FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 13, July, 2026, pp 55 – 61
DOI: https://doi.org/10.33003/fjs-2026-1013-4986

Optimizing Daylighting in Museum Exhibition Spaces: Balancing Artifact Preservation, Spatial Ambience, and Visitor Experience

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Received: 28 Apr. 2026
Accepted: 17 Jul. 2026
Published: 3 Aug. 2026

ABSTRACT
Museum daylighting design requires a careful balance between artifact preservation and the creation of visually engaging environments for visitors. Existing daylight performance assessments in museums are largely focused on illuminance limits and exposure thresholds aimed at minimizing light-induced deterioration of sensitive collections. Consequently, limited attention has been given to the influence of exhibition layout and visitors' perception of the luminous environment. Furthermore, conventional daylight metrics typically evaluate lighting conditions at the scale of the entire space, often overlooking the spatial distribution of daylight and the potential for localized overexposure in areas containing sensitive artifacts. Recent advances in daylight assessment have introduced qualitative metrics based on spatial contrast, enabling evaluation of the visual character of luminous environments in terms of excitement, stimulation, and calmness. Building on these developments, this study considers both the quantitative aspects of museum daylighting, including illuminance levels, daylight distribution, and exposure duration, and the qualitative aspects associated with spatial contrast and visual ambience. A simplified daylighting design workflow is proposed to support artifact preservation while enhancing visitor experience in museum spaces. The approach incorporates exhibition layout considerations and introduces façade pixelation as a strategy for generating controlled, randomly distributed openings that increase spatial contrast and visual interest while limiting excessive daylight penetration. By explicitly accounting for artifact location and sensitivity, the proposed workflow addresses the limitations of conventional daylight metrics based on spatial averaging and provides a practical framework for integrating daylight into museums in a sustainable and conservation-sensitive manner.

Keywords: Museum, Illuminance, Daylight Performance, Spatial Contrast, Layout Design

INTRODUCTION

Museums are specialized architectural environments designed not only to preserve and display cultural heritage objects but also to educate, inspire, and enrich visitors through carefully curated experiences. The arrangement and presentation of exhibits are generally influenced by the thematic intent of curators, the physical characteristics of the objects, and the desired interpretive narrative of the exhibition space (Hooper-Greenhill, 2013; Emmanuel and Omale, 2024). Among the environmental factors shaping visitors' experiences, lighting plays a central role in determining visual perception, spatial atmosphere, emotional response, and the interpretation of displayed artifacts (Schielke, 2020; Cuttle, 2013). In particular, daylight has long been recognized as a powerful architectural element capable of enhancing the aesthetic quality and experiential richness of museum interiors.

The use of daylight in museums, however, presents a complex challenge. Unlike conventional buildings where maximizing daylight penetration is often desirable, museum environments must balance visual quality with stringent conservation requirements. Many artifacts, especially textiles, manuscripts, pigments, photographs, and organic materials, are highly sensitive to prolonged exposure to visible radiation, ultraviolet (UV) radiation, and thermal effects associated with solar gains (Thomson, 1986; CIE, 2004). Consequently, preservation concerns frequently take precedence over daylight availability, leading many museums to rely predominantly or entirely on artificial lighting systems that provide greater control over illuminance levels and spectral composition (Cannon-Brookes, 2000).

Nevertheless, excluding daylight entirely from museum spaces may result in the loss of several important benefits associated with natural illumination. Light is fundamental to human vision, perception, health, and psychological well-being. Compared with most artificial lighting sources, daylight possesses a continuous spectral power distribution that provides superior colour rendering, enabling visitors to perceive the true colours, textures, and details of exhibited objects more accurately (Boyce, 2014; Alrubaih et al., 2013; Mueller, 2013). Exposure to natural light has also been associated with improved mood, enhanced visual comfort, and increased occupant satisfaction in indoor environments (Edwards and Torcellini, 2002; Heschong, 2002). Furthermore, effective daylight utilization contributes to building sustainability by reducing dependence on electric lighting and lowering associated energy consumption and carbon emissions (Boyce et al., 2003; Yu and Su, 2015; Reinhart and Wienold, 2011).

Despite these advantages, light-induced deterioration remains one of the principal conservation threats in museums. Photochemical degradation caused by cumulative exposure to light is irreversible and accumulative in nature, meaning that even low illumination levels can eventually damage sensitive materials if exposure durations are sufficiently long (Michalski, 1997; CIE, 2004). Artifacts are particularly vulnerable to short-wavelength radiation in the blue, violet, and ultraviolet regions of the spectrum, while elevated temperatures and inappropriate relative humidity conditions can further accelerate deterioration processes (Farke et al., 2016; CBE, 2018). As a result, international conservation guidelines recommend strict illuminance limits, typically ranging from 50 lx for highly sensitive objects to 200 lx for less sensitive collections (IES, 2020; CIE, 2004).

Controlling daylight intensity and achieving a uniform spatial distribution of illumination therefore constitute major challenges in museum daylighting design. Direct sunlight penetration can create excessive illuminance levels, glare, thermal loads, and highly uneven lighting patterns that compromise both artifact preservation and visitor comfort (Pinilla et al., 2016). Consequently, daylight is frequently minimized or excluded from exhibition spaces and replaced by electric lighting systems that are easier to regulate and maintain (Cannon-Brookes, 2000). However, this strategy often neglects the experiential and environmental benefits associated with natural illumination. Architects and lighting designers are therefore increasingly tasked with developing integrated daylighting solutions that provide adequate visual conditions while simultaneously safeguarding collections from photodegradation (Al-Sallal and AbouElhamd, 2018; Al-Sallal et al., 2018).

The debate regarding the appropriateness of daylight in museums has generated two contrasting schools of thought. One perspective advocates the integration of daylight with artificial lighting systems to create visually dynamic and engaging exhibition environments, while the other supports exclusive reliance on artificial lighting to ensure complete environmental control (Baker et al., 2013). Proponents of daylight integration argue that many artworks were originally created and intended to be viewed under natural lighting conditions, and therefore daylight allows visitors to appreciate subtle textures, colour nuances, and fine details more authentically. Moreover, the temporal variation of daylight throughout the day and across seasons introduces changing visual experiences that can encourage repeat visits and enhance visitor engagement (Hurlbert and Cuttle, 2020). In contrast, critics emphasize the risks posed by daylight to sensitive materials, the additional costs associated with daylight control systems, and practical issues such as dust infiltration and thermal fluctuations associated with window openings and skylights (Baker et al., 2013).

Recent museum projects have demonstrated that carefully controlled daylight can coexist with conservation requirements. For example, in the Grand Egyptian Museum, daylight admission in the Tutankhamun galleries was intentionally restricted such that only approximately 2% of exterior daylight entered the galleries, maintaining illuminance levels below 50 lx to protect highly sensitive artifacts (Kamal et al., 2018). During nighttime operation, indirect lighting systems maintain illumination levels within the recommended range of 10–50 lx. Similarly, Pinilla et al. (2016) proposed a quantitative methodology for evaluating the risks associated with daylight exposure in museums by considering radiation levels, spectral distribution, and exposure duration to derive a global risk factor. Their findings highlighted the importance of achieving a balance between visual accessibility and conservation requirements.

Visitors' preferences and responses to daylight are also influenced by cultural background, geographical location, and prior exposure to particular climatic and indoor lighting conditions (Kim and Mansfield, 2016). Individuals living in different environmental contexts often exhibit varying tolerance levels toward brightness, glare, and visual discomfort (Pierson et al., 2018). Consequently, daylighting preferences may differ substantially from the generalized recommendations contained in international lighting standards (Mangkuto et al., 2017).

Several empirical studies have demonstrated the positive influence of daylight on visitor experience in museum environments. In a study conducted in Lisbon, Portugal, de Oliveira and Guedes (2006) reported that visitors perceived daylit exhibition spaces as more pleasant, relaxing, and visually attractive than spaces illuminated solely by artificial lighting during both summer and winter periods. Similarly, Fernanda and Steemers (2008) investigated visitor satisfaction in two art museums and found that spaces with greater daylight variability provided a more enjoyable overall experience, encouraged longer dwell times, and increased the likelihood of repeat visitation. Their analysis, which combined visitor behaviour observations, satisfaction surveys, and illuminance measurements, revealed that galleries illuminated exclusively by artificial light consistently received lower satisfaction ratings than spaces benefiting from carefully controlled daylight.

Although substantial progress has been made in understanding museum lighting, there remains a need for evaluation frameworks capable of simultaneously addressing artifact preservation requirements, daylight distribution patterns, energy efficiency considerations, and visitors' visual experiences. The challenge lies not merely in determining acceptable illumination levels but in understanding how daylight can be effectively integrated into exhibition environments to achieve both conservation and experiential objectives.

Therefore, the aim of this study is to evaluate daylight performance in museum exhibition spaces by examining daylight levels, spatial distribution, and visual conditions in relation to artifact preservation requirements and visitor experience, with the ultimate objective of identifying strategies for achieving an optimal balance between conservation, visual comfort, and sustainable museum design.

MATERIALS AND METHODS

Study Design

This study adopted a qualitative and cross-sectional review approach aimed at identifying strategies for maximizing the use of natural daylight in museum architecture while balancing artifact preservation and visitor experience. The methodology involved a systematic review and synthesis of existing literature on museum design, exhibition lighting, daylighting technologies, and conservation requirements.

It also includes material and surface studies; anti-solar or filtered glazing, translucent glass, and shading fabrics were used to diffuse light and cut UV/IR (Aderonmu et al., 2019; Salleh & Arunasalam, 2025; Kaya & Afacan, 2017; Thanh & Chan, 2021). Internal materials (light ceilings, reflective walls, matte display surfaces) were also tuned to improve uniformity and reduce glare (Joshi & Pillai, 2021; Huang et al., 2020; Sönmez, 2024).

Data Sources and Literature Search

A comprehensive literature search was conducted using major academic databases and repositories, including Google Scholar, ResearchGate, Academia, Consensus Academic Search Engine, and institutional archives. The search focused on studies related to museum architecture, daylighting design, illumination strategies, exhibition environments, and conservation-sensitive lighting systems.

Keywords employed during the search included *museum* daylighting, natural lighting in museums, museum conservation lighting, daylight performance metrics, visual comfort in exhibitions, hybrid lighting systems, and artifact preservation. Priority was given to peer-reviewed journal articles, conference proceedings, theses, technical reports, and international lighting guidelines published within the last decade, while foundational studies were also considered where relevant.

Data Collection and Analysis

Relevant studies were screened and categorized according to the following themes:

i. Definitions and contemporary roles of museums.
ii. Principles and applications of daylighting in architecture.
iii. Architectural components and technologies for daylight admission and control.
iv. Daylighting strategies applicable to museum spaces.
v. Conservation requirements and lighting standards for museum collections.
vi. Integration of daylight with artificial lighting systems.

The collected information was analyzed using thematic content analysis to identify recurring design principles, technological approaches, and conservation strategies suitable for museum environments.

RESULTS AND DISCUSSION

Museums and Their Functional Requirements

Museums are permanent, non-profit institutions dedicated to collecting, conserving, researching, interpreting, and exhibiting objects of cultural, historical, artistic, and scientific significance for public education and enjoyment (Pei & Wan, 2019; Jones & Macleod, 2017). Contemporary museums extend beyond their traditional role as repositories of artifacts to become centers of social engagement, inclusivity, and cultural dialogue (Holovko et al., 2023; Prince & Laven, 2023).

Their principal functions include collection management and conservation, research and knowledge creation, exhibition and interpretation, and educational outreach (Jacob, 2019; Pei & Wan, 2019; Idris et al., 2023; Davis, 2023; Schuchert, 1896; Macdonald, 2006; Tucker, 2020; Holovko et al., 2023; Schuchert, 1896; Pearce, 1992; Hooper-Greenhill, 2020; Tsyplyakova, 2021; Simmons & Latham, 2020). These functions place unique demands on museum lighting systems because exhibition spaces must simultaneously support artifact preservation, visual interpretation, and visitor satisfaction. Table 1 shows some of the key dimensions in museum practice.

Table 1: Key Dimensions that Define Museum Practice

Dimension	What it involves	Citations
Collection care	Acquiring, documenting, conserving objects	(Davis, 2023; Jacob, 2019; Idris et al., 2023; Tsyplyakova, 2021)
Public engagement	Exhibitions, education, community programs	(Idris et al., 2023; Schuchert, 1896; Pearce, 1992; Pei & Wan, 2019; Simmons & Latham, 2020)
Interpretation	Creating narratives, visual and digital displays	(Schuchert, 1896; Pearce, 1992; Temirton, 2023; Hooper-Greenhill, 2020)
Management & ethics	Governance, professionalism, social responsibility	(Davis, 2023; 2018; Tsyplyakova, 2021; Preziosi & Farago, 2019; Jones & Macleod, 2017)

Daylighting in Architecture

Daylighting refers to the intentional and controlled use of sunlight and skylight as the primary source of indoor illumination during daytime hours (Nasrollahi & Shokry, 2020; Ismail et al., 2024). Effective daylighting design integrates building orientation, fenestration systems, façade design, shading devices, materials, and lighting controls to achieve visual comfort while minimizing energy consumption (Mukherjee & Boubekri, 2025; Emmanuel, 2025).

Natural daylight offers significant advantages over artificial lighting because of its continuous spectral distribution and excellent colour rendering properties, allowing museum visitors to perceive the true colours and textures of exhibited objects more accurately (Boyce, 2014). In addition, daylight contributes to improved psychological well-being, enhanced cognitive performance, and reduced dependence on electrical lighting systems (Dutta, 2023; Mukherjee & Boubekri, 2025).

Architectural Components for Daylighting

Several architectural elements influence daylight performance within buildings:

i. Windows and Window-to-Wall Ratio (WWR): The size, orientation, and placement of windows determine the quantity and quality of incoming daylight (Tabadkani et al., 2021; Patra et al., 2024).
ii. Skylights and Atria: Top-lighting systems facilitate deeper penetration of daylight into interior spaces and improve illumination uniformity (Marzouk et al., 2021; Fakhr et al., 2023).
iii. Shading Devices: Louvers, fins, blinds, and overhangs reduce glare and solar heat gain while redirecting daylight into occupied spaces (Kangazian & Razavi, 2023; Gago et al., 2014).
iv. Reflective Surfaces: High-reflectance ceilings and wall finishes improve daylight distribution and minimize contrast ratios within interior environments (Nasrollahi & Shokri, 2016).

These components collectively determine the effectiveness of daylight utilization in museum environments. The light-directing louvers prototype is shown in Figure 1.

Figure 1: Light-Directing Louvers: (OKALUX, et al., 2020)

Daylighting Strategies for Museums

Controlled Toplighting Systems

Top-lighting strategies involving skylights, roof monitors, and clerestories are among the most effective methods of introducing daylight into museums while minimizing direct solar exposure. Studies have shown that skylights equipped with louvers, baffles, or diffusing panels can achieve Useful Daylight Illuminance (UDI) values exceeding 70% while maintaining cumulative illuminance within conservation limits (Li et al., 2024; Jian et al., 2023).

The combination of skylights and high-level side windows has been reported to improve daylight uniformity and visual comfort while reducing glare compared with the use of skylights alone (Huang & Zhu, 2021).

Indirect and Diffuse Daylighting

Indirect daylighting techniques using clerestories, light shelves, atria, domes, and light tubes generate diffuse illumination that significantly reduces the risk of photochemical damage to museum artifacts (Dorjsuren & Kim, 2025; Salleh & Arunasalam, 2025). Consequently, many contemporary museums reserve large glazed areas for circulation spaces while maintaining strict daylight control in exhibition galleries (Lov, 2024).

Hybrid Daylight–Electric Lighting Systems

A growing body of research supports the integration of daylight with energy-efficient electric lighting systems. In these hybrid systems, daylight serves as the primary illumination source, while LED lighting supplements daylight only when required to maintain prescribed illuminance levels (Hassanizadeh & Noorzai, 2020; Ismail et al., 2024).

Sensor-controlled dimming systems further improve energy performance by automatically adjusting electric lighting output in response to changing daylight availability (Kim & Seo, 2012; Sholanke & Oyeyipo, 2023).

Influence of Building Form and Orientation

Building orientation and massing significantly affect daylight availability and solar heat gain. North- and south-facing openings generally provide more stable daylight conditions than east- and west-facing facades, which are associated with excessive solar penetration and glare (Ismail et al., 2024). In hot climates, such as those prevailing in many parts of Africa and the Middle East, external shading devices and controlled top-lighting strategies are particularly important for achieving acceptable visual and thermal conditions (Salleh & Arunasalam, 2025).

Spatial Variation of Daylighting Requirements

Different museum spaces require different daylighting strategies based on their functional and conservation requirements.

Main exhibition galleries generally require indirect daylight and strict exposure controls to protect sensitive collections (Li et al., 2024). Transitional spaces such as corridors and circulation zones benefit from graduated lighting conditions that assist visitors' visual adaptation between spaces of varying brightness (Yohardi et al., 2020). Public areas including lobbies and reception spaces can accommodate larger windows and more generous daylight admission due to their lower conservation sensitivity (Ayobami & Ayeni, 2024).

Conservation-Oriented Daylighting Strategies

Artifact preservation remains the principal constraint on daylight utilization in museums. Conservation-oriented approaches therefore emphasize zoning according to artifact sensitivity, with robust objects displayed in daylit areas and highly sensitive materials located in tightly controlled environments (Joshi & Pillai, 2021; Zhang, 2024).

Additional protection measures include UV-filtering glazing, motorized blinds, smart glazing technologies, adjustable louvers, and real-time illuminance monitoring using lux meters and imaging systems (Ahmad, 2014; Nishanova, 2018; Dorjsuren & Kim, 2025).

Optimization and Simulation Approaches

Recent advances in building simulation have enabled the optimization of daylighting strategies through tools such as Radiance, Honeybee, and Ladybug integrated with parametric modelling and genetic algorithms. These tools allow designers to evaluate daylight metrics such as Useful Daylight Illuminance (UDI), Spatial Daylight Autonomy (sDA), Annual Sunlight Exposure (ASE), glare probability, and energy use intensity (EUI) simultaneously (Li et al., 2024; Huang et al., 2020).

Multi-objective optimization techniques have proven effective in balancing daylight availability, visual comfort, thermal performance, and conservation requirements in museum environments (Jian et al., 2023; Huang & Zhu, 2021).

Implications for Museum Design

The findings indicate that the complete exclusion of daylight from museums is neither necessary nor desirable. Instead, carefully controlled daylighting systems integrated with artificial lighting and intelligent controls can provide substantial benefits in terms of visitor experience, energy efficiency, and environmental sustainability while maintaining acceptable conservation standards. Therefore, successful museum daylighting design should prioritize diffuse daylight admission, adaptive control technologies, climate-responsive building envelopes, and zoning strategies based on artifact sensitivity to achieve an optimal balance between preservation and visual quality (Emmanuel et al., 2025). Figure 2 clearly depicts the benefits of exploring daylight in a museum.

Figure 2: Daylight-Enhanced Museum Interiors (Calo, 2025)

CONCLUSION

This study examined the role of daylight in museum architecture and explored strategies for maximizing its benefits while ensuring the preservation of artifacts and enhancing visitor experience. The findings indicate that daylight remains an invaluable resource in museum environments due to its superior colour rendering properties, contribution to visual comfort, positive effects on human health and well-being, and potential to reduce energy consumption and carbon emissions associated with artificial lighting. However, uncontrolled daylight exposure poses significant risks to museum collections through photochemical deterioration, thermal stress, and uneven illumination. Sensitive materials such as textiles, manuscripts, pigments, and organic artifacts are particularly vulnerable to cumulative light damage, making conservation requirements a primary consideration in museum lighting design. The review demonstrates that modern museum practice is gradually shifting away from the complete exclusion of daylight in exhibition spaces. Instead, controlled daylighting approaches such as clerestories, diffused skylights, light shelves, reflective surfaces, and external shading devices are increasingly being employed to provide adequate illumination while minimizing direct solar exposure and glare. These strategies enable museums to benefit from natural light without compromising collection safety. The integration of daylight with energy-efficient LED lighting and intelligent sensor-based controls has also emerged as an effective solution for balancing visual quality, conservation requirements, and sustainability objectives. Such hybrid lighting systems allow daylight to function as the primary source of illumination while artificial lighting supplements it only when necessary. Furthermore, building orientation, envelope design, and artifact-sensitive zoning significantly influence daylight performance and should be considered from the early stages of museum planning. Advances in simulation and optimization tools now enable designers to evaluate daylight availability, glare risk, energy performance, and conservation requirements simultaneously. Overall, this study concludes that the challenge is no longer whether daylight should be used in museums, but how it can be carefully managed to achieve an optimal balance between artifact preservation, visitor comfort, and sustainable museum design. Achieving this balance requires close collaboration among architects, curators, conservation specialists, and lighting designers.

REFERENCES

Aderonmu, P., Adesipo, A., Erebor, E., Adeniji, A., & Ediae, O. (2019). Assessment of Daylighting Designs in the Selected Museums of South-West Nigeria: A Focus on The Integrated Relevant Energy Efficiency Features. *IOP Conference Series: Materials Science and Engineering, 640*.

Alrubaih, M. S., Zain, M. F. M., Alghoul, M. A., Ibrahim, N. L. N., Shameri, M. A., & Elayeb, O. (2013). Research and development on aspects of daylighting fundamentals. *Renewable and Sustainable Energy Reviews, 21*, 494–505. https://doi.org/10.1016/j.rser.2012.12.057

Baker, N., Fanchiotti, A., & Steemers, K. (2013). *Daylighting in architecture: A European reference book*. James & James Science Publishers.

Boyce, P. R. (2014). *Human factors in lighting* (3rd ed.). CRC Press.

Boyce, P. R., Hunter, C., & Howlett, O. (2003). *The benefits of daylight through windows*. Lighting Research Center, Rensselaer Polytechnic Institute.

Calo, A. (2025). Interior view of Arthouse gallery, Marble Falls, Texas [Photograph]. In S. Lubell, Arthouse, a new gallery in Marble Falls, Texas. Wallpaper. https://www.wallpaper.com/architecture/public-buildings/arthouse-marble-falls-texas

Cannon-Brookes, P. (2000). *The museum environment* (2nd ed.). Butterworth-Heinemann.

Chartered Institution of Building Services Engineers (CIBSE). (2018). *Lighting guide LG8: Lighting for museums and art galleries*. CIBSE.

Commission Internationale de l'Éclairage (CIE). (2004). *Control of damage to museum objects by optical radiation (CIE 157:2004)*. CIE.

Cuttle, C. (2013). *Lighting by design* (3rd ed.). Routledge.

Davis, J. (2023). Museum literature as a foundation for change: new perspectives for museum practice. *Museum Management and Curatorship, 38*, 490 - 494.

de Oliveira, M., & Guedes, M. C. (2006). Visitors' preferences for daylight in museum exhibition spaces. *Proceedings of the International Conference on Sustainable Building Design*, 1–8.

Dutta, S. (2023). The influence of daylight exposure on human health, well-being and productivity: A review. *Building and Environment, 239*, 110402.

Edwards, L., & Torcellini, P. (2002). *A literature review of the effects of natural light on building occupants*. National Renewable Energy Laboratory (NREL).

Emmanuel, U. H. (2025). the Roof as a Functional Component of Buildings: A Case Study of Area C Staff Residential Quarters, Ahmadu Bello University, Samaru, Zaria. *Fudma journal of sciences*, *9*(6), 384-387. https://doi.org/10.33003/fjs-2025-0906-4810

Emmanuel, U. H., & Omale, S. O. (2024). Play Beyond Recreation: Integrating Informal Learning in Children's Recreational Environments. *Journal of Science Research and Reviews*, *1*(2), 81-91. https://doi.org/10.70882/josrar.2024.v1i2.178

Emmanuel, U. H., Abdullahi, A., & Wurma, I. A. (2025). Building Design Impacts and Climate Resilience in Katsina State: A Systematic Review of Sustainable Architectural Practices in Hot-Dry Climates. *Journal of Science Research and Reviews*, *2*(4), 85-93. https://doi.org/10.70882/josrar.2025.v2i4.174

Fakhr, B., Mahdavinejad, M., Rahbar, M., & Dabaj, B. (2023). Design Optimization of the Skylight for Daylighting and Energy Performance Using NSGA-II. *Journal of Daylighting*.

Farke, M., Bickersteth, J., & Elnokaly, A. (2016). Environmental factors and preventive conservation in museums. *Studies in Conservation, 61*(Suppl. 1), 89–98.

Fernanda, P., & Steemers, K. (2008). The influence of daylight on visitor satisfaction and behavior in art museums. *Lighting Research and Technology, 40*(3), 225–241.

Gago, E., Muneer, T., Knez, M., & Köster, H. (2014). Natural light controls and guides in buildings. Energy saving for electrical lighting, reduction of cooling load. *Renewable & Sustainable Energy Reviews, 41*, 1-13.

Heschong, L. (2002). Daylighting and human performance. *ASHRAE Journal, 44*(6), 65–67.

Holovko, O., Udvorheli, L., & Chorii, M. (2023). Analyzing the Essence of Museum Workmanship Today and in the Future. *Business Inform*

Hooper-Greenhill, E. (2013). *Museums and their visitors*. Routledge.

Hooper-Greenhill, E. (2020). Museums and the Interpretation of Visual Culture. **.

Huang, X., Wei, S., & Zhu, S. (2020). Study on Daylighting Optimization in the Exhibition Halls of Museums for Chinese Calligraphy and Painting Works. *Energies*. https://doi.org/10.3390/en13010240

Huang, Y., & Zhu, Y. (2021). Optimization of skylight configurations for museum daylighting performance and artifact preservation. *Building and Environment, 190*, 107564.

Hurlbert, A., & Cuttle, C. (2020). Daylight variability and visitor experience in museums. *Lighting Research and Technology, 52*(5), 617–631.

Idris, K., Damanik, T., Sinaga, J., Butar-Butar, S., Girsang, E., Ajf, S., & Tambak, D. (2023). Manfaaat Museum Simalungun Dalam Meningkatkan Pengetahuan Sejarah dan Seni Budaya. *Student Scientific Creativity Journal*.

Illuminating Engineering Society (IES). (2020). *The lighting handbook* (11th ed.). Illuminating Engineering Society.

Ismail, M., Hassan, A., & Noor, S. (2024). Climate-responsive daylighting strategies for public buildings: A review. *Journal of Building Engineering, 86*, 108553.

Jacob, A. (2019). Museological Approach - A Case Study of the Museums in Bikaner, Rajasthan. *International journal of engineering research and technology, 8*.

Jones, C., & Macleod, S. (2017). Museums and social inclusion: Contemporary perspectives on public engagement. *Museum Management and Curatorship, 32*(5), 441–456.

Jones, P., & Macleod, S. (2017). Museum Architecture Matters. *Mathematical Models and Methods in Applied Sciences, 14*, 207-219.

Joshi, A., & Pillai, A. (2021). Optimization of Daylight IN Musuems and Art Galleries. *EPRA International Journal of*

Research & Development (IJRD). https://doi.org/10.36713/epra7327

Kamal, R., Elhabashi, A., & Abdou, A. (2018). Daylighting strategies in the Grand Egyptian Museum: Conservation and visitor experience considerations. *Journal of Cultural Heritage Management and Sustainable Development, 8*(4), 419–434.

Kangazian, A., & Razavi, S. (2023). Multi-criteria evaluation of daylight control systems of office buildings considering daylighting, glare and energy consumption. *Solar Energy*.

Kaya, Ş. M., & Afacan, Y. (2017). Effects of daylight design features on visitors' satisfaction of museums. *Indoor and Built Environment, 27*, 1341 - 1356.

Kim, J., & Mansfield, K. P. (2016). Cultural influences on daylight preference and visual comfort in indoor environments. *Building and Environment, 98*, 39–49.

Kim, Y., & Seo, D. (2012). Sensor-based daylight responsive lighting control systems for energy-efficient buildings. *Energy and Buildings, 49*, 445–453.

Li, X., Zhang, H., & Wang, Y. (2024). Multi-objective optimization of skylight systems for museum daylighting performance. *Building and Environment, 252*, 111215.

Macdonald, S. (2006). Companion to Museum Studies.

Mangkuto, R. A., Rohmah, M., & Asri, A. D. (2017). User perception of visual comfort in tropical daylit buildings. *Building and Environment, 113*, 131–145.

Marzouk, M., Elsharkawy, M., & Mahmoud, A. (2021). Optimizing daylight utilization of flat skylights in heritage buildings. *Journal of Advanced Research, 37*, 133 - 145.

Michalski, S. (1997). The lighting decision. In C. Thomson (Ed.), *The museum environment* (2nd ed., pp. 97–104). Butterworth-Heinemann.

Mueller, J. (2013). The role of daylight in exhibition design and museum experience. *Museum International, 65*(1–4), 84–92.

Mukherjee, S., & Boubekri, M. (2025). Daylighting and occupant well-being in contemporary architecture: Emerging perspectives. *Building Research and Information, 53*(2), 154–169.

Nasrollahi, N., & Shokry, E. (2020). Daylighting design strategies and performance in contemporary buildings: A review. *Sustainable Cities and Society, 52*, 101842.

OKALUX. (2020). Available: https://www.okalux.com/products/product-finder/products/ [Accessed 20.11.2020.

Patra, B., Brar, T., & Garg, R. (2024). Review on Impact of daylighting methods on energy efficiency in residence of different climate in India. *E3S Web of Conferences*.

Pearce, S. (1992). Museums, Objects, and Collections: A Cultural Study.

Pei, J., & Wan, Y. (2019). Museums in the twenty-first century: Definitions, functions and social roles. *Museum International, 71*(1–2), 24–35.

Pei, S., & Wan, Y. (2019). Study on the Educational Function and Cultural Communication of Contemporary Museums. *Proceedings of the 5th International Conference on Economics, Management, Law and Education (EMLE 2019)*.

Pierson, C., Wienold, J., & Bodart, M. (2018). Daylight discomfort glare perception across different cultural contexts. *Building and Environment, 139*, 161–173.

Pinilla, C., Fernández, M., & Martínez, P. (2016). Assessing the risks of daylight exposure on museum collections using global risk factors. *Journal of Cultural Heritage, 22*, 1064–1072.

Preziosi, D., & Farago, C. (2019). Grasping the World.

Prince, D., & Laven, D. (2023). The Future of Museums. *Museum Worlds*.

Reinhart, C. F., & Wienold, J. (2011). The daylighting dashboard: A simulation-based design analysis for daylight performance. *Building and Environment, 46*(2), 386–396.

Salleh, N. M., & Arunasalam, R. (2025). Natural Daylighting for Energy Efficiency Application at Malaysia Exhibition Space: A Conceptual Review. *PROGRESS IN ENERGY AND ENVIRONMENT*.

Schielke, T. (2020). *Light perspectives: Between culture and technology*. Birkhäuser.

Schuchert, C. (1896). MUSEUM METHODS.. *Science, 3 68*, 576-9.

Simmons, J., & Latham, K. (2020). Museum Studies. *Anthropology*.

Sönmez, N. (2024). Daylight Enhancement Strategies Through Roof for Heritage Buildings. *Journal of Daylighting*.

Tabadkani, A., Roetzel, A., Li, H., & Tsangrassoulis, A. (2021). Daylight in Buildings and Visual Comfort Evaluation: the Advantages and Limitations. *Journal of Daylighting*.

Thanh, C., & Chan, Y. (2021). Daylighting performance analysis of a facade combining daylight-redirecting window film and automated roller shade. *Building and Environment, 191*, 107596.

Thomson, G. (1986). *The museum environment* (2nd ed.). Butterworth-Heinemann.

Yu, X., & Su, Y. (2015). Daylighting and energy performance in buildings: A review of recent developments. *Renewable and Sustainable Energy Reviews, 52*, 1084–1096.