



OPTIMIZING NATURAL LIGHTING TO REDUCE DISCOMFORT AND MOBILITY ISSUES IN SCHOOLS FOR VISUALLY IMPAIRED CHILDREN, BANGLADESH

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Abstract

Proper natural lighting is essential for developing comfortable learning environments, especially for visually impaired children. It develops general comfort, spatial awareness, and lowers visual strain. However, typical schools in Bangladesh frequently lack proper lighting solutions. While for normally sighted children improper lighting makes the learning process difficult, for visually challenged students the impact is much worse as it directly affects their mobility training. The study assesses existing lighting condition in a typical classroom of the existing modular school building, and offers practical design interventions such as strategic window placement, adjustable shades, and jali screens. Problems are identified by simulating the lighting condition through high-fidelity software, then practical modifications are suggested on the basis of simulating each design intervention. The findings provide guidance for architects, educators, and policymakers in developing inclusive learning settings that encourage mobility and academic achievement for the visually impaired. This study emphasizes the importance of well-designed natural lighting in improving educational outcomes for visually impaired children in Bangladesh.

Keywords: visual impairment, blind, inclusive design, classroom, corridor, lighting, elevation

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INTRODUCTION

Lighting for children with visual impairments is a crucial aspect for specialized schools but that is usually overlooked. It is important to recognize that children with visual impairments often have problems with light sensitivity, glare, and contrast sensitivity (Gould & Herman Gould, 2003). Their difficulties are compounded by poorly designed learning environments in classrooms and other impassable learning or recreational spaces in school. These challenges in their surroundings can cause eye strain, headaches, and make it hard to do the basics like read, write, and get around the school. (Ghasemi Fard et al, 2023). These issues causing unfriendly school atmosphere result in high dropout rate among visually impaired students (Shamima Nasrain, 2017). Normal lighting varies in between 300-500 lux since these are friendly to the eyes and can help improve vision. Developing appropriate lighting standards for visually impaired individuals has been challenging, since different light levels affect people in diverse ways (Lehon, 1980). But study reveals that the optimal arrangement of the lighting in classroom can considerably enhance the educational climate for such students and consequently enhance students' orientation and interaction with environments (Gellhaus & Olson, 1993). Glaucoma, MD and aniridia needs contrast to detect things as they lose peripheral vision. RP, DR, OA need least contrast and minimum glare. Due to different low vision disabilities, a wide spectrum of lighting options may be required to meet their usage requirements. Study shows that daylight has positive impacts on the students' learning environment and performance. (Altomonte, 2009; Kim et al., 2014). This can only be solved through architectural modifications to accommodate lighting conditions free from glare and environments that suit their needs. In this study, the architectural façade and opening design of classrooms and corridors is considered and appropriate luminance levels are examined to accommodate different types of visual impairments. This includes: changing window size, window levels, setting up adequate lighting controls; minimizing glare and the utilization of natural light in an attempt to support the students' learning (Lehon, 1980). The research presents comprehensive global design guidelines for creating inclusive, multisensory learning environments that serve visually impaired students to address these challenges. The research employs Bangladesh as a case study, aligning global benchmarks with local challenges and advocating for high-quality educational facilities that ensure accessibility for children worldwide.

RESEARCH METHODOLOGY

The methodology for this study adopts a modular approach to designing optimal lighting conditions specifically tailored for individuals with visual impairments. First, we classified various types of visual impairments (VI) and based on a thorough literature review, specified the specific lighting requirements for each

type. The understanding underlying this was used to revise lighting standards, pointing out that traditional lighting does not meet the comfort of visual perception for individuals with visual impairments. Building on this foundational analysis, we focused on creating modular solutions that include adaptable luminous environments that can be altered according to the users' requirements, spatial conditions, and functional purposes. We assessed various facade strategies to ensure that the proposed modular units support natural lighting, minimize glare, and maintain optimal luminance levels for a range of visual impairments. By evaluating different ratios of openings and shading devices, we created adaptable facade designs that can be implemented in diverse educational settings.

LITERATURE REVIEW

According to WHO, visual impairment is recognized as a loss of visual acuity or visual field that, despite adequate refractive correction, impairs the performance of visual activities in daily functioning (Tapu et al., 2020). This impairment is classified into blindness and low vision (AlSoufi, 2014). Some of the causes of low vision are cataract, retinopathy associated with diabetes, glaucoma, and macular degeneration (Bourne et al., 2021). Glaucoma is usually characterized by the progressive peripheral field loss and this field loss becomes worse in poor lighting. A cataract is a cloudy area in the lens of the eye that leads to a decrease in vision of the eye. RP makes cells in the retina break down slowly over time, causing vision loss. (*Retinitis Pigmentosa* | *National Eye Institute*, n.d.) Due to macular degeneration major part of central vision can be lost. Ocular albinism is associated with nystagmus and reduced visual acuity. Aniridia a condition characterized by iris hyperplasia and is often associated with reduced visual acuity, and light sensitivity.

Lighting Level Requirements for Different Spaces

Table 1: Ideal illuminance levels for school

Space Type	Standard Illuminance (lux)
1. General Teaching Spaces	300 *
2. Teaching Spaces with close and detailed work (e.g., art and craft rooms)	500 *
3. Circulation Spaces: Corridors	80
Stairs	120
Entrance halls	175
lobbies & waiting areas	250
Reception areas	350
4. Atria	400 *

Source: *Lighting Design for Schools. Building Bulletin* (Loe et al., 1999)

All schools have a range of spaces, many of which are used for a number of different activities, either at the same time or at different times. The lighting design for a school needs to provide a lit environment which is appropriate for the particular interior and indeed exterior, achieving lighting which enables students and staff to carry out their particular activities easily and comfortably in attractive and stimulating surroundings. (Loe et al., 1999). This light range is considered ideal for normally sighted children.

The ideal lighting level and light distribution varies for each visual impairment. The differences can be grouped into 3 luminance level and the classrooms can be designed accordingly.

Table 2: Ideal lighting level per visual impairment

Condition	Ideal Lighting (lux)	Recommendations
Glaucoma	500-1000(Bowers et al., 2001)	Diffused lighting to reduce glare; enhance contrast for peripheral vision.
Cataract	1100-2000(Yong et al., 2024)	Ensure even lighting distribution.
Retinitis Pigmentosa	350-800(Matusiak& Fosse, 2009)	Brighter lighting to enhance remaining visual field; avoid direct light to prevent glare.
Diabetic Retinopathy	300-600(Yong et al., 2024)	Reduce glare and improve contrast sensitivity; ensure even lighting distribution.
Macular Degeneration	500-600(Bowers et al., 2001)	Focused task lighting for central vision; adjustable lighting to suit needs.
Ocular albinism	424-1190 According photosensitivity level (Matusiak & Fosse, 2009)	Reduce glare and improve contrast sensitivity;
Aniridia	194-813 (Matusiak & Fosse, 2009)	enhance contrast for peripheral vision

Source: Author

With lighting level, the next most important part is designing lighting distribution. As almost all the groups of visually impaired children have photosensitivity and sudden change in lighting level make them very uncomfortable. The ideal lighting level is for task performing i.e. for classrooms. Classrooms can be designed for 3 different groups-

Classroom module 1- for sighted children, RP, DR, (Lower luminance level)

Classroom module 2- for G, MD and Aniridia (Mid luminance level)

Classroom Module 3-for cataract with highest luminance level.

EVALUATION OF LUMINANCE LEVELS (SIMULATION) CLASSROOM

We have tested 6 different elevation treatments on the modular classroom layout (Fig1) in GOVT. School in Bangladesh. All Openings Have Single Pane Clear Glass with 0.71 Transmittance.

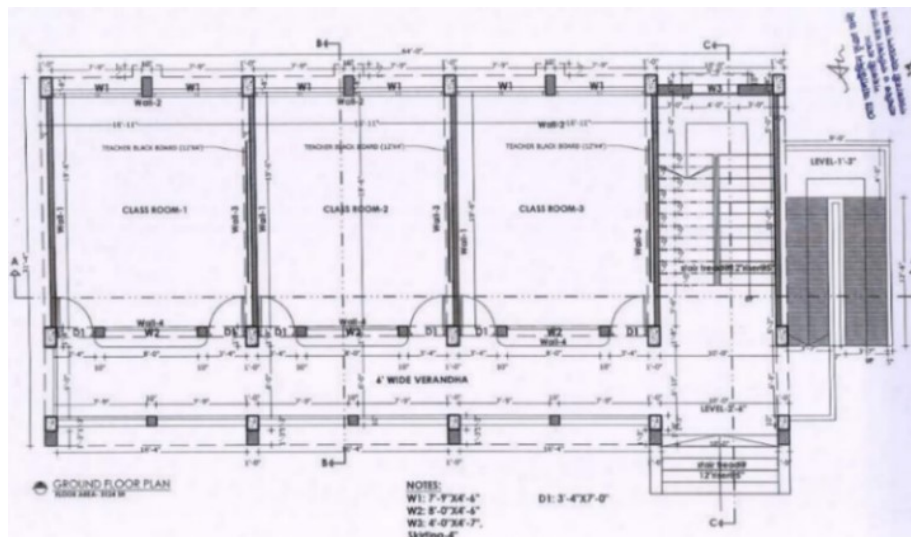


Figure 1: Existing Govt. Modular Primary school building plan
 Source: Fourth Primary Education Development Program (PEDP4) (october 2018)

Classroom Façade 1- Existing Condition

Existing classroom has Sill height of 36", window height 60" (fig2). North facade has 52% opening, South facade has 20% opening as window and 5% opening as 2 doors, opening into corridor. Maximum luminance is 980.36 lux near south windows, and minimum 113 lux near north façade (Fig2)

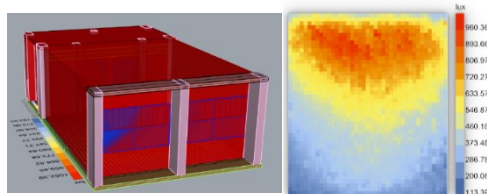


Figure 2: Existing Sill height 36", window height 60"
 Source: Author's Simulation

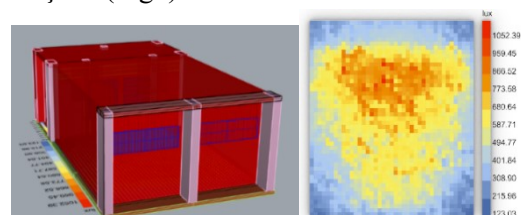


Figure 3: Facade 2; Sill height 60", window height 30"
 Source: Author's Simulation

Classroom Façade 2

Sill height changed to 60", window height changed to 27.24". (Fig3) North facade has 18% opening, South facade has 20% opening as window and 5% opening as 2 doors, opening into corridor. Maximum luminance is 1052.39 lux in middle of the room, and minimum 123 lux near walls and corners (fig3).

Classroom Façade 3

Sill height 82", window height 27.24". North facade has 18% opening, South facade has 20% opening as window and 5% opening as 2 doors, opening into corridor. Maximum luminance is 647.67 lux in middle of the room and minimum 115.16 lux near walls and corners (Fig4).

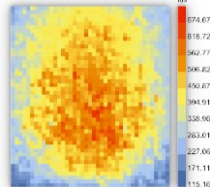
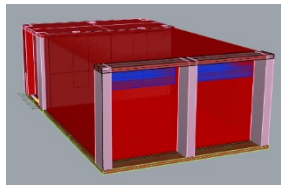


Figure 4: Façade 3; Sill height 82", window height 27.24"

Source: Author's Simulation

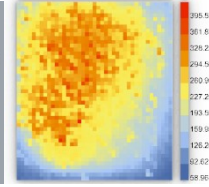
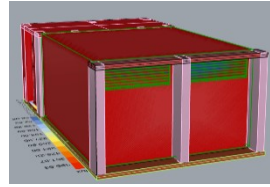


Figure 5: Façade 4; Sill height 82", window height 27.24"

Source: Author's Simulation

Classroom Façade 4

Sill height 82", window height 27.24" with horizontal louvers at 30-degree angle. North facade has 18% opening, South facade has 20% opening as window and 5% opening as 2 doors, opening into corridor. Maximum luminance is 395.5 lux left side and in middle of the room and minimum 60-100 lux near walls and (Fig5).

Classroom Façade 5

Sill height 3", window height 90" with louvre. North facade has 60% opening, South facade has 20% opening as window and 5% opening as 2 doors, opening into corridor. Maximum luminance is 1924.8 lux in middle of the room, and minimum 60 lux near walls and corners and north facade. s. Louvres depth 5in, shade count 47 with distance 3in from one another, angle 30 degree (fig6).

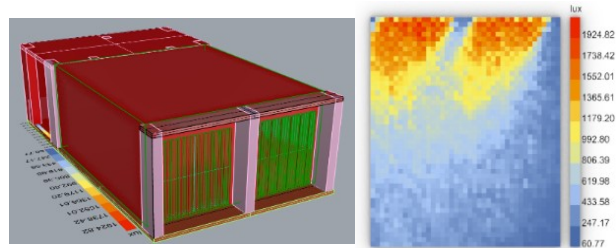


Figure 6: Facade 5; Sill height 3in, window height 90in
 Source: Author's Simulation

Classroom Façade 6

Jali Pattern-1: Pattern 2.5"x7.5" perforation after solid wall of 1'-2". Maximum light 2739 lux. 400-800 LUX on maximum surface area. Minimum light 27-50 lux near the columns. (fig7)

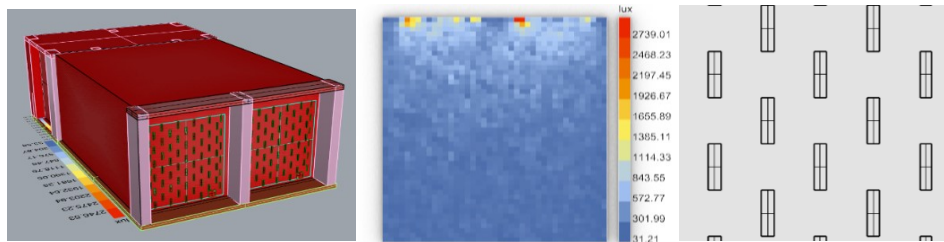


Figure 7: Facade 9; jali pattern 1
 Source: Author's Simulation

Classroom Façade 7

Jali Pattern-2: Pattern 3.5"x9" perforation after solid wall of 3.5". Maximum light 3301 lux. 450-1000 LUX on maximum surface area. Minimum light 130 lux near the columns (Fig8).

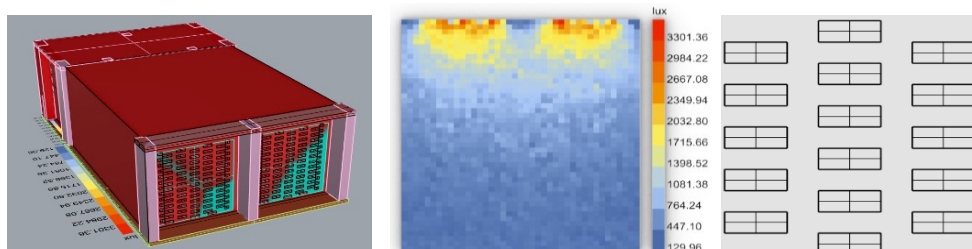
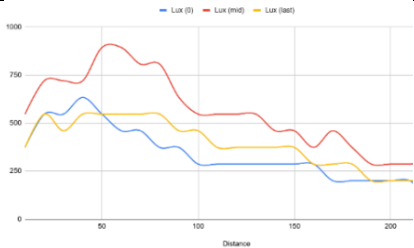
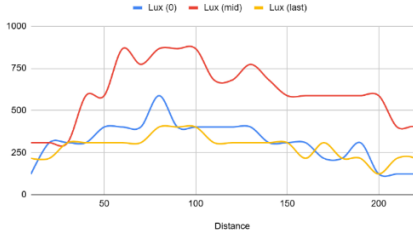
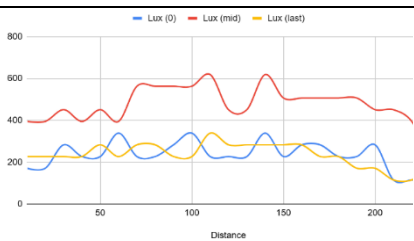
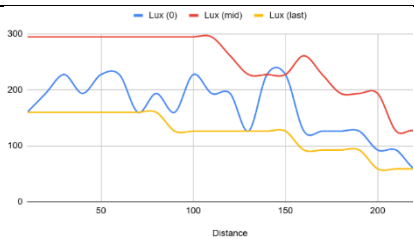


Figure 8: Facade 10; jali pattern 2
 Source: Author's Simulation

Simulation graphs showing change of luminance level at 3 lines, at left side (blue line), middle (red line) and right side (yellow line) of the room. (lines taken at right angle from window position). From the graphs we can understand the light distribution quality and amount of glare caused by each façade.

Table 3: Graph Comparison

Facade	Graph	Description
Façade 1		The peak point can be seen close to the window. Most sudden changes are seen in middle line. The highest level in the beginning indicates effect of glare and decreasing graph shows very poor light distribution.
Façade 2		The peak point can be seen in the middle of the room, changes in lighting level are not that sudden, which means moderate glare. Almost gradual change shows moderate light distribution.
Façade 3		The peak point can be seen in the lower middle part of the room, some sudden changes are seen in this line too. Light change is gradual and no sudden change show good light distribution and very little glare.
Façade 4		The peak point can be seen in the upper middle, the change in luminance here seems gradual till the midpoint, then the change becomes very insignificant, side (ending) has gradual change. Light distribution poor in part of room.

Facade	Graph	Description
Façade 5		The peak point can be seen at the nearest point of the window, near the south facade. The luminance near the south facade is very high, then decreases till the end line. Light distribution poor and will cause too much glare.
Façade 6		The peak point can be seen at the nearest point of the window, near the south facade. Glare is low near windows and almost zero in rest of the room.
Façade 7		Peak point is seen close to the window. Though light distribution seems good in maximum area of the room, near the windows the light will cause too much glare.

Source: Author's Calculation

CORRIDOR

Corridor Façade 1 -Existing Condition

North facade has 20% opening, South facade has 65% opening. Opening into corridor. Railing height is 36", opening height 6'. Maximum luminance is 5465 lux across railing, and minimum 1757 lux near north facade.

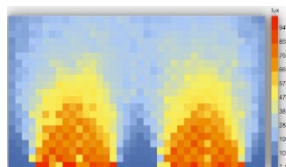
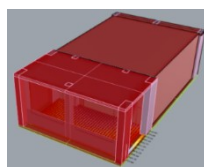


Figure 9: Corridor facade 1; existing condition

Source: Author's Simulation

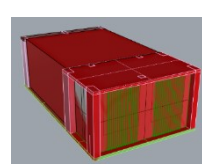


Figure 10: Corridor facade 2; with outdoor louvers

Source: Author's Simulation

Corridor Façade 2

With full height opening and outdoor louvres, 5" depth and 0-degree angle, maximum luminance 949 lux beside railing (on both side of the middle column), Minimum luminance 7.18 lux which is too low.

Corridor Façade 3

Pattern 5.5" x 1'-6" perforation after solid wall of 1'-6.5". Maximum light 200-305 lux, on maximum surface area. Minimum light 27-50 lux near the columns.

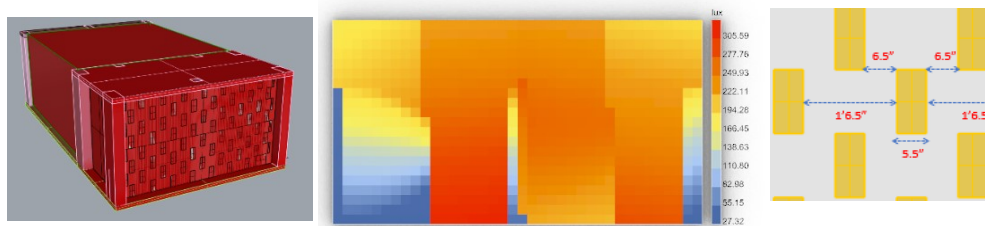


Figure 11: Corridor facade 3; Jali pattern 1
Source: Author's Simulation

Corridor Façade 4

Pattern 6" x 1' perforation after solid wall of 1'. Maximum light 2982 lux, near jali wall. Minimum light 762 lux near the opposite wall.

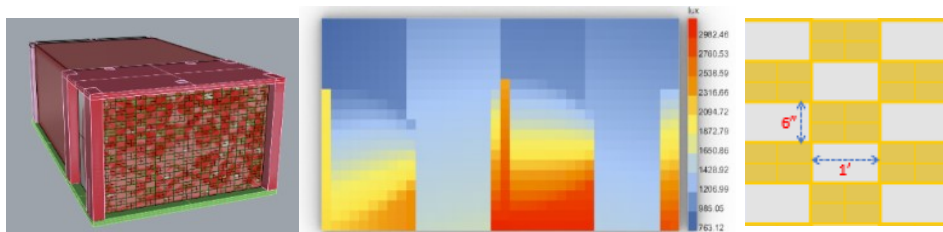


Figure 12: Corridor facade 4; Jali pattern 2
Source: Author's Simulation

Corridor Façade 5

8.5" x 6.5" perforation after solid wall of 9.5". Maximum light 453 lux, maximum surface area has 150-173 lux. Minimum light 63-93 lux near the columns. 300-400 lux is coming at intervals. Which is creating a better contrast.

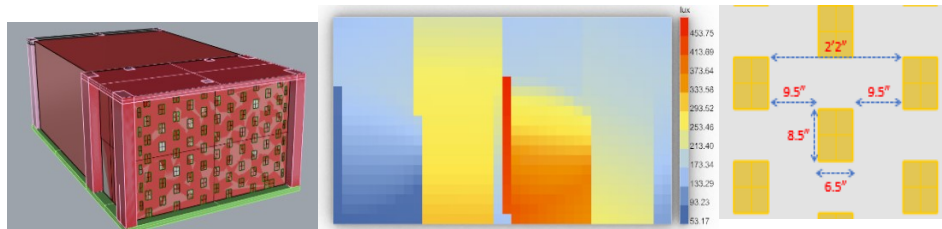


Figure 13: Corridor facade 6; Jali pattern 4
 Source: Author's Simulation

DESIGN GUIDELINES

Classrooms

The existing façade of classroom does not provide ideal lighting and poor light distribution will cause too much glare for all groups. The simulation result shows the higher the sill level, light distribution is better. All classrooms are considered with corridor on the south side and fixed openings on this side.

Table 4: Classroom Façade options comparison

Façade	North Façade Opening	Max Luminance (lux)	Min Luminance (lux)	Notes
Façade 1 - Existing Condition	52%	980.36	113	Not suitable for any group
Façade 2	18%	1052.39	123	Ideal for 1st group
Façade 3	18%	674	115	Good for photosensitive children and sighted children
Façade 4	18%	398.9	60-100	Low glare, low light transition, Good for photosensitive children
Façade 5	60%	1924.8	60	Moderate glare
Façade 6	2.5"x7.5" perforation	2739	27	Can be used for cataracts
Façade 7	6"x12" perforation	3300	129	Best for RP and MD

Source: Author's Calculation

The best option for sighted children RP, DR, (Lower luminance level) is facade 2, (Sill height 60", window height 27.24"), as maximum luminance is 1052 lux, maximum area of the room has 400 to 600 lux. The transition level is low, increased sill level provides low glare. 2 is best for classrooms where practical or handicraft works are taught. Facade 4 is a good option for group of children who are highly photosensitive, having the lowest glare and slowest light transition. Facade 7, jali pattern 2 is best for G, MD and aniridia (Mid luminance level), maximum room area has illuminance from 447 to 1200 lux. For the third

group, children with cataracts will prefer façade 5, with full height window and 30-degree louvers with reduced glare. Façade 3 showing slower transition and maximum 647 lux luminance can be considered ideal for a combined classroom.

Corridor

The circulation spaces need to be designed considering all the users, children and adults (teachers and caregivers) from all groups. The minimum lighting level for circulation space is 80 lux (Loe et al., 1999). So, the corridor needs to be evenly lighted with contrast at fixed intervals with minimum glare (diffused light). The existing condition is not ideal for any group and provides very poor condition for visually impaired group.

Table 5: Corridor façade options comparison

Façade	South Facade Opening ratio	Max Luminance (lux)	Min Luminance (lux)	Notes
Corridor façade 1	65%	5465	1757	High luminance variation unsuitable for visually impaired;
Corridor façade 2	Full	949	7.18	Provides shading but overall not sufficient for all groups;
Corridor façade 3	50.5%	305	27-50	Even light on most surfaces but low contrast unsuitable for those with peripheral vision loss.
Corridor façade 4	24.8%	2982	762	High illuminance and contrast but too bright for photosensitive individuals.
Corridor façade 5	20.4%	3706	880-1160	Adequate contrast, suitable for normally sighted but too bright for photosensitive users.
Corridor façade 6	20.8%	453	63-93	Good contrast with low, diffused light, suitable for all groups;

Source: Author's Calculation

In Corridor façade 3- jali pattern 1 though light level has been acquired, this type light distribution is not good for circulation for children with peripheral vision loss. As the contrast is very low, the intervals will not be clear. Though it can be a good option for normally sighted people, not ideal for people with photosensitivity. Corridor façade 6- Jali 4 is providing good contrast with diffused low range light. In corridor façade 4- jali pattern 2, though contrast is acquired the illuminance level is too high. So, the best elevation for corridor façade 6, with pattern 8.5"/6.5" perforation after solid wall of 9.5", considering all groups of people.

RESULTS AND DISCUSSION

Findings:

The existing condition in both classroom and corridor are not suitable for the visually impaired children. The existing classroom is divided into two zones, low light and highly intense light. The transition of light is very sudden and distribution of light is too poor. Poor light distribution and high glare make the overall school environment unsuitable and children find it difficult to even participate in regular activities. High glare will cause eye problems in normally sighted children too, this may result in various health issues. For inclusive education, the facade design needs to be changed to facade option 3. The existing corridor is not suitable for any group. Uncontrolled lighting makes it hard for them to move around and hence limit their mobility. In case of visually impaired children where walkability is very crucial for their overall growth and mobility being a must learn skill, the existing type corridor must not be used. For special schools, the corridor facade design can be changed to facade 6. For inclusive school's corridor either facade 2 or facade 6 can be used.

Implications:

- **Educational Impact:** Better lighting conditions should be considered as one of the ways that can help the students with impaired vision since it will make the school environment better for them it and lessen the dropout rate.
- **Design Recommendations:** Develop recommendations for type of lighting and design of the lighting solutions for educational facilities for visually impaired people including the principles of flexibility, control of glare and task-oriented lighting.

Limitations:

- **Simulation Constraints:** There are currently real-world issues for example dynamic daylight conditions which might not be aptly modelled in simulation.
- **Generalizability:** This may call for modifications depending on regional and architectural circumstances of each recommendation.

Future Research:

- **Technology Integration:** Exploring advanced lighting technologies like smart lighting systems that adapt in real-time to the needs of visually impaired individuals.
- **Longitudinal Studies:** Conducting studies to assess the long-term impact of optimized lighting on educational outcomes and well-being.

CONCLUSION

The existing configurations of classroom and corridor lighting in the analyzed school module were found to be inadequate in terms of illumination levels and uniform light distribution, resulting in significant visual discomfort and limited mobility for the students. In a number of simulations, this study showed that changes in size, location, and ratio of openings: window height changes, raising sill heights; incorporation of louvers and jali patterns can greatly improve the lighting conditions. In particular, the study focuses on the difficulties for visually impaired students, especially for those who are sensitive to light: it is necessary to minimize glare, but at the same time, the luminance should be sufficiently high for some groups. The placement of modular adjustments and shading elements proposed for the facades come with valuable ideas for improving learning environment for students with disabilities. Finally, the study also highlights the need for future studies into smarter forms of lighting control and potential follow-up studies to enhance these architectural approaches. Thus, following these design guidelines, educational institutions can contribute to providing comfortable visual perception and movement opportunities for students with VI and create conditions that do not hinder the learning process and, on the contrary, will encourage independent access to learning materials for students with VI.

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