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Evaluating the Impact of Skylight on Daylighting Performance for The El Guadual Children Centre.

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Abstract— This paper examines the integration of skylights in sustainable architectural design, focusing on the case of The El Guadual Children Centre, located in Villa Rica, Cauca, Colombia. The project exemplifies sustainable design principles and community-centered architecture that is also awarded by LEED Platinum-certified building. Two main issues have been identified: lacking information on the daylight performance via computer simulation and limited analysis on the impact of skylight proposals to the daylight performance. The primary objectives for this research are to evaluate and simulate the existing daylighting performance of the building by using the selected computer software. Furthermore, this research aims to investigate and quantify the impact of the proposed skylight on the daylight performance. Via integration by two simulation tools which are LightStanza and Rhino 7, the study analyses the building's baseline daylighting performance and assesses the improvements after the integration of skylights. Comparative analysis is done to evaluate key metrics of illuminance levels before and after the installation of the skylights. The results clearly show that integrating skylights provides considerably better daylight distribution, reduces the reliance on electric lighting, and consequently leads to energy efficiency.

Keywords— Skylight, Daylighting Performance, Sustainable, Computer Simulation, Comparison Analysis.

I. Introduction

Daylighting refers to the managed entry of natural light into the buildings as it influences the overall energy performance and the quality of the indoor environment for humans. Tzempelikos and Athienitis (2007) stated that incorporating daylighting systems in buildings could lead to energy savings of up to 33% due to less dependence on artificial lighting. As buildings contribute to over 40% to 50% of global energy use, optimizing daylight is crucial in producing a resilient building design (Shamri et al., 2022). Besides, the integration of other passive design elements such as clerestories and light shelves play a significant role to enhance the energy performance and human comfort (Reinhart & Weissman, 2012; Galasiu & Veitch, 2006; Kwong, 2021). Eisazadeh et al. (2022) proved that the right selection of glazing type for windows is another strategy to improve the daylight performance. Research done by Alzarooni et al. (2023) revealed that 33 % lighting energy savings in office buildings using solar-control window films, while Lee & Kang (2024) achieved almost 40 % reduction via daylight-concentrating louvers paired with LED dimming. Additionally, daylight potentially provides a positive impact to the occupant's health (Edwards & Torcellini, 2002; Al Horr et al., 2016) especially in enhancing the sleep quality among workers and improving on other health issues (Boubekri et al., 2014).

Functions as one of the important building designs, children centres should be designed in providing a better indoor environment focusing on the program and building performance. Various research has revealed the contribution of architectural building design elements that improve daylighting performance especially in solving electrical energy issues and balancing the cooling load (Eiz et al., 2021). Daylighting significantly plays a major role in the development and growth of the kids (Alkhatatbeh & Asadi, 2021). A quality daylighting approach successfully enhanced the building performance through retrofitting kindergartens in China and reduced the carbon emissions to the environment (Hu et al., 2024). Classrooms function as one of the core spaces for children centres. A comfortable classroom required to be equipped with effective window design Al-Mowallad et al. (2024) with suitable glazing for the facade design Meng & Wang (2024) and openings to achieve efficient visual comfort Atthaillah et al. (2024). Due to the deep-plan design, Kunduracı & Kızılörenli (2024) suggested a tubular daylight guidance system with movable shades to improve the daylight distribution in classrooms. Outdoor areas especially the corridor area can achieve the significant daylight distribution and illuminance via the vertical skylights design (Erdem et al., 2023). Through the various architecture building design elements to the children, learning spaces provide effective learning space that reduces fatigue, increase visual comfort Kittiwangchai et al. (2022) and thermal comfort by implementing the suitable colour for windows glazing Chinazzo et al. (2021). Besides, quality daylight helps to reduce the hyperactivity symptoms to the preschool kids (Ulset et al., 2021). The adoption of effective design elements to the children centre is crucial in improving the daylight performance of the spaces in providing a comfortable learning environment, reducing the building energy consumption and carbon emission.

Various architectural elements integrated to the children centre in improving the daylight distribution and illuminance. Skylight potentially improves the daylight performance by allowing daylight to penetrate from the above or roof area that depends on certain criteria such as climate condition, building size, space requirements and layout. The selection for skylight glazing materials is crucial to determine the daylight distribution as well as improving the visual comfort (Sonmez et al., 2024). A study done by Samiou et al. (2022) revealed that the implementation of skylight enhances the visual comfort and reduce the glare issue. Asymmetrical skylight design successfully reduced the CO_2 emission, enhanced thermal performance (Atthaillah et al., 2024) and mitigated the glare effect by 70% (Hu et al., 2024). Skylight also functions to provide a uniform daylight distribution especially for a deep-plan

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space area (Kunduracı & Kızılörenli, 2024). Deep-plan space required the architect to provide the effective strategy to let daylight penetrate at each space inside of the building design. Design consideration should initially consider the main strategy on the passive design approach especially on the building orientation to introduce daylight and reduce the thermal impact. The selection of the excellent shape for skylight is influenced by the geometrical shape of the layout plan and the windows for the specific building design (Fakhr et al., 2023). Additionally, the shape for skylight design plays a significant role in determining the cooling loans and thermal performance. Consideration on the climate and site context also need to be part of the design process to ensure the resilience of the building design.

II. Literature Review

The El Guadual Children Centre, designed by architects Daniel Joseph Feldman Mowerman and Iván Darío Quiñones Sánchez, represents a crucial leap in architectural design focused on child development in rural Colombia. Situated in Villarrica, Cauca, this initiative serves as a blueprint for merging community requirements with eco-friendly architectural methods. The architects utilized regional resources like bamboo and timber, that highlights sustainability while honouring the cultural significance of the region, adhering to low-impact building guidelines (Jadenz, 2014). The design carefully integrates the nearby landscape, enabling children to interact with nature during learning activities, thus fostering ecological consciousness among young students. Additionally, the design includes flexible areas that accommodate different activities, addressing children's wide-ranging educational and recreational requirements. This kind of flexibility is vital for fostering an atmosphere that supports growth and learning (Arquine, n.d.).

Figure 1 The El Guadual Children Centre

Source Feldman & Sanchez, 2013

Natural light and ventilation are emphasized in enhancing the health and comfort of children, hence encouraging outdoor playing and interaction with the environment. It is an essential design principle that enhances a positive developmental atmosphere. The centre meets critical developmental needs by providing a safe place for education and playing activities, which are very important in a rural context where resources are usually scarce. This focus on integral development is in line with Colombia's national policy for early childhood education, "Cero a Siempre" (Zero to Always) (Jadenz, 2014). Furthermore, the architects conducted a participatory design process with the community to make sure that the centre reflects the local culture and needs (Arquine, n.d.). Utilizing sustainable materials and methods, the project reduces its environmental impact. Elements like rainwater harvesting systems and green roofs boost their sustainability and offer educational chances for children about environmental responsibility (Jadenz, 2014).

The El Guadual Children Centre, has been awarded Platinum LEED certification for its outstanding integration of sustainable design principles with community-focused architecture. The El Guadual project was exemplary in many LEED categories and, therefore, a model for sustainable public infrastructure in rural areas. The architects employed regional materials like bamboo and wood, minimizing transportation emissions and promoting a bond with the natural surroundings. (Jadenz, 2014). The building boasts of being highly energy-efficient, as it greatly emphasizes natural ventilation and daylighting. Features include textured concrete walls to absorb heat and multilayered roofs to reduce solar heat gain and decrease the need for artificial lighting and mechanical cooling systems. All these strategies ensure thermal comfort with a substantial reduction in energy consumption (Divisare, 2014). The resources and materials employed in the building highlight its sustainability even more. Besides, the initiative emphasized the use of recycled and locally obtained materials, engaging the community in the building process.

Daylighting is an essential element of sustainable architecture, assessed within the LEED Indoor Environmental Quality (EQ) category. Its aim is to improve comfort, productivity, and well-being while decreasing energy consumption. LEED v4 assesses daylighting effectiveness by evaluating illuminance levels and glare management (USGBC, 2021). Credit is awarded to buildings when normally occupied spaces have illuminance levels between 300 lux and 3,000 lux (28 to 280-foot candles), which support visual tasks while minimizing glare. This requirement can be met through either simulations or measurements. Simulations are used to estimate the Spatial Daylight Autonomy (sDA), defined as the percent of space that receives 300 lux for at least 50% of all occupied hours. Annual Sunlight Exposure (ASE) limits excessive exposure to direct sunlight to 1,000 lux for no more than 250 hours in any year (IESNA, 2013). LEED v4 grants a maximum of three points according to compliance: one point for 55%, two points for 75%, and three points for 90% of the total floor area.

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III. Methodology

This research adopts a multi-faceted research methodology that consists of three important components: a comprehensive literature review, computational simulation and a comparative analysis approach.

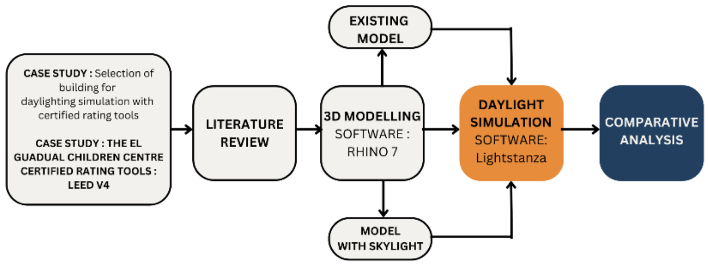

Figure 2 Flowchart for the methodology components

A. Literature Review

First, a literature review focusing on identifying the fundamental information on daylighting, the architectural elements to enhance daylighting, skylight and the background information for The El Guadual Children Centre. This study provides essential insights to inform and guide the decision-making process during the computer simulation phase. Besides, it also ensures the effective application of daylighting principles and architectural strategies to optimize the performance analysis.

B. Computational Simulation

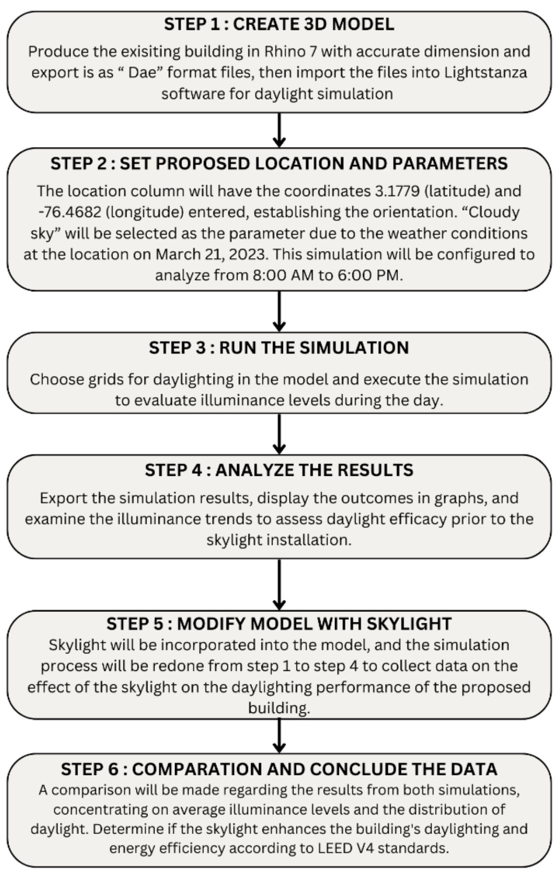

Figure 3 Flowchart on the overall computational simulation stage

The second phase of the methodology involves the application of simulation software, utilizing Rhino 7 for 3D modeling and LightStanza for daylight performance analysis. Based on Figure 4 and Figure 5, the building focuses on a single-story children's centre structure with a site area of 530 sqm². However, the computer simulation process focused on the toy library and multiple classrooms which collectively occupy within 230m². The building's orientation, aligned with the cardinal directions that function as the critical factor for the computer simulation. Placing all the other openings, windows, and skylights are critically considered that respond to the sun trajectory. A precise digital model of the toy library and multiple classroom areas are developed in Rhino 7 to replicate the building's existing design. LightStanza will then be employed to conduct simulations, initially assessing the structure's daylighting performance without skylights. Subsequently, the model will be modified to incorporate skylights, allowing for comparative analysis. This process will quantify the impact of skylight integration on daylight distribution, energy efficiency, and overall lighting quality within the building.

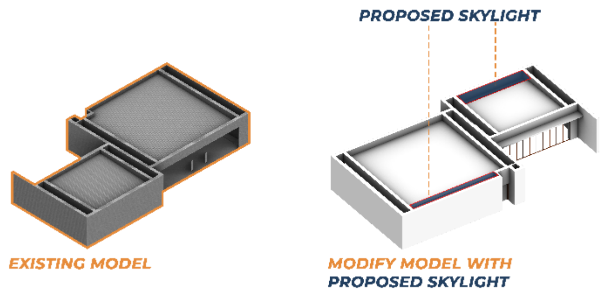

Figure 4 Isometric 3D for 2 Set Model of the toy library and multiple classroom area

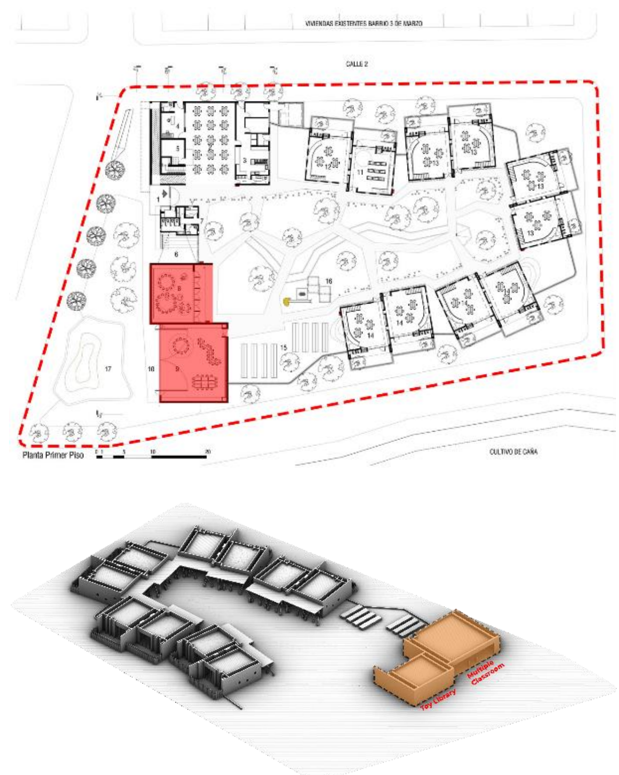

Figure 5 Target area for computational simulation stage

The scope of the simulation includes multiple essential elements that will influence the evaluation of daylight effectiveness. The analysis of the building is located in Villa Rica, Cauca, Colombia, at a precise latitude of 3.1779 and a longitude of -76.4682. These geographical factors are crucial for identifying the accurate solar trajectory and light exposure throughout various seasons. The specific parameters for the computational simulation are outlined in Table 1.

Table I the parameter for computer simulation process

No	Criteria	Descriptions
1	Month	21st March
2	Temperature	23°C and 28°C
3	Sky condition	Overcast sky
4	Time	8am to 6pm
5	Location	Latitude of 3.1779 and a longitude of -76.4682.
6	Climate	Tropical climate

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C. Comparative Analysis Approach

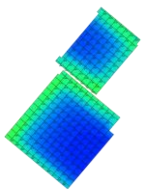
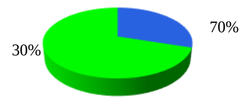
Next, a comparative analysis approach served to critically analyse the daylight performance outcome based on the computer simulation result. The integration of the three components is crucial in critically evaluating the skylight performance in producing an effective daylight effect for The El Guadual Children Centre.

IV. Findings and Discussions

A. Existing condition

Table II

Daylight Simulation Data of Existing Model

<table>
<tr><th>Time</th><th colspan="2">Result</th></tr>
<tr><td>8am</td><td></td><td>

<table>
<tr><th>Illuminance (lux)</th><th>Area (m^2)</th><th>Percentage (%)</th></tr>
<tr><td><300</td><td>$70m^2$</td><td>30%</td></tr>
<tr><td>300 - 3000</td><td>$160m^2$</td><td>70%</td></tr>
<tr><td>>3000</td><td>$0m^2$</td><td>0%</td></tr>
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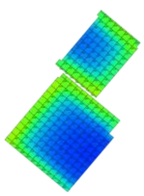
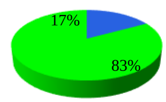
<tr><td>9am</td><td></td><td>

<table>
<tr><th>Illuminance (lux)</th><th>Area (m^2)</th><th>Percentage (%)</th></tr>
<tr><td><300</td><td>$40m^2$</td><td>17%</td></tr>
<tr><td>300 - 3000</td><td>$190m^2$</td><td>83%</td></tr>
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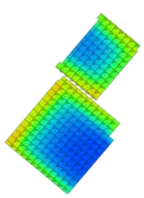
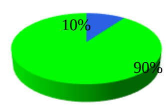
<tr><td>10am</td><td></td><td>

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<tr><th>Illuminance (lux)</th><th>Area (m^2)</th><th>Percentage (%)</th></tr>
<tr><td><300</td><td>$22m^2$</td><td>10%</td></tr>
<tr><td>300 - 3000</td><td>$208m^2$</td><td>90%</td></tr>
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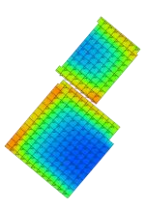
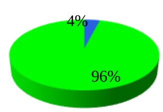
<tr><td>11am</td><td></td><td>
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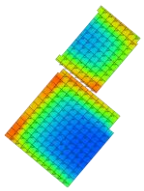
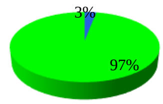
Illuminance (lux)	Area (m^2)	Percentage (%)
<300	$8m^2$	4%
300 - 3000	$222m^2$	96%
>3000	$0m^2$	0%

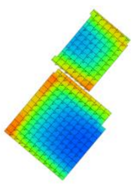
12pm

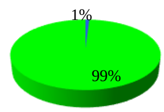




Illuminance (lux)	Area (m^2)	Percentage (%)
<300	$6m^2$	3%
300 - 3000	$224m^2$	97%
>3000	$0m^2$	0%

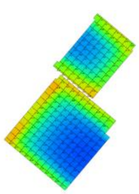
1pm

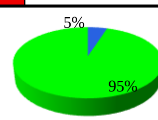




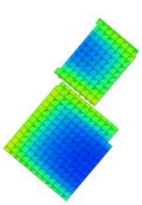
Illuminance (lux)	Area (m^2)	Percentage (%)
<300	$3m^2$	1%
300 - 3000	$227m^2$	99%
>3000	$0m^2$	0%

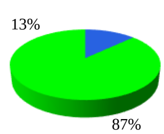
2pm





Illuminance (lux)	Area (m^2)	Percentage (%)
<300	$12m^2$	5%
300 - 3000	$218m^2$	95%
>3000	$0m^2$	0%





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<tr><td>300 - 3000</td><td>$200m^2$</td><td>87%</td></tr>
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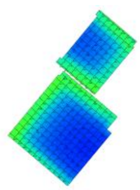
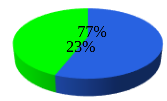
<tr><td>4pm</td><td></td><td>


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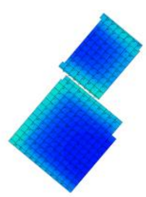
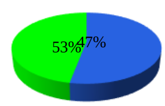
<tr><td>5pm</td><td></td><td>


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<tr><td>300 - 3000</td><td>$109m^2$</td><td>47%</td></tr>
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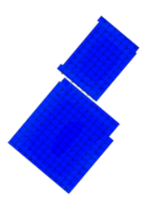
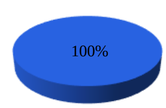
<tr><td>6pm</td><td></td><td>


<table>
<tr><th>Illuminance (lux)</th><th>Area (m^2)</th><th>Percentage (%)</th></tr>
<tr><td><300</td><td>$230m^2$</td><td>100%</td></tr>
<tr><td>300 - 3000</td><td>$0m^2$</td><td>0%</td></tr>
<tr><td>>3000</td><td>$0m^2$</td><td>0%</td></tr>
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</td></tr>
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lux

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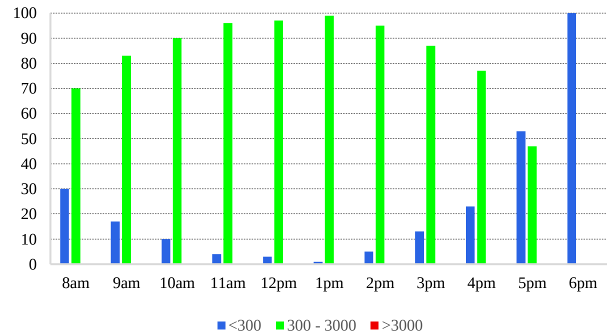


Figure 6 Graph for daylight simulation (set 1 - existing model*)*

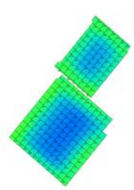
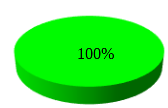
According to Table II and Figure 6, majority of the quality daylight illumination occurs start from 8am until 4pm that demonstrating an average daylight performance of 76%. It indicates that both of the Toy Library and Multiple Classroom received a quality level of daylight with comfortable space for activities and educational program for the kids. The percentage of optimal daylight performance increase progressively from 8am to 1pm but gradually decline from 1pm to 4pm. The efficient daylight performance occurs at 1pm due to the majority of the area received the targeted illuminance range. From 11am to 1pm, it indicates that the daylight illuminance increases on the western parameter of the Multiple Classrooms due to the west-facing orientation and lack of obstructions compared to the Toy Library as it protected by the landscape area.

The most insufficient daylight occurs at 6pm as 100% for both of the spaces received less than 300lux that required to rely on the artificial light. A secondary insufficient daylight occurs at 5pm where 53% of the spaces received less than the recommended daylight level. Definitely, this situation potentially disrupts the educational program, increasing the artificial lighting reliance and building energy performance. From 8am to 4pm, the insufficient daylight illumination performance is less than 30% for majority of the space area compared to the comfortable daylight performance. Only 1% of the space area received the insufficient daylight at 1pm that would be the most effective time to receive the comfortable daylight level. Throughout the simulation process, the daylight level remained below 3000lux for both spaces where there are no glare issues occurs that significantly affect the education program and produced more wasted space area. Due to the direct sunlight exposure, certain perimeter space area approached 3000lux that required effective strategy to avoid over-illumination issue.

B. Proposed skylight

Table III

Daylight Simulation Data of Proposed Skylight

<table>
<tr><th>Time</th><th colspan="2">Result</th></tr>
<tr><td>8am</td><td></td><td>

<table>
<tr><th>Illuminance (lux)</th><th>Area (m^2)</th><th>Percentage (%)</th></tr>
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<tr><td>300 - 3000</td><td>230m^2</td><td>100%</td></tr>
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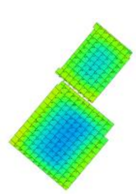
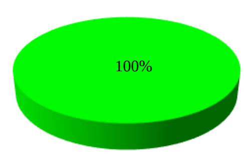
<tr><td>9am</td><td></td><td>
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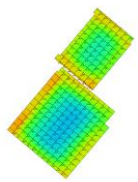
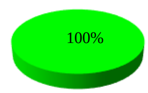
<tr><td>10am</td><td></td><td>


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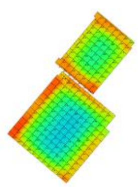
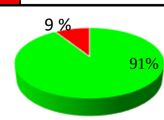
<tr><td>11am</td><td></td><td>


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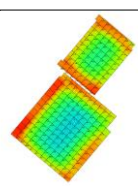
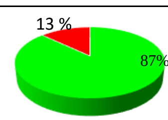
<tr><td>12pm</td><td></td><td>


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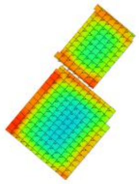
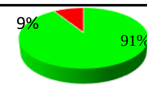
<td></td>
<td>

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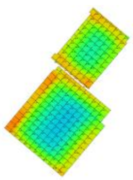
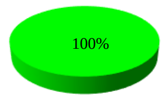
<td></td>
<td>

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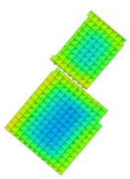
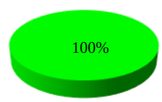
<td></td>
<td>

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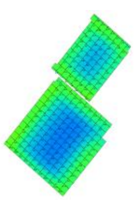
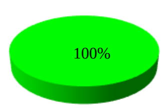
<td></td>
<td>

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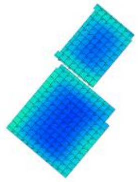
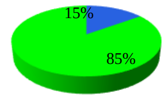
<td></td>
<td>

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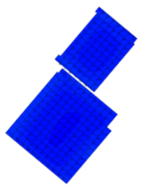
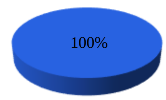
<td></td>
<td>

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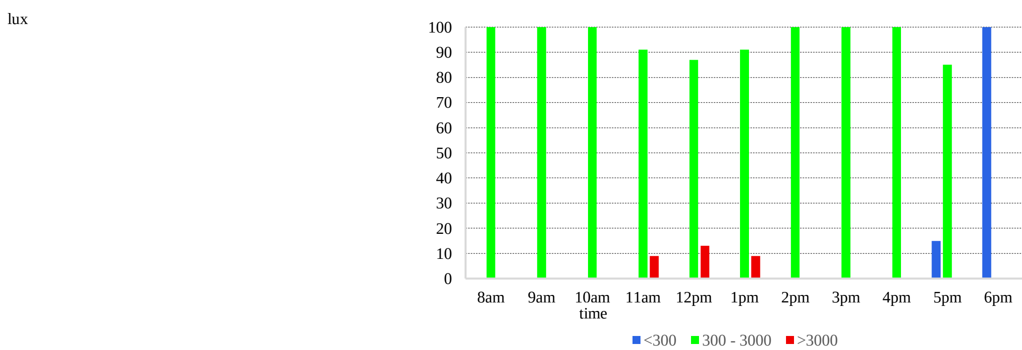

Figure 7 Graph for daylight simulation (set 2 – proposed skylight*)*

Table III and Figure 7 illustrates the notable enhancement in daylighting performance realized by the suggested skylight design. The simulation findings indicate that a significant portion of the indoor areas currently receives daylight levels within the ideal range of 300 to 3000 lux for the majority of the day. Particularly, between 8am and 4pm, remain stable and complying with the LEED v4 guidelines for daylight quality. This enhancement showcases the skylight's effectiveness in facilitating quality daylight distribution throughout the building, thereby promoting a quality indoor environment.

The chart further emphasizes a reduction in insufficient daylight levels (<300 lux) occurring after 5pm, as the availability of natural light diminishes**.** Elements like the nation's latitude, weather patterns, and the winter period led to the early darkness felt at 5pm. These findings highlight the skylight's capacity to enhance daylight utilization during peak daylight hours while ensuring excessive daylight levels (>3000 lux), which may lead to glare and overheating. The skylight's effectively design minimizes the visual discomfort demonstrated by the minimal percentage of space experiencing daylight levels over 3000 lux during the day. The addition of the skylight has also improved the overall daylighting illuminance from 76% to 90%, indicating a significant enhancement in the building's daylight performance.

The 14% increment reflects an enhancement in the quality, distribution and functionality of daylight within the indoor space. In the framework of LEED v4 daylighting standards, this change indicates that a considerably larger area of frequently used floor space is now exposed to illuminance levels in the ideal range of 300–3000 lux for a substantial portion of the day. The enhancement of

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daylight illumination for both spaces are illuminated more fairly and efficiently to produce a comfortable environment for educational activities. The skylight's effectiveness in attaining this enhancement also mirrors thoughtful attention to the tropical climate of the site. The design maximizes diffuse daylight and minimizes direct solar exposure that might lead to discomfort in hot, humid conditions. Consequently, the 76% to 90% rise in daylighting coverage acts as both a performance indicator and proof of considerate, climate-aware architecture that improves occupant comfort and supports environmental responsibility.

Though the skylight effectively improves daylighting at peak daylight times, it's crucial to acknowledge the restrictions of natural light after 5pm, particularly in tropical areas such as Villa Rica, Cauca, Colombia, where daylight duration remains steady throughout the year, yet natural light intensity decreases swiftly in the evenings. Additional artificial lighting might be necessary to ensure operation during the late evening. Moreover, employing water-resistant and sturdy materials for the skylight is essential in Villa Rica's tropical climate, characterized by elevated humidity and regular rainfall. These considerations guarantee the lasting durability and effectiveness of the daylighting system.

In conclusion, the simulation validates the skylight's efficiency in improving daylighting capabilities while complying with LEED v4 criteria. The project highlights the potential of passive design strategies in tropical areas like Villa Rica, where consistent solar angles and abundant natural light can be harnessed to create sustainable and energy-efficient buildings. Upcoming evaluations may encompass various sky conditions, such as overcast or wet scenarios, to improve the daylighting design and its efficiency year-round.

C. Comparison Daylighting Performance

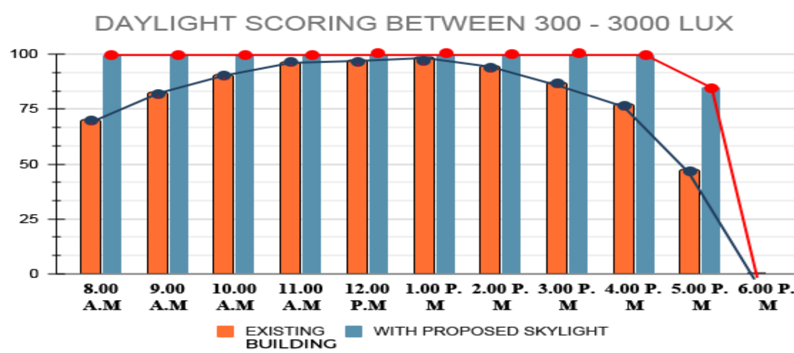

Figure 7 Graph for Comparison of Daylight Scoring Between 300 - 3000 lux.

The implementation of the skylight in the "Toy Library and Multiple Classrooms" at the El Guadual Children's Centre has greatly enhanced daylighting efficiency, shown by an increase in the daylighting score from 76% to 90% in the suggested design. This enhancement emphasizes the skylight's capacity to improve the quality and spread of natural light during the day, satisfying the criteria for a LEED v4 daylighting credit. The suggested design guarantees that most indoor areas reach ideal daylight levels (300–3000 lux) from 8am to 4pm, which are essential hours for activities in classrooms and libraries. Additionally, high levels of daylight (>3000 lux), which may lead to glare and heat issues, are minimal with the adoption of skylight as the design successfully regulates light entry to enhance occupant comfort.

The Lightstanza raw data indicates that inadequate daylight levels (<300 lux), which were more common in the early morning and late afternoon in the current model, are greatly diminished with the skylight. This provides improved functional lighting during essential hours, although times such as 5pm to 6pm continue to exhibit inadequate natural light because of diminished sunlight availability. The visual comparison of the existing model and the suggested skylight design shows a more even distribution of daylight across the areas, especially from 10am to 3pm, during which daylighting scores remain notably high.

The suggested skylight corresponds to the local tropical climate of Villa Rica, Cauca, utilizing steady daylight hours because of the area's closeness to the equator. The design tackles elevated solar angles and regular cloudiness to provide sufficient daylight functionality while preventing overly bright lighting scenarios. Nonetheless, it is essential to evaluate the long-term resilience of the skylight materials, particularly due to the area's elevated humidity and precipitation, to guarantee that the system remains effective over time.

Additionally, the importance of climate-sensitive design in Villa Rica is highlighted by the area's distinct microclimatic patterns, where regular rainfall and elevated humidity levels often surpassing 80% that poses challenges to the long-term resilience of architectural elements like skylights. In these tropical settings, materials face not only significant UV exposure but also rapid deterioration due to moisture infiltration and biological development. Thus, it is essential for skylight materials to have high thermal resistance, low water absorption rates, and corrosion resistance to maintain prolonged performance. Laminated or insulated glass units featuring protective coatings, along with effective flashing and sealing methods, can assist in reducing these vulnerabilities caused by climate.

Furthermore, incorporating passive ventilation openings close to the skylight can help control humidity accumulation, lowering the likelihood of condensation on the inside surface. The combination of material choice and passive environmental regulation enhances both the durability of the installation and promotes indoor air quality and occupant well-being an ever more significant factor in educational design approaches following the pandemic.

While the skylight greatly boosts daylighting efficiency, supplementary methods could enhance outcomes even more. For instance, incorporating energy-efficient artificial lighting systems could enhance natural light in the evenings, while adjustable shading or diffusing systems might respond to possible fluctuations in lighting intensity caused by seasonal changes. Holding user feedback sessions can enhance the equilibrium between natural and artificial lighting to maximize occupant satisfaction. The installation of the skylight has improved the building's daylighting capabilities that respond to LEED requirements while boosting occupant comfort and energy efficiency. The intervention shows how careful design changes can foster sustainable and practical environments in educational contexts.

V. Conclusions

This study explored the daylighting efficiency of the toy library and multiple classrooms at El Guadual Children's Centre located in Villa Rica, Cauca, Colombia, emphasizing its compliance with LEED v4 guidelines and the impact of skylight design on improving daylight quality. The results indicate that the current building design attains a daylighting compliance score of 76%, fulfilling the minimum criteria for LEED v4. Nonetheless, the implementation of a suggested skylight system raised this score to 90%, indicating a significant enhancement in the building's visual comfort and distribution of daylight. This enhancement emphasizes the capability of effectively integrated daylighting methods to improve the indoor environment quality and reduce the reliance on artificial light.

The upgraded lighting conditions due to the skylight design are expected to positively affect the educational program and children's daily activities at the El Guadual Children's Centre. Sufficient levels of daylight have been strongly linked to effective cognitive function, greater focus, and heightened mood, that are crucial in early childhood education program. The even distribution of daylight for the both spaces foster a welcoming and engaging environment that enhances diverse learning experiences, including reading, imaginative play, and teamwork. Moreover, the decreased dependence on artificial lighting during the day leads to energy savings, close to the more natural elements that aligns with biophilic design concepts, highlighting the mental and physical advantages of exposure to daylight. Through the enhancement of visual comfort and reduction of glare, the skylight intervention improves space usability during the day, promoting engagement and enriching the overall learning experience for educational program.

Future research should explore the performance of skylight in different sky condition such as cloudy and clear sky condition to evaluate the effectiveness of skylight design to El Guadual Children's Centre. Various selection of sky configurations significantly produced different impact on the daylight performance due to the different sky condition throughout the year. Additionally, future research can be enhanced by proposing a range of skylight typologies that respond to different of skylight conditions to facilitate designer in identifying the optimal skylight design. Rigorous future research that effectively examine diverse skylight configurations and varying sky conditions will enhance the daylight performance and improving the educational program.

This study recognizes the constraints of the main daylight simulation tool employed, LightStanza, which affected the workflow as well as the precision of the analysis. A major challenge encountered involved file compatibilit such as .skp, .obj, .fbx, and .ifc, while intricate exports from Rhino frequently necessitate manual conversion and adjustment for accurate geometry interpretation. This extra step not only required extended preparation time but also jeopardized the possibility of losing specific details during file conversion. Additionally, challenges in interpreting geometry, including the misunderstanding of slender glazing or the omission of minor architectural features like mullions and blinds, created possible discrepancies in the daylighting outcomes.

Computational constraints were also noticeable, as intricate, high-resolution models and year-long simulations greatly prolonged processing durations, with LightStanza missing real-time feedback features present in other renderers such as Enscape. Moreover, limitations in user interface, especially on the restricted viewport customization and a reasonable learning curve for complex metrics like glare analysis or yearly sunlight exposure, demanded extra time to learn effectively. Finally, the cost and licensing issues related to LightStanza's subscription pricing model might restrict its availability. These constraints emphasize the necessity of validating findings with alternative simulation tools or performing real-world measurements in future studies.

The simulations carried out under overcast skies demonstrated that the innovative skylight design successfully enhanced the daylighting atmosphere, attaining lux levels that aligned with the LEED-suggested range of 300 to 3000 lux for the majority of the day. This intervention demonstrates the importance of incorporating climate-responsive strategies that tackle local climatic limitations while improving indoor environmental quality. In summary, the results of this research highlight the significance of incorporating effective daylighting strategies in tropical regions to improve sustainability and occupant well-being. The suggested skylight addition at the El Guadual Children's Centre acts as a model that can be duplicated for comparable initiatives in equatorial areas, in line with worldwide endeavours to promote sustainable and climate-resilient architecture.

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