ISSN (Print): 2959-4391 ISSN (Online): 2959-4405

JOURNAL OF SOCIAL SCIENCES DEVELOPMENT

www.jssd.org.pk editor@jssd.org.pk

LIGHTING QUALITY ASSESSMENT OF A HERITAGE LIBRARY: A CASE STUDY OF MONTGOMERY HALL, QUAID-E-AZAM LIBRARY, LAHORE

Muhammad Faiq Mateen[1], Muhammad Moiz Akram[2], Nijah Akram[3], Muhammad Rameez[4], Muhammad Arslan[5] & Uzair Rasool [6]

[1]Department of Architectural Engineering Technology, Punjab Tianjin University of Technology, Lahore, Pakistan. Email: 23-ar-011@students.ptut.edu.pk

[2]Department of Architectural Engineering Technology, Punjab Tianjin University of Technology, Lahore, Pakistan. Email: 23-ar-007@students.ptut.edu.pk

[3]Department of Architectural Engineering Technology, Punjab Tianjin University of Technology, Lahore, Pakistan. Email: akram.nijah@ptut.edu.pk

[4]CEO, Dreamzdesignerz studio, Lahore, Pakistan. Email: archstudiopkr@gmail.com

[5]Department of Architectural Engineering Technology, Punjab Tianjin University of Technology, Lahore, Pakistan. Email: marslang567@gmail.com

[6]Bim Modular and CFS Detailer, Steltech Solutions Limited, Lahore, Pakistan. Email: uzairakbar14@gmail.com

KEYWORDS

Heritage Building; Lighting Quality; Illuminance; Visual Comfort; Daylighting; Library Lighting; Montgomery Hall, Quaid-e-Azam Library

ARTICLE HISTORY

Date of Submission: 18-09-2026

Date of Acceptance: 27-10-2026

Date of Publication: 01-11-2026

ABSTRACT

Heritage buildings adapted for contemporary library use often face difficulties in providing adequate and uniform lighting while preserving their architectural character. This study evaluates the lighting quality of Montgomery Hall, a historic Neo-Classical reading space within the Quaid-e-Azam Library, Lahore, with particular emphasis on illuminance, visual comfort, and compliance with recommended lighting requirements. A case-study methodology was adopted using field measurements, architectural documentation, a user questionnaire, and lighting assessment modelling. The study area was divided into a 3 m × 3 m measurement grid, and illuminance was measured at 20 points at a desk height of 0.75 m during daytime operating hours. Measured values were compared with recommended illuminance levels for reading, bookshelf, and circulation areas. A questionnaire survey was conducted to assess users' perceptions of lighting quality, satisfaction, visual comfort, and reading conditions. Statistical analysis was performed using SPSS. The field assessment revealed spatial variation in illuminance. Areas adjacent to the large arched windows received higher daylight levels, whereas central and interior zones, particularly bookshelf areas, experienced lower illumination. Glare and excessive brightness were observed near window-adjacent seating. Questionnaire analysis indicated significant relationships between lighting-related variables and perceived visual comfort and satisfaction, with regression models statistically significant at $p < 0.001$. The findings indicate a performance gap between the existing lighting environment and contemporary library requirements. Conservation-sensitive interventions, including improved luminaire distribution, glare control, optimised daylight integration, and energy-efficient lighting controls, are recommended to enhance visual comfort and lighting uniformity while preserving the heritage character of Montgomery Hall.

2026 Journal of Social Sciences Development

Corresponding Author Nijah Akram

Email: akram.nijah@ptut.edu.pk

DOI https://doi.org/10.59075/jssd.v5i9.425

Volume/Issue 5(9), 2026, 111-151

Introduction

Background

Lighting is one of the key factors for indoor environment quality in buildings with long-term visual work. Adequate lighting should be provided for reading, writing, information retrieval and computer-based activities in library settings. The quality of lighting is more than just the amount of light; it also relates to illuminance, uniformity, glare control, colour rendering, and daylight/artificial light interaction (Boyce, 2005; van Bommel, 2019; Veitch & Newsham, 1996; Vision). In a reading environment, the lack of or uneven lighting may lead to loss of visual comfort and impair the ability to undertake continuous visual activities. This means that the lighting condition assessment should include both the measurable lighting performance and occupants' perception of the lighting environment.

It is especially significant for buildings that are heritage structures and have undergone adaptations for new uses. High ceilings, heavy masonry walls, large openings, deep interior spaces and architectural features have an impact on daylight and light distribution and are often found in historic buildings. These qualities can conflict with contemporary "functional spaces. Various studies of human factors in lighting have shown that lighting affects the visual performance of people, their comfort, satisfaction and other responses in buildings (Boyce, 2005; Veitch & Newsham, 1996). Adaptive reuse thus imposes interventions which need to maximise the improvement of the building's performance, while maintaining significant architectural and cultural features (Augustiniok et al., 2025).

The Quaid-e-Azam Library (QAL) in Bagh-e-Jinnah, Lahore is a relevant example of this linkage between the heritage and the use of the contemporary. The historic complex is made up of Lawrence Hall (1861) and Montgomery Hall (1866). Both buildings are Neo-Classical in architectural style, and together with the other buildings in this library complex, they have experienced various functional changes in the course of time (Boubekri, 2008; e Silva et al.). The new use of Montgomery Hall as a reading and research space allows students, researchers and other users to engage in extended periods of visual work.

These architectural features control the lighting conditions present in Montgomery Hall. The hall has large, arched windows to let light in, and the high ceiling and generous depth of space influence the spatial lighting distribution of both natural and artificial light. There is a possibility of improving the indoor environment by the availability of daylight, but if it is not controlled, it can also generate too much brightness and glare in the vicinity of windows (Boubekri, 2008; Kelley-Quon). Artificial lighting is therefore needed to supplement the daylight in those areas where natural lighting is not adequate. It is necessary to achieve an objective assessment in order to understand the actual performance of space because these lighting sources interact with each other.

Problem Statement

The Quaid-e-Azam Library is an important heritage and research institution, but the reading rooms created in the library were not intended for the intensive visual environment of the modern library. The spacious windows, deep interior and high ceiling of Montgomery Hall may lead to significant variations in natural lighting between bright window side spaces and dark interior spaces. Brightness and glare may be excessive near windows, and light may not be sufficient in areas further away from light openings.

The current lighting system, therefore, offers room for potential mismatching between the historic building's architectural attributes and the visual needs of a modern reading space. There are a number of international sources highlighting the need for proper illuminance and uniformity when performing visual tasks (Duff, 2012; van Bommel, 2019; Vision). At this time, however, the current condition of Montgomery Hall has not been adequately described using a systematic approach to lighting measurements conducted in the field, followed by perception assessment.

The complexity of the problem is exacerbated by the fact that the building is listed. Some lighting changes can impact important architectural features, and poor lighting changes can fail to create an appropriate environment for the users. If lighting improvements are being recommended, then a balanced assessment is needed prior to making recommendations. This should be done by assessing the level or levels of illumination that are inadequate and/or excessive, identifying how users react to the light and what actions should be taken to enhance the performance of the light, whilst not affecting the heritage character of the building.

Research Gap

The lighting quality, daylighting, visual comfort and human response to indoor lighting have been studied previously (Boubekri, 2008; Boyce, 2005; de Kort, 2019; Heschong et al., 2025; Hönekopp & Weigelt, 2023; Kelley-Quon; van Bommel, 2019; Veitch & Newsham, 1996). Criteria for assessing lighting conditions in indoor working environments and in reading environments are also given in international standards and professional guidance (Duff, 2012; van Bommel, 2019; Vision). Much of the available research is, however, focused on contemporary buildings or on generic interior libraries.

An interesting gap is the empirical evaluation of the lighting conditions in heritage library buildings in the Pakistani context. The existing literature related to the Quaid-e-Azam Library has mainly emphasised historical and architectural aspects, whereas there is limited quantitative data available on the current lighting performance of the reading areas in this library. Field-based measurements that illustrate the distribution of illuminance and areas where illuminance may not meet recommended lighting levels are needed.

In addition, objective measurements are not always a good indicator of users' experience of a lighting environment. The subjective responses (visual comfort, satisfaction, brightness perception,

daylight preferences) have been highlighted in previous studies to be included in consideration with the physical ones (Kelley-Quon; Veitch & Newsham, 1996). Thus, it is necessary to have an integrated assessment based on both measured illuminance and user perceptions.

The present study fills this gap by looking at Montgomery Hall as an adaptive re-use project in which a historic architectural context is being utilised for intensive reading and research applications. The study uses field measurements, user assessment by questionnaires, and architectural analysis to create a set of evidence on the current lighting performance and the opportunities for improvement.

Research Aim

The aim of this study is to assess the existing lighting quality of Montgomery Hall at the Quaid-e-Azam Library, Lahore, by integrating objective illuminance measurements and user perceptions, and to identify conservation-sensitive strategies for improving visual comfort, lighting uniformity, and functional performance while retaining the architectural character of the heritage building.

Objectives

The study is guided by the following objectives:

1. To quantitatively assess the existing illuminance distribution in Montgomery Hall using field-based lux measurements.
2. To evaluate the measured lighting conditions against recommended lighting requirements for reading, bookshelf, and circulation areas.
3. To investigate library users' perceptions of lighting quality, visual comfort, satisfaction, and reading conditions through a structured questionnaire survey.
4. To identify the major architectural and lighting factors contributing to uneven illumination and visual discomfort within the study area.
5. To propose practical and conservation-sensitive lighting improvement strategies that enhance visual performance and energy efficiency without compromising the heritage character of Montgomery Hall.

Contribution and Significance

The study helps in the understanding of the performance of lighting systems in heritage buildings adapted to modern library use. The main value it added lies in the inclusion of objective field illuminance measurement, user perception and architectural analysis in a heritage reading environment. The approach to the assessment of lighting is not based on the quantity of installed lights or the average brightness of the light, but on the spatial distribution of the light and the user's experience of extended visual tasks.

In addition, the study provides empirical evidence for Montgomery Hall, which is an important historic element in the Quaid-e-Azam Library for which there is a limited amount of systematic lighting-performance data. Bright and glare-prone areas and comparatively under-illuminated

areas can help the building manager and designer to plan for interventions that address specific areas of the historic interior rather than a uniform approach.

The research also emphasises the importance of balancing the lighting needs of the present with the architectural heritage of historic structures from a heritage-conservation point of view. The main constraints for adaptive reuse are the buildings' cultural and architectural significance and their ability to continue functioning (Augustiniok et al., 2025). The proposed solution therefore focuses on measures like changes to the luminaire distribution, the controlled integration of daylight, the reduction of glare and energy-saving lighting solutions – but not on extensive changes to important architectural elements.

The results are also applicable for sustainable building operation. The use of improved lighting distribution and/or adequate control of artificial lighting may be able to decrease unnecessary energy consumption and still provide adequate lighting for the user. The methodology, presented in its general form, offers a model which can be applied to other heritage libraries and public institutional buildings where space must be functional while also being conserved.

Literature Review

Lighting Quality in Library and Reading Environments

Lighting quality is a more complex component of IEQ than just providing a specific amount of light. It is a combination of the concepts of illuminance, luminance distribution, uniformity, glare, colour rendering, visual performance and the subjective response of the occupants. Veitch and Newsham (Veitch & Newsham, 1996) pointed out the potential effect of lighting on task performance, visual comfort, health and safety, social interaction and aesthetic judgements. Likewise, Boyce (Boyce, 2005) found that lighting should also be related to the visual needs of the tasks being carried out, as well as the visual characteristics of the people involved. These attitudes are especially relevant to libraries as they involve sustained visual attention for longer periods of time in reading and information processing.

One of the most frequent measures to assess lighting performance is illuminance. It is the luminous flux that falls upon a surface and is commonly expressed in units of lux. But a good average illumination level is not sufficient to guarantee a satisfactory visual environment. Van Bommel (van Bommel, 2019) defines lighting quality as both quantitative and qualitative and defines it as: suitable light levels, distribution, limitation of glare, colour properties, and users' needs. Therefore, reading environment lighting should be evaluated taking into account the spatial distribution of lighting, instead of the overall average value only.

In the case of university libraries, the importance of illuminance evaluation in the field was proven. To study differences between reading areas, days and opening hours, Silva et al. (e Silva et al.) explored the illuminance conditions of reading areas in a central university library by measuring illuminance with a lux meter and analysing the data statistically. Their work illustrates how the direct measurement method can be used to detect differences in the light conditions in which

library users are working. This has special relevance in large reading halls, where the available daylight in the room, the layout of space, the positioning of furniture and artificial lighting can lead to significant variations in space.

For the user of the library, uniformity is also of significance since a large difference between two bright and dark regions is subject to continuous visual adaptation. The quality of light should be viewed in terms of the quality of the distribution of light, as highlighted by Van Bommel (van Bommel, 2019), and the lighting conditions are linked to visual comfort and task-related responses, as shown by Veitch and Newsham (Veitch & Newsham, 1996). An evaluation of a reading environment must therefore be conducted to determine not only if there is adequate light, but also if it is adequately applied to reading surfaces, circulation spaces and other visually demanding areas.

The appearance of the light source also affects the quality of the lighted environment as seen by the observer. Colour rendering impacts the look of materials and objects, and the spectral characteristics and colour temperature can impact occupants' reactions to artificial lighting. Wei et al. (Wei et al., 2014), included in the present study's reference database, studied responses of occupants to fluorescent lights of varying correlated colour temperature and lumens output, showing the importance of both the quantity and the nature of the light. The above considerations suggest that lighting quality should be viewed as a blend of physical performance and human response and not as a single criterion of illuminance.

Daylighting, Visual Comfort, and User Perception

Daylighting is one of the significant elements of sustainable and comfortable interior spaces. If feasible, take advantage of natural light to help illumination and minimise the need for artificial lights when operating during the daytime. Boubekri (Boubekri, 2008) explored the theme of daylighting and the human body, focusing on the wide scope of daylighting's role in architecture and human wellbeing. Recent studies have also added to knowledge of the link between daylight exposure and human biological responses. Heschong et al. (Heschong et al., 2025) note new research on the non-visual impact of daylight and the implications for daylight exposure and health and building design.

Daylight is not necessarily equal to visual comfort, however. The lighting from the large windows can cause significant differences in illuminance in different rooms and can cause glare or bright rooms in the rooms facing the windows. Giarma et al. (Giarma et al., 2017) reviewed the treatment of the issue of visual comfort by building environmental-performance assessment tools, and concluded that daylight availability, daylight illumination and daylight glare are important elements of visual-comfort assessment. In their review, they show that daylight metrics can't be a single metric for visual comfort, and they have to take into account several factors that need to be considered together.

Thus, the objective lighting conditions – subjective perception relationship is important. De Kort (de Kort, 2019) highlighted the importance of taking human factors into consideration in lighting

planning, especially because the lighting influences the occupants in two ways, firstly through measurement (performance) and secondly through subjective evaluation. As long as the lighting is physically acceptable, this does not necessarily mean that it will be perceived as satisfactory to the user, due to other factors such as glare, brightness contrast, reflections, etc.

Questionnaire-based assessment can then be used as a complement to physical measurements. Combining quantitative and qualitative approaches to the investigation of human responses was discussed by Kelley-Quon (Kelley-Quon). The information obtained from the questionnaire responses about brightness adequacy, daylight preference, reading visibility, glare, visual discomfort, and satisfaction is not available by measuring lux, in the context of the present study.

The synergistic approach is supported by recent library research. In a public library study with the aim of evaluating lighting satisfaction in 2025, quantitative data did not fully reflect light users' perception and satisfaction, so it was used in conjunction with a structured questionnaire. This research, which was undertaken in a modern public-library environment, does not involve a heritage building, but the approach used does underpin the importance of combining an objective approach to the assessment of lighting with a subjective approach when undertaking lighting research in the public-library context.

Lighting in Heritage and Adaptive-Reuse Buildings

Assessing a lighting project becomes more complicated when the project relates to a building with Historic Interest. The design of historic buildings was usually based on the environmental, functional and technological conditions of their historical period. The dimensions and features they offer, such as window openings, ceiling heights, wall thickness, materials used and decorative features, can significantly affect daylight penetration and artificial-light distribution. If they are renovated for modern use, then their original environmental features should meet the needs of the new use that was not anticipated by their original design.

Adaptive reuse is more than merely reusing an historic building for a new purpose. According to Augustiniok et al. (Augustiniok et al., 2025), adaptive reuse is a mode of use that preserves the heritage values and at the same time gives new values and contemporary requirements by means of the required architectural measures. During the design process, it is important to identify and negotiate their heritage values, as this information is highlighted in their study. The principle has direct application to lighting interventions, as the design of luminaires, wiring, ceiling surfaces, window treatments and architectural features can impact on the character of a historic interior.

The tug-of-war between conservation and modern performance demands is especially pertinent in situations where the buildings feature wide openings and deep interior rooms. A large amount of daylight can be provided in certain historic halls at the window, but it is less in the interior. On the other hand, introducing more artificial light may lead to glare, over-lit and cluttered views or interference with important architectural features.

The lighting plan of a heritage building thus needs to be sensitive to building performance and conservation requirements. Van Bommel (van Bommel, 2019) stresses the need to take lighting quality into account with the right distribution, control of glare, visual performance and user needs. If the above principles are applied to a heritage building, the assessment must also take into account the potential of any proposed changes to not harm or overpower any key architectural elements.

There is also literature from the perspective of adaptive reuse which provides support for an evidence-based approach. As shown by Augustiniok et al. (Augustiniok et al., 2025), modern interventions in heritage buildings ought to be based on the values embedded in the existing building structure. This is true for any historic library, and not just for lighting improvements – lighting improvements ought not to only maximise illumination. They should look for an appropriate balance between functional requirements, visual comfort, energy performance and conservation of architectural character, rather than the former.

Assessment Methods for Lighting Performance and Visual Comfort

Lighting assessment has been shown in the past to be improved by using both physical measurement and architectural analysis together with an evaluation from the occupants. Direct illuminance measurement can yield quantitative information relating to the quantity and spatial distribution of light. The architectural documentation gives information regarding the physical conditions that caused those patterns, such as window size, room dimensions, luminaire placements, ceiling height, orientation, and surface conditions. Questionnaire surveys supplement the assessment of the perceived luminous environment.

It is not a novel concept to use light meters in environmental or building research. Hönekopp and Weigelt (Hönekopp & Weigelt, 2023) discussed the application of light meters in research and pointed out the significance of the measurement method and device properties when studying illuminance-related situations. This facilitates the use of systematic measurement procedures in which the locations for measurement, height of work plane, time of measurement and environmental conditions are explicitly specified.

Giarma et al. (Giarma et al., 2017) also show that several indicators can be used in visual comfort assessment, such as illumination and aspects related to glare. In their survey of environmental-performance assessment tools, they found that visual comfort is viewed as a bundle of criteria and not a single one. This is in line with the present study, which investigated illuminance, alongside the user's perception of brightness, glare, visual comfort and satisfaction.

Another methodologically-based approach is human-factor research. Given the need to carefully design research studies involving occupants, De Kort (de Kort, 2019) states that lighting needs to account for physical, perceptual and contextual factors. In a review of the literature, Veitch and Newsham (Veitch & Newsham, 1996) also found that lighting quality is correlated with several different outcomes of the occupants, not just one outcome of performance.

In the context of library environments, the combination of field measurements and the results of a questionnaire is especially suitable. This enables the researcher to find out if zones of low or high illuminance correlate with perceived issues like low brightness, glare, reading problems or visual discomfort.

Energy Efficiency and Lighting Improvement in Existing Buildings

Energy efficiency is also a factor in lighting quality, especially in buildings that may be in operation for long periods of time. There may be a need to add some extra lighting to provide more light – this can be appropriate in some areas but can also increase energy use. Therefore, it would be more appropriate to discuss lighting improvement strategies that work to maximise the use of daylight and artificial lighting rather than merely adding more lighting.

Mahdavi (Mahdavi) noted the possibility of simulating lighting and shading performance and using it to inform control strategies in buildings. These methods can help to grasp the relationship between daylighting, shading and artificial lighting before taking physical measures. Edwards and Torcellini (Edwards & Torcellini, 2002) also examined the body of evidence related to natural light and the building's occupants and concluded that daylighting is an important environmental resource.

The issue of energy efficiency is especially relevant to adaptive reuse, as historic buildings may have existing electrical systems or luminaire designs that were designed for a previous use. Retrofitting with efficient light sources can help to decrease the electrical load, but any retrofit must also consider light distribution, glare, colour quality of the light sources, control systems, and the visual integrity of the historic interior.

Energy efficiency should thus be linked to conservation and visual-comfort standards in the context of heritage libraries. There are a few ways lighting interventions can be achieved that do not require a reduction in energy, but rather integrate the use of more efficient light sources, proper zoning, daylight-responsive controls, glare control and improved spatial distribution. This is in line with the idea of adaptive reuse, where contemporary performance requirements are combined with the existing heritage values of the building (Augustiniok et al., 2025).

Table 1. Summary of Previous Studies Relevant to Lighting Quality, Visual Comfort, and Heritage/Library Environments

References	Study focus	Method/Approach	Contributions
(e Silva et al.)	Illuminance in university library	Lux-meter measurements and statistical analysis	Supports field-based assessment of reading areas

(Boubekri, 2008)	Daylighting, architecture and health	Literature-based analysis	Establishes relevance of daylight in building environments
(Boyce, 2005)	Human factors in lighting	Comprehensive review	Supports consideration of visual performance and human response
(Veitch & Newsham, 1996)	Determinants of lighting quality	Literature review	Establishes lighting quality as multidimensional
(Heschong et al., 2025)	Daylight and health	Review/research synthesis	Expands understanding of daylight beyond illumination
(Augustiniok et al., 2025)	Adaptive reuse of built heritage	Comparative heritage case studies	Supports conservation-sensitive intervention
(Tzouvaras et al.)	Daylighting and visual comfort	Critical review of assessment tools	Supports consideration of illumination and glare
(Hönekopp & Weigelt, 2023)	Light-meter use in research	Literature review	Supports systematic measurement methodology
(de Kort, 2019)	Human factors in lighting research	Theoretical/methodological review	Supports integration of physical and subjective assessment
(van Bommel, 2019)	Lighting quality and standards	Technical review	Supports assessment through multiple lighting-quality parameters
(Wei et al., 2014)	Responses to different CCT and lumen output	Field study	Supports consideration of source characteristics and user response
(Mahdavi)	Lighting and shading control	Predictive simulation	Supports optimisation of daylight and artificial lighting
(Edwards & Torcellini, 2002)	Natural light and occupants	Literature review	Supports daylight as an environmental and human-factor consideration

There is an increasing trend in recent research toward the need for a holistic approach to building performance management, based on the simultaneous application of technological innovations, environmental performance and economic feasibility, combined with appropriate and suitable management strategies. Public-private partnerships and project management implications of artificial intelligence (AI) research emphasise the challenges in managing planning, decision-making and the use of technology in the workplace for better building project performance (Akram, Zubair, et al., 2023; Naveed et al., 2024; Zia et al., 2024). The research on sustainable

construction materials also shows the increasing attention towards reducing environmental impacts by using wastewater-integrated concrete materials, low-grade clay minerals, fly ash, hemp, biochar, palm oil ash, eggshell powder, sugarcane bagasse ash, silica fume and other alternative materials (Nijah Akram, Muhammad Zeshan Ashraf, et al., 2025; Nijah Akram, Muhammad Usama Hakeem, et al., 2025; N. Akram et al., 2025; Arshad et al., 2025; Asif et al., 2025; Blouch et al., 2021; Javed et al., 2025; Muneer et al., 2025; Nawaz et al., 2025; Nishtar et al., 2023; Sohail et al., 2026; ur Rehman et al., 2025). Similarly, studies on renewable energy integration, financing as "green finance" and energy-saving technologies underline the importance of analysing the sustainability aspects technically, economically and environmentally (Akram, Farooq, et al., 2024; Akram, Gul, et al., 2023; Akram et al.; Akram, Mubin, et al., 2024; Nijah Akram, Gohar Nadeem, et al., 2025; Blouch et al., 2021). Enhancing building efficiency and sustainability through integrated and data-driven building strategies is also demonstrated with BPA and human-centred approaches such as Industry 5.0 and smart sustainable workflows (N. Akram et al., 2026; Nijah Akram, Nosheen Blouch, et al., 2025; Nijah Akram, Ayesha Mehmood Malik, Roma Mukhtar, et al., 2026). All of these studies show that the implementation of measures in the field of sustainable building cannot be limited to a specific technology, but needs to involve aspects of energy performance, environmental impact, economic viability and user requirements - all interdependencies.

More directly relevant to the topic of lighting, daylighting and heritage buildings are recent studies. Studies on the eco-friendly design of lighting products, the link between lighting and space, passive daylight methods and economic feasibility of integrating daylight reveal a need for a combination of various aspects relating to the quality of the light source, daylight availability, energy consumption and the needs of the user (Nijah Akram, Ayesha Mehmood Malik, Wasim Rafi Khan, et al., 2026; Akram, Mubin, et al., 2024; N. Akram et al., 2025; Nijah Akram, Gohar Nadeem, et al., 2025). Building energy efficiency studies, together with building sustainability studies (Nijah Akram, Nosheen Blouch, et al., 2025; Akram, Gul, et al., 2023; Arshad et al., 2026), also provide support for the use of energy-efficient strategies in building performance assessment. Prolonged studies of the life-cycle cost and carbon footprints of lighting upgrades in listed buildings also emphasise the need to consider the environmental and economic impact of lighting interventions, as well as their contribution to the improvement of the lighting. Significant consideration should also be given to interventions which enhance lighting in listed buildings alongside the effects on the environment and economy (Ullah et al., 2023); long-term studies of their life-cycle costs and carbon footprint have occurred for lighting treatments to listed buildings, supporting this thinking. Studies relating to the understanding of the cultural context of the historic environment, Bagh-e-Jinnah, Shadi Lal Building, architectural documentation and characterisation of historic lime mortars have all highlighted the significance of the historic environment in relation to its cultural, architectural and material value when proposing interventions (Abdullah et al., 2026; Nijah Akram, Ayesha Mehmood Malik, Fatima Tuz Zahra, et al., 2026; Hussain et al., 2025; Khalil et al., 2024; Khalil et al., 2025; Malik et al., 2022; ul Haq et al., 2025). Extreme heat (Nijah Akram, Ar Mohsin Iqbal Deo, et al., 2026; Akram et al.; Nijah Akram, Ayesha Mehmood Malik, Wasim Rafi Khan, et al., 2026; Nijah Akram, Ayesha Mehmood

Malik, Roma Mukhtar, et al., 2026) research on climate change responsiveness and adaptable architecture further illustrates the importance of context-responsive design responses for adapting to environmental change. The various studies continue to reinforce the idea that it is important to assess the lighting conditions in Montgomery Hall, including consideration of how to enhance the light levels, control distracting light, make the lighting more energy efficient, and distribute the light spectrum, while maintaining the historic architectural character.

The reviewed literature offers some significant guidelines for the evaluation of lighting in a heritage/library context. Those two properties, namely luminous intensity and illuminance, are just part of lighting quality and cannot be the only measures used to represent it. Second, the presence of daylight can offer positive changes to the indoor environment and energy efficiency, but at the same time overbrightness and glare should be minimised (Boubekri, 2008; Heschong et al., 2025; Tzouvaras et al.). As a third aspect, user perception is important: objective assessments of lighting are not enough to determine user satisfaction and/or visual comfort (perceived adequacy level of the lighting) (de Kort, 2019; e Silva et al.; Veitch & Newsham, 1996). Fourth, heritage and adaptive-reuse projects need interventions which are able to enhance the current performance of the existing building while maintaining the values and architectural character of the building (Augustiniok et al., 2025).

In reading spaces, direct measurement of illuminance has proven to be beneficial in previous library research (e Silva et al.), and research on visual comfort has identified the importance of daylight, glare and other lighting factors (Tzouvaras et al.). Regrettably, the available literature is rather scarce when it comes to empirical studies of combined measured illuminance, users' perception and architectural dimensions of a library in a heritage library in Pakistan.

The same is more pronounced in the case of Quaid-e-Azam Library, Lahore, which falls in the category of one of the most beautiful libraries in Pakistan. It is appreciable in relation to Quaid-e-Azam Library, Lahore, which is one of the most beautiful libraries in Pakistan. The hall was designed with the spatial characteristics of a Neo-Classical building of the 19th century, yet also to satisfy the requirements of the modern era: a space that is highly utilised for reading and research. It has a large arched window, a high ceiling, a great interior space depth and an average interior light mix (daylight / artificial lighting), giving rise to the possibility of significant light changes in the interior. A systematic evaluation of this specific context is missing, however, from the literature reviewed.

Therefore, in the present study, a hybrid approach of field measurement of illuminance, questionnaires to assess user perception and architectural analysis is combined. This method not only considers the intensity of adequate light but also sheds new light on the distribution of light in a heritage reading environment and how it is perceived. The evidence created provides a foundation to identify visual and functional lighting improvements that will meet the requirements without sacrificing the architectural integrity of Montgomery Hall.

Case Study and Research Methodology

Case Study: Montgomery Hall, Quaid-e-Azam Library

The empirical investigation was conducted in Montgomery Hall, one of the two principal historic halls forming the Quaid-e-Azam Library (QAL), located within Bagh-e-Jinnah, Lahore. Montgomery Hall was constructed in 1866 during the British colonial period and follows the Neo-Classical architectural style. The hall was originally intended for social gatherings and civic activities and was subsequently adapted for use as a public reading and study space. The Quaid-e-Azam Library was opened to the public in 1984, and Montgomery Hall currently serves students, researchers, CSS/PMS aspirants, faculty visitors, and regular readers.

Figure 1. External View of Quaid-e-Azam Library

Figure 2. Evening View of Quaid-e-Azam Library

The selection of Montgomery Hall was based on its historical significance, mixed natural and artificial lighting environment, high user occupancy, architectural complexity, and its adaptation from a historic social building to a contemporary academic reading environment. The hall's high ceilings, large arched windows, substantial spatial depth, and heritage character create particular lighting conditions that require assessment in relation to modern reading activities.

The study specifically focused on the selected reading-hall area of Montgomery Hall to evaluate the adequacy and distribution of illuminance for prolonged reading activities. The existing lighting environment consists of daylight entering through the large arched windows together with artificial lighting provided by ceiling-mounted and wall-mounted luminaires.

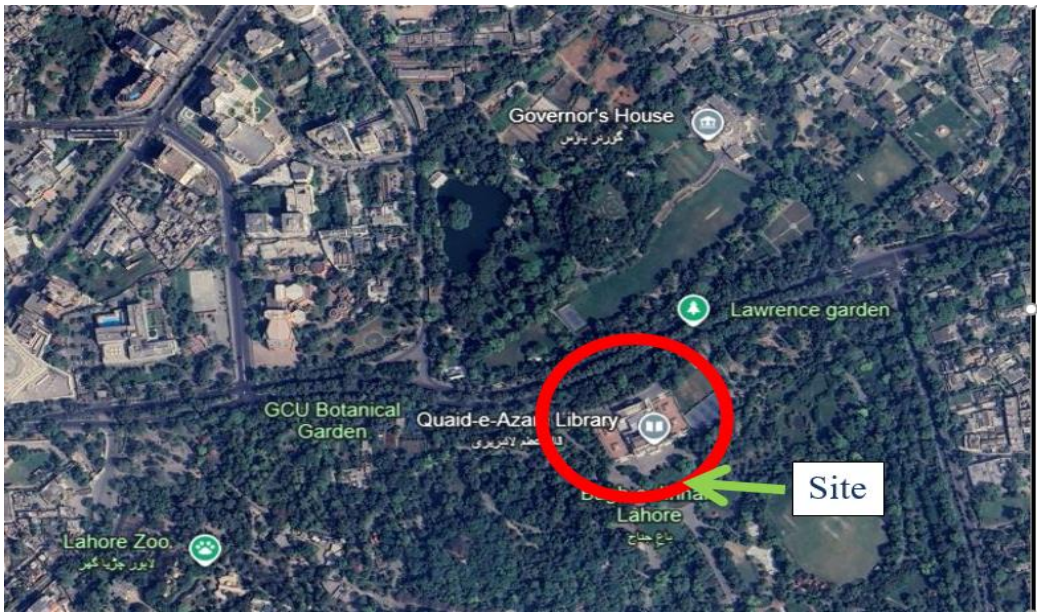


Figure 3. Satellite View of the Study Site

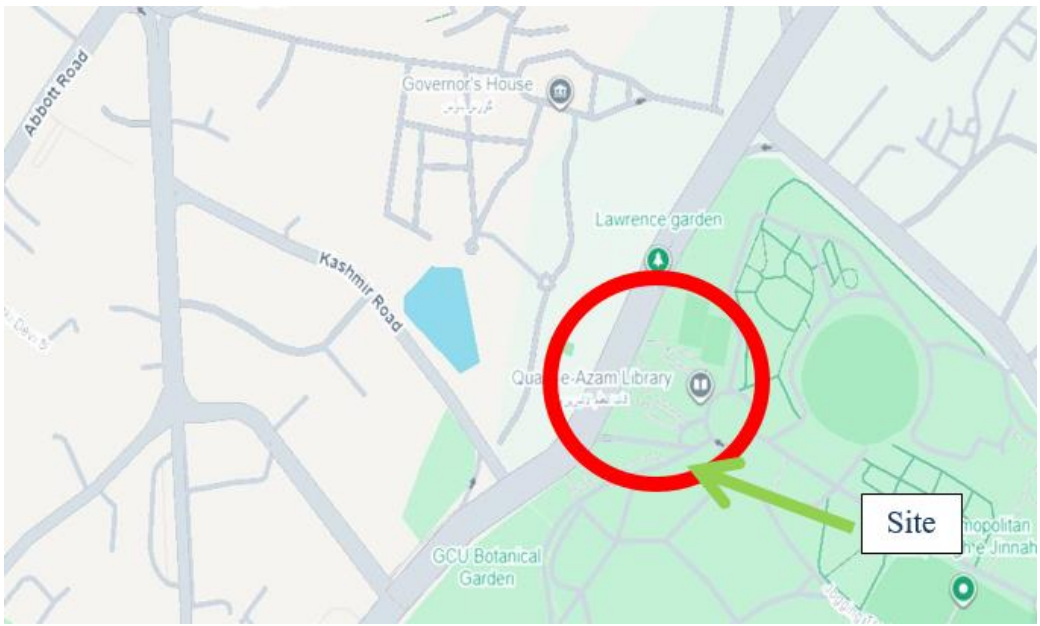
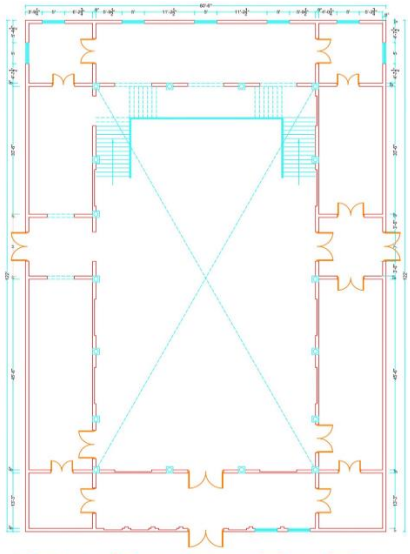
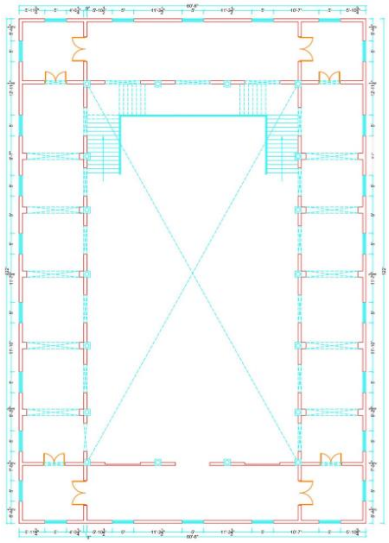


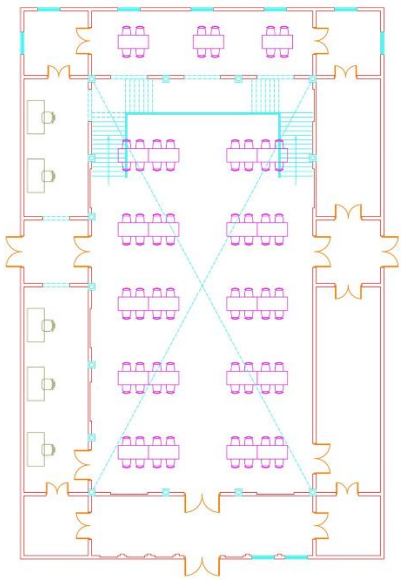
Figure 4. Map View of the Study Site

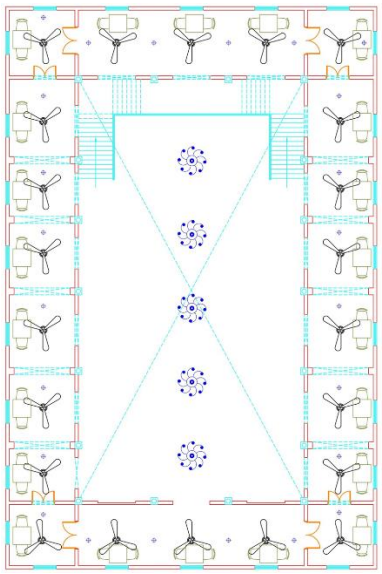
The existing historical-background text concerning Lawrence Hall (1861), Montgomery Hall (1866), the 1878 covered corridor, Lahore and Mian Mir Institute, Lahore Gymkhana Club, the 1972

administrative training academy, the 1981 establishment of QAL, its opening to the public in 1984, and the 2013 expansion should be retained as a short contextual paragraph here rather than repeated later in the methodology.









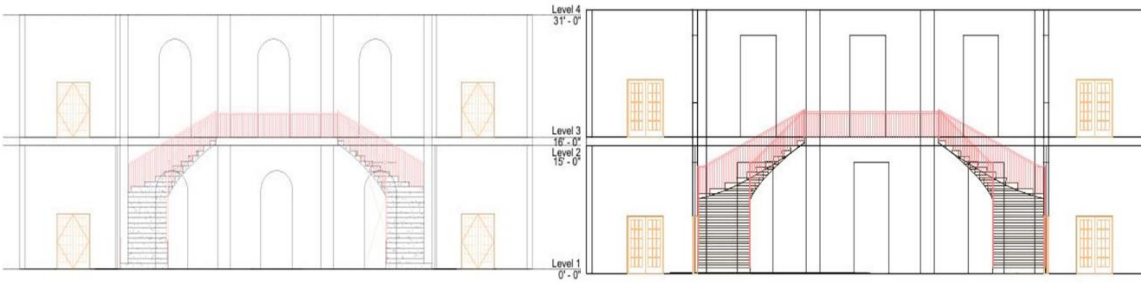


Figure 5. Ground and first floor plans, furniture layout plans, sections, and elevations of Montgomery Hall, Quaid-e-Azam Library, Lahore.

Architectural Characteristics

Montgomery Hall represents a significant example of Neo-Classical colonial architecture. Its architectural configuration directly influences the distribution and quality of natural and artificial lighting within the reading environment. The hall has high vaulted ceilings, thick masonry walls, large arched windows, decorative elements, and a large spatial volume.

The approximate architectural dimensions recorded during the field investigation are presented in Table 2.

Table 2. Architectural Dimensions of Montgomery Hall

Parameter	Measurement
Hall Length	108 ft
Hall Width	49 ft
Hall Height	52 ft
Total Floor Area	504 m^2
Ground Floor Windows	3
First Floor Windows	20
Window Height	8 ft
Window Width	5 ft

The large arched windows located on the east and west façades allow substantial daylight penetration, particularly during morning and afternoon hours. The high vaulted ceiling creates a large interior volume, while the thick masonry walls influence the depth to which daylight penetrates into the hall. Decorative chandeliers and wall-mounted fixtures also contribute to the ambient lighting environment.

The architectural features relevant to the lighting conditions can be summarised as follows:

- High vaulted ceilings create a large interior volume and reduce the efficiency of artificial lighting.

- Thick masonry walls provide thermal stability but limit light penetration depth.
- Large arched windows allow substantial daylight entry during daytime hours.
- Decorative chandeliers and wall-mounted fixtures contribute to ambient illumination.
- The symmetrical interior planning enhances spatial aesthetics but produces uneven lighting zones.

The architectural configuration originally prioritised natural daylight and visual grandeur rather than the ergonomic requirements of a modern library. Consequently, the present reading environment experiences differences between bright window-adjacent areas and deeper interior areas.

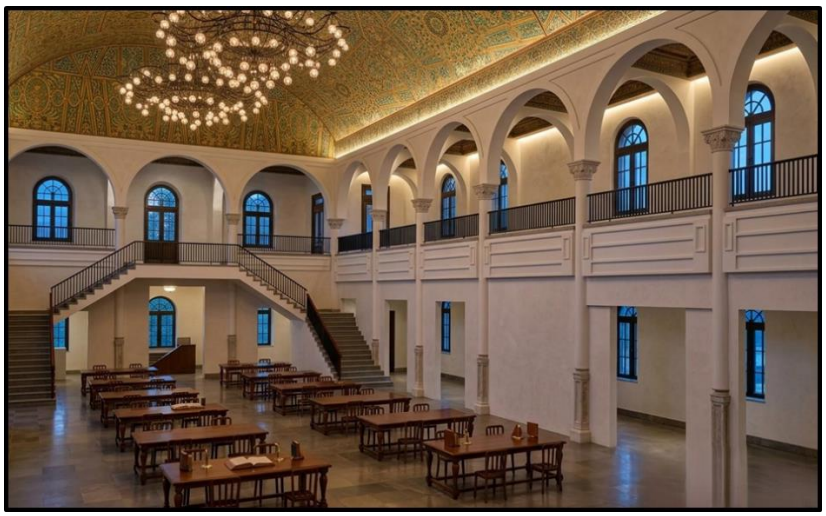


Figure 6. Existing 3D model and rendered views of Montgomery Hall, Quaid-e-Azam Library, Lahore.

Existing Lighting System

Montgomery Hall utilises a combination of natural daylight and artificial lighting fixtures (Fig. 7 & 8). The artificial lighting system recorded during the field investigation is summarised in Table 3.

Table 3. Existing Lighting System of Montgomery Hall

Lighting Component	Quantity	Average Power
Ceiling LED Fixtures	23	18–25 W
Down Ceiling Fixtures	5	25–50 W
Wall Mounted Fixtures	11	18–32 W

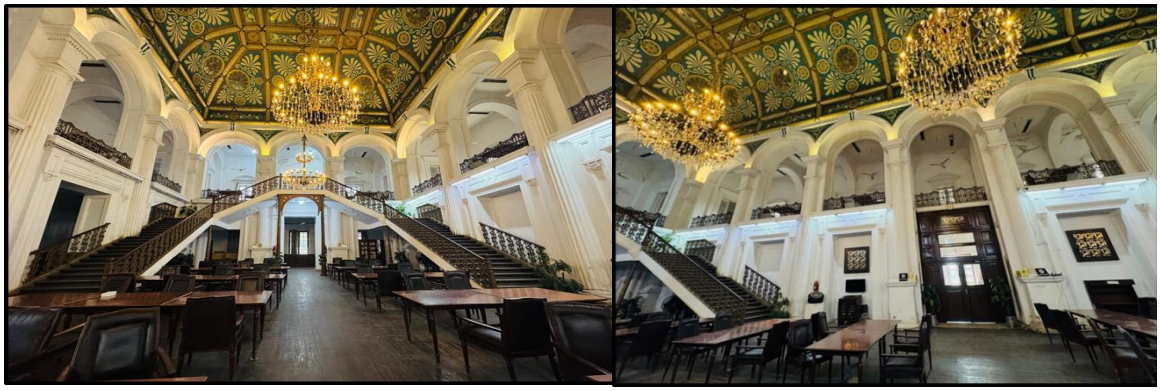


Figure 7. Existing luminaire types, locations, and lighting layout in Montgomery Hall, Quaid-e-Azam Library, Lahore.

These luminaires provide general ambient lighting throughout the reading space. However, the high ceiling height and wide spatial layout affect the efficiency of artificial lighting, particularly within the central areas of the hall.

Figure 8. Types and specifications of luminaires used in the lighting simulation, reflecting the actual lighting setup of Montgomery Hall, Quaid-e-Azam Library, Lahore.

Field Measurement Procedure

The field investigation involved architectural documentation, physical measurement of the hall, and quantitative measurement of illuminance. The following instruments and materials were used for data collection:

1. Digital Lux Meter: Used to measure illuminance levels in lux at different locations within the hall.
2. Digital Measuring Meter (Laser Distance Meter): Used to measure the physical dimensions of the hall, including length, width, ceiling height, and window spacing.
3. Measuring Tape: Used to verify smaller distances, including desk spacing and fixture placement.
4. AutoCAD Layout Plan: Used to prepare a scaled layout and establish the measurement grid.
5. Field Data Recording Sheets: Used to document the lux readings collected during the site survey.

Measurement Grid

To obtain representative lighting data, the selected study area was divided into a 3 m × 3 m measurement grid using the AutoCAD floor layout. A total of 20 measurement points were selected across the hall (Figure 9). The measurement points included:

- Window-adjacent areas;
- Central reading tables;
- Bookshelf zones; and
- Circulation pathways.

This arrangement was used to obtain a spatial representation of the lighting distribution within the selected reading area.

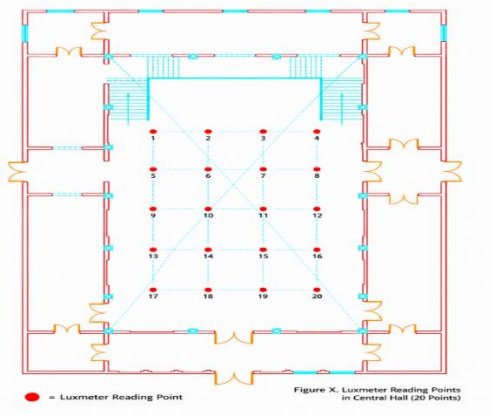


Figure 9. AutoCAD floor plan showing the measurement grid and 20 evenly distributed lux meter reading points within the central hall of Montgomery Hall, Quaid-e-Azam Library, Lahore.

Lux Measurement Procedure

Illuminance measurements were conducted using a digital lux meter under the normal operational conditions of the library. The lux-meter sensor was positioned at a height of 0.75 m above the floor, representing the average reading surface level.

Measurements were recorded at the 20 predefined grid points during daytime hours between 11:00 AM and 2:00 PM (Figure 10). This period was selected to account for the combined contribution of daylight and artificial lighting. At each measurement point, the sensor was positioned horizontally to obtain the illuminance reading. The recorded values were subsequently tabulated and averaged to determine the overall lighting condition of the selected study area.

Figure 10. On-site documentation of the field survey, including observations of existing lighting conditions and the lux meter and measuring instruments used for illuminance measurements

Questionnaire Survey

A structured questionnaire survey was conducted to evaluate users' perceptions regarding the lighting quality inside the Quaid-e-Azam Library, particularly within Montgomery Hall. The survey examined how the existing lighting conditions affected visual comfort, reading efficiency, safety perception, and user satisfaction during prolonged study periods.

The questionnaire was organised around four primary assessment parameters:

1. Lighting Performance and Visibility
2. Satisfaction with Lighting
3. Visual Comfort and Fatigue
4. Safety and Security Perception

The survey included different categories of library users, including undergraduate students, CSS/PMS aspirants, postgraduate researchers, faculty visitors, and regular readers. These groups were considered because they use the reading halls for extended periods and interact continuously with the lighting environment during their study activities.

The questionnaire included closed-ended and observational questions addressing brightness adequacy, visibility of reading material, glare near windows, eye strain, and comfort during prolonged reading, daylight preference, and alertness, colour of light, and overall satisfaction with the lighting environment. The questionnaire items and their stated references in the research paper are presented in Table 4.

Table 4. Questionnaire Items Used for Assessment of User Perception

Reference	Factor	Questionnaire Item
(Kahaki et al., 2022)	Lighting perception	How would you rate the brightness of the lighting?
		How satisfied are you with the lighting quality?
(Xue et al., 2014)		Do you prefer more or less daylight?
		Can you work without artificial lighting?
(Avcı & Memikoğlu, 2017)	Visual comfort	Do you feel discomfort from brightness?
(Giarma et al., 2017)		How satisfied are you with the amount of daylight?
		Do you prefer more daylight or less?
(Avcı & Memikoğlu, 2017)	Visual perception	Is the lighting adequate for reading?
(Giarma et al., 2017)		Rate your window-related discomfort.
(Avcı & Memikoğlu, 2017)	Mood & perception	Does lighting affect your alertness?
(Kahaki et al., 2022)		This colour of light allows me to carry out tasks.
		The lighting is too warm / too cold.

The questionnaire references stated in the paper are retained as follows: Kahaki et al. (Kahaki et al., 2022), Xue et al. (Xue et al., 2014), Avcı and Memikoğlu (Avcı & Memikoğlu, 2017), and Giarma et al. (Giarma et al., 2017).

Data Analysis

The field measurements and questionnaire responses were analysed separately and subsequently considered together to assess the lighting environment of Montgomery Hall.

Analysis of Illuminance Measurements

The recorded lux values were first tabulated according to the measurement points. The following analytical procedures were applied:

- The recorded lux values were tabulated for all measurement points.
- The average illuminance level was calculated for the study area.
- The lighting uniformity ratio was evaluated by comparing the minimum and maximum illuminance values.
- The measured illuminance values were compared with the recommended lighting levels for the relevant library areas.
- This analysis was used to identify areas with insufficient illumination, excessive brightness, and uneven light distribution.

Questionnaire Data Analysis

The questionnaire responses were analysed using SPSS regression analysis, as reported in the research paper. The analysis examined the relationship between lighting quality and user-related outcomes, including visual comfort, reading performance, and user satisfaction.

The paper reports that the SPSS analysis indicated an effect of lighting quality on visual comfort, reading performance, and user satisfaction. The analysis also considered the role of uniform light distribution, adequate illuminance, glare-free lighting, and daylight integration in relation to the users' responses.

Lighting Assessment Criteria

The measured illuminance values were evaluated against the lighting levels stated in the research paper for library environments. The assessment focused on the adequacy of illumination for different functional areas within the hall.

Table 5. Lighting Assessment Criteria Used in the Study

Area	Recommended Illuminance
Reading Areas	300–500 Lux
Bookshelves	200–300 Lux

Circulation Areas	100–200 Lux

The paper states that these recommended levels are based on guidelines provided by the Illuminating Engineering Society (IES) and the Chartered Institution of Building Services Engineers (CIBSE).

The assessment therefore considered the measured illuminance in relation to the functional requirements of reading areas, bookshelf zones, and circulation areas. In addition to illuminance adequacy, the study considered the spatial distribution of light by examining the difference between minimum and maximum measured values and the resulting uniformity condition. The assessment also considered the relationship between the measured lighting conditions and the subjective responses obtained through the questionnaire, particularly with respect to brightness, daylight preference, reading adequacy, window-related discomfort, alertness, and colour of light.

The combined field and questionnaire assessment provided the basis for identifying areas of inadequate illumination, excessive brightness, glare, and uneven light distribution within Montgomery Hall and for subsequently discussing possible lighting improvements while maintaining the architectural character of the heritage building.

Results

Existing Lighting Conditions of Montgomery Hall

The field investigation of Montgomery Hall at the Quaid-e-Azam Library, Lahore, identified variations in the distribution of natural and artificial lighting within the reading hall. Natural daylight entering through the large arched windows contributes substantially to the illumination of the reading areas during daytime. However, the distribution of daylight is not uniform throughout the hall.

Higher illuminance was observed in areas adjacent to the windows, while comparatively lower illumination was recorded in the central interior and bookshelf zones. The existing artificial lighting system, consisting of ceiling-mounted LED fixtures, down-ceiling fixtures, and wall-mounted luminaires, supplements daylight. Nevertheless, the high vaulted ceiling and large spatial volume influence the distribution of artificial light, particularly in the central areas.

The field observations identified the following characteristics of the existing lighting environment:

- Higher illuminance near windows due to daylight penetration.
- Moderate illumination in central reading areas, primarily supported by artificial lighting.
- Lower illumination in interior bookshelf zones, potentially affecting reading visibility.
- Glare near window-adjacent seating, particularly during afternoon sunlight.
- Uneven light distribution, resulting in contrasting bright and dark areas across the hall.

These observations indicate that the lighting environment varies according to the location within the hall. Although daylight contributes to illumination, its distribution creates challenges in maintaining consistent lighting conditions throughout the reading space.

Spatial Distribution of Illuminance

The spatial distribution of illuminance was examined using the measurement grid established across the selected study area (Figures 11 & 12). The grid consisted of 20 measurement points arranged on a 3 m × 3 m layout, with readings taken at a workplane height of 0.75 m above the floor during daytime operational hours between 11:00 AM and 2:00 PM.

The observed lighting conditions showed differences between window-adjacent areas, central reading tables, bookshelf zones, and circulation pathways. Window-adjacent areas received greater daylight, whereas areas deeper within the hall received comparatively less natural illumination. Artificial lighting provided supplementary illumination but did not eliminate the differences between brighter and darker areas.

The resulting distribution indicates that the lighting environment is influenced by the interaction of daylight penetration, window location, the hall's architectural configuration, and the arrangement of artificial lighting fixtures.

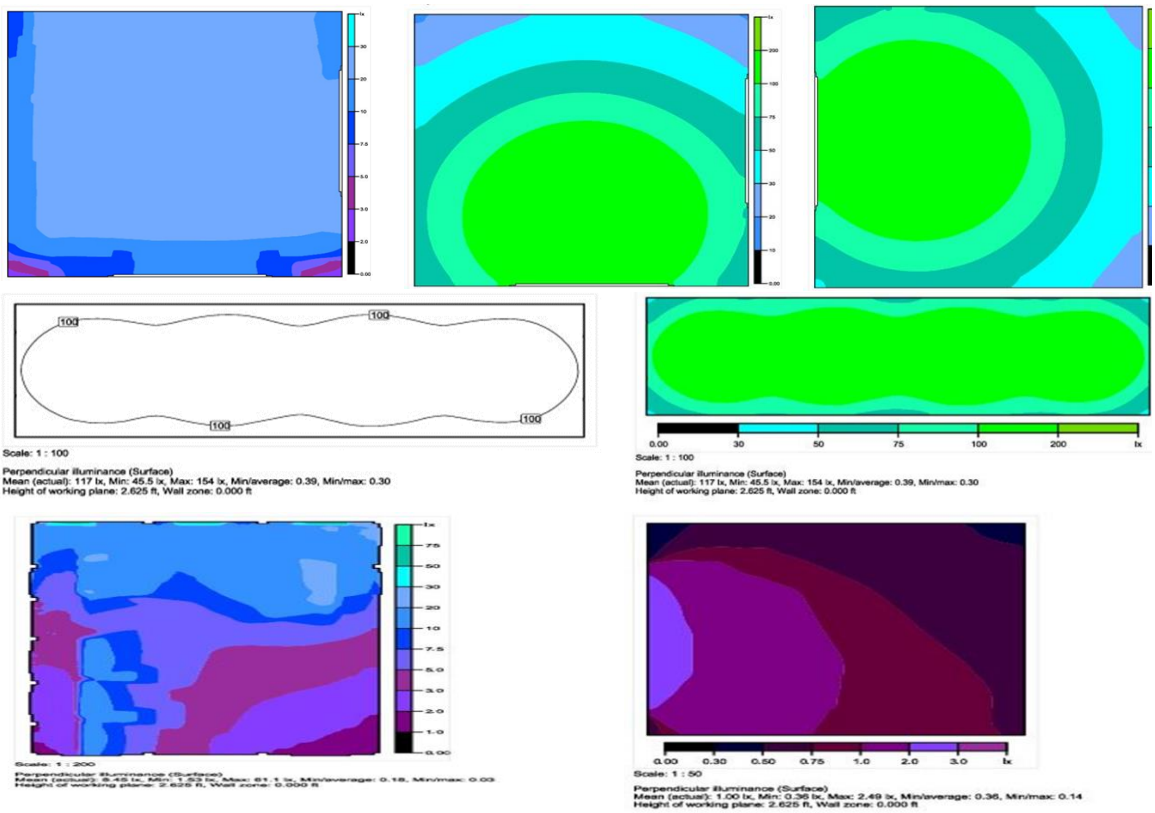


Figure 11. Workplane (Hall and Corridors) illuminance distribution under combined daylight and artificial lighting conditions

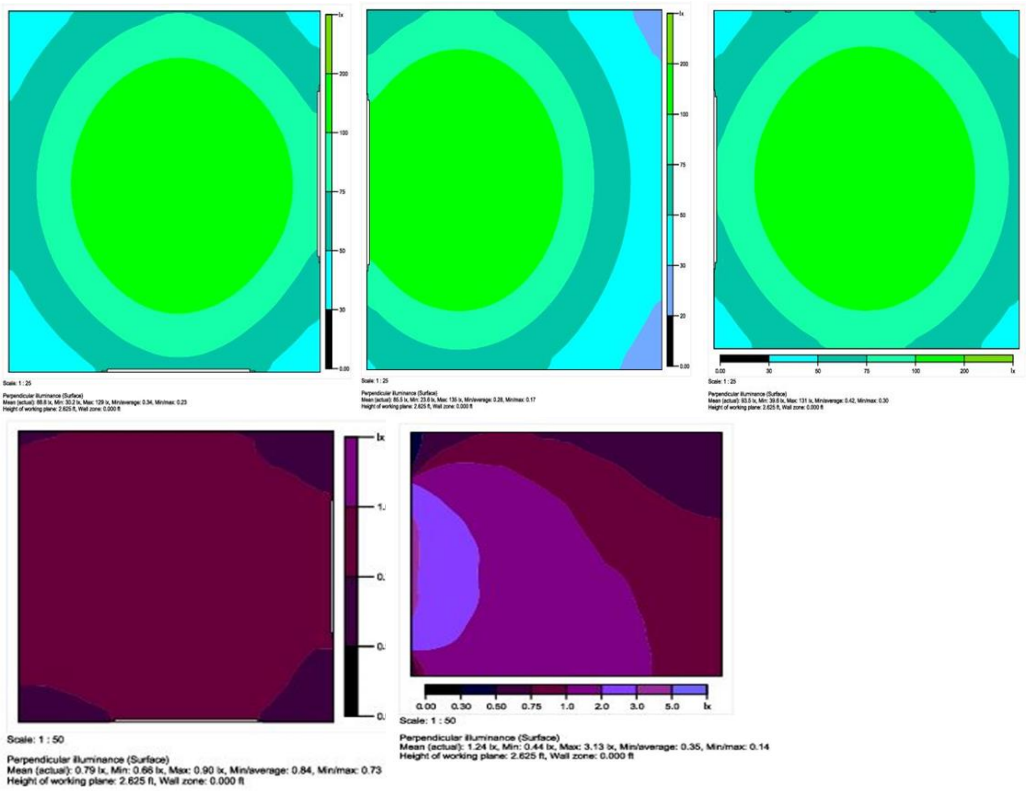


Figure 12. Workplane (Hall and Corridors) illuminance distribution under artificial lighting conditions only

The workplace figures showing combined daylight and artificial lighting, followed by the workplace figures showing artificial lighting only, represent the lighting configuration used in the assessment.

Comparison with Lighting Assessment Criteria

The measured lighting conditions were intended to be evaluated against the recommended illuminance levels for different functional areas of the library, as presented in Section 3.6. The assessment criteria stated in the research paper are 300–500 lux for reading areas, 200–300 lux for bookshelves, and 100–200 lux for circulation areas.

The field observations indicate that the hall does not experience uniform illumination across all functional zones. Areas close to the windows receive comparatively higher daylight, while central and bookshelf areas experience lower illumination. Glare near window-adjacent seating is also identified as a concern.

These observations suggest that lighting adequacy varies according to the location and function of each area. However, a complete numerical assessment of compliance requires the recorded lux values for the individual measurement points and their comparison with the relevant recommended ranges.

Questionnaire and Statistical Analysis Results

The questionnaire survey aimed to explore the perception of users about the lighting quality in the Quaid-e-Azam Library, particularly in the Montgomery Hall of the library. The questionnaire focused on lighting perception, satisfaction with lighting, visual comfort, colour of the light, window discomfort, reading visibility, alertness, and lighting satisfaction.

According to the research paper, SPSS regression analysis was performed to see the relationship between lighting quality and all user-related parameters such as visual comfort, reading performance, user satisfaction, etc.

Lighting level was correlated with the subjective feeling of visual comfort, reading performance and user satisfaction as reported. Favourable illuminance and light uniformity were reported to have a favourable effect on better visibility and reduced eye strain during lengthy study periods. The paper also points to lighting systems that are glare-free and lighting that integrates daylight aspects to concentration, comfort, and reading efficiency. Good lighting distribution and high illuminance, however, were claimed to have a negative impact on user productivity and visual comfort, whereas the opposite was reported to have a positive impact. The bright areas close to the windows and darker interior areas found in the field correspond to the results of this analysis, which show that illumination distribution was uneven across the hall.

According to SPSS regression analysis, inside the library, the quality of the lighting environment significantly influences the visual comfort, reading performance and satisfaction of library users. A uniform distribution of light and sufficient light levels will enhance legibility when studying for extended periods and minimise eye fatigue. Good light integration and good glare reduction increase concentration, comfort and reading efficiency. Low illuminance and unbalanced lighting have a negative impact on user productivity, and visual comfort is also revealed from our results.

Across the board, good lighting levels are important in providing an environment for safe, comfortable learning within Montgomery Hall.

Normality Test

The Kolmogorov–Smirnov and Shapiro–Wilk tests indicated (Table 6) significant deviations from normality across all questionnaire variables ($n = 129$; $p < 0.001$). The results covered perceived brightness, lighting quality, daylight preference, artificial lighting, visual discomfort, reading adequacy, alertness, and the overall lighting conditions and occupant responses. Accordingly, the data were not normally distributed, and this characteristic was considered when selecting appropriate statistical procedures.

Table 6. Results of the Normality Test for the Study Variables.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Question / Variable	Statistic	df	Sig.	Statistic	df	Sig.
How would you rate the brightness of the lighting?	.290	129	<.001	.805	129	<.001
How satisfied are you with lighting quality?	.234	129	<.001	.884	129	<.001
Do you prefer more or less daylight?	.276	129	<.001	.870	129	<.001
Can you work without artificial lighting?	.220	129	<.001	.888	129	<.001
Do you feel discomfort from brightness?	.256	129	<.001	.843	129	<.001
How satisfied are you with the amount of daylight?	.239	129	<.001	.871	129	<.001
Do you prefer more Artificial light or less?	.237	129	<.001	.841	129	<.001
Is the lighting adequate for reading?	.219	129	<.001	.831	129	<.001
Rate your window-related discomfort	.217	129	<.001	.852	129	<.001
Does lighting affect your alertness?	.234	129	<.001	.844	129	<.001
This colour of light allows me to carry out tasks	.248	129	<.001	.809	129	<.001
The lighting is too warm / too cold	.213	129	<.001	.865	129	<.001
Lighting Conditions	.219	129	<.001	.831	129	<.001
Occupant Responses	.248	129	<.001			

a. Lilliefors Significance Correction

Regression Model Summary

The regression analysis examined occupant responses in relation to satisfaction with daylight availability and overall lighting quality (Table 7). Model 1, which included satisfaction with the amount of daylight as a predictor, produced an R value of 0.327 and an R^2 of 0.107, with an adjusted R^2 of 0.100 and a standard error of 1.336. This indicates that the model accounted for 10.7% of the variance in occupant responses. Model 2 incorporated both satisfaction with daylight availability and satisfaction with lighting quality. Its R value increased to 0.382, while R^2 increased to 0.146 and adjusted R^2 to 0.132, with the standard error decreasing to 1.312. The second model therefore explained 14.6% of the variance in occupant responses, representing a 3.9-percentage-point increase in explained variance compared with Model 1.

Table 7. Regression Model Summary for Predicting Occupant Responses.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.327[a]	.107	.100	1.336
2	.382[b]	.146	.132	1.312

a. Predictors: (Constant), How satisfied are you with the amount of daylight?

b. Predictors: (Constant), How satisfied are you with the amount of daylight?, How satisfied are you with lighting quality?

Regression Model Significance

The ANOVA results (Table 8) confirmed that both regression models were statistically significant. Model 1 yielded ($F = 15.212$), ($p < 0.001$), while Model 2 yielded ($F = 10.749$), ($p < 0.001$). These findings indicate that the predictors collectively explained a statistically significant proportion of variation in occupant responses in both models. Model 2 demonstrated greater explanatory power by incorporating satisfaction with lighting quality alongside satisfaction with daylight availability. However, the ANOVA results alone do not establish the individual significance or direction of each predictor's relationship with occupant responses.

Table 8. ANOVA Results for the Regression Models Predicting Occupant Responses.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.167	1	27.167	15.212	<.001[b]
	Residual	226.802	127	1.786		
	Total	253.969	128			
2	Regression	37.016	2	18.508	10.749	<.001[c]
	Residual	216.953	126	1.722		

Total	253.969	128

a. Dependent Variable: Occupant Responses

b. Predictors: (Constant), How satisfied are you with the amount of daylight?

c. Predictors: (Constant), How satisfied are you with the amount of daylight?, How satisfied are you with lighting quality?

The regression results indicate that satisfaction with daylight availability and lighting quality jointly provide a statistically significant explanation of occupant responses in Montgomery Hall, Quaid-e-Azam Library, Lahore. The increase in R^2 from 0.107 to 0.146 suggests that including lighting-quality satisfaction improved the explanatory capacity of the model. Nevertheless, Model 2 explained 14.6% of the variance, indicating that other factors not included in the model may also contribute to occupant responses. These findings highlight the relevance of both daylight and overall lighting quality to occupants' reported experiences, while the magnitude and direction of their individual effects require confirmation from the regression coefficients table.

Lighting Assessment Model and Energy Calculations

The research paper presents a lighting assessment model developed using the architectural geometry of Montgomery Hall, including reading areas, circulation pathways, bookshelf zones, and window openings. The model considers the contribution of natural daylight and artificial lighting fixtures to the interior lighting environment.

The model was used to examine luminaire placement, fixture spacing, mounting height, and light distribution, with attention to the distribution of illumination across the hall. The stated purpose was to assess the existing lighting arrangement and support the identification of potential improvements in lighting uniformity, visual comfort, glare control, and energy efficiency while retaining the architectural character of the heritage building.

The energy-calculation section records additional geometric measurements for the lighting model. These values are reproduced in Table 9.

Table 9. Geometric Measurements Reported for the Lighting and Energy Model

Component	Measurement (Imperial)	Measurement (Metric Approx.)
Hall Height	48 feet	14.6304 m
Arc-to-Arc Distance (Span)	14 feet	4.2672 m
Main Hall Width Including Walkway	80 feet	24.384 m
Central Hall Area (Median)	49 feet	14.9352 m
Walkway Width	14 feet 3 inches	4.2672 m

The lighting assessment model (Figures 13 & 14) incorporates both daylight penetration and artificial lighting fixtures. The proposed lighting strategy described in the paper aims to improve light distribution, reduce glare and dark zones, support visual comfort, and improve energy efficiency without compromising the historic architectural character of Montgomery Hall.

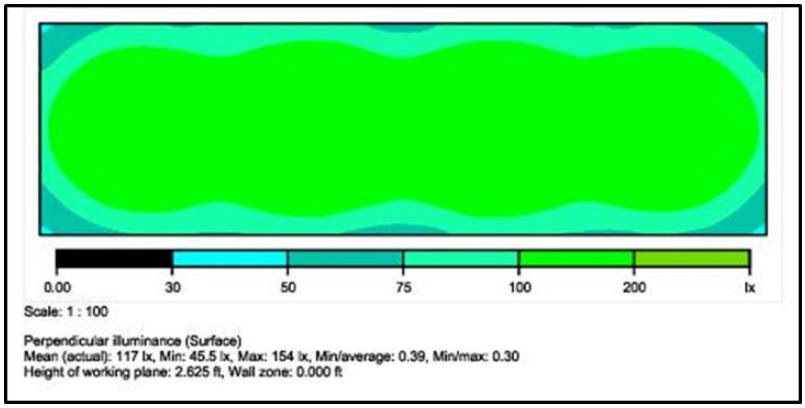


Figure 13. Work plane illuminance distribution in the library hall after lighting interventions, showing the combined effect of daylight and artificial lighting.

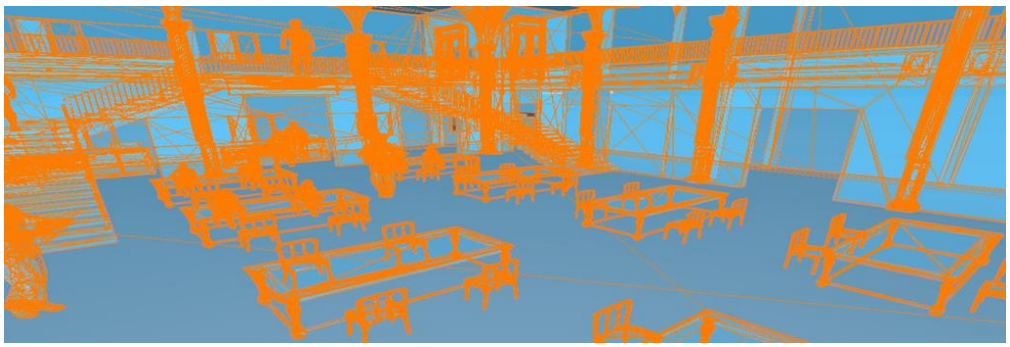


Figure 14. DIALux simulation model of the library hall during the lighting assessment.

Results presented in the paper show that the Neo-Classical structure of Montgomery Hall, its large arched windows, high vaulted ceiling, and pre-existing artificial lighting system influence the lighting environment of the building. The addition of daylight has a significant impact in areas close to the windows and also contributes to the illumination of the central and bookshelf zones in comparison.

The key lighting issues found from field observations are the uneven lighting distribution and glare near the windows in the window-adjacent seats. The current artificial lighting system ensures additional lighting but has an irregular distribution. An additional relationship between lighting quality and user-related outcomes, i.e. visual comfort, reading performance and satisfaction, is also reported in terms of the SPSS interpretation.

The lighting assessment model will form the basis to scrutinise the distribution of natural and artificial light, and to explore the opportunities for enhancing the illumination and glare, whilst creating energy-efficient solutions. The modern requirements for a reading environment are highlighted whilst the character of the heritage building is maintained.

Discussion

This study quantifies the interplay between historic aspects of a city hall building, daylighting, and current lighting, ultimately showing the lighting environment of Montgomery Hall to be a strong function of this interplay. Field measurements indicated relatively high levels of illuminance in the areas next to the large arched windows, while the reading areas and bookshelf areas measured relatively low levels. This spatial variation is significant as it is not sufficiently representative of the lighting quality of a reading environment to judge the environment merely from the light level at any point of interest, but also from the distribution of light and its visual balance. This approach is in agreement with the principles of the quality of light discussed in references (Boyce, 2005) and (Veitch & Newsham, 1996) by Boyce and Veitch and Newsham respectively, that emphasise that visual performance and comfort rely on the quality and distribution of light and not just illuminance.

Measured conditions describe the specific challenge of providing even lighting in an historic property that contains a substantial interior space. Montgomery Hall has a high vaulted ceiling, great depth and great daylighting with big arched windows. Therefore, the areas immediately around the windows receive illumination directly, while the interior spaces receive more illumination from artificial lights. The effect is that a non-uniform environment is created of light and darker areas. Some of the same issues of evaluating illuminance were also found in earlier lighting assessment research (e Silva et al.). The results thus suggest that attributes supportive of the heritage character of Montgomery Hall also pose problems in achieving modern lighting standards.

It was found that during the time of measurements, Daylight was one of the important contributing factors to the illumination of the hall. The results, however, indicate that an increase in daylight does not directly translate into an improvement in the visual conditions throughout the space. Lots of bright and glaring situations in the areas around the windows, especially on the west end of the building during the hours of daylight. In contrast, those further away from windows had relatively low levels of light. The result reinforces the idea that visual comfort aspects, along with availability, must be taken into account when it comes to daylight. In the writing of Boubekri (Boubekri, 2008) and de Kort (de Kort, 2019), there is a strong focus on the role of daylighting and lighting in human responses, whereas Tzouvaras et al. (Tzouvaras et al.) note the importance of glare and other visual-comfort parameters for the evaluation of luminous environments.

This is especially significant as the 'hall' is used for extended periods of reading/study, close to the windows (observed glare). Excessively high illumination or contrast levels in the field of view can result in a poor visual environment and not meet a high level of illumination. The current results are in line with the literature on visual comfort and acknowledge that glare is one of the characteristics of the light quality (Tzouvaras et al.). The results also corroborate the relevance of the SLL Code for

Lighting as a relevant reference for library and study environments, especially for uniformity of lighting and glare control (Duff, 2012). The glare observed in the present study was not calculated as a formal glare index; for this reason, it should be compared and taken as a field-based observation and not as a quantitative measure of glare.

The relatively weaker illumination in the central and bookshelf regions is further evidence of non-uniform distribution of light in the hall by the present set-up of the artificial lighting system. Prior to installation, there was a significant amount of ceiling height and space configuration in the building of Montgomery Hall, which influenced the effectiveness of the LED system. This is significant for several reasons as well because replacing luminaires with more efficient lighting sources is not enough to solve problems with spatial distribution. Positioning, light distribution, mounting conditions, and considering light source and daylight are other factors that affect the quality of lighting. It is also observed from the literature reviewed in this study that illuminance is not the only parameter to consider for lighting quality (Boyce, 2005; van Bommel, 2019; Veitch & Newsham, 1996).

A human-centred perspective on the measured lighting conditions is provided with the questionnaire and the SPSS findings. This analysis suggests that there is a correlation between lighting quality, visual comfort, reading performance and user satisfaction. In particular, good illumination levels and more even lighting were linked with better visual comfort and poor illumination and glare were linked with worse visual conditions. The results obtained are broadly similar to the outcomes of the questionnaire-based studies reported in the present work, especially that of Kahaki et al. (Kahaki et al., 2022), showing the importance of subjective user responses in the assessment of lighting environments, and of Xue et al. (Xue et al., 2014), Avcı and Memikoğlu (Avcı & Memikoğlu, 2017) and Giarma et al. (Giarma et al., 2017). It is therefore beneficial that the present study will combine both physical illuminance observations and users' perceptions instead of relying solely on numerical measurements.

The results also show that there is a difference between the current lighting conditions and the ones expected for modern reading standards in the library. Based on the literature review, the illuminance level for the general reading range was identified as 300-500 lux, and the importance of uniformity and control of glare was emphasised (Duff, 2012; Veitch & Newsham, 1996). Montgomery Hall incorporates some locations with very good daylight and other areas that are comparatively badly lit. Ensuring acceptable lighting conditions at selected points is not guaranteed to mean that an acceptable lighting environment is created over the whole reading space. The study, thus, supports the need for spatiological assessment of the performance of lighting rather than assessing the hall as a uniformly illuminated volume.

These findings, however, are complicated by the fact that Montgomery Hall has a historical character. In contrast to a new library building, massive alterations of the architectural fabric, ceiling, windows, or other historic features may not be an appropriate course of action. The concept of adaptive reuse is also discussed in the literature, specifically the ability to respect the values of historic buildings in conjunction with the contemporary functional requirements. Hence, the light

deficiency problems observed in this work should not be solved only using a traditional replacement or installation approach. Rather, enhancements need to be sensitive to the architectural character of the hall and must aim to augment the lighting performance and efficiency while remaining respectful of the historic qualities of the hall.

Based solely on energy consumption, the results indicate that the association between daylighting and artificial light should also be reviewed. In this scenario, there are already a large number of windows that allow daylight into Montgomery Hall, but there are no daylight controls in place, which hinders the adjustment of artificial light to meet varying daylight conditions. In this study, literature was reviewed that identified energy-efficient lighting and retrofit as becoming important aspects of the present building performance (Mahar et al.; Mendonca et al., 2025). Thus, a better lighting design in Montgomery Hall would be to achieve a better distribution of artificial light and to use daylight better.

In summary, the results show that there is nothing particularly lacking in light in Montgomery Hall. Instead, it is a challenge facing daylight/artificial light spatial imbalance, glare distribution and integration. The study thus suggests the adoption of a layered lighting strategy, with daylight being kept as a key element, artificial light properly positioned, control of glare and installation of energy-efficient luminaires with appropriate lighting controls. This interests visitors and provides functionality, whilst simultaneously reducing unwarranted encroachments on the historic building fabric, and is an approach that is especially suitable for a heritage library.

The discussion then shows that, from a practical standpoint, the challenge of creating a lighting environment that will be both comfortable for extended reading and provide sufficient and uniform lighting for library uses and richness of historic character for Montgomery Hall can be met only through a combination of these three goals. They give light design strategies a framework for further technically sound and architecturally appropriate studies of lighting improvement in Montgomery Hall.

Recommended Lighting Improvement Strategies

Based on the findings (Figure 15), the following measures are recommended to improve lighting quality in Montgomery Hall while maintaining its heritage character:

1. Layered Lighting: Integrate daylight with appropriately distributed artificial lighting to achieve more balanced illumination.
2. LED Retrofit: Optimise the existing LED system through efficient fixture placement and distribution, particularly in darker interior and bookshelf areas.
3. Daylight and Glare Control: Retain natural daylight while introducing appropriate glare-control measures at window-adjacent areas.
4. Lighting Controls: Introduce daylight-responsive dimming and occupancy controls to reduce unnecessary artificial lighting and improve energy efficiency.
5. Heritage-Sensitive Intervention: Ensure all lighting modifications respect the architectural character and historic fabric of Montgomery Hall.

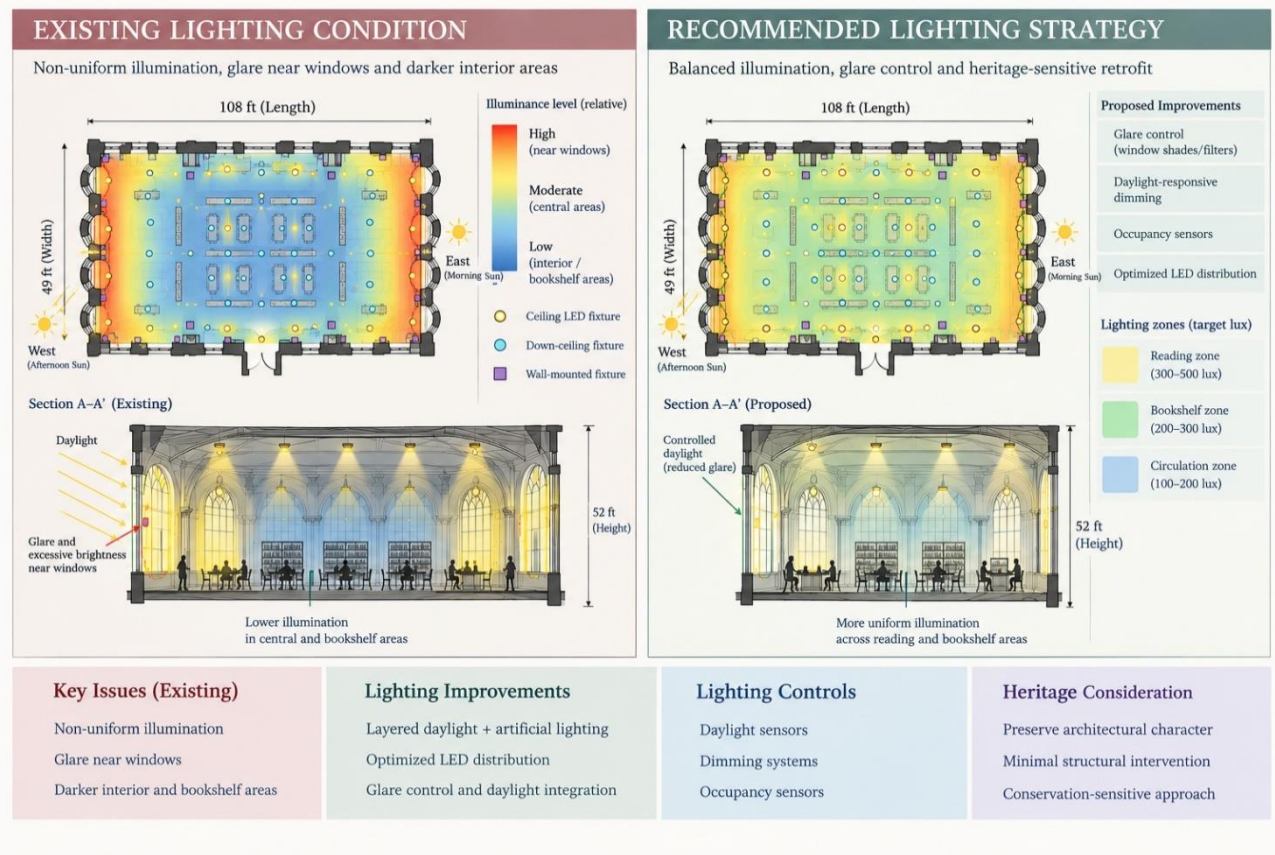


Figure 15. Existing Lighting Problems and Proposed Heritage-Sensitive Lighting Strategy for Montgomery Hall

Limitations

This study has the following limitations:

1. The assessment was limited to Montgomery Hall and did not cover all sections of the Quaid-e-Azam Library.
2. Illuminance measurements were conducted only during daytime hours (11:00 AM–2:00 PM).
3. Seasonal variations in daylight were not evaluated.
4. Night-time artificial lighting was not independently assessed.
5. The study primarily focused on illuminance and did not include quantitative glare indices such as UGR or detailed spectral analysis.
6. User-perception assessment was limited, and a large-scale occupant survey was not conducted.

Conclusion

The light assessment of Quaid-e-Azam Library Montgomery Hall, Lahore, shows that the relationship between the architectural features of the heritage of the hall and the existing lighting of the hall is clear. The study took place in an approximately 108 ft. x 49 ft. x 52 ft. 3.0 m^2 hall consisting of 23 ceiling LED lights, 5 down ceiling lights and 11 wall-mounted lights. Illuminance was measured from 11:00 AM to 2:00 PM in daytime hours on 20 locations on the measurement grid of size 3 m × 3 m at a height of the desk at 0.75 m using the digital lux meter.

Illuminance levels measured were found to be higher in the zones near the windows, moderate illuminance levels in the central "reading zone", and relatively low levels in interior "bookshelf" areas. The field observations also revealed the presence of light and dark spots throughout the hall, and reflected light from window-side seating, especially in the afternoon daylight. The results show that the high volume of natural daylight (specifically, through these large arched windows) is not distributed evenly across the large interior volume. The 52-ft high vaulted ceiling and the large spatial volume further reduce the effectiveness of the existing artificial lighting system to provide adequate, uniform lighting throughout the space.

Based on this, the study suggests that the current lighting environment in the library partially meets the functional needs of today's reading areas but needs to be improved in terms of light uniformity, light distribution, and glare control. Evaluation of the assessment was made against the recommended range of illuminance for the reading area: 300–500 lux, bookshelves: 200–300 lux. However, as can be seen, there was a difference in the lighting levels between more brightly lit window spaces and darker interior spaces, so there was a need for a more balanced lighting approach.

The results of the study in SPSS also confirm the significant effect of lighting quality on visual comfort, reading performance and user satisfaction. Therefore, a "lighting architecture" that optimises daylight integration, re-illuminates the LED screens, manages the control of unwanted glare and optimises lighting control capabilities is suggested. These interventions will enhance the functional performance and energy efficiency of Montgomery Hall, and help to maintain the building's historical architectural integrity.

References

Abdullah, M., Saleem, A., Blouch, N., Akram, N., Deo, M. I., & Khalil, A. (2026). Integrated Architectural Documentation and Multi-Analytical Characterisation of Historic Lime Mortars in the Tomb of Ali Mardan Khan, Lahore, Pakistan. The Critical Review of Social Sciences Studies, 4(1), 5479-5504.

Akram, N., Asghar, F., Abbas, K., Abbasi, M. H., & Bangash, S. A. (2026). Industry 5.0, Human-Centric Innovation, and Green Operational Efficiency: Evidence from Smart Sustainable Workflows. The Asian Bulletin of Big Data Management, 6(1), 1-14.

Akram, N., Ashraf, M. Z., Jamil, M., Hasan, B., & ul Haq, M. (2025). Green Concrete: Enhancing Strength And Workability For Sustainable Construction. Kashf Journal of Multidisciplinary Research, 2(07), 87-120.

Akram, N., Blouch, N., Malik, A. M., Sher, F., Mukhtar, R., & Khan, W. R. (2025). Building performance analysis and optimization: A study on energy efficiency and sustainability. Social Science Review Archives, 3(4), 702-712.

Akram, N., Deo, A. M. I., ul Haq, M., Kamal, A. S., & Khalil, A. (2026). Exploring Tidal Architecture: Amphibious Building Systems for Coastal Communities in Flux. Social Science Review Archives, 4(1), 1357-1364.

Akram, N., Farooq, P., Haq, M. U., Nabeel, M., & Asghar, F. (2024). Evaluating the financial feasibility of renewable energy integration in construction sector. The Asian Bulletin Of Green Management And Circular Economy, 4(1), 1-15.

Akram, N., Gul, M. S., Nazir, M. W., Asghar, F., & Atta, F. (2023). Unlocking Sustainable Horizons: Explaining The Role of Green Finance in Advancing Sustainable Construction Practices among Building Professionals. Journal of Economic Impact, 5(3), 217-224.

Akram, N., Hakeem, M. U., Yasin, S., & Kumar, P. (2025). ROLE OF PHOTOCATALYTIC NANOMATERIALS IN DEGRADING INDUSTRIAL WASTEWATER POLLUTANTS: THE MEDIATING EFFECT OF LIGHT INTENSITY. Spectrum of Engineering Sciences, 236-247.

Akram, N., Hussain, A., & Naheed, K. Moderation of Uncertain Circumstances among the relationships of Strategic Management and Adaptation Challenges on Operational Efficiency of Construction Firms. Journal of Law & Social Studies (JLSS), 5(2), 223-240.

Akram, N., Malik, A. M., Khan, W. R., Zulfiqar, S., & Rashid, M. (2026). EXPLORING ADAPTABLE ARCHITECTURE FOR CLIMATE MIGRATION COMMUNITIES. Spectrum of Engineering Sciences, 4(2), 718-727.

Akram, N., Malik, A. M., Mukhtar, R., Shahid, S., & Khan, W. R. (2026). Architectural Responses to Extreme Heat: Designing For 50 C Cities of Punjab, Pakistan. ASSAJ, 5(01), 759-769.

Akram, N., Malik, A. M., Zahra, F. T., & Deo, M. I. (2026). Assessing Life-Cycle Cost And Carbon Footprint Of Lighting Upgrades In Grade I And Ii Listed Buildings. Research Consortium Archive, 4(2), 1771-1783.

Akram, N., Mubin, S., Malik, A. M., Imran, R., & Jamil, M. (2024). Decoding the Interplay of Lighting and Spatial Dynamics: A Simulation-Based Case Study Analysis across Diverse Building Orientations. Metallurgical and Materials Engineering, 30(4), 434-458.

Akram, N., Mubin, S., Masood, R., Malik, A., Naeem, S., Gulzar, R., & Rashid, M. (2025). Beyond Illumination: Stakeholders' Perspectives and Preferences on Eco-friendly Lighting for Sustainable Cities. Metallurgical and Materials Engineering, 31(1), 249-276.

Akram, N., Nadeem, G., Malik, A. M., Sher, F., Zulfiqar, Z., & Tahir, S. (2025). Optimizing Daylight Using Passive Strategies: Light Shelves and Solar Tubes. Spectrum of Engineering Sciences, 474-489.

Akram, N., Zubair, S. S., Asghar, F., Nishtar, Z., & Lodhi, K. (2023). Public-private partnerships (PPPs) in construction projects: A study on the utilization, effectiveness, and challenges in Pakistan. Bulletin of Business and Economics (BBE), 12(3), 402-409.

Arshad, M., Khan, A. R., Chaudhary, R., & Akram, N. (2026). Environmental Governance Innovation and Community Climate Resilience: The Mediating Role of Institutional Trust. The Regional Tribune, 5(9), 67-82.

Arshad, W., Akram, N., Kamal, A. S., ul Haq, M., Khurshid, A. M. M., & Qayyum, A. A. (2025). ECO-FRIENDLY CONCRETE: MERGING FLY ASH AND HEMP FOR GREEN BUILDING PRACTICES. Spectrum of Engineering Sciences, 1000-1019.

Asif, M., Akram, N., Khurshid, M. M., Kaynat, A., Naeem, S., Malik, A. M., & ul Haq, M. (2025). Recycling Agricultural Waste for Green Concrete: The Case of Palm Oil Ash. THE PROGRESS: A Journal of Multidisciplinary Studies, 6(3), 27-42.

Augustiniok, N., Houbart, C., Plevoets, B., & Van Cleempoel, K. (2025). Adaptive reuse of built heritage: conserving and designing with values. Journal of Cultural Heritage Management and Sustainable Development, 15(1), 24-41.

Avcı, A. N., & Memikoğlu, İ. (2017). Effects of LED lighting on visual comfort with respect to the reading task. International Journal of Electrical and Computer Engineering, 11(8), 974-978.

Blouch, N., Akram, N., Malik, A. M., Rashid, M., & Siddiqui, F. A. (2021). Economic Feasibility of Energy Saving by Incorporating Daylight: A Case Study of College Building in Multan-Pakistan. Technical Journal of University of Engineering & Technology Taxila, 26(2), 67.

Boubekri, M. (2008). Daylighting, architecture and health: building design strategies. Routledge.

Boyce, P. R. (2005). Human factors in lighting.

de Kort, Y. A. W. (2019). Tutorial: Theoretical considerations when planning research on human factors in lighting. Leukos, 15(2-3), 85-96.

Duff, J. T. (2012). The 2012 SLL code for lighting: the impact on design and commissioning. SDAR* Journal of Sustainable Design & Applied Research, 1(2), 4.

e Silva, A. R. M. V., das Neves Almeida, M., Cavalcanti, H., Neto, A., de Carvalho, B. C. C. B., & Fortes, J. I. Illuminance assessment: a case study in a central library of a federal university.

Edwards, L., & Torcellini, P. (2002). Literature review of the effects of natural light on building occupants.

Giarma, C., Tsikaloudaki, K., & Aravantinos, D. (2017). Daylighting and visual comfort in buildings' environmental performance assessment tools: a critical review. Procedia Environmental Sciences, 38, 522-529.

Heschong, L., Lang, R. A., & Vemaraju, S. (2025). New dimensions of daylight and health: How opsin biology may inform lighting standards in the near future. Lighting Research & Technology, 57(6-7), 636-648.

Hönekopp, A., & Weigelt, S. (2023). Using light meters to investigate the light-myopia association—A literature review of devices and research methods. Clinical Ophthalmology, 2737-2760.

Hussain, N., Akram, N., Asif, S. H., Khalil, A., & Kamal, S. (2025). Low-Carbon Concrete Using Agro-Waste Eggshell Powder And Mineral Fillers. Journal of Architecture and Built Environment Research (JABER), 2(1), 37-56.

Javed, M. F., Akram, N., Malik, A. M., Khan, W. R., Asim, Z., & Rashid, M. (2025). Biochar-Based Concrete Blocks from Rice Husk: A Sustainable Solution for Low-Carbon Construction. Spectrum of Engineering Sciences, 687-707.

Kahaki, Z. R., Jahangiri, H., Smith, A., & Kazemi, R. (2022). Subjective and objective survey of office lighting: effects on alertness, comfort, satisfaction, and safety. La Medicina del lavoro, 113(3), e2022024.

Kelley-Quon, L. I. (2018). Surveys: Merging qualitative and quantitative research methods.

Khalil, A., Akram, N., Malik, A. M., & Asif, S. H. (2024). Tracing the Ethereal: Exploring Aesthetic Heritage and Cultural Identity in Historic Gardens-A Case Study of Shalimar Garden. Journal of Arts & Social Sciences, 11(1), 37.

Khalil, A., Akram, N., Malik, A. M., Kaynat, A., & Zulfiqar, Z. (2025). Bagh-e-Jinnah, Lahore: Contextualising Its Historical Evolution and Socio-Cultural Significance. Qlantic Journal of Social Sciences and Humanities, 6(3), 230-243.

Mahar, W. A., Anwar, N. U. R., & Attia, S. (2019). Building energy efficiency policies and practices in Pakistan: A literature review.

Mahdavi, A. (2008). Predictive simulation-based lighting and shading systems control in buildings.

Malik, A. M., Blouch, N., & Akram, N. (2022). OPENING THE BLACK BOX OF WATER CONSERVATION BEHAVIOR: HOLISTIC PERSPECTIVE OF A DEVELOPING COUNTRY. Pakistan Journal of Social Research, 4(04), 1096-1105.

Mendonca, R. S., da Silva, M., Ayres Jr, F. A. C., Bessa, I. V., Medeiros, R. L. P., & Lucena Jr, V. F. (2025). Development of a novel retrofit framework considering Industry 4.0 concepts: a case study of a modular production system. Processes, 13(1), 136.

Muneer, A., Akram, N., ul Haq, M., Khurshid, A. M. M., Qayyum, A. A., & Kamal, A. S. (2025). USE OF AGROINDUSTRIAL WASTE AS SUPPLEMENTARY CEMENTITIOUS MATERIALS IN MORTAR: A STUDY ON SUGARCANE BAGASSE ASH AND SILICA FUMES. Annual Methodological Archive Research Review, 3(6), 353-380.

Naveed, A., Bukhari, S. M. A., Husnain, N., Baloch, N., Noor, S., Ahmad, W., Sarfraz, S., Wajahat, N., & Siddiqui, F. A. (2024). Structural Integrity and Cost Analysis of a Connecting Rod for Articulated Robotic Arm Using Various Stainless Steel and Aluminium Alloys. Technical Journal of University of Engineering & Technology Taxila, 29(2), 24.

Nawaz, S., Akram, N., Sher, F., Tahir, S., Khan, W. R., Malik, A. M., & Siddique, F. A. (2025). Agro-waste-based cement substitution: synergistic effects of green gram pod ash and eggshell powder on concrete strength. Kashf Journal of Multidisciplinary Research, 2(09), 208-226.

Nishtar, Z., Munir, M. A., Akram, N., Masood, B., Asghar, F., & Meahrayen, M. A. (2023). Green Finance and the Automate Solar Tracking System: Assessing Efficiency, Financial impact, and Environmental Benefits. Inverge Journal of Social Sciences, 2(3), 134-147.

Sohail, A., Bashir, F., Akram, N., Khan, S., & Qamar, M. (2026). Experimental Assessment of Treated Wastewater for Sustainable Mud Brick Production: Integrating Architectural Sustainability and Engineering Performance. The Regional Tribune, 5(4), 177-199.

Tzouvaras, C., Dimara, A., Papaioannou, A., Karatzia, K., Anagnostopoulos, C.-N., Krinidis, S., Arvanitis, K. I., Ioannidis, D., & Tzovaras, D. (2023). A Guide to Visual Comfort: An Overview of Indices and Its Applications.

ul Haq, M., Khokhar, M. Z., Akram, N., Malik, A. M., Kamal, S., Ashraf, Z., & ur Rehman, S. (2025). SHADI LAL BUILDING, LAHORE: A HISTORICAL AND ARCHITECTURAL ANALYSIS FOR CONSERVATION. Kashf Journal of Multidisciplinary Research, 2(03), 12-29.

Ullah, N., Akram, N., Lao, C., Saleem, A., Salaria, U. A., & Ashraf, M. (2023). Evaluating the Cost Effectiveness and Environmental Benefits of Renewable Energy Sources like Solar and Wind Power. Journal of Biomedical Engineering, 40(3), 462-471.

ur Rehman, S., Blouch, N., Jamil, S., Akram, N., Farooq, M., Rasool, U., & Husnain, N. (2025). Evaluation of Mechanical Properties of Glass Fiber Reinforced Concrete (GFRC) for Sustainable Construction. THE PROGRESS: A Journal of Multidisciplinary Studies, 6(4), 1-18.

van Bommel, W. (2019). Lighting quality and standards. In Interior Lighting: Fundamentals, Technology and Application (pp. 389-406). Springer.

Veitch, J. A., & Newsham, G. R. (1996). Determinants of Lighting Quality II: Research and Recommendations.

Vision, S. 4. The Illuminating Engineers. Visions of Electric Media, 161.

Wei, M., Houser, K. W., Orland, B., Lang, D. H., Ram, N., Sliwinski, M. J., & Bose, M. (2014). Field study of office worker responses to fluorescent lighting of different CCT and lumen output. Journal of Environmental Psychology, 39, 62-76.

Xue, P., Mak, C. M., & Cheung, H. D. (2014). The effects of daylighting and human behavior on luminous comfort in residential buildings: A questionnaire survey. Building and Environment, 81, 51-59.

Zia, M. T., Nadim, M., Khan, M. A., Akram, N., & Atta, F. (2024). The role and impact of artificial intelligence on project management. The Asian Bulletin of Big Data Management, 4(2), 178-185.