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ENHANCING MUSEUM ACCESSIBILITY: LIGHTING STRATEGIES FOR VISITORS WITH LOW VISION

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Abstract

Museums must balance preservation with accessibility, yet lighting strategies for low-vision visitors in Indonesia remain underexplored. This study investigates the Jakarta History Museum through literature review, observational analysis, and calibrated lux meter measurements. Findings reveal that suboptimal illuminance and glare hinder accessibility, underscoring the need for layered lighting approaches integrating ambient, task, and accent illumination. These strategies enhance legibility, spatial perception, and visitor inclusivity while safeguarding artefacts. The study contributes to inclusive design discourse in Southeast Asia and calls for future research on adaptive technologies to optimise perceptual experiences under varying lighting conditions.

Keywords: Layering Light, Museum Design, Low Vision, Exhibition Display, Accessibility and Inclusivity

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INTRODUCTION

Recent demographic data from Indonesia (2022) indicates that approximately 8 million individuals live with visual impairments, including 1.6 million people over the age of 50 who are blind (Bandung, 2022). Despite these significant statistics, empirical research on the participation of visually impaired individuals in Indonesian museums remains limited. Since 2007, the International Council of Museums (ICOM) has underscored the obligation of museums to provide equal access for all visitors, particularly those experiencing permanent or age-related sensory decline (Vaz, 2020). Within this framework, lighting is crucial for accessibility, as it not only aids in interpretation and navigation but also intersects with conservation requirements that often limit lighting levels (Ajmat et al., 2011; Fortuna et al., 2023).

This study aims to deepen the understanding of museum inclusivity by redefining accessibility through the lens of lighting for low-vision (LV) visitors. Inclusivity is examined across three interconnected dimensions: navigation within museum spaces, the accessibility of visual information such as captions and labels, and the overall sensory experience, which includes comfort and the mitigation of visual strain. By analysing the lived experiences of low-vision visitors and evaluating current lighting practices, this article provides evidence-based recommendations to help museums implement lighting strategies that balance preservation priorities with the sensory needs of diverse audiences.

LITERATURE REVIEW

Lighting Strategy at the Museum

Museum lighting must balance artifact protection and visitor engagement (Ajmat et al., 2011; Hurlbert & Cuttle, 2020; Piana & Merli, 2020) by ensuring consistent illumination, minimizing glare and shadows, and supporting mobility, navigation, and wayfinding to enhance spatial perception and aesthetic experience (Che Mohd Nasir, 2024), yet must also meet preservation standards, making design decisions complex (Hassanizadeh & Noorzai, 2021). A widely adopted solution is **layered lighting**, which integrates ambient, task, and accent sources to create a balance between functionality and atmosphere (Hunt, 2009). This approach not only supports navigation and storytelling but also reduces risks to sensitive collections.

The shift from halogen and fluorescent sources to LEDs adds further complexity. Despite concerns regarding potential material degradation, LEDs offer energy efficiency, sustainability, and visual comfort when paired with high Colour Rendering Index (CRI) values (Lee & Yoon, 2021). CRI directly influences perceptual accuracy, though lower CRI levels may, in some contexts, improve contrast (Ajmat et al., 2011). Equally critical are illuminance and Correlated Colour Temperature (CCT). Guidelines recommend 100–300 lux for preservation and 200–250 lux for paintings, with acceptable CCT ranges of 2500–

7000 K (Sholanke & Oyeyipo, 2023). Mid-range stability, such as 3600 K, is considered optimal (Hassanizadeh & Noorzai, 2021), while practical applications often combine general and accent lighting at 2700–4000 K (Gao et al., 2020; Odabaşioğlu & Olguntürk, 2015).

Lighting strategies must also adapt to the various types of exhibitions. Two-dimensional works benefit from uniform wall-washing, while three-dimensional artifacts require adjustable, targeted illumination (Hunt, 2009). Contrast ratios further shape visitor experience: high contrast can dramatise objects, whereas low contrast fosters openness (Schielke, 2020). Ultimately, effective museum lighting requires balancing **accessibility, conservation, and visitor comfort**. When executed thoughtfully, it becomes a cornerstone of inclusive and sustainable exhibition design, aligning technical standards with the goal of equitable cultural participation (Piana & Merli, 2020).

Lighting Strategy for Low Vision (LV) in the Museums

Museums often face significant accessibility challenges for LV visitors due to insufficient inclusive design measures. These challenges include inadequate lighting, limited auditory interpretation, and restricted tactile opportunities (Henrich et al., 2014; McMillen & Alter, 2017; Walters et al., 2021). Positive cultural experiences for visually impaired individuals rely on the integration of multiple senses to navigate spaces and access information (Vaz et al., 2020). However, museum practices predominantly focus on visual experiences, creating barriers to engagement and limiting access to interpretive content.

Poor lighting exacerbates these difficulties by obstructing navigation and diminishing opportunities for meaningful interaction with exhibits (Hunt, 2009). Walters et al. (2021) highlight that dim lighting obscures labels, while strategic lighting placement can enhance contrast without causing glare. Therefore, inclusive lighting must preserve artefacts while accommodating low-vision needs through high-contrast, glare-free solutions (Ajmat et al., 2011; Hurlbert & Cuttle, 2020; Schielke, 2020).

LV visitors require longer adaptation periods when moving between different lighting conditions, making controlled transitions in brightness essential (Jackson & Wolffsohn, 2007). Both CCT and illuminance play a critical role in this process: warmer CCTs tend to enhance comfort, whereas cooler tones improve visual clarity (Zhai et al., 2015). Inadequately managed lighting can increase visual fatigue, diminish perceptual sharpness, and impair overall performance (Lei et al., 2024). Empirical evidence indicates that optimal comfort is achieved with a CCT of approximately 4000 K combined with an illuminance level of 750 lux (Fu et al., 2023). Complementing these findings, accessibility guidelines, such as those issued by the Smithsonian Institution (2021), highlight the importance of maintaining circulation routes at a minimum of 100 lux,

ensuring gradual transitions, providing shadow-free labelling, and minimising glare for both seated and standing visitors.

The literature highlights three crucial technical parameters for inclusive lighting: a CRI of 100 for accurate perception, a CCT range of 2700–5000 K depending on context, and lux levels above standard museum practice, as low-vision visitors often require 400–800 lux. A balance of 300–400 lux is considered optimal for reconciling accessibility with conservation priorities (Oyeyipo et al., 2024). Despite these insights, research on tailored lighting strategies for LV visitors remains limited, particularly in Indonesia. Addressing this gap is essential for advancing inclusive museum practices and fostering equitable cultural participation.

Synthesis and Conceptual Framework

Overall, the reviewed literature converges on the notion that effective museum lighting must balance three interdependent goals: **(a) conservation of artefacts**, **(b) accessibility for diverse audiences**, and **(c) enhancement of experiential quality**. For low-vision visitors specifically, inclusive design requires higher illuminance thresholds, careful colour temperature management, and glare-free contrasts, as reinforced by international standards such as the Smithsonian Guidelines (2021). These findings underscore a research gap in the Indonesian context, where systematic studies on inclusive lighting remain scarce.

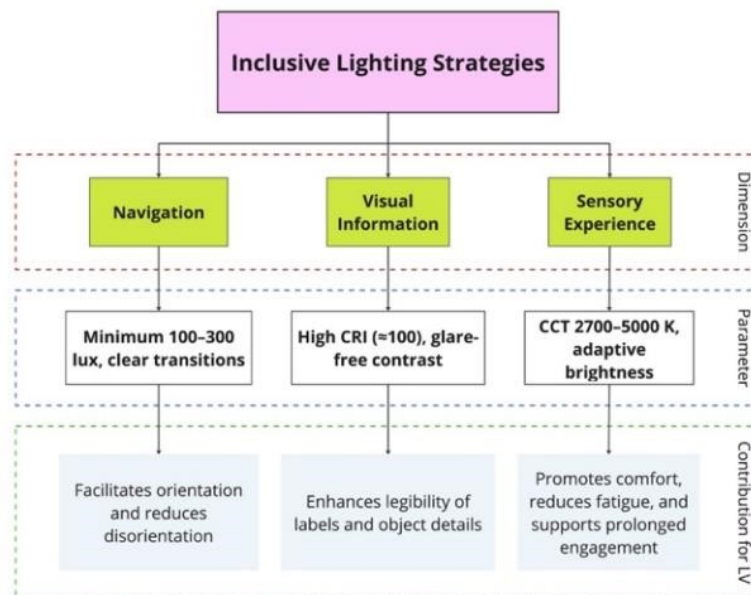


Figure 1: Inclusive Lighting Strategies Conceptual Framework
Source: Authors (2024)

RESEARCH METHODOLOGY

To gather empirical data, this research employed structured observation to document lighting-related phenomena across the study site, complemented with pictorial evidence for spatial reference. The observation was conducted at the Jakarta History Museum (JHM), formerly Museum Fatahillah, located in Jakarta's Old Town. As a preserved colonial-era city hall, the museum was selected due to its cultural significance and the diversity of its collection, which offers varied spatial and curatorial contexts for testing lighting strategies. A floor plan was used to identify and map measurement points, enabling the documentation of spatial configuration in measurable terms (see Figure 1). The evaluation focused on visitor-accessible exhibition areas, circulation paths, and signage, while staff-only, toilet, and other supporting facilities areas were excluded to maintain the study's emphasis on visitor inclusivity. This delineation also opens a discussion on the future importance of employment accessibility within museums.

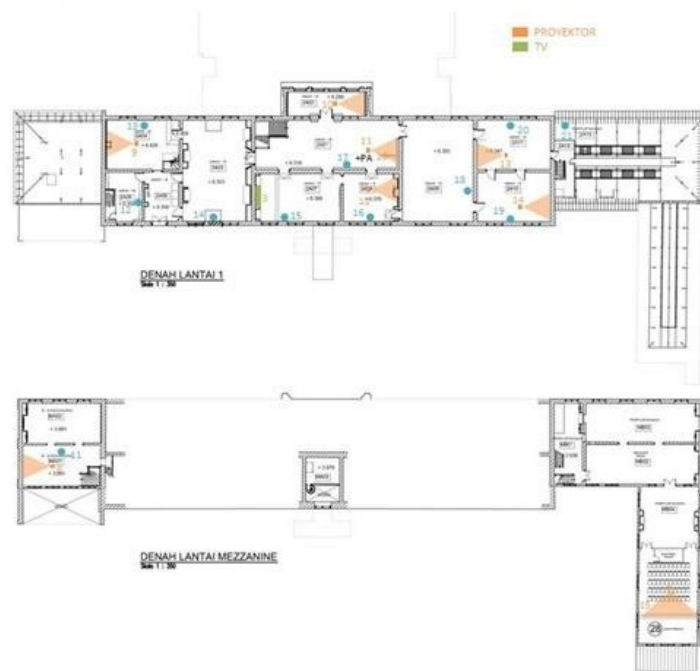


Figure 2: The Jakarta History Museum Plan 1st and 2nd floor
for Lighting Observation
Source: Authors (2024)

Measurements were conducted at 30 predetermined points distributed across galleries and circulation zones. Using a calibrated Opplé Light Master IV lux meter, data were collected between 10 am and 3pm in March 2025. The lux

meter was positioned horizontally and aligned with the measured plane to ensure consistency. Observed parameters included **illuminance levels (lux), contrast ratios, signage visibility, and label legibility**, as these directly affect navigation, comprehension of exhibits, and sensory comfort for low-vision visitors. These aspects were selected based on international standards, the Smithsonian Accessible Exhibition Design Guidelines (2021), which recommend minimum lux thresholds for circulation, glare control, and shadow-free presentation of interpretive materials. While natural light variations were not fully controlled, repeated measurements at different display points reduced observer bias, enhancing reliability.

To complement observations, expert interviews with museum staff and lighting designers were conducted using semi-structured protocols addressing technical constraints and accessibility. Direct observation of low-vision visitors added empathy-driven insights into navigation, comfort, and interpretive clarity. Triangulating expert perspectives, user experience, and technical measurements reinforced methodological rigour (Trochim et al., 2016). Data validity was strengthened through comparison with literature and guidelines, producing structured insights into inclusive lighting strategies that balance conservation and accessibility in heritage-based museum environments.

FINDINGS AND DISCUSSION

Findings reveal a persistent gap between museum lighting standards and the needs of visitors, who require higher illuminance and controlled contrast for full engagement. Hunt's (2009) layered lighting strategy offers a framework for balancing conservation and accessibility, yet its application at JHM shows operational shortcomings. An observation of 15 points measuring illuminance, CCT, and CRI highlighted inconsistencies: some spaces exceeded conservation thresholds, risking photodegradation, while others fell below minimum accessibility levels, particularly in circulation and digital displays.

Digital Display

Measured lighting levels across all four digital displays fell below the recommended 300–400 lux, with projection mapping and animation walls critically underlit (<50 lux). LV visitors frequently reported “dim text” and difficulty perceiving details, exacerbated by dark projection areas that complicated transitions into standard galleries. These findings support Jackson and Wolffsohn's (2007) view that LV visitors require extended adaptation between lighting conditions, underscoring the need for controlled brightness transitions. Staff noted limited ambient light control and non-functional accent lighting, consistent with Schielke (2020).

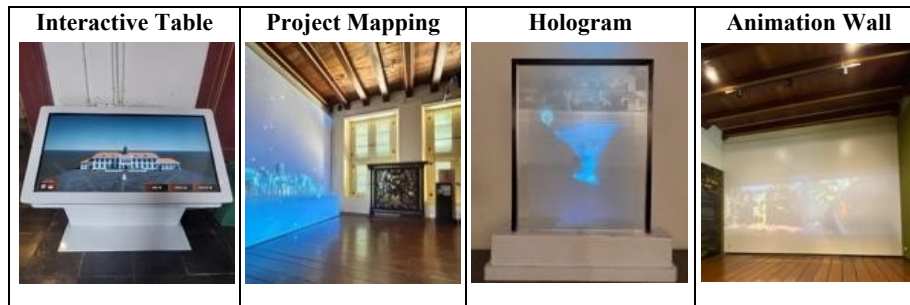


Figure 3: Digital Display in Jakarta History Museum
 Source: Author's (2025)

3D Display without Case

For 3D displays without protective cases, lighting relied on ambient and accent illumination. Display A (original artefact) measured 417–498 lux, exceeding the 300-lux conservation threshold (Scuello et al., 2004; Sholanke & Oyipo, 2023), raising concerns over photodegradation. Display B (replica) reached 518 lux, below Gao et al.'s (2020) recommendation of 750 lux and 4000 K CCT for visual comfort. Interviews highlighted tensions: curators prioritised preservation, while low-vision visitors valued higher illuminance for improved detail visibility, underscoring conservation–accessibility trade-offs.



Figure 4: 3D Display without Case in Jakarta History Museum
 Source: Author's (2025)

Although the CRI was exceptionally high (95.7), ensuring colour fidelity and supporting sustainability goals (Lee & Yoon, 2021), the warm CCT values (2894–2972 K) created suboptimal conditions for low-vision visitors, who require higher brightness and cooler tones for detail perception. This underscores the limits of relying solely on ambient and accent lighting. A layered strategy, as recommended by Smithsonian Guidelines (2021), can adjust illuminance by object type, balancing conservation needs with inclusivity for low-vision audiences.

3D Displays with Case

Accessibility challenges in the 3D displays with protective glass were pronounced due to glare and inadequate task lighting. Although all cases were originally equipped with task lights, only one remained functional with 114 lux, while others provided <50 lux, far below accessibility standards (Figure 5). This insufficient illumination reduced object visibility, making it difficult for low-vision visitors to perceive contours and details. Such conditions support Walters et al. (2021), who identify glare as a critical barrier, and Blind (2015), who note difficulties with underlit displays near brighter zones.

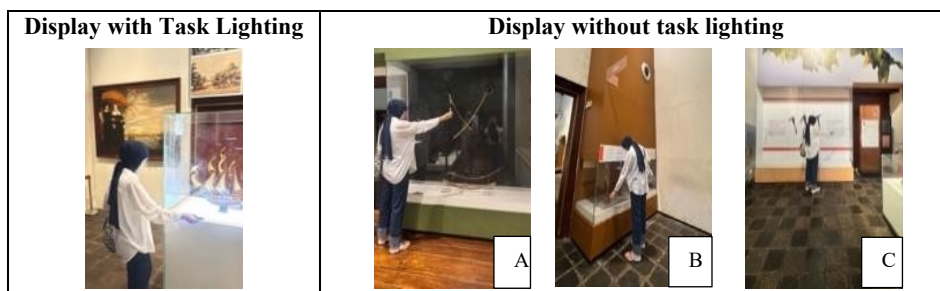


Figure 5: Lighting for 3D Display with Case in Jakarta History Museum
Source: Author's (2025)

Interview findings confirmed observational data: low-vision visitors struggled to perceive object outlines, while staff cited maintenance constraints limiting consistent lighting. Although CCT values (2851–3205 K) and CRI scores (90.2–95.9) indicate high visual quality, the absence of task lighting negated these benefits. Blind (2015) suggests integrating lighting into gallery furniture, provided reflective surfaces are minimised to reduce glare. Thus, accessibility in glass-encased 3D displays requires not only higher, consistent illuminance but also careful design balancing conservation, glare reduction, and inclusivity.

2D Display

The evaluation of 2D displays at the JHM highlights a misalignment between conservation, accessibility, and visitor experience. Historical paintings were illuminated at only 82 lux (CRI 95.5; CCT 2933K), far below the 200–400 lux recommended by Scuello (2004), Sholanke and Oyeyipo (2023), and the Smithsonian Guidelines (2021). While such low levels aid preservation, they hinder detail recognition for LV visitors, who reported difficulty perceiving tonal contrasts and captions in shadowed areas. Printed photographs, measured at 133 lux, also failed to meet the 400–800 lux threshold for LV accessibility. Despite high CRI values (95.5–96), uneven lighting and shadowing exacerbated readability issues. Interview data confirmed that under-illumination and poor

distribution compromise engagement, underscoring the need for lighting strategies that balance conservation with inclusive accessibility.

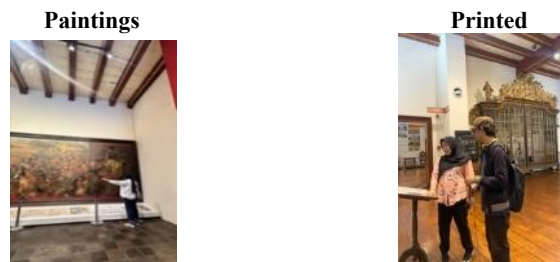


Figure 6: Lighting for 2D Display in Jakarta History Museum
 Source: Author's (2025)

Caption or Labels

Captions and labels serve as critical mediators of interpretive accessibility in museums, yet findings from the Jakarta History Museum (JHM) reveal substantial shortcomings in their design, illumination, and placement. Transparent captions affixed to glass surfaces demonstrated the most pronounced accessibility barriers. Despite achieving a CRI of 96 and a CCT of 3089K, both generally acceptable for producing visual comfort, the recorded illuminance was only 133 lux, significantly below the Smithsonian's recommended 400–800 lux range. The reflective quality of the glass generated glare, a condition repeatedly cited by LV participants who described text as “nearly invisible.” These observations corroborate Walters (2021) and Schielke (2019), who emphasise that insufficient illuminance, when combined with glare and poor contrast ratios, substantially diminishes text readability.



Figure 7: Lighting for Caption and Labels in Jakarta History Museum
 Source: Author's (2025)

Printed captions placed on solid substrates with high-contrast backgrounds performed marginally better, registering 247 lux, a CRI of 95.9, and a CCT of 2936K. While the higher illuminance provided comparatively clearer visibility, values still fell short of accessibility standards. Furthermore, their

location behind glass display cases introduced shadowing and light reflection that obstructed clear viewing angles. This finding aligns with Blind's (2015) observation that obstructed or poorly positioned captions undermine visitor comprehension even when text quality is sufficient. In interviews, museum staff acknowledged the readability challenges but noted that interventions were not prioritised due to budgetary limitations, reflecting a broader institutional struggle to balance conservation, interpretive clarity, and resource constraints.

Background-integrated captions represented the most problematic format. Although typically larger in font size, they recorded illuminance as low as 27 lux, rendering them almost unreadable for LV visitors despite an optimal CRI of 97.2 and an acceptable CCT of 3166K. Participants frequently reported difficulty distinguishing letters, particularly in shadowed sections, underscoring Walters' (2021) claim that poor lighting placement exacerbates legibility issues regardless of font scale. This mismatch between design intent and accessibility outcomes highlights the limited effectiveness of background integration as a strategy for inclusive communication.

Taken together, these findings underscore the urgent need for a holistic approach to caption and label design, which combines adequate lighting levels, glare-free materials, and ergonomic placement. Without such interventions, museums risk excluding a significant demographic of visitors. Prioritising adaptive captioning strategies not only enhances accessibility but also supports broader inclusivity goals central to contemporary museum practice.

The integration of empirical measurements, visitor interviews, and staff insights reveals both systemic shortcomings and viable opportunities for enhancement. Although JHM officially implements a layered lighting strategy, operational challenges, such as maintenance issues, outdated systems, and inadequate adaptive controls, diminish its effectiveness. These observations highlight the pressing need for lighting solutions that are adaptive, glare-free, and dynamically controlled, striking a balance between conservation and inclusivity. By adopting a thematic, user-centred approach to lighting that combines quantitative data with lived experiences, we can create a model for advancing accessibility in Indonesian museums.

Table 1: Summary of Lighting Application at the JHM

No	Space / Display Type	Illuminance (Lux)	CCT (K)	CRI	Standard Reference (LV)
1	Interactive Table	139	3952	91	300 – 750 lux 4000-5000K (CCT) CRI ≥ 90
2	Hologram Display	243	2888	90	
3	Projection Mapping	12	3868	92	
4	Animation Wall	31	3853	91	
5	Display Without Case A (artefact)	417	2894	95,7	400-750 lux 4000-5000K (CCT) CRI ≥ 90
6	Display Without Case B	518	2972	95,7	400–800 lux (LV) 2700–5000 K (CCT) ≥100 (CRI)
7	Display with case and Task Lighting	114	2944	91	
8	Display with case A	36	3205	93,1	
9	Display with case B	151	2851	90,2	
10	Display with case C	261	2943	95,9	200–250 lux 2500–7000 K (CCT)
11	2D Painting	82	2933	95,5	
12	2D Printed	133	3069	96	400–800 lux 4000–5000 K CRI ≥90
13	Transparent Caption	133	3089	96	
14	Caption on Solid Case	247	2936	95,9	
15	Background Caption	27	3166	97,2	



Meet the Standard



Below the Standard

Comparative Context: Lighting Practices in Other Indonesian Museums

The accessibility challenges identified at the JHM are consistent with patterns observed in other Indonesian museums, particularly those housed in heritage buildings. For instance, Fort Vredeburg Museum in Yogyakarta exhibits similar constraints in achieving uniform illuminance due to reliance on natural daylight and minimal adaptive control. In contrast, contemporary institutions such as Museum MACAN in Jakarta have adopted adaptive LED systems with higher colour rendering indices and variable correlated colour temperatures, resulting in improved legibility and visual comfort. This comparison indicates that lighting strategy remains a key determinant of inclusive accessibility across Indonesian museums, highlighting the urgent need for national standards that balance conservation requirements with perceptual equity.

CONCLUSIONS

This study demonstrates that inadequate lighting within the JHM continues to restrict accessibility for visitors with LV. Triangulated findings from illuminance measurements, staff interviews, and field observations reveal systemic deficiencies, including substandard brightness levels, non-functional task lighting, and captions compromised by glare and low contrast. These constraints

are compounded by financial limitations and the spatial rigidity of colonial-era buildings that were never designed to accommodate inclusive museum functions.

A layered lighting approach is therefore critical to reconcile conservation and accessibility goals. Uniform, low-glare ambient lighting should establish visual coherence; accent lighting must be strategically refined to enhance artefact visibility; and functional task lighting reinstated to support close-range engagement. Integrating high-CRI LEDs, glare-reducing diffusers, and furniture-embedded lighting provides cost-effective and contextually adaptable solutions to improve visual legibility without compromising preservation.

Although this study emphasised empirical lighting evaluation, future research should advance participatory methods involving LV visitors through sensory walkthroughs and co-design workshops. Such engagement will deepen understanding of perceptual adaptation, inform adaptive lighting controls, and reinforce a user-centred approach within Indonesia's climatic and architectural constraints.

The findings also carry significant policy implications. Current Indonesian museum management frameworks tend to prioritise conservation, with limited provisions for inclusive design. Incorporating accessibility-oriented lighting benchmarks, aligned with ICOM's (2007) accessibility mandate and Indonesia's heritage management policies, will institutionalise inclusive practices. Routine lux audits, adaptive LED maintenance, and staff capacity-building should form part of these policies. Ultimately, inclusive lighting must be recognised not merely as a design intervention but as a foundation for cultural equity and sustainable museum development across Southeast Asia.

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