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The Daylight Assessment of classrooms in Community schools of Kathmandu Valley

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Abstract

Indoor comfort is a major consideration in the construction industry. School is an important place for kids to hone their various abilities. One of the most important requirements that buildings must meet is the provision of a safe and comfortable internal environment. It has a major contribution to the creation of an adequate educational environment. Visual comfort can be achieved either by artificial lighting or by daylight. Appropriately implementing daylighting into the building design can enhance a school's finances, have a favorable impact on utility costs and, as a result, the environment, as well as boost the health, productivity, and mood of those who work and learn there. This paper presents an overview of indoor daylighting assessment in classrooms of community schools of Kathmandu valley. It compares the window floor ratio to the size of windows offered in various classroom types and their contribution to visual comfort in terms of illuminance and daylight levels. Energy performance in school buildings is very significant, for ascertaining the health and productivity of students and teachers. So visual comfort has high importance for new buildings design as well as retrofit of existing ones. The purpose of this research is to study daylighting performance of the various community schools' classroom in the case of Kathmandu valley. Daylight analysis of all seven case classrooms was studied through their opening positions and orientation of building. The study concludes that Daylight analysis of existing classrooms of various case studies didn't meet adequate lighting levels for reading purpose during the day. Only case I-W classroom meets above the standard daylight illuminance of 300 lux for reading desk in classroom. The minimum value obtained in the desk plane is 326 lux. Daylighting analysis shows that renovations are needed in most of the classrooms to meet the standard illuminance for reading plane.

Keywords
Daylight, Classrooms, Community Schools, WWR, WFR, Daylighting Levels

1. Introduction

Good daylight is closely related to improving student performance and promoting better health [1]. Natural light offers significant physiological benefits in school buildings, and it can improve energy efficiency while lowering the building's operating energy use. As a result, it's critical to increase the amount of natural light and improve its quality in educational settings [2]. Providing a safe and comfortable indoor environment is one of the main requirements that buildings must meet; indeed, the standards of the indoor environment defined by its main axis, namely thermal, acoustic and visual comfort, and indoor air quality, can be a key factor. The reason is not only related to health problems, but also to the happiness and productivity of the building occupants [3]. When inspecting from the perspective of the entire inventory of the building, it belongs to the most important category of institutions in our community; educational facilities play a central role and children spend approximately 25 percent of their time in class. Furthermore, the school's occupancy rate is much higher than that of any other building [4].

New building design generally does not consider climate-sensitive design strategies or apply any energy- efficient technology, because the government has not formulated any energy-saving regulations [5]. Especially school buildings have become an object of interest in energy conservation. Energy efficiency and indoor climate comfort are key performance characteristics of schools of good practice in line with the principles of sustainable construction [6]. Depending on the appropriate window shape, size (window to wall ratio), and type of glass, beams can significantly reduce the need for artificial lighting. Integrating lighting strategies with electric lighting control can provide automatic adjustments to provide the lightest levels of energy use at the lowest possible levels [7].

In Nepal, many educational buildings are designed without lighting, which affects the energy consumption and performance of students and teachers. In addition, after the 2015 earthquake, school buildings were design-based, meaning similar structures were implemented across the country, regardless of whether the building's climate, materials, and layout were appropriate. From direct observation, the opening of the prototype or historical institution is opaque and the direction is random, which generates insufficient light in the classroom and affects the physical and mental existence of students and teachers. Furthermore, artificial lighting can be uneconomical for developing countries like ours. Several studies have been conducted on the visual comfort of classrooms around the world. But when it comes to Nepal, we can hardly find such research. New building design generally does not consider climate-sensitive design strategies or apply any energy-efficient technology, because the government has not formulated any energy-saving regulations [5].

Therefore, it is necessary to make an analysis for a better understanding of indoor visual comfort in classrooms. The aims are to find the daylighting performance of the various community schools' classrooms to save energy use in the case of Kathmandu valley. The main objectives of this study are: 1) To evaluate daylight performance classrooms of four schools' classrooms and the potential of daylighting to save energy use and 2) To compare the current state and renovation scenarios for saving energy use with investigated of windows fenestrations.

2. Methodology

The study uses a survey-based method to describe and collect data on current community schools' classrooms inside the Kathmandu valley. The quantitative and qualitative techniques have been used to ensure that the information gathered throughout the study is worth analyzing and evaluating. It follows the investigation of classrooms of various schools in Kathmandu valley to understand the actual situation of the daylight performance and their necessary improvement measures to reduce energy consumptions.

To achieve this aim, firstly, a literature review on Daylighting, metrics of Daylight, and sidelights have been done. Then, various schools were selected for the study of related topics. Necessary data i.e., orientation, layout, sizes, floor height, windows sizes, windows position, surrounding etc. were taken through field surveys, interviews, and measurements.

Lastly, the various results obtained during the study have been compared, analyzed and suggestions on the selected strategies have been made. Furthermore, detailed analysis of schools' classrooms were done through simulation tools. For the simulation, Autodesk Ecotect 2011 was utilized, and the performance of classroom daylighting was measured in terms of illuminance level and daylight factor. To further uncover common factors, a comparing chart based on survey data has been developed, and the performance of each cases analysed and carried to intervention parts.

3. Literature Review

3.1 Daylight

Natural light affects indoor climate and health. Especially in educational buildings, visual comfort is very important. Daylight has a positive effect on the alertness and health of students [6].Most lighting needs can be met without unwanted heat gain or glare if lighting representatives design windows, skylights, and overhead monitors effectively [8]. Proper daylighting can lower the energy expenditures of a typical school by 25 percent to 40 percent. From dawn to dusk, from day to day, from season to season, the intensity and color of daylight change. Some people think of it as a fickle source of sunlight and best ignored, but it can also be a powerful vehicle for architectural expression. Because it moves, changes features, and changes with the weather, it can provide buildings with a quality of life that other design elements cannot achieve [9].

The standard of daylight as a light source is an important reason to use daylight in buildings. Daylight is a mixture of sunlight and light from the sky, and it is the type of light that most people have the closest visual response to. Daylight has been full spectrum light for many years, the human eye has evolved using this full spectrum light due to the light source compared to all other light sources [10].

3.2 Light in School Buildings

Visual comfort is an emerging field of research, but generally involves the use of natural light sources to achieve appropriate light levels for building users through glass design considerations. Classroom lighting also affects the student's circadian rhythm system, which in turn affects test scores, attendance, and behavior. Natural light is the most important resource for improving the interior quality and energy efficiency of educational buildings, as well as their long-term sustainability [11]. A well-integrated daylighting design has a higher positive impact on a school than other sustainable design solutions. The addition of daylight will not result in a significant increase in the number of windows. If uncontrolled direct beam radiation penetrates the classroom window and strikes a pupil in the face, the instructor will simply close the curtains, negating their lighting plan entirely [12].

3.3 Daylighting in Typical classrooms

In the case of a sustainable approach, natural light is used as the main indoor light source. The classrooms provide daylight through the windows, which provide various lights and pavilions. When it's cloudy, the daylight in the classroom should provide enough light, and when it's sunny and sunny, it should provide comfortable lighting conditions. Lighting is important for visual tasks and helps you stay focused. Few students stare at the desk all day; Frequent interactions with teachers, classmates, and teaching surfaces (blackboards, chalkboards, or interactive displays) mean that your eyes travel through space and your attention is constantly shifting. The facades and roofs of buildings, depending on their ratio of glazed area, shading or natural lighting system, can greatly affect the lighting energy consumption, of course, the premise is to turn off the lights when there is natural light. Many studies have reported results related to the use of daylight, namely the replacement of electric lights with daylight.

3.4 Metrics used to assess daylight performance

3.4.1 Illuminance

The first and most common indicator for providing natural light is illuminance. The ratio of the incident light flux on an infinitesimal surface at the point to the surface area is measured in lux at a certain position on the working plane and at a specified instant in time. According to various standards, the illuminance in the classroom should be kept above 300 lux [13].

3.4.2 Daylight factor

The daylight factor (DF) is the ratio of solar illuminance measured at the same time under an obstacle-free horizontal surface to solar illuminance recorded at a specific place in the area. The DF must be determined under cloudy conditions according to the specification, therefore it ignores the impacts of direct sunshine. These figures are based on the following premise: The exterior illuminance is roughly 10,000 lux when the sky is cloudy: As a result, even in the absence of direct sun irradiation, the average DF = 3 percent may ensure at least 300 lux on the working plan.

3.5 Lighting Policy and strategies

Lighting policy is the way a given entity (usually the government) decides to solve lighting development issues, including light distribution and energy consumption. As a developing country, Nepal's infrastructure industry has formulated various parameters and rules. The lighting policies and strategies of the Nepalese infrastructure industry have degraded to the point that their importance and the resulting problems are not adequately considered. The lighting system plays an important role in the building envelope in psychological, environmental and economic aspects. Nepal has not yet issued a policy on the level of lighting for different spaces in different building envelopes. This research can help stakeholders and government departments develop lighting prerequisites for school buildings. The standard window-to-wall ratio of a room in Nepal is 25 percent of the building area. It is recommended that the minimum aperture area for daylight is 1/10 of the room area in mountainous areas, and the reference aperture area required for a 4m x 4m room is 1m x 1.5m.

3.6 An overview of previous studies

The indoor climate of the classroom is greatly affected by the windows. Solar gain will affect indoor thermal stability and natural lighting. The quality of the thermal insulation of the building envelope and the efficient curtain system seems to be the basic tasks of the teacher's renovation strategy [6]. The huge layer of insulation has a positive effect on reducing heat loss, but will prevent solar energy and sunlight from entering the room [14]. Compared to the open position, the opening area has a greater impact on power consumption. As the aperture area increases, the cooling load increases sharply [15].

4. Research Context and Case Studies

Kathmandu is a capital city located at latitude 27.7172ºN and a longitude of 85.3240 ºE in the central part of Nepal. Kathmandu represents Nepal's pleasant and comfortable temperate climate, which is particularly prevalent in the Hilly Region. The climate of a location is influenced by a variety of geographical elements, but topography and altitude are the most important. In the flat plains of Terai and the Himalayas, Nepal endures extremes of hot and cold temperature.Kathmandu is located in the Warm Temperate Zone, which means it has a good climate. The climate of Kathmandu is sub-tropical moderate, with slightly hot summers and cold winters, according to a study of climatic data acquired from the Meteorological Department for Kathmandu airport. At 1350 meters above sea level, Kathmandu enjoys all four seasons: summer, autumn, winter, and spring. All the case studies are the Community-school buildings located within the Kathmandu valley. The two schools studied buildings are recently constructed after the Gorkha earthquake in 2015 and the remaining two buildings are old ones. And the case-studied school buildings with the necessary data needed for this research are described below.

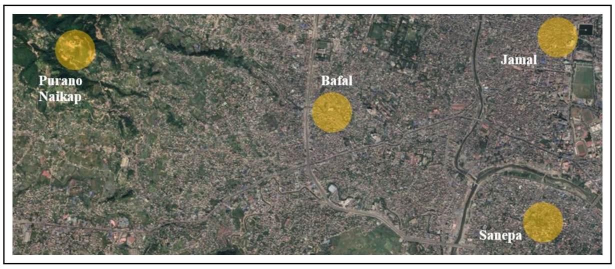

Figure 1: Case study area in google map

4.1 Case I

Durbar High School is located near Ranipokhari in Kathmandu Metropolitan City-27 and is stretched across nine and a half Ropani of land. The Chinese government provided full financial support for the reconstruction of this school, which was done using modern building materials while maintaining its traditional appearance. The four-story building has 40 rooms. But this school was originally built using mud, bricks, pulses, and lime.

Figure 2: Exterior view of Durbar High School

Among forty rooms, two classrooms from the ground floor and one classroom from the first floor are selected for the study. The building is oriented north-south elongated with window openings in both east and west side of the building. The ground floor of DHS includes two large entrance lobbies connecting to a central Eight feet wide lobby with adjacent two staircases. Washrooms are provided in the northwest corner and a canteen are provided on the south side of a building. The important part is that pre-primary classes are provided on the ground floor. And rest primary and secondary classes are provided on the first floor. And higher secondary classes and multipurpose halls are provided on the top floor of the building. The typical classrooms of size 5.72 m x 8.23 m are designed for 36 students. Similarly, two doors of size 1.22m x 3.15m and three windows of size 2m x 2m and 1.07m x 3.13m are provided in each classroom.

Figure 3: Photograph of classroom at first and second floor

The interior walls of classrooms are painted with blue and white colour. Similarly, study desk and sitting chair with light brown with blue border.

Figure 4: Photograph of east side view

Figure 5: Photograph of west side view

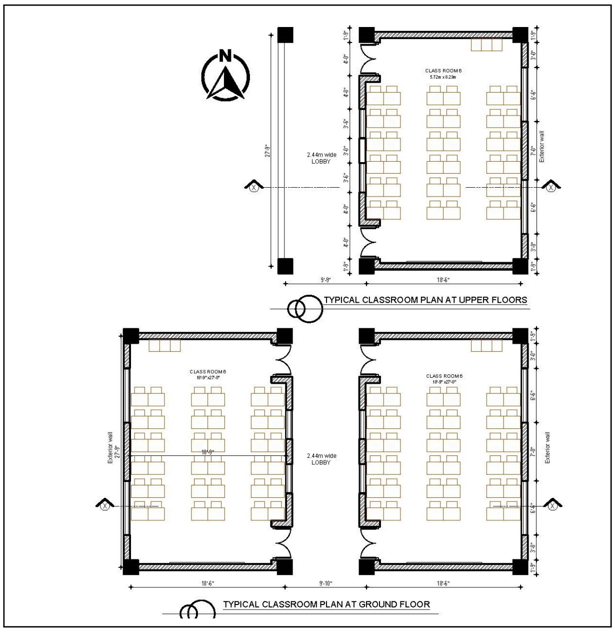

Figure 6: Typical floor plans of Durbar High Schools Classrooms

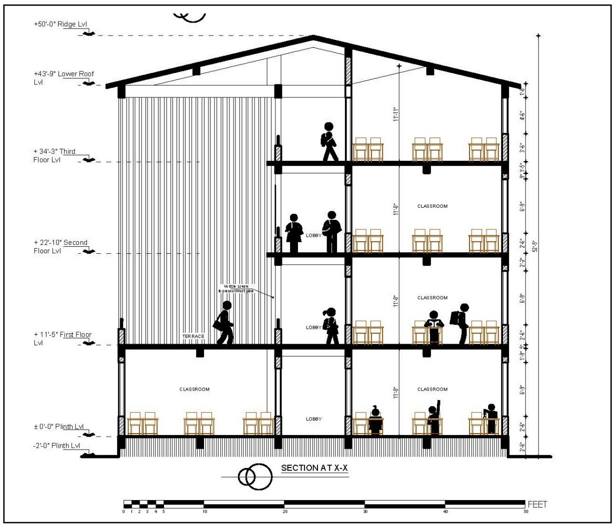

Figure 7: Typical section of Durbar High Schools Classrooms

4.2 Case II

Shree Tika Vidhyashram Secondary school is situated at Sanepa, Lalitpur in the core of the residential area. There are a total of seven blocks and the classroom block was inspected for research. This building is recently constructed after the Gorkha earthquake 2015 by JICA aid. In the classroom block, there are nine classrooms on each floor there are three classrooms. The building is oriented north-south elongated with a 2.5m width lobby at the west side. The typical classroom size is 6.75m x 6.775m with 2 entrance doors from the west lobby. Two windows are provided on the east side and one on the west side for proper daylighting. The size of the windows and door is 1.1m x 1.45m and 1.1m x 2.2 m respectively. The total capacity of the classroom is 42 students. The south classroom is considered for this study.

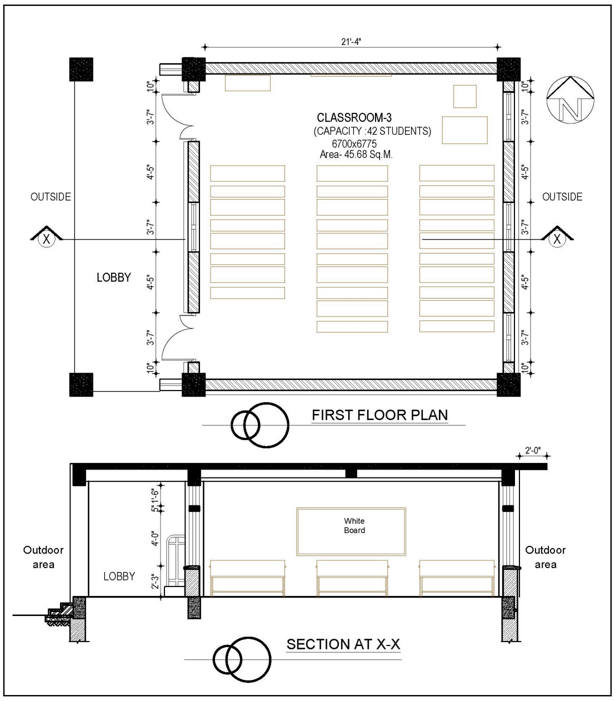

Figure 8: Classrooms Detail plan and section of Shree Tika Vidhhyashram Secondary School Classroom

Figure 9: Photograph of Classroom of Shree Tika Vidhyashram School

4.3 Case III

Gyanodaya Secondary School is located in Bafal, Kathmandu Metropolitan city 13. This school was established in 2020 B.S. There are a total of four buildings in the school building. The classrooms of block C are carried out for this research. The selected block plinth area is 409.72 sq.m. The building is oriented North-South elongated. There are 20 classrooms and 1 library and 1 multipurpose hall. The main entrance is from the west side which is connected to the central 2m width elongated lobby. There are two windows and one door for each classroom. The size of the classroom is 5m x 5.34m and each classroom has 33 students' capacity. Wooden timbers are used in both door and windows opening.

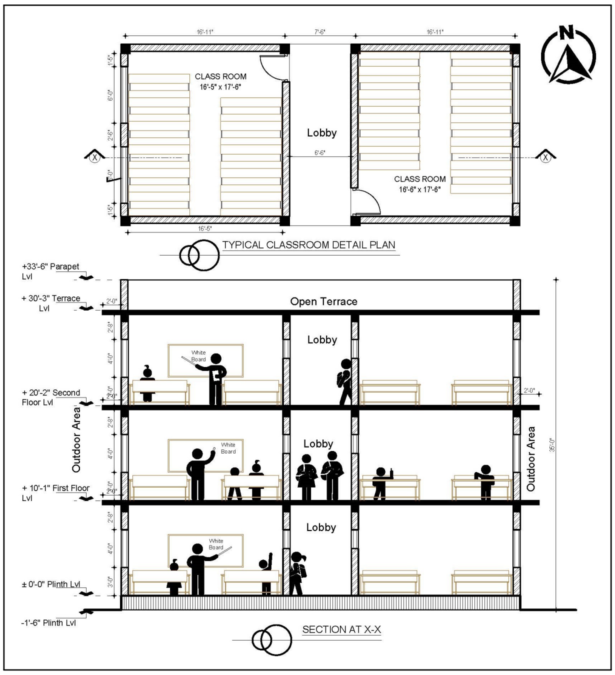

Figure 10: Typical Classrooms floor plan and Detail section of Gyanodaya Secondary School

Figure 11: Photograph of classroom

4.4 Case IV

Shree Kankali Secondary School is a community school situated in Purano Naikap, Chandragiri, Kathmandu. The school lies on a small hill Kankali on the west side which is nearly 3.7 km from the Kalanki chowk. There are 8 building blocks inside the site. Block D is selected for the research purpose. The plinth area of Block D is 217 Sq.m. The building is a two-story where ground floor containing five classrooms and the first floor containing the library, Dance room, meeting hall, and Laboratories.

The building is a single bay orienting east-west elongated with a 1.5 m open lobby on the south side. The size of typical classrooms is 7m x 5m. the capacity of the classroom is 30 students. Each classroom contains four timber windows and one timber panel door. The ceiling height of the room is 2.85 m and the sill level is 0.75 m. The classroom looks quite managed with proper necessities for both teachers and students. blue and yellow color are used in students desk and similarly blue and white colours in class interior walls.

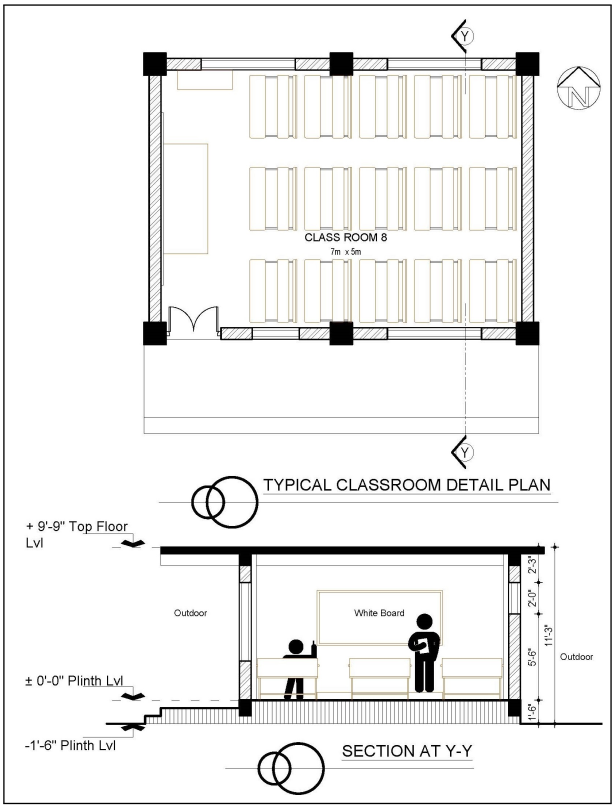

Figure 12: Detail floor plan and section of Shree Kankali Secondary School Classroom

Figure 13: Photograph of interior Classroom with openings

Figure 14: Photograph of typical Classroom of Shree Kankali Secondary School

5. Finding and Analysis

5.1 WWR and WFR

Table 1: WWR and WFR of case studied classrooms

Case	WFR	WWR
Ia	12	22
Ib	18	31
Ic	18	31
II	16	29
IIIa	17	28
IIIb	17	28
IV	15	19

Table 1 shows the existing WWR and WFR of classrooms computed from case study site inspection and measurements. WFR and WWR are higher in case I classrooms. Similarly, in the case IV classrooms, has the lowest value of WWR and WFR.

5.2 Simulation

The daylight simulation of classrooms in the Autodesk Ecotect software consisted of various stages. In the first stage, the base model of the building resembling the present school buildings in Kathmandu was simulated and the results of daylighting were seen. After combining the weather file of Kathmandu in Ecotect, daylight analysis was the major concern to study in case of classrooms the next stage consisted of changing the design parameters to improve the daylighting inside the classrooms. Daylighting in all selected classes in each school was simulated in cloudy sky conditions with a design sky illuminance of 10,000 lux for the chosen site. For testing, a window cleanliness value of 0.90 was used. Daylight was measured for a working plane at a height of 0.70 m above surfaces. Finally, simulation was performed on a selected classroom analysis grid while taking into account natural lighting levels.

5.2.1 Case I

Figures 15 and 16 illustrate the daylighting analysis of Durbar High Schools typical classrooms. The east classroom has a minimum and maximum daylighting level of 180 lux and 2380 lux, respectively. Similarly, the lighting levels in the west side classrooms ranged from 120 to 2820 lux. Again, the daylight factors for the east and west sides of the classroom were in the range of 1.2-21.2 and 1.8-21.8, respectively.

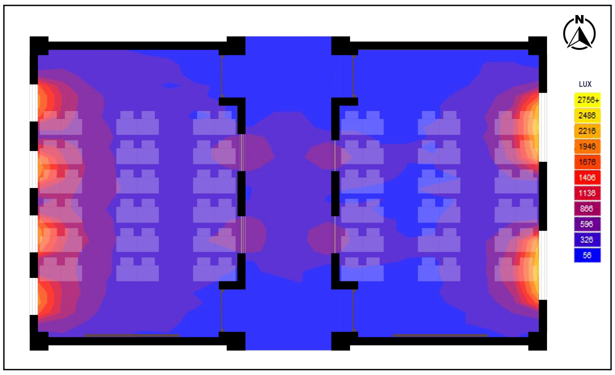

Figure 15: Daylighting analysis of selected ground floor classrooms of Durbar High School

The lowest and maximum daylighting levels calculated at the first-floor classroom are 210 lux and 3210 lux, respectively. The computed daylight factor ranges from 2.1 to 22.1 percent.

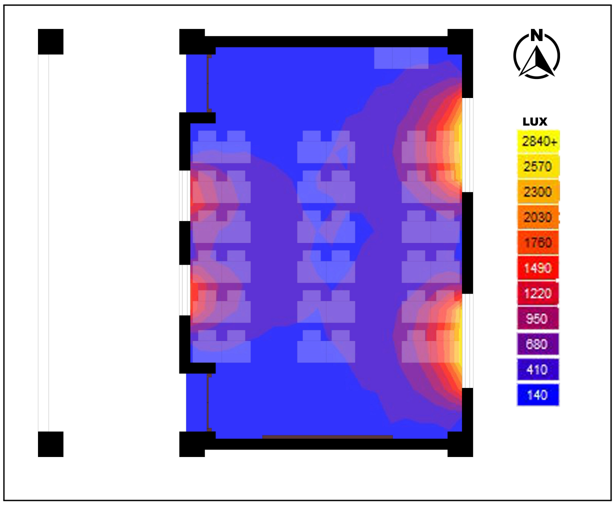

Figure 16: Daylighting analysis of selected first floor classroom of Durbar High School

5.2.2 Case II

Similarly, a daylight analysis of Shree Tika Vidhyashram's classroom was performed, yielding a minimum daylighting level of 64 lux and a maximum daylighting level of 1764 lux. This building's orientation and window placement are comparable to Case I. The daylight factor varies between 0.6 and 20.6 percent.

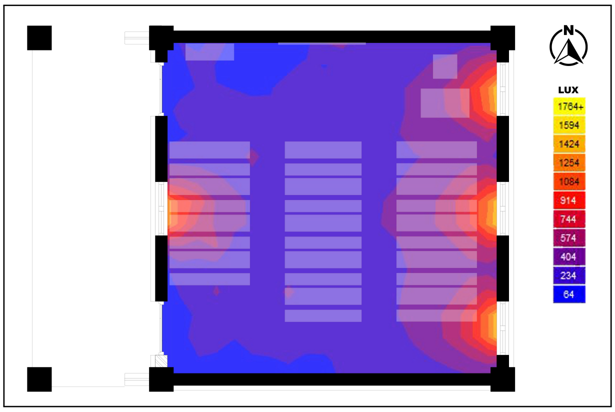

Figure 17: Daylighting analysis of selected classroom of Shree Tika Vidhyashram Secondary School

5.2.3 Case III

During the simulation of Gyanodaya Secondary School, both classrooms windows were taken as void because of less area of glaze in windows shutter. Figure 18 shows the minimum and maximum daylighting levels at the east classrooms of GSS with

81 lux and 2381 lux respectively. And daylight factor for classrooms ranges of 0.8 to 20.8.

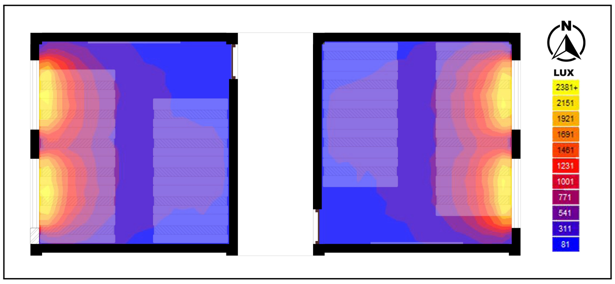

Figure 18: Daylighting analysis of selected classroom of Gyanodaya Secondary School

5.2.4 Case IV

Finally, the classroom of Shree Kankali Secondary School was selected for daylight analysis. The daylight analysis of the classroom revealed that the minimum daylighting level was 120 lux and the highest daylighting level was 1820 lux. Case III is distinguished from the others by the building's south orientation and opening positions on both the south and north sides.

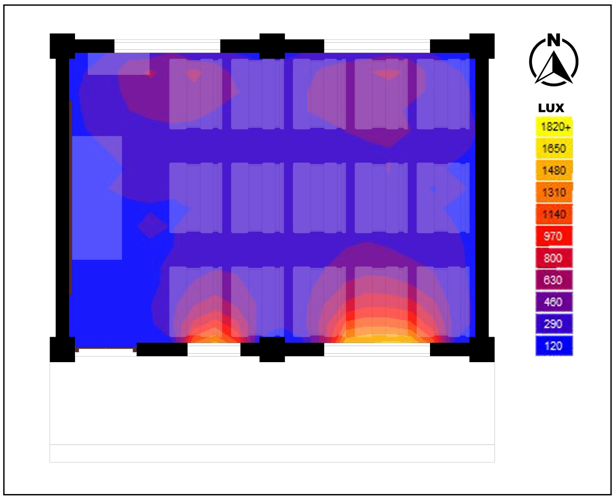

Figure 19: Daylighting analysis of selected classroom of Shree Kankali Secondary School

6. Discussion

Daylight analysis of all seven case classrooms was studied through their opening positions and orientation of building. Only in the case of DHS west side unilateral windows position meets above the standard daylight illuminance of 300 lux for reading desk in classroom. The minimum value obtained in the desk plane is 400 lux DL or 3.8 DF. Similarly, bilateral E/W side windows position classrooms and east side unilateral windows classroom don't meet the standard illuminance in indoor desk plane.

The east side classroom at Durbar High School had a minimum of 2.8 daylight factor. The east side windows were considered rectangular performing daylight analysis because the circular part above rectangular windows is permanently opaque. Similarly.SKSS being different orientation than that of other classrooms, it meets the standard levels of daylight in students reading desks. This might be because of openings in the south side maximum sun expose and sun angle. But the result shows that the remaining studied classrooms didn't obtain the required daylight level in the whole area inside the classrooms. So, the renovation is required to meet required the standard level of daylighting by changing the position and sizes of the windows or by providing the necessary artificial light.

Although being a newly constructed classroom of Shree Tika Vidhyashram School, it doesn't even meet standard daylight levels in desk plane.Talking about Gyanodaya Secondary School, the wooden window contains very small glazings, the analysis was done windows as a void in that face of the building. Even it doesn't meet standard illuminance in whole space inside classroom. The daylighting lighting levels of all the cases are shown below in figure 20.

Figure 20: WWR, WFR and Daylight level comparison chart of case studies

Improved Scenario Finally. Daylighting analysis shows that renovations are needed in most of the classrooms to meet the standard illuminance for reading plane. In the case of Durbar High School, if the circular part of windows in the eastside classroom is made transparent, then the intervened classroom will get a minimum of 299 daylight levels which meet the standard illuminace in the classroom. Similarly, the minimum value obtained in the desk plane is 400 lux illuminance in Durbar High School west side classoom. The shadings should be placed to reduce maximum illuminance inside the classroom. The wooden windows of case III Gyanodaya Secondary School should be replaced with large windows with glazed shutter. And Similarly north window's size should be increased to get more daylight for case I.

7. Conclusion

Classroom daylighting analysis in several schools was examined in this study. Daylighting analysis was focused in windows position, WWR, WFR and building orientation. For both unilateral and bilateral use of daylight in classrooms, daylight assessments were done using a simulation program.

The study concludes that Daylight analysis of existing classrooms of various case studies don't meet adequate lighting levels for reading purpose during the day. Only west side DHS classroom is adequate daylighting levels for reading. Others lacked adequate daylight in their classes' general indoor desk plane with minimum daylighting levels range from 56 lux to 140 lux. Finally, the combination of thermal analysis and daylight analysis in the early phases of building design can contribute to energy savings, indoor comfort, and the visual comfort of school classrooms. Finally, the daylight analysis in the early phases of building design can contribute to energy savings and visual comfort in indoor school classrooms.

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