed by Muslim scholars. These artifacts are exhibited across six galleries organized chronologically, with some items being displayed for the first time. Among the most distinguished exhibits are Qur'ans, Islamic manuscripts, outstanding architectural models, a series of historical photographs of Hajj rituals, and a unique piece, the Kiswa (cover) of the Holy Kaaba. Together, these exhibits narrate of Islamic civilization across different historical periods. The museum was inaugurated in 2008, making it the first of its kind in the UAE. Its architectural design blends traditional Islamic style with modern elements, giving it a distinctive aesthetic character [17].

Gallery No. 4 (shown in Figure 2) is dedicated to showcasing handicrafts and weapons dating back to the 13th and 14th centuries AH (19th and 20th centuries AD). During this period, the Islamic world witnessed an economic flourishing that strengthened artistic and cultural exchange between the Islamic and European worlds. The exhibits in this gallery reflect this civilizational interaction.

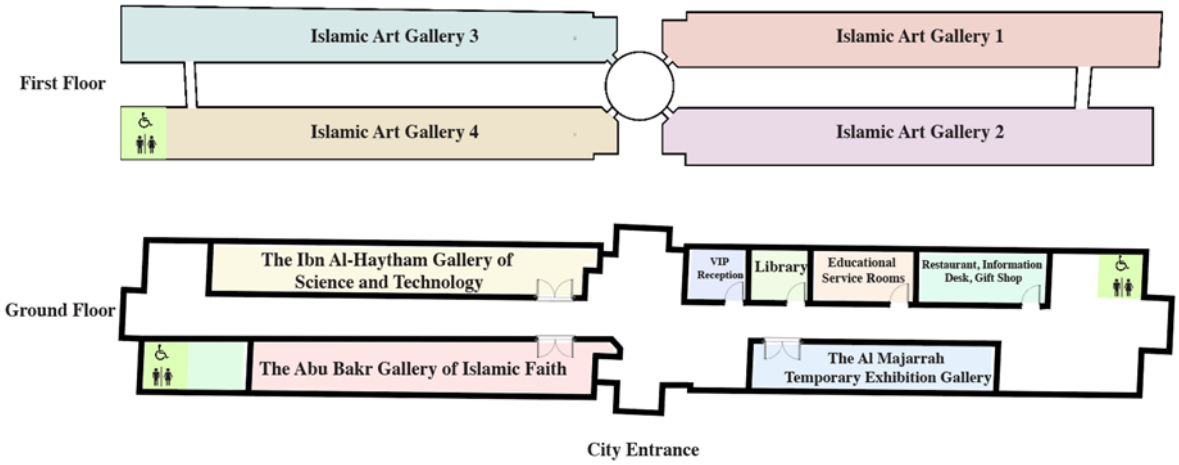

Figure 2. Detailed floor plan of the Sharjah Museum of Islamic Civilization

3. Research methodology

As shown in Figure 3, the research began by identifying the research gap, followed by defining clear research objectives. Data collection was conducted through both a literature review and distributed questionnaires. Two quantitative surveys were administered: the first targeting the general public (223 respondents), and the second focusing on museum visitors (74 respondents). The collected data were analyzed using SPSS and Excel

software. Furthermore, lighting conditions were assessed using the LT300 Light Meter in accordance with TS 16163 standards, alongside AI-based rendering tools (Rendering AI and PromeAI) for Simulation and Conformity Assessment.

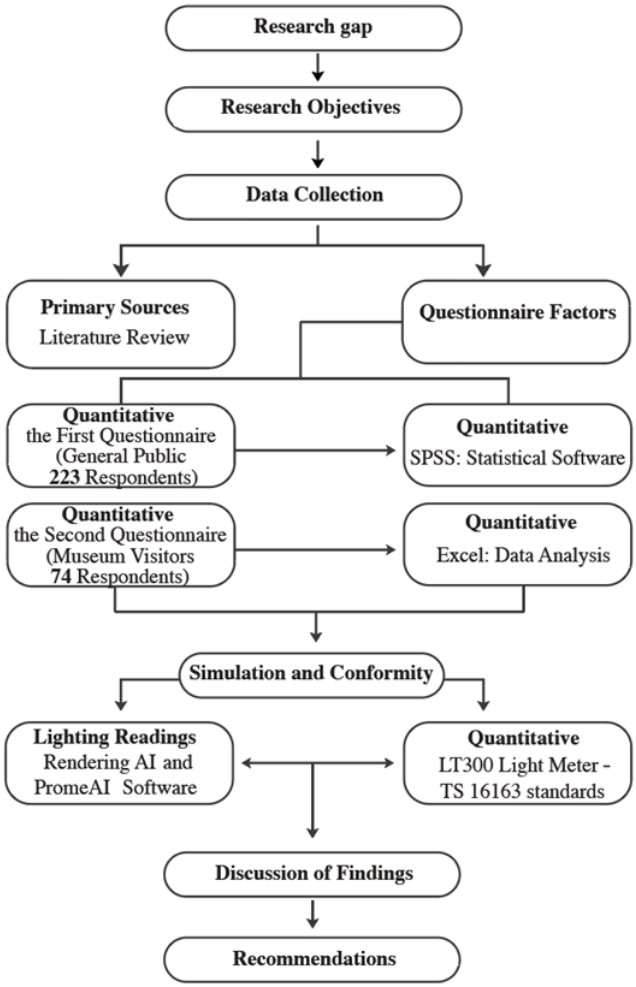

Figure 3. Research methodology

3.1. Data collection and analysis

The research used a descriptive analytical approach, with data collected through two surveys: the First Questionnaire aims to explore how artificial lighting affects museum visitors' satisfaction with ambient lighting. A total of 223 responses were collected. The Second Questionnaire focuses on the impact of artificial lighting on the visual experience at the Sharjah Museum of Islamic Civilization. 74 responses were gathered from visitors via QR codes.

Based on the survey results, a simulation was conducted for Gallery 4, which received the lowest satisfaction ratings. By utilizing light specialized programs, such as Rendering AI and PromeAI, the lighting distribution was optimized to enhance artifact details and improve the overall visual comfort.

3.2. Design of the first questionnaire

The objective of the questionnaire was to explore the role of artificial lighting in influencing museum visitors' satisfaction with the ambient lighting. It consisted of 29 questions, divided into four main sections: Section 1 includes the participants general information, Section 2 gathers general perceptions of artificial lighting within museums, Section 3 explores the impact of artificial lighting on visitors' visual comfort, and Section 4 includes the impact of artificial lighting on the psychological experience of museum visitors (shown in Table C1 and Appendix C).

3.3. Sample size determination

The minimum required sample size was calculated using Cochran's formula, which considers the total population size and an acceptable margin of error. In this context, n denotes the required sample size, Nrepresents the total target population, and e is the margin of error. The calculation was based on the population of the Sharjah Emirate, which is estimated to be around 1.8 million, with a 7% margin of error. The used formula is shown in Equation 1.

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Based on these values, the minimum required sample size was determined to be 204 participants. However, the actual number of responses collected reached 223 responses, thereby enhancing the reliability and validity of the findings and ensuring broader representation of the participants' perspectives in the study.

3.4. Demographic data of the participants

A total of 223 individuals from various categories participated in the study. Table 2 presents a summary of the participants' demographic characteristics. Gender distribution among participants is 35.4% male and 64.6% female. Regarding participants' age, 43.9% of the participants are between 25-34 years old, as the highest age range. In terms of education level, more than half of the participants hold a bachelor's degree. Regarding their last visit to the museum, only 1.8% of the participants have never visited the museum. Regarding the time spent in the museum, almost the majority of the participants spend between 30 minutes to 4 hours in the museum.

Table 1. Descriptive summary of participants' demographic characteristics

Variable	Category	Frequency	Percentage
Gender	Male	79	35.4%
	Female	144	64.6%
Age	18–24 years	36	16.1%
	25–34 years	98	43.9%
	35–44 years	56	25.1%
	45–54 years	17	7.6%
	55–64 years	13	5.8%
	65 years and above	3	1.3%
Educational Level	High school or below	35	15.7%
	Bachelor's degree	122	54.7%
	Postgraduate studies	49	22%
	Post-university education	17	7.6%
Date of Last Visit to the Museum	Never	4	1.8%
	Within the last 6 months	89	39.9%
	Within the last year	65	29.1%
	One year or more	65	29.1%
With Whom Do You Visit the Museum	Alone	55	24.7%
	With family	137	61.4%
	With friends	128	57.4%
	Tour groups	81	36.3%
	Other	16	7.2%
Duration of Time Spent in the Museum	30 minutes to 1 hour	57	25.6%
	1 to 2 hours	75	33.6%
	2 to 4 hours	71	31.8%
	More than 4 hours	20	9.0%

3.5. Descriptive data analysis

To assess the reliability of the questionnaire, Cronbach's alpha coefficient was used, where the value is considered acceptable and moderate if it falls between 0.5 and 0.8; higher values indicate higher reliability [18]. Table 3 presents the Cronbach's Alpha results for each category or domain within the study. The results show that all Cronbach's Alpha values were high and within the acceptable and satisfactory range for reliability. Additionally, the questionnaire validity was assessed by presenting it to 2-3 academics and experts in the field. Based on their feedback and comments, certain questions were revised, where unclear, ambiguous, or irrelevant items were removed. As a result, the number of questions was reduced from 40 to 29, ensuring that the questionnaire is more accurate and aligned with the study's needs.

Table 2. Cronbach's alpha coefficient for measuring the reliability of the questionnaire

No.	Domains	Number of domains	Cronbach’s alpha coefficient
1.	General perceptions of artificial lighting in museums	5	0.592
2.	Impact of artificial lighting on the visual comfort of museum visitors	8	0.919
3.	Impact of artificial lighting on the psychology of museum visitors	9	0.950
	All questionnaire domains	22	0.820

3.5.1. Measures of central tendency and Likert scale

Measures of central tendency reflect the central value in a data set. Common measures of this type include the mean, mode, and median. In this study, the mean was used as the central tendency measure, as it is the most commonly applied metric in this context [19].

The five-point Likert scale was also employed in this study, as it is considered one of the most practical and effective tools for gauging the strength of participants' opinions [20]. The values on this scale ranged from 1 to 5, with "Strongly Agree" = 1 and "Strongly Disagree" = 5. These values were converted into averages to provide the weighted mean for the studied variables. Based on the values outlined in Table 4, the results were interpreted as indicating the degree of influence of the participants' opinions, ranging from "Very Influential" to "Not Influential at All" [21].

Table 3. Weighted means of the five-point Likert scale measures

Weighted Mean	Result	Interpretation of the result
1 - 1.79	Strongly agree	Very influential
1.80 - 2.59	Agree	Influential
2.60 - 3.39	Neutral	Neutral or do not know
3.40 - 4.19	Disagree	Uninfluential
4.20 - 5	Strongly disagree	Very uninfluential

3.5.2. Statistical analysis using SPSS

The collected data were analyzed using the Statistical Package for the Social Sciences software (SPSS). The measured variable includes three domains assessing the impact of artificial lighting on enhancing the visual experience of museum visitors. Table 5 presents the mean, standard deviation, and the level of influence for each domain.

Table 4. Mean scores, standard deviations, and level of influence for all questionnaire items

No.	Domains	Number of Items	Mean	Standard Deviation	Interpretation of the Result
1.	General perceptions of artificial lighting in museums	5	1.95336	0.9072	Influential
2.	Impact of artificial lighting on the visual comfort of museum visitors	8	1.719175	0.74537	Very influential
3.	Impact of artificial lighting on the psychology of museum visitors	9	1.763033	0.70483	Very influential

As shown in Table 5, participants' responses regarding general perceptions of artificial lighting in museums were highly positive and influential (mean = 1.953, standard deviation = 0.9072). Approximately 89.2% of the respondents agreed that the design of the museum's interior environment, particularly the lighting style used, plays an important role in choosing their preferred museum. Additionally, 85.2% considered artificial lighting to be a key factor in enhancing their visual experience inside the museum. Furthermore, 87.9% confirmed that ambient lighting significantly influences their decision to stay longer in the museum.

The overall mean score of the impact of artificial lighting on the visual comfort of museum visitors was 1.719 with a standard deviation of 0.745, indicating a strong impact on visual comfort. The results revealed that 90.1% of participants believed that excessive lighting in museums leads to visual fatigue. Moreover, 91.0% stated that improved lighting quality enhances visual clarity. Approximately 89.2% affirmed that lighting plays a crucial role in highlighting exhibits and main pathways, thereby facilitating their movement throughout the space. Additionally, 86.1% agreed that a balance between warm and white lighting contributes to better visual comfort. Furthermore, 91.0% of the participants noted that properly directed lighting enhances their interaction and learning experience, thereby improving their overall engagement with the exhibits.

The psychological effects of artificial lighting on museum visitors were also assessed. The findings showed a mean score of 1.7630 and a standard deviation of 0.7048, suggesting a noticeable psychological impact. About 88.8% of respondents reported that artificial lighting affects their ability to concentrate and remain attentive while exploring exhibits. Additionally, 90.6% believed that appropriate lighting enhances their comfort and satisfaction levels. Furthermore, 91.0% asserted that distractions caused by poor lighting conditions, such as glare or imbalance, negatively affect their ability to focus and fully engage with the museum content. Lastly, 87.4% of visitors reported that artificial lighting quality influences their mood and emotional state during their museum visit.

The findings demonstrate that artificial lighting plays a crucial role in enhancing the overall museum experience. Its impact on both visual and psychological comfort is significant, as participants emphasized the need for improved lighting distribution to achieve optimal visual and emotional effects. The results also highlighted the importance of selecting the right type of lighting and directing it appropriately to enhance visitor comfort and reduce visual fatigue. Moreover, there is a general consensus among respondents on the role of artificial lighting in shaping overall museum perception, whether through improving visibility or highlighting exhibits and circulation routes. These insights point to the necessity of a well-thought-out lighting design in museum interiors to provide an optimal environment that fosters visitor engagement, psychological comfort, and a more immersive museum experience.

3.6. Second questionnaire

The second questionnaire was designed to investigate the impact of artificial lighting on the visual experience at the Sharjah Museum of Islamic Civilization. It consists of 17 questions divided into two sections: Section 1, which includes general information, and Section 2, which covers the impact of artificial lighting on the visual experience at the Sharjah Museum of Islamic Civilization (shown in Tables 6 and 7, and in Appendix B).

3.6.1. Sample representation and data collection

The sample was selected to ensure it represents various groups of visitors to the Sharjah Museum of Islamic Civilization. A random sampling method was employed by distributing the questionnaire in both Arabic and English languages via QR codes over a period of three weeks. This approach provided all visitors an equal opportunity to participate, enhancing the data collection objectivity. The sample size consisted of 74 participants, a suitable number for preliminary analysis, taking into account the nature of the research and the time constraints on data collection. To ensure statistical representation, the sample was divided according to several key variables, such as nationality, age group, educational level, frequency of museum visits, and the amount of time spent in the museum. This breakdown helps explain differences in the visual lighting experience across various visitor categories. Additionally, the representation of different age groups was considered to ensure that the results did not reflect bias toward any specific generation but rather offered a comprehensive perspective on the lighting experience in the museum. Moreover, the frequency of museum visits was considered with the questionnaire, targeting both new visitors and individuals who had visited the museum before, providing a comparative view of how lighting influences initial impressions versus repeated experiences.

3.6.2. Demographic data of the participants

Table 5. Descriptive summary of the demographic characteristics of participants in Survey 2

Factors	Category	Frequency	Percentage
Nationality	Citizen	37	50.0%
	Tourist	31	41.9 %
	Resident	6	8.1%
Age	18–24 years	8	10.8%
	25–34 years	22	29.7%
	35–44 years	30	40.5%
	45–54 years	11	14.9%
	55–64 years	2	2.7%
	65 years and above	1	1.4%
Educational level	High school or below	11	14.9%
	Bachelor’s degree	46	62.2%
	Postgraduate studies	15	20.3%
	Post university education	2	2.7%
Duration of time spent in the museum	30 minutes to 1 hour	3	4.1%
	1 to 2 hours	10	13.5%
	2 to 4 hours	29	39.2%
	More than 4 hours	32	43.2%

Table 6 presents the distribution of nationalities among the participants in the second survey, indicating that local citizens make up the largest percentage (50%), followed by tourists (41.9%), while residents had the least participation (8.1%). Regarding age groups, the most active group was between 35-44 years, with a percentage of 40.5%, followed by participants in the 25-34 years age range at 29.7%. The 45-54 years age group accounted for 14.9%, while the 18-24 years age group represented 10.8%. Participation from older age groups was limited, with 2.7% from the 55-64 years group, and the least participation came from those aged 65 and above at 1.4%. In terms of educational level, the majority of participants hold a bachelor's degree (62.2%), while 20.3% have

postgraduate qualifications. On the other hand, 14.9% of participants either did not complete secondary education or have a high school diploma, and only 2.7% hold postgraduate degrees. Regarding the duration participants spend in the museum, the data shows that 43.2% of participants spend over 4 hours, while 39.2% spend between 2 to 4 hours. Additionally, 13.5% of participants spend between 1 and 2 hours, and only 4.1% spend between 30 to 60 minutes. These figures reflect the visitors' interest in the museum's content and their willingness to spend long periods exploring it.

3.6.3. Descriptive data analysis

This section includes an analysis of the participants' responses regarding the impact of artificial lighting on their visual experience within the Sharjah Museum of Islamic Civilization. It examines the lighting across different galleries and assesses its influence on visitors' overall experience and visual comfort.

After analyzing the second survey results (Table C1 in Appendix C), it was found that the Ibn Al-Haytham (refer to Figure 4) received the highest ratings in terms of lighting quality and its positive impact on the visitor experience, with a total of 93.2% of participants selection. Moreover, 91.9% of respondents confirmed that the lighting in this gallery helped them understand the exhibits and effectively highlight their value. Additionally, the gallery received the highest rating for achieving a balance between warm and cool lighting, which enhanced visitors' visual comfort, as reported by 89.2% of participants.

Figure 4. Lighting in the Ibn Al-Haytham Gallery of Science and Technology

On the other hand, Gallery 4 (refer to Figure 5) received the lowest ratings among the galleries, with 85.1% of participants considering it uncomfortable and causing visual fatigue. Furthermore, 79.7% of participants observed a lack of lighting variation in this gallery, negatively impacting their viewing experience. Additionally, 66.2% of participants noted that the lighting in this gallery caused the formation of shadows, affecting visibility, and 83.8% found that the inadequate lighting impacted their ability to focus while walking through the gallery.

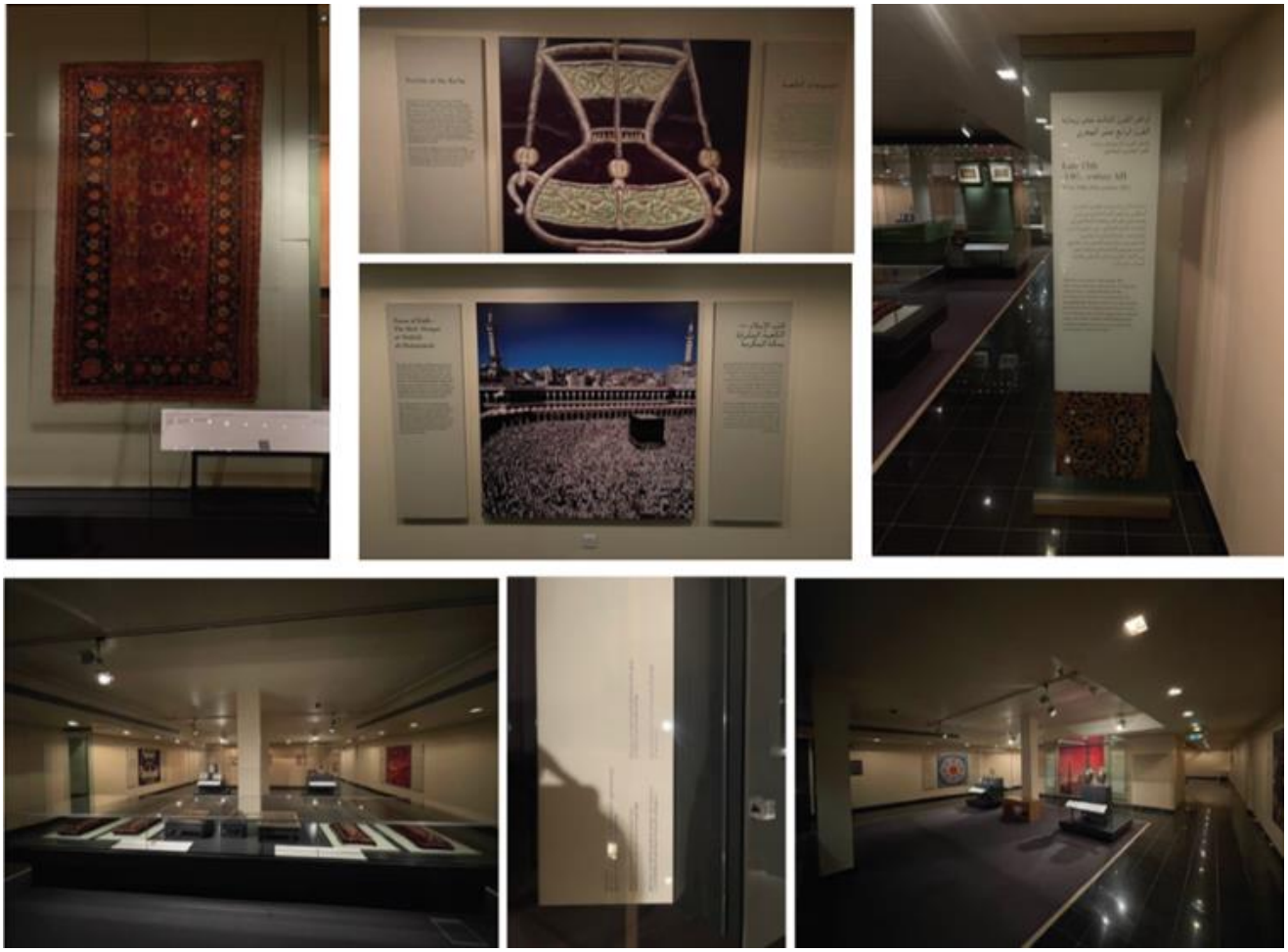

Figure 5. Lighting in Gallery 4

Based on the results of this survey and its recommendations, a simulation was conducted to improve the lighting in Gallery 4, which received the lowest ratings. This was done using specialized programs such as Rendering AI and PromeAI. These rendering engines can assist designers in enhancing visual comfort by enabling the exploration and refinement of lighting scenarios. Although these AI-generated sketches do not replicate precise physical lighting metrics, such as DIALux, it allows designers to input base models and define lighting characteristics through descriptive prompts. The AI then generates visual outputs that simulate a variety of lighting conditions. While the resulting images can closely resemble realistic scenes, it serves as preliminary conceptual tools.

4. Results

Figure 6 shows the main plan for the Islamic Art Galleries, where surveys indicated that Gallery 4 has the weakest lighting, requiring improvements. The study aims to develop this gallery and enhance the lighting distribution to ensure that the fine details of the exhibited pieces are optimally highlighted. Figure 7 illustrates the detailed plan of Gallery 4.

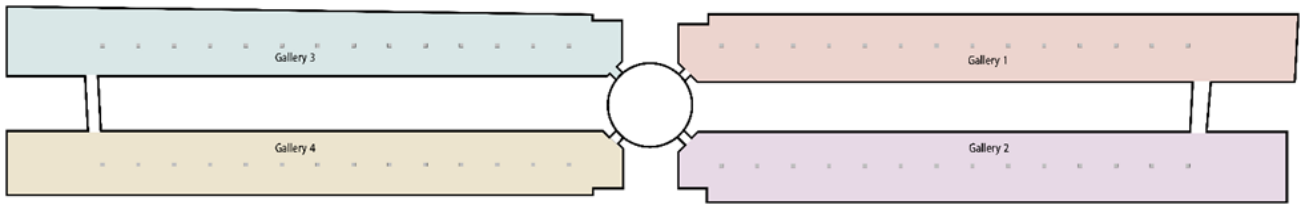

Figure 6. The Master Plan of the Islamic Art Gallery at the Sharjah Museum of Islamic Civilization

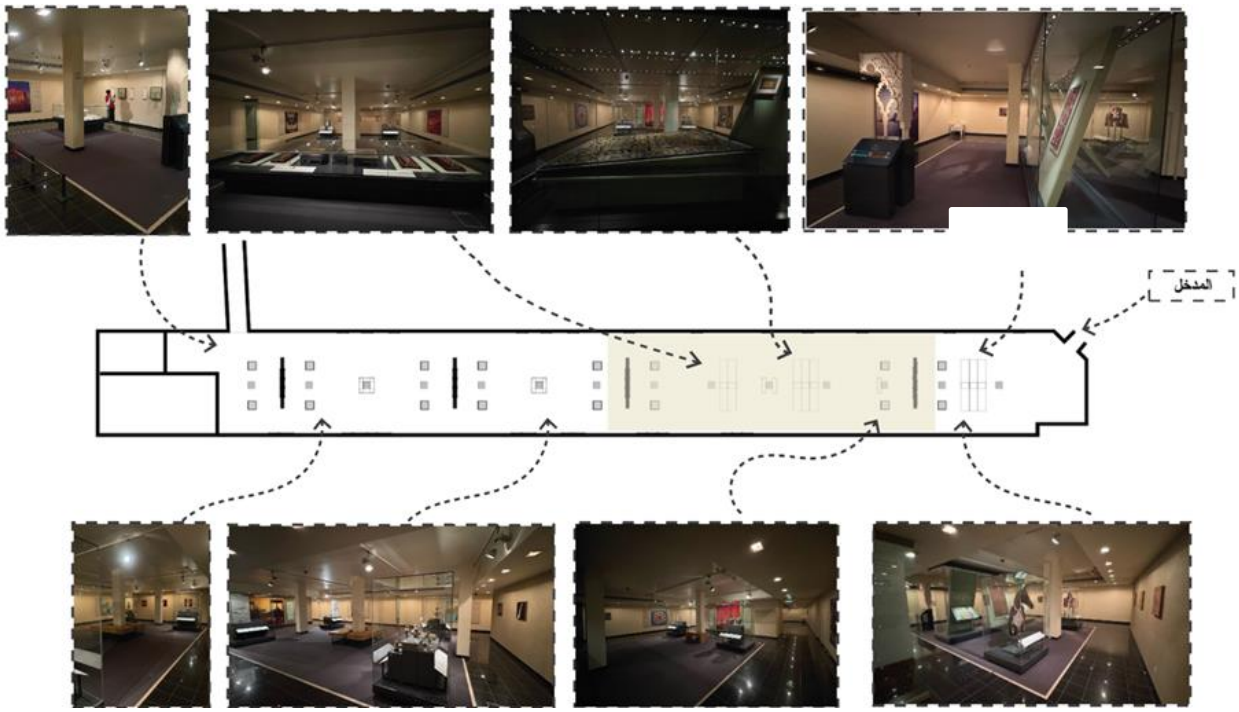

Figure 7. Detailed plan for Gallery 4, the highlighted section of the plan was selected for analysis

4.1. Readings of Gallery 4 with a lux meter

Table 7 shows the lighting readings in Gallery 4 using a lux meter, compared to the recommended levels based on the sensitivity of the materials displayed and the impact of light on them. The lighting levels have been adjusted according to the TS 16163 standards to ensure optimal protection of the displayed materials (CEN, 2014).

Table 7. Light readings of Hall 4 with recommended lighting levels

Element	Current Lux	Recommended Lux Level
Glass Display Cabinets (Height)	45.1* Lux	50 Lux - 200 Lux
Lighting on Exhibits	35.7 Lux	Less than 50 Lux
Under Lighting (Height)	169.4* Lux	50 - 200 Lux
Spotlight on Carpet Box (Height)	41.9* Lux	50 Lux
Under Carpet Box	14.9 *Lux	50 Lux
Art Paintings (Height)	10.9 Lux	Less than 50 Lux
Under Art Paintings	34.7* Lux	200 Lux for oil paintings, 50 Lux for watercolors, pastels, and manuscripts.
Images on Walls	65.9* Lux	Less than 50 Lux
Glass Display Cabinets (Height)	23.7* Lux	50 lux

An asterisk (*) has been marked on the current lighting values that need adjustment to comply with the recommended lighting levels, either by increasing or decreasing them to ensure a suitable lighting environment for the exhibits.

4.2. Lighting analysis in Gallery 4

This study used PromeAI and Rendering AI tools to simulate the target lux levels in Gallery 4 to visualize the recommended lux levels. Several conceptual renders that capture the desired lighting factors were assessed by entering light design sketches. Table C2 (Appendix C) presents the lighting analysis in Gallery 4 before and after modification to achieve a significant improvement in the visual experience. A 50% increase in display quality was achieved compared to the previous state. This improvement resulted from the precise balance

between warm and cool lighting, which enhanced visitors' perception of visual details and provided greater clarity for both the artworks and explanatory texts.

The lighting levels were carefully adjusted to achieve uniform distribution, which helped reduce unwanted shadows and glare, thereby enhancing the viewer's comfort. Additionally, the improvement in the Color Rendering Index (CRI) and color temperature highlighted the colors more naturally, making the exhibits appear more realistic and attractive. Furthermore, the use of directional and concealed lighting contributed to focusing attention on key elements while reducing negative reflections, which will help visitors concentrate on the details without visual distractions. As for the explanatory texts, their clarity was improved through thoughtful light distribution that reduces glare and enhances contrast, making the information easier to read and understand.

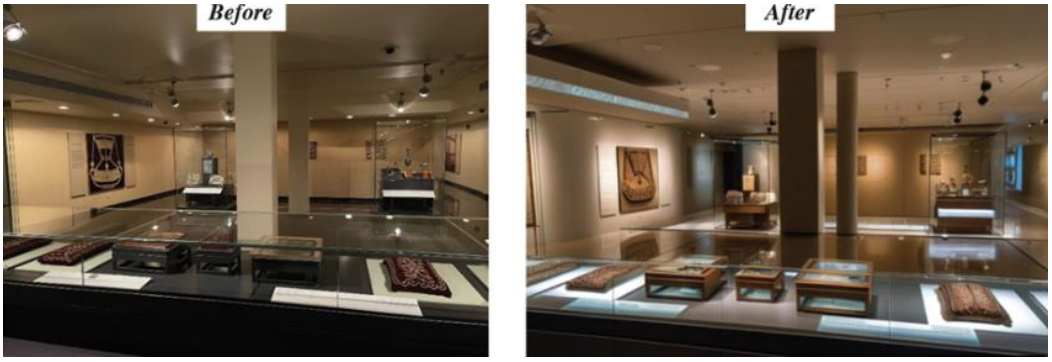

Figure 8. The Exhibition Hall before and after simulation

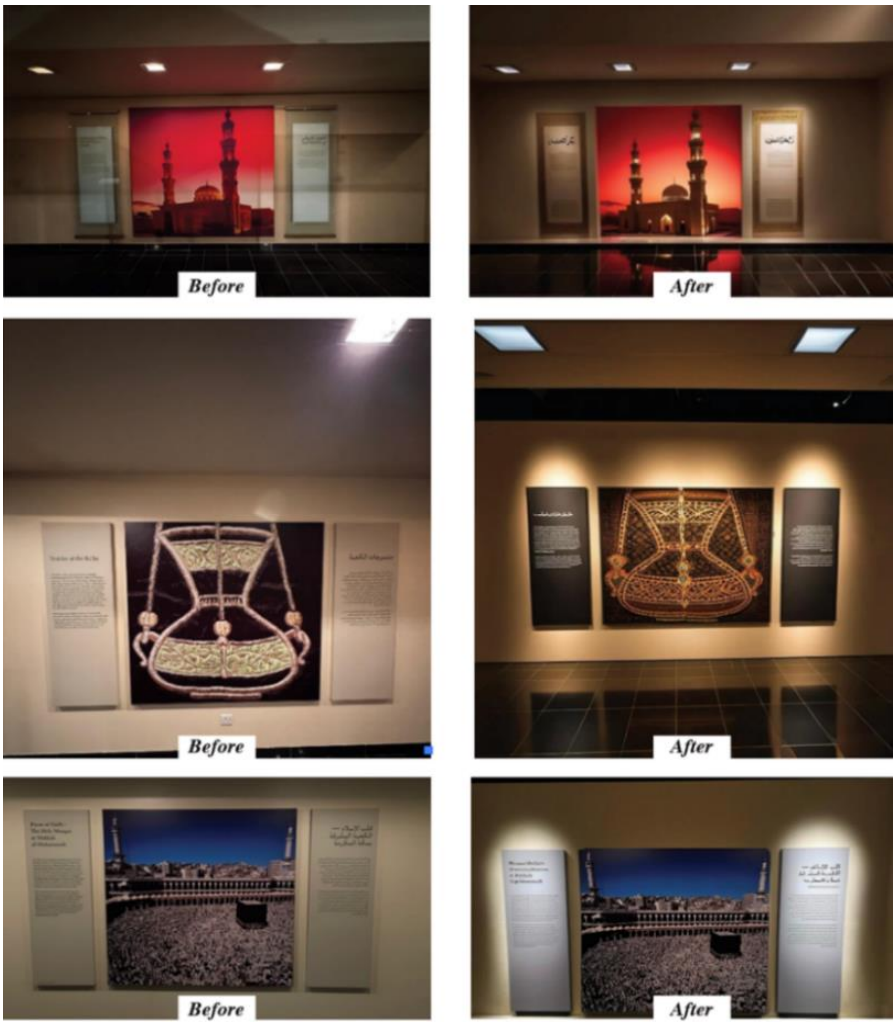

Figure 9. The wall paintings before and after simulation

Figure 10. The explanatory panels before and after simulation

The final result was a more integrated and harmonious exhibition environment, where lighting became a supportive element for the visitor experience, making it more interactive and dynamic. These modifications helped present the artworks within a more sophisticated visual context, enhancing the appeal of the exhibits and facilitating a deeper exploration and understanding of them.

Figure 11. Proposed simulation for Gallery 4

5. Discussion

The study's findings demonstrate that artificial lighting plays a crucial role in the visual experience of museum visitors, directly influencing their satisfaction, visual comfort, and psychological experience during the visit. The data revealed that 89.2% of participants considered lighting design a key factor in their preference for a museum, while 85.2% confirmed that lighting enhances their visual experience. Additionally, 87.9% of participants indicated that ambient lighting influences their length of stay in the museum, reflecting its importance in enhancing visitor experience and interaction with the exhibits. As [10] noted, lighting is not merely an aesthetic element, but a narrative tool that enhances visitors' interaction with the museum environment. Furthermore, improper lighting design can lead to the deterioration of artifacts.

The study showed that 90.1% of participants believed that excessive lighting inside museums caused visual fatigue, while 91.0% confirmed that improving lighting quality enhances visibility. Additionally, 89.2% of participants indicated that lighting plays a significant role in highlighting exhibits and corridors within the museum, making it easier for visitors to navigate between different sections. Furthermore, 86.1% found that achieving a balance between warm and white lighting contributed to their visual comfort, while 91.0% confirmed that proper light direction increased engagement and learning during the visit, supporting the interactive experience for visitors. In this context, [15] explained that lighting quality affects visitors' emotions through factors such as uniformity, contrast, and color rendering, noting that the optimal color temperature for visual comfort ranges from 2500 to 3500 Kelvin.

Moreover, the study confirmed that artificial lighting affects visitors' psychology, with 88.8% of participants reporting that lighting influenced their ability to concentrate and focus within the museum. Additionally, 90.6% stated that appropriate lighting enhanced their sense of comfort and satisfaction during the visit, while 91.0% noted that visual distractions caused by unbalanced lighting affected their ability to absorb the exhibits. Moreover, 87.4% found that lighting quality directly influenced their mood while touring the museum. [13] emphasized that lighting has a psychological impact on visitors, contributing to the creation of an engaging visual experience or, conversely, leading to distraction and visual fatigue if not designed properly.

When analyzing the impact of lighting in the Sharjah Museum of Islamic Civilization, it was found that the "Ibn Al-Haytham Gallery of Science and Technology" had the most significant effect in creating an enjoyable visual experience, with 93.2% of participants stating that the lighting enhanced their interaction with the exhibits. Additionally, 91.9% of participants confirmed that this gallery helped highlight the value of the artifacts clearly. In contrast, Gallery 4 was the least preferred in terms of lighting quality and its effect on the visual experience of visitors, with 85.1% of participants stating that the lighting in the gallery caused eye strain, indicating poor light distribution or uncomfortable contrasts between light and shadow. Furthermore, 83.8% of participants mentioned that the lighting conditions in the gallery were unbalanced or caused glare, affecting their ability to concentrate while exploring the exhibits, while 79.7% reported that this gallery was the least varied in terms of light distribution based on the nature of the exhibits, which negatively impacted detail visibility and accuracy. Research [14] emphasized the importance of lighting, explaining that the appropriate selection of lighting helps create a visual experience that aligns with the nature of the displayed works.

When comparing these results with previous studies, they align with the findings of [10], who confirmed that good lighting design enhances visitor experience while preserving artifacts from damage caused by improper light exposure. The results also correspond with the findings of [11], who highlighted the importance of lighting as an element of sustainable planning, noting that good lighting contributes to visual comfort, improves visitor comprehension of the exhibits, and reduces visual distractions. Furthermore, the results align with [15], who emphasized the importance of balancing contrast, glare, and color rendering to ensure an integrated visual experience for visitors. Additionally, the findings are coherent with [12], who discussed the extensive impact of lighting in highlighting and showcasing objects around us, and how its proper and effective use enhances enjoyment and awe within museums. Moreover, [22] investigates how different lighting conditions impact the

emotional state and drawing performance of students. It makes students feel relaxed and perform better in fluorescent light incorporated with natural light sources.

Table 8 shows the recommendations concluded from this study that have been translated into specific design guidelines for each lighting element, directly informed by the negative visitor feedback on existing conditions. Feedback from visitors reveals several persistent problems with the lighting in the museum, such as uncomfortable, uneven illumination, inaccurate color, inappropriate color temperatures, and distracting shadows or glare. These flaws have a detrimental effect on visitors' psychological engagement as well as their visual experience. Through the promotion of well-balanced, adaptable, and superior lighting solutions that improve color rendering, increase visual comfort, and foster a welcoming environment, the suggested design guidelines seek to directly address these issues. The aesthetic and experiential quality of museum exhibitions can be greatly improved by coordinating technical design decisions with visitor-centered insights.

Table 8. Lighting design guidelines based on visitors' feedback

Element	Visitor Feedback	Design Guidelines
Visual Comfort	Visitors reported discomfort under harsh or uneven lights, making navigation difficult.	Select warm and cool lighting for clarity and comfort.
		Ensure homogenous lighting for navigation.
		Research tech for enhancing comfort and experience.
Color Rendering Index (CRI)	Visitors noted that the colors of exhibits appeared dull or inaccurate under the current lighting.	Use high CRI lighting for color fidelity.
		Ensure consistent CRI across all galleries.
Color Temperature	Some visitors felt the lighting was either too cold or too warm, affecting the perception of exhibits.	Select warm and cool lighting for clarity and comfort.
		Use remote-controlled, adaptive lighting.
Museum Visitors' Psychology	Visitors felt disconnected or uncomfortable in some exhibition areas due to poor lighting and ambiance.	Expand research to diverse museum environments.
		Increase participants for representativeness.
		Use AI to optimize lighting by predicting preferences.
Warmth Evaluation	Lighting was perceived as sterile or uninviting in certain spaces.	Combine natural and artificial lighting for sustainability and engagement.
Visual Perception Evaluation	Visitors mentioned difficulty focusing on displays and reading captions due to distracting lighting or uneven brightness.	Use directed/concealed lighting to highlight and reduce distractions.
		Control intensity and distribution to reduce visual fatigue.
Comfort Evaluation	Some visitors, especially older ones, complained about the lighting being too harsh or glaring, causing discomfort.	Analyze lighting effects on age groups.
		Adjust brightness and glare to accommodate various visitor needs.
Glare	Glare on display surfaces made viewing artworks difficult from certain angles.	Minimize shadows and glare for a better experience.
		Use lighting simulation software for accuracy.
Shadows	Obstructive shadows cast on exhibits restrict clear visibility.	Minimize shadows and glare for better experience.
		Use lighting simulation software for accuracy.

5.1. Limitations and challenges

Despite the significance of the findings revealed by this study, several challenges were encountered to be taken into consideration. Generalizability may be limited by the study's exclusive focus on the Sharjah Museum of Islamic Civilization. A greater number of participants could improve the results, even though the sample was representative. Responses might have been impacted by visitor expectations and past experiences. Perceptions may have been impacted by environmental elements such as exhibition design or noise levels. Lastly, for technical accuracy, the AI-based lighting simulations need to be verified using specialized software, such as DiaLux light software.

6. Conclusion

In conclusion, this study examined the multifaceted role of artificial lighting in museum environments by addressing its functional and aesthetic standards, its influence on visitor satisfaction, and the lighting conditions necessary to achieve visual comfort. Through a detailed analysis of lighting metrics and visitor feedback within the Sharjah Museum of Islamic Civilization, the findings highlighted how artificial lighting significantly shapes visitor perception, emotional response, and overall experience. The study confirmed that well-designed lighting enhances visitor visual comfort. These insights underscore the importance of integrating technical lighting standards with visitor-centered design approaches in future museum lighting strategies.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

A. Meera was responsible for the study conception and design, data collection, analysis, interpretation of results, and draft preparation. M. Emad provided supervision, as well as editing and review of the manuscript. All authors read and approved the final version of the manuscript.

Ethical approval statement

Our institution does not require research ethics approval for reporting individual cases or case series.

Informed consent

Informed consent for the publication of personal data in this article was obtained from the participant(s).

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Appendix A. First Questionnaire

Demographic Data

1. Gender
2. Age
3. Educational Level
4. Date of Last Visit to the Museum
5. With Whom Do You Visit the Museum
6. Duration of Time Spent in the Museum

General perceptions of artificial lighting in museums (5 Questions)

7. The design of the museum's interior environment, especially the lighting style used, is important in your choice of a preferred museum.
8. Ambient lighting influences your decision to stay longer inside the museum.
9. Artificial lighting is considered an important factor in enhancing your visual experience within the museum.
10. What do you dislike about museums?
11. What usually needs improvement in museums?

Impact of artificial lighting on visual comfort of museum visitors (8 Questions)

12. The use of warm lighting enhances your experience in museums and improves your understanding of the exhibits.
13. A balance between warm and white lighting in museums contributes to improving your visual comfort.
14. Excessive lighting inside museums causes you visual fatigue.
15. Lighting plays a role in highlighting exhibits, pathways, and main corridors within the museum, facilitating your movement between displays.
16. Properly directed lighting enhances your level of interaction and learning as a museum visitor.
17. Varying lighting zones according to the exhibits within the museum contributes to improving your visual comfort during the visit.
18. The higher the quality of artificial lighting, the clearer the visibility.
19. Shadows created by artificial lighting negatively affect your visual comfort within the museum environment.

Impact of artificial lighting on psychology of museum visitors (9 Questions)

20. The quality of artificial lighting inside the museum affects your mood and emotions while exploring the museum.
21. Artificial lighting impacts your ability to focus and pay attention while examining the exhibits.
22. Distractions caused by poor lighting conditions, such as glare or imbalance, affect your ability to concentrate and fully engage with the museum content.
23. You are more likely to revisit museums that provide psychologically comfortable and purpose-appropriate lighting compared to others.
24. Appropriate lighting inside museums can influence your level of comfort and satisfaction as a visitor.
25. Lighting plays a role in shaping your behavior and experience as a museum visitor.
26. Adequate lighting levels contribute to your sense of safety and comfort, enhancing your positive experience and encouraging longer stays in the museum.
27. Artificial lighting supports the storytelling process in exhibit presentations and enhances your understanding of historical and cultural narratives.
28. The quality of artificial lighting can affect the clarity and readability of exhibit labels in the museum.

Appendix B. Second Questionnaire

Demographic Data (4 Questions)

1. Nationality
2. Age
3. Educational Level
4. Duration of Time Spent in the Museum

The Impact of Artificial Lighting on the Visual Experience at the Sharjah Museum of Islamic Civilization (13 Questions)

5. Which gallery did you find to be the most well lit and most effective in creating an enjoyable visual experience that encouraged you to stay longer?
6. In which gallery did the lighting help attract your attention and enhance your understanding of the main exhibits and their value?
7. Which gallery had the least variation in lighting zones according to the displayed items?
8. In which gallery did the lighting contribute positively to your understanding and interpretation of the museum artifacts?
9. In which gallery do you believe the balance between warm and white lighting contributed to better illumination and improved your visual comfort?
10. In which gallery was the lighting uncomfortable and caused eye strain?
11. In which gallery did the lighting play a role in highlighting the exhibits, surrounding paths, and main circulation areas, making it easier for you to move around?
12. Which gallery was the best in varying lighting zones based on the exhibits, thereby enhancing your visual comfort?
13. In which gallery did shadows created by artificial lighting negatively affect your visual comfort?
14. In which gallery do you feel your mood and emotions were most positively influenced by the lighting and clarity of the exhibits?
15. In which gallery were lighting conditions suboptimal such as glare or imbalanced lighting and affected your ability to focus?
16. In which gallery did the lighting support the narrative of the display and enhance your understanding of historical and cultural details?
17. In which gallery did the lighting make it easier to read the interpretive texts and labels next to the exhibits?

Appendix C. Survey Results

Table C1. Impact of Lighting in Museum Galleries Based on Visitors' Opinions (Second Survey results)

Question	**Abu Bakr Gallery of Islamic Fait**	**Ibn Al-Haytham Gallery of Science and Technology**	**Gallery 1**	**Gallery 2**	**Gallery** 3	**Gallery** 4
Which gallery had the best lighting and most engaging visual experience?	40 (54.1%)	69 (93.2%)	37 (50%)	23 (31.1%)	6 (8.1%)	6 (8.1%)
Which gallery's lighting best highlighted the exhibits and their value?	45 (60.8%)	68 (91.9%)	38 (51.4%)	30 (40.5%)	11 (14.9%)	7 (9.5%)
Which gallery had the least variation in lighting zones according to the displayed items?	14 (18.9%)	6 (8.1%)	13 (17.6%)	20 (27%)	57 (77%)	59 (79.7%)
Which gallery's lighting helped you better understand the artifacts?	49 (66.2%)	68 (91.9%)	43 (58.1%)	37 (50%)	10 (13.5%)	4 (5.4%)
Which gallery had the best warm-white lighting balance for visual comfort?	29 (39.2%)	66 (89.2%)	24 (32.4%)	17 (23%)	7 (9.5%)	4 (5.4%)
In which gallery was the lighting uncomfortable and caused eye strain?	10 (13.5%)	2 (2.7%)	8 (10.8%)	15 (20.3%)	56 (75.7%)	63 (85.1%)
Which gallery's lighting helped highlight exhibits and pathways for easier movement?	38 (51.4%)	34 (45.9%)	62 (83.8%)	55 (74.3%)	40 (54.1%)	21 (28.4%)
Which gallery best used varied lighting zones to enhance visual comfort?	37 (50%)	62 (83.8%)	33 (44.6%)	23 (31.1%)	6 (8.1%)	2 (2.7%)
Which gallery had shadows that reduced your visual comfort?	8 (10.8%)	9 (12.2%)	6 (8.1%)	9 (12.2%)	58 (78.4%)	49 (66.2%)
Which gallery's lighting and exhibit clarity most positively influenced your mood?	21 (28.4%)	71 (95.9%)	16 (21.6%)	7 (9.5%)	5 (6.8%)	5 (6.8%)
Which gallery had poor lighting conditions, like glare, that affected your focus?	6 (8.1%)	3 (4.1%)	9 (12.2%)	17 (23%)	60 (81.1%)	62 (83.8%)
Which gallery's lighting enhanced the display's story and cultural details?	54 (73%)	65 (87.8%)	49 (66.2%)	35 (47.3%)	11 (14.9%)	7 (9.5%)
Which gallery's lighting made it easiest to read exhibit texts and labels?	57 (77%)	69 (93.2%)	52 (70.3%)	48 (64.9%)	21 (28.4%)	8 (10.8%)

Table C2. Lighting Analysis of Gallery 4 Before and After Modification

Element	**Before Modification**	**After Modification**
Types of lighting used	Integrated Ceiling Lighting (Downlights) Track Lighting Spotlight Lighting.	General Lighting (Ambient Lighting), Directional Lighting (Spotlights), Wall Washer Lighting, Concealed Lighting (Cove Lighting).
Shadow effects	Inconsistent shadows affecting the clarity of artifacts.	Soft and balanced shadows that enhance visual details .
Glare	High glare due to light reflection on surfaces.	Glare reduction through improved light distribution and the use of appropriate light sources.
Color Rendering Index (CRI)	Low Color Rendering Index (CRI), classified under Category 2B (70 > Ra > 60); colors appear dull and unsaturated, with insufficient clarity in details and tonal variations.	The Color Rendering Index (CRI) was improved to category 1B (90 > Ra > 80), resulting in better color quality, with more clarity and precision.
Color temperature	Lack of contrast between warm and cool lighting, Color temperature approximately: 3000K - 3500K.	A combination of warm and cool lighting was used to enhance colors and provide better clarity of details, achieving an improved visual balance. Approximately in Kelvin: 3500K - 4500K
Legibility of interpretive texts	Weak light intensity and poor distribution, causing the explanatory texts to appear faded and unclear; undesirable reflections impacted readability.	Custom lighting was directed at the explanatory panels, which improved text clarity and appeal by enhancing contrast, boosting light levels, and minimizing glare through careful light distribution.
Lighting uniformity	Non uniform lighting: some areas are too dark, while others are overly bright.	Uniform light distribution, making the scene more balanced.
Illuminance level	Low and insufficient illumination level to highlight details.	Improved light levels enhance the clarity of details and elements.