PERFORMANCE EVALUATION OF DAYLIGHT IN TERMS OF VISUAL COMFORT IN DESIGN STUDIOS AND CLASSROOMS

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Abstract

In educational buildings, in addition to classrooms where only the act of reading is carried out, studies that include different activities are also carried out. The design studio used for architecture and other branches of art is one of these. The spaces defined here can either exist within a newly designed building or be realized by transforming an existing building into an educational building. In this process, the daylighting of the planned or converted classrooms and design studios is important. This study covers a review on the performance evaluation methods of the daylighting of design studios and classrooms in educational buildings through computer programs and the examination of the computer programs used. The static metrics and climate-based metrics performed in the work plane are analyzed separately, and glare analyses are also presented. The daylight factor (DF) under overcast skies, and daylight autonomy (DA), useful daylight illuminance (UDI), which can use variables based on a certain time interval under different sky conditions, are the metrics used in the work plane. The studies examined are classified as the tools and methods of daylighting analysis for educational buildings and how they are used in different educational buildings is discussed. As a method, a systematic classification, analysis, evaluation and presentation of the literature review is made, and the study is actually a preliminary research of another scientific study to be conducted in the future. The study planned in the next phase involves the re-functioning of a building used as an office building by converting it into an educational building. Different transformations were applied on different floors of the building designed and used as a multi-storey office. As a result of this transformation, there is a need for performance analysis of the design studios and classrooms on different floors in terms of daylighting, and their role in integrated lighting needs to be revealed. The building automation system has an instant reflection through point light measurement and activates the artificial lighting system sufficiently when necessary. With the data to be obtained from here, targets for the use of artificial lighting automation will be revealed. It is aimed to transfer data to automation system design. Therefore, the work presented in this paper aims to define the scientific foundations, justification and methods prior to a series of computer simulations on the daylighting performance as a result of refunctionalization.

Keywords: daylighting performance, computer simulation, classroom visual comfort

1 Introduction

Daylight affects human psychology and physiological features, as it can influence mood, awareness, and vision. Daylight is an essential component of the classroom environment, and its role in improving the education and productivity of students has been widely studied. In the learning environment, daylight plays a significant role in creating a better environment for teaching and learning, as poorly lit classrooms negatively affect students' health and learning ability (Sabbagh, Mandourah & Hareri, 2022). It is essential that comfortable visual conditions should be created in school buildings which will unequivocally contribute to the teaching-learning process in schools (Azodo, 2017). Daylight has direct effect on learning achievement and psychology of the students in classrooms (Azodo, 2017; Rahman & Tuhin, 2019). Daylight is predominantly engaged in schools because most schools operate exclusively during daylight hours with the sunlight being the main and in most cases the only lighting source for the amount of light received within the classroom spaces (Azodo, 2017). The careful introduction of daylight

into educational buildings reduces operating costs, improves students' vision and perception, and contributes to students' health, comfort, and productivity. Effective use of daylighting can reduce energy consumption as well as make the classroom feel more human and less institutional (Rahman & Tuhin, 2019). A recent study noted that schools and colleges delineate an essential quality of student's life as they spend at least one-quarter of the day (6 hours) in the schools and colleges. To support and enhance students' safe learning environment for qualitative and quantitative impacts, the level of light sufficiency in the environment has to be assessed for alteration if need be (Azodo, 2017).

The study is divided into three parts. In the first part (section 2), the daylighting metric is defined and the topics of "visual discomfort and glare" and "static and dynamic metrics" are examined. In the second part (section 3), under the main topic of "daylight-oriented educational building design", "achievements for energy certificate" and "targeted illuminance values for classrooms" are discussed. In the last part (section 4) "simulation variables" and the necessary parameters for a simulation such as "sky model", "time-period", "light reflectance value" are explained.

2 Daylighting metrics

Most of the daylighting metrics are based on hourly daylight values (i.e. illuminance) calculated during occupied daytime hours at points on a grid over a daylight zone at work plane height, typically 0.75 m, and are used to assess the daylight availability in a space (Lakhdari, Sriti & Painter, 2021). The metrics are separated into two categories, which are luminance-based, including glare and spatial visual discomfort, and illuminance-based, such as illuminance, uniformity ratio, and daylight factor (Yunitsyna & Toska, 2023). The most common metric for assessing daylight exploitation are Illuminance, Uniformity ratio, and Daylight factor (Mehta, 2020). Considering the kind of calculations, the simulation results analysis is divided into two sets of dynamic and static. Static calculation is a kind of calculation assessed in a special time and fixed conditions, whereas dynamic calculation is assessed during the year, based on annual weather information and changing conditions. Using these analyses and comparing daylight systems' options in different models with different conditions pave the way for choosing proper and optimal option by considering daylight (Moazzeni & Ghiabaklou, 2016). However, time-varying predictions (climate-based metrics) proved to be more realistic than these metrics. These include Useful Daylight Illuminance (UDI), Daylight Autonomy(DA), Spatial Daylight Autonomy(sDA), Annual Sunlight Exposure(ASE), Discomfort Glare Probability(DGP), and Spatial Visual Discomfort(SVD). High Dynamic Range (HDR) imaging technology has also been proved helpful (Mehta, 2020). The dynamic metrics based on climate data (CBDM) have opened a new perspective for daylight studies, since they respond to the local climate, which account for the amount of daily and seasonal variations of daylight, combined with weather data. These have displaced old daylight metrics, like the daylight factor (DF), whose limitation is that it does not consider the dynamic aspects of light: the latitude, the different seasons, the different times of the day, the variations of the skies and the orientation of the building (Moreno & Labarca, 2015).

2.1 Visual discomfort and glare

Daylighting is desirable in classrooms but can pose a challenge to classroom illumination when there is a risk of discomfort from glare from windows and sunlight (Viula, Bokel & Tenpierik, 2023). The visual comfort is often defined in literature as the absence of discomfort, i.e. glare. Proper daylighting in school buildings significantly affect students whereas poor daylighting causes discomfort and reduces learning capacity. It is also harmful to the physical and mental health of students. Learning space that receives high daylight intensity with low glare, added with high quality artificial light source improves the visual comfort, which improves the learning space environment (Rahman & Tuhin, 2019). For a school building, good lighting design, natural and artificial needs balanced, diffuse and glare free daylight from two or more directions, sufficient light levels for the tasks in the space. Building orientation (sun path), windows, and location are three practical design options according to the study that determine the visual comfort and glare-free in the building environment (Azodo, 2017). There are several metrics in use for the analysis of visual discomfort from daylight glare (Viula & Hordijk, 2017). A previous study found that Daylight Glare Probability (DGP) produced a relatively better predictive power of the reported discomfort from glare in a classroom compared to other metrics (Viula & Hordijk, 2017). In a study, an experiment room for glare analysis is performed. The classroom is daylit

from one side through a full-length window (63% transmission glass) to the Southwest as an example. The interior of the room is mostly made of diffuse surfaces of light colour (Viula & Hordijk, 2017).

As a analysis method, there are two metrics that have been widely used from the very beginning. First one is daylight factor DF intervals and the second one is daylight glare probability (DGP). DF values are defined as lower than 1% and above than 6% and its impact on glare and thermal comfort. Based on this definition, DF values ranging from 1% to 6% are reported as satisfactory (Obralic & Jeghel, 2021). The comfort criteria of glare are proposed by four main domains. (Bakmohammadi & Noorzai, 2020).

Uniformity which is defined as the ratio of the minimum daylight factor to the average daylight factor within the space creates a uniform distribution of illuminance and luminance (Zomorodian, Korsavi & Tahsildoost, 2016). The uniformity ratio of each simulation result is also calculated using the following formula: Illuminance (minimum) / Illuminance (average) = Uniformity Ratio (Apriliawan, Fadhila & Alkadri, 2023). Many lighting standards require a uniformity ratio of 0.8 (minimum/average) or 0.7 (minimum/maximum) (Zomorodian, Korsavi & Tahsildoost, 2016). Uniformity ratio is used to study daylight distribution. Higher uniformity ratio means better daylight distribution. It is measured as the ratio of minimum workplane illuminance to average workplane illuminance. The maximum number for uniformity ratio is one (Susan & Prihatmanti, 2017). In a study, the prescribed threshold values for the uniformity ratio in a sample classroom are outlined (Maurya, Kumar & Kumar 2023).

2.2 Static and dynamic metrics

Illuminance is the amount of light falling on a surface per unit area, measured in lux (Zomorodian, Korsavi & Tahsildoost, 2016). Daylight Factor is the ratio of the internal illuminance at a point in a building to the unshaded, external horizontal illuminance under a CIE overcast sky (Koti & Munshi, 2009). Daylight factor DF (%) is the simplest and the most common static metric to quantity the daylight allowed by a window (Dolnikova et al., 2020; Yunitsyna & Toska, 2023). $DF = E_{internal} / E_{external} \cdot 100$ (%) where $Ei_{nternal}$ is illuminance of internal horizontal plane (lx) and $E_{external}$ is illuminance of external horizontal plane (lx) (Dolnikova et al., 2020). Penetration of daylight based-on DF metrics is generally accepted sufficient between 2% and 3% as per European Norms.

Among the metrics whose analyses are based on the time variable (dynamic metrics), we have daylighting autonomy (DA), useful daylight illuminance (UDI) and continuous daylight autonomy (DAcon), which have given a more comprehensive evaluation, based on climate files, of the building's orientation and the time that this is occupied (Moreno & Labarca, 2015). Nowadays, the most widely used dynamic daylight metrics are Daylight Autonomy(DA) which is defined as the percentage of annual work hours where daylight is sufficient to exceed a benchmark illuminance and Useful Daylight Illuminance (UDI) which is similar to DA except that the benchmark is replaced by the illuminance range 100 to 2000 lx. Due to the advantage of dynamic daylight parameters that make consideration of daylight annual performance, DA and UDI are utilized continually and widely in daylight assessment and relative design process in recent years (Guan & Yan, 2016).

Daylight Autonomy (DA), defined as the percentage of the occupied hours of the year when a minimum illuminance threshold is met by daylight only (Koti & Munshi, 2009; Li et al., 2023). It takes geographic location and specific weather information into account on an annual basis. The threshold value depends on the activity type / space function and users are can set the threshold accordingly. The sDA describes the amount of sufficient daylight received by a given space (Li et al., 2023). Spatial daylight autonomy (sDA) was used to determine the distribution of daylight in a room with an illuminance value of more than 300 lx with the coverage time of the illuminance value being at least 50% of the total measurement time, generally known as sDA300/50% (Hakim et al., 2021). In addition, it describes the percentage of floor area that exceeds a specified illuminance level (e.g., 500 lux) for a standard percentage (e.g., 75%) of the annual occupied hours (e.g., from 8 a.m. to 4 p.m.). sDA500/75% represents the specified illuminance of 500 lux and the standard percentage of 75%. The Illuminating Engineering Society (IES) guideline recommends two different levels for sDA: the first level is preferred daylight sufficiency, if more than 75% of the analysis area meet the above criteria; the second level is nominally accepted daylight sufficiency, if 55% or more of the analysis area meet the

above criteria (Li et al., 2023). Useful Daylight Illuminances aims to determine when daylight levels are useful for the occupant, in terms of being neither too dark nor too bright (between 100 lux and 2000 lux) (Koti & Munshi, 2009; Sönmez & Kunduracı, 2021). For each point in the room, the UDI indicates the percentage of occurrence for a point with its daylight illuminance higher than 100 lux and lower than 2000 lux (Guan & Yan, 2016; Hakim et al., 2021). Daylight illuminance below the lower threshold (e.g., 100 lux) gives few useful assistances in the perception of the visual environment or performance of visual tasks. Daylight illuminance higher than the maximum threshold (e.g., 2000 lux) may produce visual or thermal discomfort (Lakhdari, Sriti & Painter, 2021; Li et al., 2023). It has been enhanced by partitioning the UDI100-2000 range into 100–500 lx and 500–2000 lx, called UDI-supplementary and UDI-autonomous respectively (Moreno & Labarca, 2015; Guan & Yan, 2016). There are at most three possible outcomes excessive, within or below the desired range (Guan & Yan, 2016). UDI is selected as the principal measure of daylighting performance because a good daylighting solution meets both the illuminance and visual comfort requirements of occupants. UDI is an excellent indicator of both (Bakmohammadi & Noorzai, 2020). Useful Daylight Illuminance (UDI), in which daylight levels fall within certain bins. Usually, three bins are identified by setting a lower and an upper illuminance threshold (Nocera et al., 2018). Useful Daylight Illuminance (UDI) analysis is carried out using three standard metric bins hourly time values (Azodo, 2017). This range, originally suggested to be between 100 and 2000 lux for a typical workplace, has recently been revised to be from 100 lux to 3000 lux. UDI (300–3000 lux) is the band that has largely removed the requirement for artificial lighting systems, and is used in various standards (Lakhdari, Sriti & Painter, 2021). Based on the first UDI definition, where it is stated that there is risk of glare above 2000 lux, this limit value was later reformulated to a higher illuminance value, considering an excessive UDI above 3000 lux; starting from this interval, it is established that between 2000 and 3000 lux, there is a glare risk threshold. Identifying the percentage within this range will allow recognizing the need for integrating design strategies or architectural elements to prevent glare, thus taking its values to the “in range” illuminance. As a consequence, as the top limit value for this study, those illuminance values above 3000 lux (“too high”) are set. To define the “low” limit value set at 200 lux, the minimum value established by the European norm for workspaces with continuous norm was taken as the reference with the interval between 200–300 lux being an intermediate zone. Finally, the illuminance values of the ranges are: “too low” < 200 lux, “low” ≥ 200 lux to < 300 lux, “in range” ≥ 300 lux to < 2000 lux, “high” ≥ 2000 lux to < 3000 lux and “too high” ≥ 3000 lux (Moreno & Labarca, 2015). In 2013, in an effort to improve the visual environment in future schools, a UK regulation specified mandatory daylight evaluations using, for the first time, climate-based metrics (Drosou, Mardaljevic & Haines, 2015).

3 Daylight-Oriented Educational Building Design

Daylight in classrooms have shown positive effects on students' health, well-being, performance, behaviour, productivity, and even seating preference of the students (Mehta, 2020). Daylight is an essential part of educational building design, to accommodate the type and needs of activities carried out within them, creating an optimal environment for students, and improving their ability to concentrate and perform visual tasks such as reading and writing (Sabbagh, Mandourah & Hareri, 2022; Savrunlu, 2024). Many different activities that require specific visual settings happens in the same classroom. The activities include reading, writing, and communication supported by audio and visual tools, computers, and internet access. All these regularly developing advancements have made learning more interactive, at the same time, an additional issue for the designers (Mehta, 2020). The energy consumption of classroom lighting can reach up to 50% of the school’s total electricity costs—this is because the energy used for lighting is consumed at a daily rate, and is expensive (Dolnikova et al., 2020). Building design aiming to provide the maximal level of daylight reduces the lighting energy loads (Yunitsyna & Toska, 2023). The daylight distribution could be considered sufficient for design studios depending on their orientation with the help of placement and the sizes of the windows. There are several design considerations that could be improved upon to ensure a comfortable and functional environment for its occupants (Dökmeci, 2023). Visual arts, such as painting, sculpture, carving, textile design and photography, require specific lighting conditions, which are different from the regular classroom standards (Yunitsyna & Toska, 2023).

Creating an ideal classroom environment depends on so many different factors, including the structure of the building, classroom size, windows, orientation to the cardinal, glare protection,

interior equipment, color of surfaces, etc. (Dolnikova et al., 2020). Since most school buildings have a three-zone (classroom - corridor - classroom) layout, with the classrooms aligned along the two sides of the communication space (the corridor), this means that classrooms that have vertical windows are illuminated from one side only. An alternative to this concept, which can provide better daylighting, is a two-zone (classroom - corridor) form of school building. This provides the possibility of illuminating the classrooms from two sides by using the additional light that comes from the corridor (Bezjak et al., 2003). Two basic groups are defined as follows:

- classrooms with one-sided illumination - the three-zone form (classroom - corridor - classroom)
- classrooms with two-sided illumination - the two-zone form (classroom - corridor)

This optimization process tends to make the corridor of the school building as short as possible, and so the classrooms tend to be relatively deep. This allows for a reduced external area of the building in relation to its volume, which also results in a more energy-efficient design of the school building. In an attempt to reduce energy consumption, today's classrooms have stabilized at a height of 3.20 m. As the height of the classroom increases, the depth of the classroom will also increase as natural lighting will penetrate more into the interior. Two different corridor widths are proposed as the one is 2.40 m, as a minimum, empty corridor width (without desks and cupboards), and the other is 3.60 m, as a more comfortable corridor (or hallway) width that would enable it to be used as a communication space, or for educational and social purposes. The most effective design from visual comfort point of view is two-zone form of school building with two-sided illumination of the classrooms (Bezjak et al., 2003).

3.1 Achievements for energy certificate

LEED NC-v.2.2 EQ 8.1: requirement for LEED 2.2 EQ addresses a minimum daylight illumination of 25 foot candles (270lux) to be achieved in at least 75% of all regularly occupied areas (Zomorodian, Korsavi & Tahsildoost, 2016). LEED rating system originally required a DF 2% for at least 75% of the critical visual task zones to achieve indoor environment credit 8.1. BS 8206-2 requires DF 2 or 5 depending on electric lighting requirements to support human well-being (Piparsania, Vaidya & Kalita, 2020). According to Norwegian Green Building Council and BRE Global minimum and average daylight factor for classrooms have been defined as 2% and 5%, respectively (Zomorodian, Korsavi & Tahsildoost, 2016). In general, the minimum daylight factor (DF) for any space, according to LEED v4, BREEAM and Green Star, is 2% (Galal, 2019).

Based on the LEED v4 standard, it is recommended that buildings to meet specific daylight design criteria, namely sDA30050% > 55% (Hakim et al., 2021). The Leadership in Energy and Environmental Design (LEED) awards Credit Points 1, 2 and 3 to the sDA300/50% for the regularly occupied floor area at least 40%, 55% and 75%, respectively. The sDA can well reflect the indoor daylight uniformity, while it cannot evaluate the visual glare issue (Li et al., 2023). cDA is the basic modification of DA. The cDA represents the percentage of occupied hours during the year when the illuminance of a particular point in the room is at or above the target threshold level, with proportional credit given for cases if its daylight contribution meets this level partially. For example, if the value of daylight illuminance is 250 lux at an interior grid point, DA500 lux would give it 0 point whereas cDA500 lux would give it 250/500 = 0.5 point. This daylight metric will help estimate the energy savings by dimming or multistage switching controls. DA and cDA, however, can only evaluate the performance of indoor daylighting environment for a particular point rather than an area (Li et al., 2023).

Useful daylight illuminance (UDI) as a modification of Daylight Autonomy is extensively used to evaluate daylight performance, providing full credit only to values ranged between 100 lux and 2000 lux (Kwon & Lee, 2018). The UDI scheme reflects the distributions of annual daylight level by determining the occurrence of daylight illuminances within the upper and lower thresholds, indicating whether the indoor daylight is insufficient, desirable, tolerable, and excessive. However, there is some debate about the choice of 2000 lux as an 'upper threshold' above which daylight is not required due to potential glare or overheating. For example, LEED V4.1 option 2 adopts the illuminance levels between 300 lux and 3000 lux (Li et al., 2023). Meanwhile, the UDI100-3000lx average of > 80% was first set as an appropriate daylight level in a classroom space in a Priority School Building Program (PSBP) in the UK (Hakim et al., 2021). BREEAM HEA1: The BREEAM Health and Wellbeing Credit, HEA1, pass requires that

both the following conditions are met: 1. For pre-schools, schools and further education colleges, at least 80% of floor area in occupied spaces should be day lit, having an average daylight factor of 2.25 at the height of 0.8 meters for a multi-story building in a city with latitude less than 40. 2. A uniformity ratio of at least 0.4 (spaces with glazed roofs, such as atria, must achieve a uniformity ratio of at least 0.7 or a minimum point daylight factor of at least 1.4%) (Zomorodian, Korsavi & Tahsildoost, 2016). Several standards use a threshold of 300 lux to evaluate the daylighting conditions in schools (Chi, 2024).

3.2 Targeted illuminance values for classrooms

The importance of daylight in classrooms is highlighted in various standards and guidelines. Illuminating Engineering Society of North America (IESNA) recommended 300 lux to 500 lux of illuminance level for learning tasks (Rahman & Tuhin, 2019; Nocera et al., 2018; Lakhdari, Sriti & Painter, 2021; Moazzeni & Ghiabaklou, 2016). The illumination uniformity ratio should be no lower than 0.5 (Arabi et al., 2019; Ho et al., 2008). On the other hand, recommended average illuminance values are between 300 and 700 lux for visual tasks in classrooms, including reading and writing respectively (Zomorodian, Korsavi & Tahsildoost, 2016). It was also found that the Chartered Institution of Building Services Engineers (CIBSE) in the UK similarly defines the classroom standards as 300 lux and laboratory as 500 lux. The International Commission on Illumination (CIE) suggests limiting by 700 lux for indoor learning for learning & writing (Kwon & Lee, 2018). According to the European norm EN 12464-1, the illuminance level in classrooms and tutorial rooms must be a minimum of 300 Lux, which rises to 500 Lux for evening classes, adult education and blackboard applications. Therefore, 300 Lux can be the minimum requirement for daylighting applications and a threshold of 500 Lux may be applied to evening applications (Galal, 2019). Visual arts, such as painting, sculpture, carving, textile design and photography, require specific lighting conditions, which are different from the regular classroom standards. Due to the limited number of studies in this area, it is necessary to examine the specificities of different types of visual arts and to provide specific design guidelines for lighting enhancement (Yunitsyna & Toska, 2023).

The illuminance values are defined based on the object of study, classrooms, for which a revision of the regulatory and standard aspects was carried out to define the illuminances considered for the “in range” values: target illuminance. A minimum limit value of 300 lux (simple task) and a maximum limit value of 2000 lux (accurate visual perception) are established as defined by Illuminating Engineering Society of North America (IESNA) (Moreno & Labarca, 2015). The following lux level for daylight standards of illumination according to the space function is determined; 300 lux is for classrooms, tutorial rooms, music practice rooms, computer practice rooms, language laboratories; 500 lux is for lecture halls, art rooms, practical rooms and laboratories, handicraft rooms, libraries and reading areas; 750–1000 lux is for technical drawing room, art rooms in art schools (Sabbagh, Mandourah & Hareri, 2022). The UK Guidelines for the Environmental Design in Schools and the European Indoor Lighting Standard set up the 300 lux illuminance as appropriate for the regular classrooms and the music practice rooms, the 500 lux to be applied in case of the workshops, art and handicraft rooms, auditoriums, and 750 lux in the art and technical drawing classrooms in the art schools (Yunitsyna & Toska, 2023).

In standard classrooms the light should be distributed in a way to provide the uniformity of 0.6 (Uo) and the color rendition (Ra) of 80, however in the visual art classrooms these parameters are higher due to the specificity of the artwork, where the color rendering is essential. For the visual art classrooms, the Ra can be set over 90. The lighting requirements for different classrooms are summarized in lighting standards (Yunitsyna & Toska, 2023).

4 Simulation Parameters

Simulation tools avoid the costly and time-consuming field data collections (Mehta, 2020). It has been suggested, as a principle for investigation, that the old daylight analysis methods provide very limited information compared to the dynamic methods that integrate factors like the types of skies and the local light conditions. These methods strengthen the evaluation of the daylight strategies applied and favor an integrated design (Moreno & Labarca, 2015). Results of daylight simulations have allowed evaluating extensively parameters such as Daylight Factor, Daylight Autonomy, and Useful Daylight Illuminance (Guan & Yan, 2016). The interior illuminance was evaluated in relation to a target illuminance value (goal-oriented

assessment), for which five intervals are defined: low, too low, in range, high and too high. The aim of the goal-oriented approach is to set a target range of values and assess the percentage of time over the year where each range is reached and the percentage of spaces in a temporal map within in range during the year (Moreno & Labarca, 2015).

4.1 Sky models

Sky models play a crucial role in predicting solar radiation and capturing the sun's path and its interactions with the atmosphere, influencing the distribution, intensity, direction, and colour of daylight (Nazari & Matusiak, 2024). Direct sun ray from the sun at clear sky or slightly cloudy sky and diffused daylight are components of daylight. The light intensity of the sun changes depending on the atmosphere, the state of the sun and the latitudes. Reflected light, is described as light reflected from surfaces created by nature and man. The sun illuminates the surfaces, providing additional light sources (Bor, 2021). Today, the Perez sky model and CIE standard have defined sky models for clear, intermediate, and overcast skies, and further developments have included recommendations for 15 CIE standard different sky types. Among all sky models for the luminous distribution function, the CIE general sky and the Perez sky are widely implemented. The CIE general sky defines 15 parameter sets for a range of sky conditions (clear, intermediate, or overcast), while the Perez sky model adjusts these parameters based on direct and diffuse irradiance (Nazari & Matusiak, 2024). The four types of skies included are defined starting from two parameters, the clarity and the brightness of the sky, which are derived from the direct or global diffuse irradiance; the interpolation of these parameters through the luminance distribution of the skies allows determining the type of sky (Moreno & Labarca, 2015; Guan & Yan, 2016).

4.2 Time period

In daylight calculations, it is necessary to determine the occupancy period of the spaces. Different time periods can be selected for different building programs. For schools, it may vary according to the intended use of the building and local conditions and practices of the schools. For example, one field study shows that a school provides education in a time period from 7 am to 3 pm, while another study shows that a school provides education in a time period from 8 am to 4 pm. Therefore, depending on the field study, the time period should be selected and the simulation parameter should be entered (Moreno & Labarca, 2015). The academic calendar also varies from country to country and institution to institution. For instance; in the academic calendar of elementary schools in Chile, classes begin on the first week of March and end by the second week of December. In China, students have three months off per year: February, July and August, and daily academic schedule is from 8:00 a.m. to 6:00 p.m. (excluding lunch break from 12:00 p.m. to 2:00 p.m. The diagram of occupancy and unoccupied time and an example of a temporal map with occupancy time marked in a case study (Guan & Yan, 2016).

4.3 Light reflectance value

Reflectance is the amount of light which reflects off an object (Url 1, 2024). The surface reflectance properties are assigned based on design intent (primarily walls, ceiling and floor). In addition, visible light transmittance (VLT) data is essential for window glazing (Koti & Munshi, 2009). For the calculation, a horizontal grid representing the student's work plane is used. Before the simulations to be performed on the work plane, it is necessary to define the reflectivity properties of the materials of the walls, floors and ceilings that make up the space. The properties of the interior materials are defined by the reflection coefficient based on values recommended for classrooms in percentages (Moreno & Labarca, 2015). High reflectance of the ceiling provides for a more equal daylighting of the working surfaces along the depth of the classroom (Bezjak et al., 2003). The attributes of the classrooms shall be shown in the case study and the classroom elements, surface finishing, and materials at the school shall be listed (Sabbagh, Mandourah & Hareri, 2022).

5 Conclusion

In many analyses of educational buildings, standard classrooms are mostly included, and performance measurements in classroom use situations such as design etc. are encountered in a limited number of studies. In the case of reuse of existing buildings for different purposes other than their original design, there is also a need to analyse whether the illuminance levels in the interior are sufficient. In this context, this study aims to determine the daylighting analysis

method for an educational building that has been converted into a design studio through reuse. When daylighting metrics are analysed, it is determined that “visual discomfort and glare” is a metric that needs to be simulated for educational building design. It has been observed that more accurate results are obtained from climate-based simulation. In some countries, climate-based simulations have been made compulsory in the certification systems to be obtained for educational buildings and have started to be widely used today. Unlike standard classrooms, the target illuminance levels of classrooms whose purpose of use is more specialized also change and attention should be paid to this issue in simulations. In terms of simulation parameters, different types of sky models are now used along with dynamic simulation models. The standard CIE overcast sky used in static simulations now has many alternatives. In addition, the time frame for the use of the space in the simulation varies and the time frame within the education system in the case study needs to be considered. Another issue is the correct input of the light reflection values of the materials that make up the space, such as floors, walls and ceilings, into the simulation tool. Here, the light transmittance coefficient of the glass forming the window also comes to the fore. With this described methodology, daylight performance can be simulated for design studios, which are considered as a specialized use in an educational building.

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