



Vol. 4 No. 3 (March) (2026)

## **Investigating Adaptive Daylight Integration Strategies Using Light-Pipe Technologies In Heritage Building Envelopes**

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### **ABSTRACT**

This paper explored the adaptive strategies of daylight integration with light pipe technologies on building envelopes of heritage buildings in the Pakistani setting. The study was done on the improvement of traditional architectural fabric of old buildings in Pakistan by the addition of modern light-pipes without interfering with the cultural and aesthetic integrity of the old buildings. The paper reviewed the chosen heritage structures in the large Pakistani cities such as Lahore, Multan, and Peshawar where the high urban form and the tightness of street grid substantially limited the natural daylight entering the interior areas. The study evaluated both thermal and luminous performance of tubular daylight equipment embedded into the already existing heritage envelopes with the consideration of the various climatic zones in Pakistan, including arid and semi-arid climatic zones. It was measured in the field to test the level of illumination, energy use, and occupant visual comfort in the building prior and following light-pipe integration. The research also investigated the compatibility of light-pipe mounting schemes with the structural limitations of the load-carrying masonry and decorative fronts found on the Mughal and colonial buildings in Pakistan. The results showed that adaptive light-pipe technologies enhanced interior daylighting environments and at the same time maintained the architectural character of old buildings. The study added a context-related framework of sustainable retrofitting of daylight in Pakistani heritage buildings, which is



## Vol. 4 No. 3 (March) (2026)

important to national conservation purposes and energy conservation aims.

**Keywords:** Adaptive Strategies, Daylight Integration, Light Pipe Technologies, Heritage Buildings, Architectural Fabric, Luminous Performance.

### INTRODUCTION

The Heritage buildings are an invaluable part of the Pakistani cultural identity which symbolizes centuries of architectural development under the influence of the Mughal, Sultanate, and colonial cultures. There are cities like Lahore, Multan and Peshawar which are rich in their historic buildings that have been utilized in a functional way and are also present as a relic of collective civilizational memory. But due to the speedy urbanization the cities have undergone during the last several decades, the built heritage has also been presented with an urgent problem: the gradual extinction of natural daylight at the inside space (Mujtaba, Zulfiqar et al. 2025). A combination of dense street grids, tall neighbouring buildings, and the tight urban form typical of the old city cores of Pakistan have contributed to making many of the heritage interiors permanently underlit requiring the inhabitants to have to use a lot of artificial lighting to light up the areas during the day with serious impacts on energy use and occupant health (Khan, Bhatti et al. 2023).

The interaction of natural light and architectural space has been one of the characteristics of the classic South Asian building culture (Akshar and Solissa 2025). Classical Mughal buildings, such as the planned use of jali screens to direct the movement of the sun on sunny days, open spaces, and the planned placement of apertures could create spaces that were bright, cool and spiritually stimulating at the same time (Khan, Al-Kodmany et al. 2024). The buildings of the colonial period further extended these strategies by using the features of verandas, clerestory windows, and the use of the shutters louvred to suit the high solar climate of the subcontinent. What was unique about these pre-modern strategies was the fact that they were sensitive to the local climatic conditions and highly sensitive to the fact that natural illumination could be used as a functional and aesthetic source. It is the loss of these conditions of daylighting in modern use thus not only a technical failure but also a loss of experience and cultural reality (Kumar and Jha 2024).

It is against this backdrop that the light-pipe technologies have become an interesting and non-invasive technology of reintroducing natural daylight in buildings where the traditional fenestration becomes structurally unfeasible or aesthetically inappropriate (Ortiz Ortega, Hosseinian et al. 2022). Light pipes also known as tubular daylighting devices operate by reflecting sunlight at a rooftop collector into a highly reflective pipe, which then reflects into interior spaces with the help of a ceiling-mounted diffuser. These systems can be installed with minimal structural interference, can be run through existing building fabric with minimal disturbance, and are available in designs that allow sympathetic installation with historic surfaces unlike a conventional skylight or window enlargement. It is these properties that render the light-pipe technologies of special value in heritage conservation environments where the concept of minimal intervention is paramount (Decker 2025).

The problem of the heritage conservation industry in Pakistan has always been the inability to balance the need to preserve a historic cloth with the need to turn such structures into a place where people can live comfortably and the energy requirements of modern times (Fatima, Ahmed et al. 2023). Department of Archaeology and Museums and other provincial heritage authorities have undertaken some great efforts to conserve and rehabilitate important monuments but the issue of sustainable retrofitting or making



## Vol. 4 No. 3 (March) (2026)

the historic buildings better in environmental performance but not affecting their cultural value is not given due attention in national conservation policy and practice. In addition to the international conventions, such as those expressed by UNESCO and ICOMOS, this country has a duty to meet international expectations and it is upon that basis that technically rigorous and culturally sensitive solutions to the heritage building adaptation are needed (Blouch, Akram et al. 2021).

Pakistan is a country that has a rich climatic diversity, which makes any daylighting retrofit strategy that more complex (Akram, Nadeem et al. 2025). Arid weather conditions that are typical of most parts of Punjab and Sindh, the semi-arid areas of Khyber Pakhtunkhwa, and the diverse seasonal cycles of different areas imply that a one-fits-all solution to daylighting is not accurate. The amount of solar available, dust coverages on collector surfaces, thermal gains issues, and chances of glare are highly diverse across these climatic zones requiring different adaptive solutions that are sensitive to the local climate (Akram, Mubin et al. 2024). Studies that examine the effectiveness of light-pipe technologies in these diverse environments are therefore of immediate interest to the process of implementing these systems in the Pakistani heritage industry (Akram, Mubin et al. 2025).

The paper lies at the crossroads of the heritage conservation, sustainable building technology and environmental performance research. Investigating the concept of integrating adaptive light-pipe systems into the envelopes of several heritage buildings in Lahore, Multan and Peshawar, it aims at creating empirically informed knowledge of both the technical performance of the systems and of its suitability to the material and aesthetic needs of the built heritage in Pakistan. The study is based on a mixed-methodology that includes field tests of the illuminance and energy consumption, simulations of computational performance, structural evaluations of current building cloth, and post-occupancy tests of the occupant comfort. With its in-depth study, the project is set to not only add to the existing body of research on the topic of retrofitting of heritage buildings, but also to the arsenal of effective instruments that conservation practitioners operating in Pakistani environment may utilize.

This question is not merely important in terms of its immediate technical discoveries. In a time when Pakistan is experiencing severe energy problems and there is an understanding of the economic and cultural importance of its historic built environment, this type of research that shows that there are possible avenues to more sustainable and glowing enriched heritage buildings has significant policy implications. The establishment of a context-specific model of daylight retrofitting, which is based on the facts of Pakistani climatic and natural conditions, traditions in construction and conservation priorities, is a significant contribution to the larger nation-wide project of heritage stewardship and environmental accountability.

### **Research Objectives**

To assess the luminous and thermal properties of adaptive light-pipe technologies incorporated into the building envelopes of several heritage buildings in Lahore, Multan and Peshawar in varying climatic conditions.

To evaluate the structural and aesthetic fit of light-pipe mounting system with the load bearing masonry systems and decorative facades of Mughal and colonial heritage buildings in Pakistan.

To design context-specific sustainable retrofitting of daylighting of Pakistani heritage buildings that would meet national conservation and energy efficiency goals.



## Vol. 4 No. 3 (March) (2026)

### Research Questions

How can adaptive light-pipe technologies be used to enhance the illumination levels in interiors of heritage buildings and decrease energy usage of artificial lighting in the buildings found within high-density urban morphologies in Pakistani cities?

What are the ways of structurally and aesthetically fitting the light-pipe systems into the existing fabric of Mughal and colonial heritage buildings, without making them lose their cultural and architectural integrity?

What location-based recommendations are needed so that daylight retrofitting approaches are not out of place to the varied climatic regions, conservation interests, and typology of buildings found in the heritage building inventory in Pakistan?

### Significance of the Study

This research is very important to the conservation of heritage in practice, sustainable architecture and the energy policy of Pakistan. Producing empirical data on the effectiveness of light-pipe technologies in the context of real heritage buildings, it fills one of the most critical gaps between the theory of conservation and the actual implementation of the said technology. The study has direct implications on the activity of conservation professionals, architects and policy-makers as it presents an effective, context-specific retrofitting framework that is specific to the climatic diversity and architectural heritage in Pakistan. Moreover, in a nation where energy conservation and the increasing need to conserve built heritage are becoming critical issues, this research will come in handy as a timely and practical intervention to reach a compromise between the cultural preservation and the environmental sustainability objectives.

### LITERATURE REVIEW

Incorporation of natural daylight in historic structures has been a permanent topic of interest to scholars and professionals in a variety of fields due to the tenets of conservation ethics, environmental science, and heritage management converging (Zhou 2025). The existing literature in this field has determined that daylighting performance is indeed not only about occupant comfort, but it is also closely linked to the cultural authenticity of architectural locations, especially that of the South Asian tradition where the control of natural light was an intentional design tool with symbolic and spatial meanings (Khorasgani 2024). There has always been debate among scholars that the impairment of original daylighting conditions is one form of heritage loss, which, although not visually obtrusive like other forms of corrosion on ornamental surfaces, is nonetheless consequential to the expressive integrity of historic interiors (Rashdan and Ashour 2024).

Since the 1990s, light-pipe or tubular daylighting technology has received, and continues to receive, significant research interest, with a literature base describing the performance properties of this technology, over a variety of building types and climatic conditions (Song, Dessie et al. 2023). Initial research concentrated mostly on the photometric performance of tubular daylighting equipment and looked at how the size of collector apertures, the length and diameter of tubes, and their interior light delivery were influenced. Later studies built on this basic study to answer questions of thermal performance, especially in climates where solar gain caused by daylighting apertures is a major issue (Wu, Jin et al. 2024). In hot arid and semi-arid climates similar to those occurring in much of Pakistan, it has been established through research that well-structured light-pipe systems can provide significant gains of daylight with acceptable thermal performance, especially with spectrally-selective glazing or thermal break at the



## Vol. 4 No. 3 (March) (2026)

collector level (Li, Wu et al. 2022).

The integration of contemporary technology dealing with daylighting in the context of heritage buildings poses thorny questions of conservation philosophy and practical compatibility which have been tackled with varying levels of rigor in the literature that exists to date (El-saggan, Abdelrahman et al. 2023). The ethical framework on which such technologies should be judged is the doctrine of minimal intervention, which states that any intervention with historic fabric should be restricted to that which is entirely necessary and to be reversed wherever possible (Malet-Damour and Fakra 2022). Research undertaken into the retrofit of active environmental systems into historic buildings in Europe and North America has established that tubular daylighting devices do have specific benefits in a conservation perspective due to their small footprint, ability to be installed through existing service penetrations, and a range of mounting hardware that ensures minimal contact with historic fabric (Etemad, Zare et al. 2024). The applicability of these results to the material circumstances, structural designs, and conservation regulatory settings of the South Asian heritage buildings, however, is a question demanding special research (Younus, Gulzar et al. 2025).

The architectural heritage of Pakistan offers a unique range of challenges and opportunities of daylighting retrofit not covered fully by the international literature (Akram, Ashraf et al. 2025). The heavy-weight masonry construction of buildings of Mughal age, with thick brick walls, shallow vaulted roofs and elaborate surface decoration in lime plaster, brick work and tile, puts severe restrictions on the path of the light-pipe tubes in building mass. Although using slightly varied logics of construction based on the British engineering experience modified to the local conditions, colonial-era buildings also pose the same challenge of accommodating modern intrusions without affecting the structural integrity or injuring decorative surfaces of heritage value. Studying similar forms of buildings in India and the wider Islamic architecture has also started to chart these limitations, but little research is available specifically on Pakistan (SHAH 2023).

The Pakistani heritage city urban morphology is another aspect of complexity that has not been well addressed in the daylighting retrofit literature (Waheeb). The tight, multi-story street structure of the walled city of Lahore, the high density of courtyard house typology of Multan and the organic structure of the urban fabric of the historic bazaar areas of Peshawar all give rise to a state of severe overshadowing that essentially limits the amount of solar access a traditional rooftop collector system can receive (Hussain 2024). Studies of the solar access in dense historic urban areas have determined that prudent simulation-based study of collector location is crucial to the determination of plausible locations to install, and that ingenuous utilization of the roof geometries, inside-yard, and light wells can enlarge the diversity of potential locations by a factor of many. The scholars who study these urban situations have to thus use both building-level and urban-level analytical frames (Riaz 2022).

Comfort of occupants and aesthetic appearance in the daylit areas are another aspect of the literature that has a direct relationship with the current study (Kim, Lee et al. 2023). The visual comfort research has come to create advanced measures of assessing the quality of daylit environments such as useful daylight illuminance, daylight autonomy, and unified glare rating that go beyond simple measures of lux to measure the temporal variability and spatial distribution of natural light in manners that are more likely to correlate with occupant satisfaction (Hafiz 2024). Research of human behavior towards light-pipe delivery of daylight in non-heritage settings has generally reported high degrees of satisfaction, especially in areas that were previously deprived of natural



## Vol. 4 No. 3 (March) (2026)

daylight, although other research has suggested that the relative lack of size of the aperture of the typical tubular devices may limit the perception of connection to the outside environment that occupants appreciate. These perceptual dimensions are especially important to be considered in the case of heritage building contexts, where the existing spatial character already predetermines the expectations of occupants (Abdelrahman 2024).

The implications of daylighting retrofit on energy performance related to heritage buildings are related to a wider body of literature on sustainable conservation which has increased significantly in the past decades. As research has always shown, gains in quality of daylighting can produce considerable savings in the energy demand of artificial lighting, and the size of the savings is determined by the quality of the lighting controls currently in place, by the time of the year during which the building is occupied, and by the pre-intervention levels of natural light (Nair, Verde et al. 2022). The Pakistani heritage buildings with their usual primitive and inefficient artificial lighting infrastructures are especially sensitive to the possibility of achieving meaningful energy savings through the effective daylighting retrofit. Some studies have also observed that better natural light can minimize the use of air conditioning by replacing cooler, naturally diffused lights with the use of heat-producing artificial lighting, but this advantage needs to be weighed against the thermal gain risks of solar apertures in hot climatic environments (Salam, Zafar et al. 2024). The current literature, therefore, offers a very rich, yet geographically indiscrete base upon which the current study is based due to its particular attention towards Pakistan situation, typology construction, and conservation priorities.

### **RESEARCH METHODOLOGY**

The researchers adopted mixed-methodology which included the use of the field measurements, performance simulations and qualitative measurements to determine the performance of light-pipe technologies in the chosen heritage buildings located in Lahore, Multan and Peshawar.

#### **Case Selection and Site Analysis**

The researchers sampled the representative sample of heritage buildings in each city based on the priority of buildings reported to have daylight inadequacies due to urban morphology and the narrow street forms. The criteria used in the selection was structural condition, heritage classification, and representation of climatic zone to make sure that both arid and semi-arid environment that was common throughout Pakistan was covered.

#### **Field Measurements**

There were pre and post intervention measurements to determine baseline and comparative performance data. The investigators measured the interior light levels in specific points of each building on a grid with calibrated lux meters in accordance with the Commission Internationale de l'Eclairage (CIE) guidelines. Simultaneous thermal performance measurements and the energy consumption measurements were recorded during seasonal monitoring intervals to reflect the changes in climatic variations throughout the year.

#### **Light-Pipe Integration and Structural Assessment**

The researchers made structural assessments of the load-bearing masonry walls and ornamental facades that were typical of Mughal and colonial architecture before their



## Vol. 4 No. 3 (March) (2026)

installation. Mounting designs were developed in such a manner that there were minimal physical processes involved in mounting the designs and preserving the ornamentative surfaces and structural integrity and the tubular daylight devices could be bent to fit within the current envelope designs.

### Performance Simulation

The simulation software to model luminous and thermal performance scenarios was validated and thus enabled the researchers to compare the measured results with the predicted results and also refine the integration strategies.

### Occupant Comfort Evaluation

Subjective reactions to the recently retrofitted daylighting conditions were captured through post-occupancy surveys and visual comfort evaluation of the building occupants and conservation experts.

### Data Analysis

The quantitative data were statistically compared to identify the improvement of the performance, and the qualitative data were thematically coded to guide the creation of the context-specific retrofitting concept based on the Pakistani heritage conservation criteria.

## RESULTS AND DATA ANALYSIS

### QUANTITATIVE ANALYSIS

Table 1 presents the pre- and post-intervention illuminance levels recorded at designated interior measurement points across the three heritage sites in Lahore, Multan, and Peshawar. The data reveal consistent and statistically significant improvements in interior lux levels following light-pipe installation across all sites. Lahore recorded the highest absolute improvement, with mean interior illuminance rising from 42 lux to 187 lux, representing a 345% increase. Multan and Peshawar registered improvements of 298% and 276% respectively, confirming that light-pipe technologies deliver substantial daylighting gains even within densely built urban morphologies characteristic of Pakistani heritage districts. Readings were taken at peak, mid, and low solar conditions to ensure seasonal reliability.

*Table 1: Pre- and Post-Intervention Interior Illuminance Levels (Lux) by Site*

Site	Pre-Intervention Mean (Lux)	Post-Intervention Mean (Lux)	% Improvement	CIE Target (Lux)
Lahore	42	187	345%	150–300
Multan	38	151	298%	150–300
Peshawar	45	169	276%	150–300
Overall Mean	41.7	169	306%	150–300

Table 2 summarizes the measured energy consumption data for artificial lighting recorded at each site before and after light-pipe integration. The data demonstrate that the improved interior daylighting conditions enabled a substantial reduction in artificial lighting operating hours, with corresponding decreases in monthly electricity



## Vol. 4 No. 3 (March) (2026)

consumption. Across all three sites, monthly energy consumption attributed to artificial lighting declined by an average of 34.7%, with Lahore achieving the highest absolute saving of 38.2%. These reductions carry direct relevance to national energy conservation objectives and validate the potential contribution of adaptive daylighting strategies to sustainable heritage building management in Pakistan's energy-constrained context.

**Table 2: Monthly Artificial Lighting Energy Consumption Before and After Intervention (kWh)**

Site	Pre-Intervention (kWh/month)	Post-Intervention (kWh/month)	Energy Saving (kWh)	% Reduction
Lahore	312	193	119	38.2%
Multan	287	191	96	33.4%
Peshawar	298	196	102	34.2%
Overall Mean	299	193.3	105.7	35.3%

Table 3 presents the thermal performance data collected during peak summer and winter monitoring periods, comparing interior operative temperatures at light-pipe diffuser zones against ambient measurements in adjacent unmodified spaces. The data indicate that light-pipe integration produced only marginal thermal effects, with mean temperature differentials remaining within 1.2°C across all sites and seasons. This finding is particularly significant given the arid and semi-arid climatic conditions prevailing at the study sites, where solar heat gain through daylighting apertures represents a substantive risk. The results confirm that appropriately specified tubular daylighting devices with spectrally selective glazing maintain acceptable thermal neutrality in Pakistani heritage building conditions.

**Table 3: Thermal Performance — Mean Operative Temperature Differentials at Diffuser Zones (°C)**

Site	Summer Ambient (°C)	Diffuser Zone (°C)	Winter Ambient (°C)	Diffuser Zone (°C)	Max Differential (°C)
Lahore	38.4	39.1	14.2	14.8	+0.7 / +0.6
Multan	40.1	41.0	12.8	13.6	+0.9 / +0.8
Peshawar	35.6	36.8	8.4	9.6	+1.2 / +1.2
Overall Mean	38.0	38.97	11.8	12.67	+0.93

Table 4 documents the Useful Daylight Illuminance (UDI) scores achieved at measured interior points following light-pipe installation, expressed as the percentage of occupied hours during which illuminance fell within the target range of 100–2000 lux. The results indicate that post-intervention UDI scores improved dramatically across all sites, with Lahore achieving 71.4% of occupied hours within the UDI target band compared to a



## Vol. 4 No. 3 (March) (2026)

pre-intervention score of only 18.3%. These UDI improvements directly translate into enhanced occupant visual comfort and reduced dependence on supplementary artificial lighting, validating the effectiveness of the adaptive light-pipe strategy in producing measurably better daylighting conditions within complex heritage building envelopes.

**Table 4: Useful Daylight Illuminance (UDI) Scores — Pre and Post Intervention (% of Occupied Hours within 100–2000 Lux)**

Site	Pre-Intervention UDI (%)	Post-Intervention UDI (%)	Improvement (%)
Lahore	18.3%	71.4%	+53.1%
Multan	15.7%	64.8%	+49.1%
Peshawar	20.1%	67.3%	+47.2%
Overall Mean	18.0%	67.8%	+49.8%

### QUALITATIVE ANALYSIS

The qualitative study provided five major thematic results based on post-occupancy questionnaires, structured interviews with the occupants and conservation experts of the buildings, and thematic analysis of the observational field notes. All these themes shed some light on the experiential, professional, and institutional dimensions of light-pipe integration in Pakistani heritage buildings which are not solely represented by the quantitative performance data.

#### **Theme 1: Enhanced Perceptual Quality of Heritage Interiors**

The participants in all the three locations agreed that the incorporation of natural daylight with light-pipe systems created a qualitative enhancement of the sensual interior space atmosphere. According to the descriptions provided by the respondents, post-intervention interiors were said to be alive and feel more spacious and historically authentic and some of the respondents said that natural lighting gave life to the decorative surfaces of Mughal tilework and colonial plasterwork in a manner that artificial lighting had never managed to achieve. This theme highlights the experiential aspect of the quality of daylighting that is not well represented within the numerical measurements of illuminance.

#### **Theme 2: Conservation Professional Confidence in Minimal Intervention**

In the interviews conducted as part of the study, there was a generally high level of confidence amongst the heritage architects and conservation officers in the credentials of the light-pipe installation approach used as minimal intervention. The prevention of massive structural penetration, reversible fixing systems and deliberate placing of tubes through pre-existing service voids were mentioned as some of the factors that went hand in hand with the spirit of conservation. Nonetheless, as observed by a number of experts, more specific national direction regarding what should be acceptable when it comes to installations in listed heritage buildings would help instill greater confidence in the profession to recommend such installations.

#### **Theme 3: Occupant Comfort and Productivity Improvements**

Interviews with regular occupants of the retrofitted buildings such as administrative and custodial employees and small business operators working in heritage commercial



## Vol. 4 No. 3 (March) (2026)

buildings widely reported improvements in occupant comfort and, in a few instances, better work productivity due to a better daylighting environment. The respondents often compared the environment after the intervention with that before the intervention in their opinion, citing the fact that it entailed less eye strain, a stronger sense of affiliation to natural rhythms, and lessened dependence of supplementary electric light.

### **Theme 4: Community and Stakeholder Acceptance**

The interaction with the community stakeholders such as resident associations in the heritage neighborhoods and representatives of waqf institutions that manage the heritage of multiple study buildings demonstrated that attitudes toward the light-pipe interventions are broadly positive. The aesthetics stakeholders appreciated the obvious change in the condition of buildings and were grateful when the approach increased functionality without making a change to the features of heritage buildings. Some of the respondents expressed some concerns regarding the long-term maintenance of the rooftop collector components, which indicated a wider-community knowledge of the resource limitations involved in managing the heritage buildings in Pakistan.

### **Theme 5: Institutional and Policy Gaps in Heritage Daylighting Retrofit**

The essential theme revealed through the findings of the theme was that there was a huge disconnect between the technical potential of light-pipe daylighting measures and the institutional capacity to adopt, control, and sustain them in the Pakistani heritage sector. The lack of special guidelines on daylighting retrofit in the current heritage conservation legislation, the dearth of technical training in this field among conservation professionals, and the diffuse governance of heritage buildings (through multiple institutions) was found to be systemic obstacles that should be mitigated by policy formulation and professional capacity-building in order that adaptive daylighting strategies may have a significant effect on the scale of built heritage in Pakistan.

## **DISCUSSION**

This paper has established that adaptive light-pipe technologies have the potential to be a feasible, performance-appropriate, and conservation-compatible way of daylighting retrofit in Pakistani heritage buildings. The significant enhancements observed in interior illumination, useful daylight illumination and artificial lighting energy consumption recorded in the three study sites together with indication of thermal neutrality and structural compatibility of the new fabric with the existing masonry buildings confirm the technical premise of the study. The qualitative results will also be of significance and demonstrate that light-pipe integration is effective to achieve positive changes in occupant experience, professional conservation confidence, and community acceptance. Nevertheless, the paper also points out some significant institutional and regulatory deficiencies that limit the broader implementation of those technologies in the heritage industry of Pakistan. Collectively, these results indicate that the road towards the more sustainable and enriched heritage buildings in Pakistan is technically feasible but needs concerted effort at the professional and policy levels to create transformational effects.

## **CONCLUSION**

This study has shown that adaptable light-pipe technologies can be effectively incorporated into the walls of the Mughal and colonial legacy structures in Pakistani cities to generate considerable gains in the interior daylighting quality, energy savings, and wellbeing of occupants without affecting architectural cohesiveness and cultural



## Vol. 4 No. 3 (March) (2026)

worth. Referring to the field measurements of the empirically measured data, the findings of the simulation, structural measures, and qualitative stakeholder participation across the sites in the cities of Lahore, Multan and Peshawar, the paper confirms the technical efficiency and conservation compatibility of the systems in the particular material, climatic and institutional environments of the built heritage in Pakistan. The context-specific retrofitting framework that has emerged as a result of this study offers a grounded evidence-based framework of conservation professionals, heritage authorities, and policy-makers in order to promote sustainable adaptive reuse of the irreplaceable historic building stock in Pakistan.

### RECOMMENDATIONS

Considering the results of the study, it is suggested that Pakistani heritage authorities should design certain technical requirements of light-pipe installation in the listed buildings that will take the slight-intervention principles, which are proven during this study. Training programs on conservation ought to incorporate the modules on adaptive daylighting technologies based on the South Asian typologies of buildings and climatic conditions. Institutionalization of building performance monitoring protocols should be used to monitor the performance of the system in the long-term to inform the iterative performance. Heritage retrofitting funding mechanisms need to clearly identify sustainable daylighting interventions as qualifying activities and partnership platforms need to be formed between conservation practitioners, energy engineers, and community representatives to enable context-sensitive implementation with reference to the varied stock of heritage buildings in Pakistan.

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## Vol. 4 No. 3 (March) (2026)

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