New Design Ideas
Vol.9, No.3, 2025, pp.661-687
https://doi.org/10.62476/ndi.93661

Jomard Publishing

ALTERATION OF OFFICE SPACE TO DESIGN STUDIO FOR TERTIARY EDUCATION; DAYLIGHTING IMPACT

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Abstract. This study investigates the challenge of converting office buildings into educational spaces, focusing on the higher daylight requirements of design studios (500 lux) compared to offices (300 lux). It evaluates natural daylight performance in a repurposed high-rise building adapted for design education. The primary goal is to assess daylight adequacy on repurposed floors, examining the impact of increased illuminance thresholds. Using Autodesk Revit's simulation tools, the study applies three metrics - Daylight Factor (DF), Spatial Daylight Autonomy (sDA) and point-in-time illuminance - to floors in a university building in Istanbul. Due to software limitations, illuminance analysis was prioritized for detailed evaluation. Two floors with identical exteriors but differing interiors - a subdivided 12th floor with five studios and an open-plan 15th floor - were compared. Simulations reveal that interior partitions reduce daylight uniformity and compliance. Raising the threshold to 500 lux decreases overall daylight compliance; spaces with favorable orientation and shallow depth performed better, while deeper or centrally located areas required more artificial lighting. Afternoon glare risk was highest in the best-performing zone, highlighting the influence of orientation and layout. Only a limited number of classrooms achieved daylight standards under the stricter threshold. The findings emphasize the critical role of spatial configuration and software constraints in daylighting performance, underscoring the need for adaptive design strategies and glare control in repurposed educational environments.

Keywords: *Classroom illumination, daylighting performance, daylight metrics, computer simulation, adaptive reuse.*

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Received: *31 January 2025;* ***Accepted:*** *22 May 2025;* ***Published:*** *2 December 2025.*

1. Introduction

Research shows that building design features that prioritize sustainability and environmental quality can have a direct impact on human health and performance (Alakaam & King, 2024). Among these features, daylight is a fundamental component, particularly in educational environments. Natural light plays a crucial role in creating an effective teaching and learning atmosphere, while dimly lit classrooms can negatively affect students' well-being and learning capacity (Sabbagh *et al*., 2022). Comfortable visual conditions significantly enhance the learning experience, supporting better academic outcomes (Azodo, 2017). Studies have shown that natural light in classrooms positively influences students' health, performance, behavior, productivity and even spatial preferences, such as seating choices (Mehta, 2020). Despite its benefits, daylighting in classrooms must be carefully controlled to avoid discomfort caused by glare or uneven light distribution (Viula *et al*., 2023). Effective lighting design in educational buildings requires a balanced integration of natural and artificial light to ensure adequate and visually comfortable conditions for various learning activities (Azodo, 2017).

Natural daylight has been shown to enhance students' learning outcomes, well-being, productivity and behavior (Mehta, 2020; Sabbagh *et al*., 2022). Classrooms with effective daylighting contribute to a healthy and visually comfortable learning environment, whereas poorly lit spaces can impair focus and academic performance (Azodo, 2017). However, controlling daylight is equally important, as excessive brightness or glare can reduce visual comfort (Viula *et al*., 2023). A well-designed balance of natural and artificial light not only improves learning quality but can also significantly reduce energy consumption in school buildings (Dolnikova *et al*., 2020; Rahman & Tuhin, 2019).

When existing buildings are repurposed - especially those not originally designed for educational use - it becomes critical to reassess their daylighting performance. This is particularly important when converting office floors into design studios, which require higher illumination levels and longer daily usage compared to standard classrooms. This study investigates the daylighting performance of repurposed office floors functioning as design studios in a higher education building. The analysis is based on daylight factor (DF), spatial daylight autonomy (sDA) and illuminance metrics across selected floors, using a simulation-based case study methodology.

2. Materials and Methods; Daylighting Considerations in Educational Environments

Natural light plays a vital role in the design of educational facilities by supporting a wide range of activities, including reading, writing, group discussions and the use of multimedia tools. These varied tasks require carefully crafted visual environments to ensure optimal comfort and performance for students (Sabbagh *et al*., 2022; Savrunlu, 2024). In particular, classrooms must accommodate both individual and collaborative work, which differ considerably in their visual requirements (Mehta, 2020).

To evaluate daylight performance effectively, several quantitative metrics are widely applied (Table 1). One of the most commonly used is the Daylight Factor (DF) - a static measure representing the ratio of indoor to outdoor illuminance under overcast sky conditions. It provides a weather-independent baseline for daylight access, with values between 2% and 5% generally considered adequate for classroom use (Li *et al*., 2006; IES, 2012). Complementing this, Spatial Daylight Autonomy (sDA) is a dynamic metric that assesses the percentage of floor area receiving at least 300 lux for 50% or more of the annual occupied hours. A minimum sDA(300/50%) of 55% is recommended for educational spaces to ensure sufficient daylight exposure and reduce reliance on artificial lighting (IES, 2012).

Another important parameter is illuminance level, which refers to the instantaneous intensity of light on a surface. Standard classrooms typically require around 300 lux, whereas design studios - due to their visually demanding tasks - benefit from approximately 500 lux (CIBSE, 2015). These values are often interpreted using a five-interval classification adapted from Moreno & Labarca (2015): too low (<150 lux), low (150-299 lux), within range (300-500 lux), high (500-3000 lux) and too high (>3000 lux), helping to assess visual comfort and the risk of glare. In addition, the Useful Daylight Illuminance (UDI) metric provides further granularity by dividing daylight into underlit (<100 lux), useful (100-2000 lux) and overlit (>2000 lux) zones - enabling designers to identify areas with appropriate light levels while mitigating issues like glare and over-illumination (Nabil & Mardaljevic, 2006).

Table 1. Illuminance metrics and thresholds

Metric	Abbrev.	Description	Threshold(s) Used
Daylight Factor	*DF*	*Ratio of indoor illuminance to unobstructed exterior illuminance*	*2% (general), >5% (good)*
Spatial Daylight Autonomy	*sDA*	*% of occupied hours with ≥ 300 lux from daylight only*	*≥ 50% desirable*
Useful Daylight Illuminance	*UDI*	*% of time illuminance is between 300-3000 lux*	*Optimal daylight zone*
Illuminance Range Analysis	-	*Categorical range: too low, low, within range, high, too high*	*300-3000 lux and 500-3000 lux*

Visual comfort is also influenced by control mechanisms. Manual shading devices, such as roller blinds, play a critical role in balancing daylight access and user comfort by allowing occupants to reduce glare while maintaining adequate illumination (Galasiu & Veitch, 2006; Wienold & Christoffersen, 2006). Beyond technical metrics, empirical studies have shown that well-designed daylight environments in classrooms positively influence students' academic performance, well-being and overall health (Barrett *et al*., 2015; Obralic & Jeghel, 2021). Daylight distribution and glare control can be enhanced through strategies such as optimizing window orientation, glazing type and aperture size, as well as incorporating shading systems. For instance, adjustable blinds and light shelves have proven effective in promoting daylight uniformity and reducing visual discomfort (Dökmeci, 2023; Wienold & Christoffersen, 2006).

However, achieving these daylighting standards can be particularly challenging when repurposing buildings - especially former offices - for educational use. These structures often feature deep floor plans, minimal façade exposure and window configurations not optimized for classroom environments. As a result, a comprehensive daylighting assessment becomes essential, particularly for high-demand spaces like design studios (Yunitsyna & Toska, 2023).

Daylighting performance in interior spaces can be assessed using four primary methods: 1) Computer-based simulations, 2) On-site illuminance measurements**,** 3) Physical model testing with a heliodon and 4) Occupant surveys. Each method offers distinct benefits depending on project phase and research goals. Computer-based simulations are widely favored for their ability to model complex geometries and perform dynamic analyses of daylight metrics such as sDA and UDI across different sky conditions and times of day (Reinhart *et al*., 2006; Jakubiec & Reinhart, 2011). On-site measurements, though accurate under real conditions, often require long-term monitoring and may not be practical during early design or in inaccessible buildings (Li & Tsang, 2008; Reinhart & Wienold, 2011). Heliodon-based physical model testing offers designers visual insight into daylight behavior, although it lacks quantitative precision - particularly in larger or more complex interiors (Benton, 1990; Donoff, 2009). Lastly, occupant surveys capture subjective experiences of visual comfort but may be influenced by individual preferences and environmental adaptation, limiting their reliability as standalone evaluation tools (Aries *et al*., 2010; Galasiu & Veitch, 2006). Given these considerations, computer-based daylight simulations are generally regarded as the most effective method for assessing daylight performance - especially in early-stage design, retrofitting scenarios and academic research where empirical data collection is limited or unfeasible (Reinhart & Wienold, 2011; Tregenza & Wilson, 2011).

2.1. Classroom Design Focused On Daylight

Establishing an optimal classroom environment depends on multiple factors, including building architecture, classroom dimensions, window placement and orientation, glare control measures, interior finishes and surface colors (Dolnikova *et al*., 2020). The most common school layout is a three-zone plan, consisting of classroom-hallway-classroom, where classrooms receive daylight primarily from one side through vertical windows. This unilateral lighting can limit daylight penetration and affect visual comfort.

To enhance natural lighting, an alternative two-zone layout (classroom-hallway) is sometimes used, allowing classrooms to receive daylight from two sides - directly from exterior windows and indirectly from the hallway space - thereby improving overall daylight distribution (Bezjak *et al*., 2003). Classrooms can thus be categorized into two main types based on daylighting: those with unilateral lighting (three-zone layout) and those with dual-sided lighting (two-zone layout).

Common daylight optimization strategies in classroom design include maximizing window-to-wall ratios while controlling glare through shading devices such as blinds, louvers and light shelves, which reflect light deeper into the space (Lee *et al*., 2016; Wienold & Christoffersen, 2006). Orientation plays a crucial role; classrooms oriented towards the north typically benefit from consistent, diffuse daylight, while southern exposures require more effective glare and solar heat gain control (Heschong *et al*., 2002). The use of high-reflectance interior surfaces and light-colored finishes also helps to increase daylight penetration and uniformity (Reinhart & Walkenhorst, 2001).

Moreover, daylight redirecting technologies such as prismatic glazing or light shelves can significantly improve daylight distribution by bouncing light towards the ceiling and deeper into the classroom, reducing reliance on artificial lighting and enhancing occupant comfort (Belliaa *et al*., 2014). Automated shading systems responsive to daylight intensity and glare are becoming increasingly common in modern educational buildings to dynamically optimize lighting conditions (Galasiu & Veitch, 2006).

From an energy efficiency perspective, minimizing corridor lengths reduces the building’s external surface-to-volume ratio, enhancing thermal performance while allowing for deeper classrooms that better utilize natural light. Classroom heights are often standardized around 3.20 meters to facilitate daylight penetration and visual comfort (Bezjak *et al*., 2003). Studies show that classrooms with dual-sided daylighting provide superior visual comfort, increased daylight autonomy and reduced glare compared to unilateral-lit classrooms (Mardaljevic *et al*., 2012).

2.2. Targeted Illuminance Values For Classrooms

Targeted illuminance values in educational spaces vary depending on the nature of learning activities - from general classrooms to specialized studios. Ensuring both appropriate illuminance and uniformity is essential to support educational outcomes and visual comfort, while also optimizing energy use by integrating natural and artificial lighting strategies.

Daylight levels in classrooms are governed by various international standards and guidelines to ensure appropriate lighting conditions that support diverse learning activities. The Illuminating Engineering Society of North America (IESNA) recommends illuminance levels between 300 and 500 lux for typical learning tasks (IESNA, 2011; Rahman & Tuhin, 2019). For more visually demanding activities, such as reading and writing, recommended illuminance can range from 300 up to 700 lux (Zomorodian *et al*., 2016). Similarly, the Chartered Institution of Building Services Engineers (CIBSE, UK) specifies a standard illuminance of 300 lux for classrooms and 500 lux for laboratory spaces (CIBSE, 2005). The International Commission on Illumination (CIE) further recommends a maximum limit of 700 lux for indoor educational activities, emphasizing the need to balance adequate visibility and visual comfort (Kwon & Lee, 2018).

A comprehensive review of relevant international regulations and standards reinforces these values. According to Moreno and Labarca (2015), a minimum threshold of 300 lux (for basic tasks) and a maximum threshold of 2000 lux (for high-precision tasks) is widely accepted. Specific recommendations vary depending on space type: 300 lux for classrooms, tutorial rooms, music practice rooms, computer labs and language labs; 500 lux for lecture halls, art rooms, laboratories and reading areas and up to 750-1000 lux for technical drawing rooms and specialized art studios (Sabbagh *et al*., 2022; Yunitsyna & Toska, 2023). Both the UK Guidelines for Environmental Design in Schools and the European Indoor Lighting Standard (EN 12464-1) support these illuminance targets, recommending adaptable lighting according to activity type and time of use (CEN, 2011).

Although the original UDI (Useful Daylight Illuminance) framework defined the desirable illuminance range as 100-2000 lux, recent studies and updated standards have extended this upper threshold. LEED v4.1, for instance, adopts a range of 300-3000 lux for evaluating daylight sufficiency in standard educational spaces (Li *et al*., 2023). In this study, two different illuminance thresholds are applied depending on the function of the space: 300-3000 lux is used for general classrooms, while a higher range of 500-3000 lux is considered appropriate for design studios due to their more demanding visual tasks and extended daily use. Illuminance values exceeding 3000 lux are categorized as excessive and may lead to visual discomfort, while values below 300 lux (or 500 lux for studios) are considered insufficient for effective learning or design activities.

In terms of lighting quality, the illumination uniformity ratio (Uo) - defined as the ratio of minimum to average illuminance within the space - plays a crucial role in ensuring consistent lighting distribution and preventing areas of excessive brightness or shadow (IESNA, 2011). For classrooms, a uniformity ratio of at least 0.6 is generally advised to maintain visual comfort (Arabi *et al*., 2019; Mathalamuthu *et al*., 2018). Higher uniformity reduces visual fatigue and distraction by providing balanced lighting across the learning environment.

3. Refunctioning an Existing High-Rise Office Building as an Educational Facility

In the post-pandemic context, adaptive reuse of abandoned buildings has emerged as a viable strategy for expanding university campuses within dense urban environments. Such university-led transformations are often positioned as key components of urban regeneration, particularly in areas affected by economic decline and spatial obsolescence. These projects do more than address space shortages - they reshape the sociocultural and economic dynamics of their surroundings by introducing mixed-use functions that contribute to the revitalization of metropolitan zones. Acting as catalysts for local development, they generate new employment opportunities, foster innovation and encourage social integration (Elassi, 2023).

A review of current literature on university campus planning highlights recurring themes such as sustainability, energy management and resource efficiency (Çamayaz, 2023; Gümüşbaş, 2023). Additional focal points include accessibility (Sarıalan, 2019), development of recreational and social infrastructure, landscape design, acoustic performance (Nacar, 2023) and the influence of daylight and spatial perception on the learning environment. Recent studies have also emphasized the relationship between urban design and energy performance, offering strategies that merge aesthetic urban values with sustainability goals (Changa *et al*., 2019). Urban campuses are inherently dynamic; once established, they continue to evolve in both physical and social dimensions, influencing broader patterns of regional growth. In this context, a recent study mapped the spatial expansion of Istanbul Gelişim University's urban campus, identifying key transformation strategies and their integration with the surrounding urban pattern (Figure 1) (Yildirim, 2025).

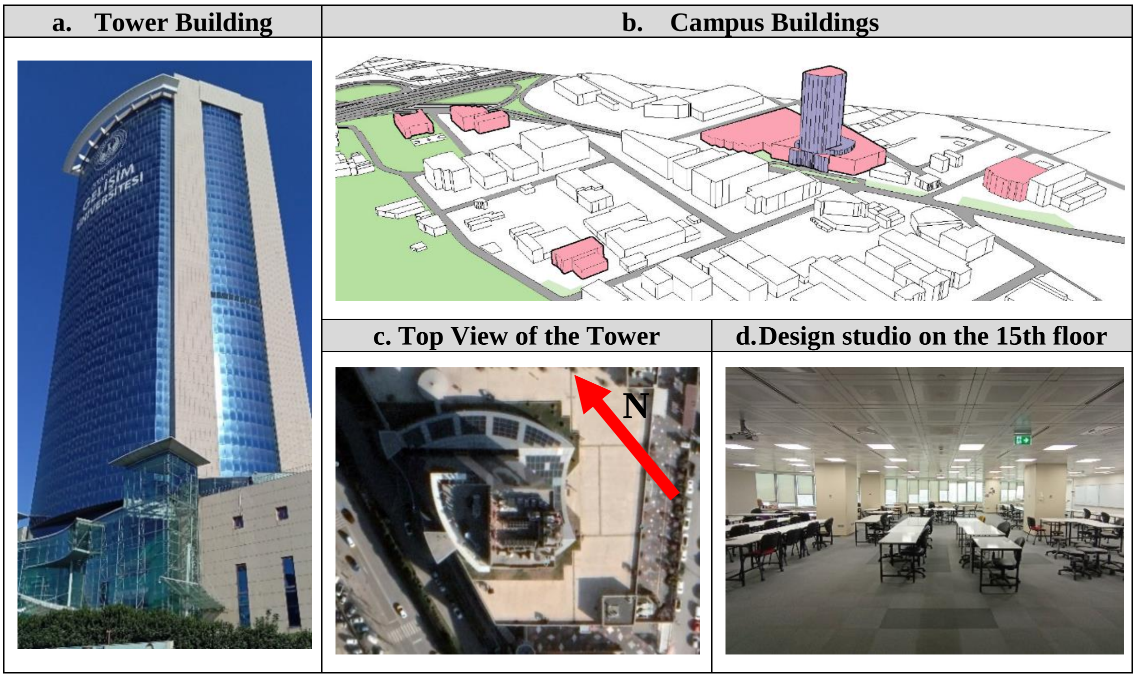


Figure 1. The high-rise office building (Tower K Block) has been repurposed as an educational facility. In the Avcılar downtown campus of Istanbul Gelisim University: a. tower building (photo credit: Semih G. Yildirim), b. campus buildings (illustration by Ali Hussein Alali), c. top view (Google Earth), d. design studio on the 15th floor (photo credit: Semih G. Yildirim)

This study focuses on the interior spatial reconfiguration within a reused high-rise office building, emphasizing the implications of natural daylighting in newly adapted educational spaces. The 30-story tower was originally designed with a standard open office floor plan oriented along a southeast-northwest axis. During its conversion for academic use, various floors were repurposed as modular offices, classrooms and design studios. The Department of Architecture currently occupies several of these reconfigured levels.

This case study specifically investigates the 12th and 15th floors, the only levels adapted into architectural design studios (Figure 2). On the 15th floor, the original open office layout was preserved, forming a large, undivided studio, while adjacent executive offices were allocated to academic staff. In contrast, the 12th floor underwent a more substantial transformation, where both the open office and executive zones were subdivided into five smaller studios. Only the spaces coded 1201-1205 and 1501 are analyzed in this study, as they function as hybrid classrooms that support both theoretical learning and design work. Each space is equipped with ceiling-mounted projectors, whiteboards and manually operated roller shades to regulate daylight and control glare during presentations.

The comparison of these two floors - identical in perimeter, orientation and façade design but differing in internal configuration - offers insight into how spatial layout influences daylighting performance. Illuminance simulations were conducted to assess how the introduction of partition walls on the 12th floor affects the distribution and intensity of natural light compared to the open-plan layout of the 15th floor. This comparative analysis highlights the impact of interior reorganization on daylight penetration, contributing to broader discussions on adaptive reuse strategies that support user comfort and energy efficiency in educational settings.

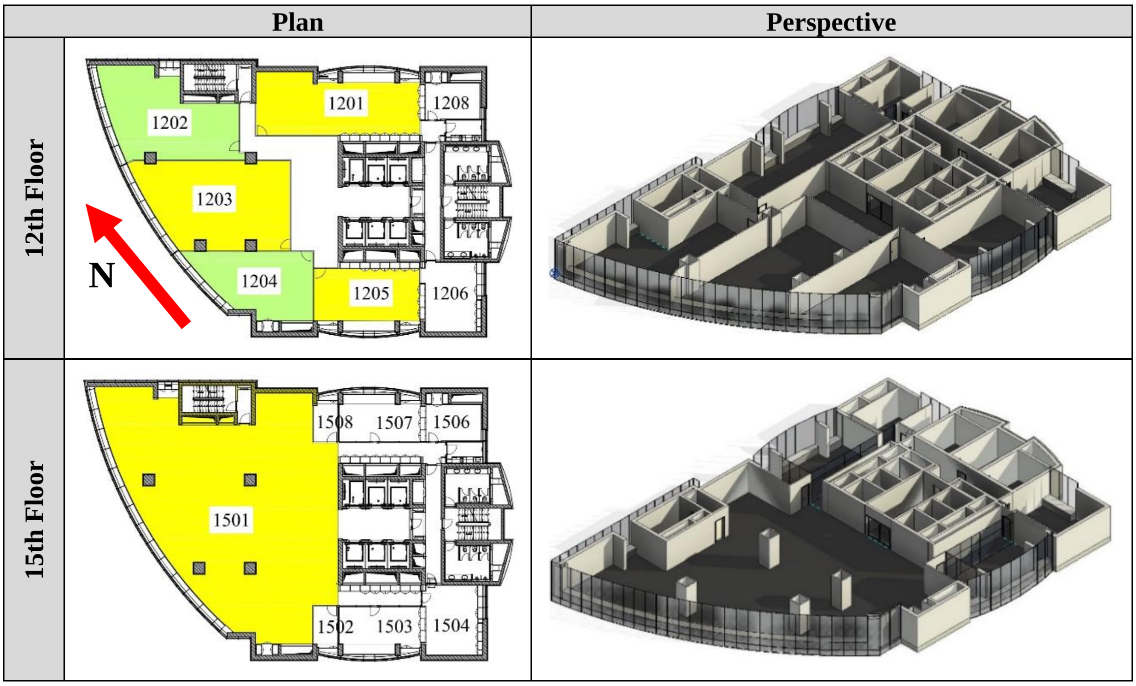


Figure 2. Separated design studios are located on the 12th floor (top - left and right), while the open studio format is situated on the 15th floor (bottom - left and right) (courtesy of the Istanbul Gelisim University Construction Works Division)

3.1. Simulation Setup

This study employed daylight simulations to assess the natural lighting performance of a repurposed university design studio space. The simulation aimed to provide a quantitative evaluation of daylight availability and visual comfort using validated metrics. The case study is located in Avcılar, Istanbul, Turkiye and simulations were conducted using Autodesk Revit due to its robust Building Information Modeling (BIM) infrastructure and integrated daylight analysis plugins. The overview of the simulation parameters is depicted in Table 2.

Table 2. Simulation parameters overview

Parameter	Value/Selection	Description / Notes
Simulation Software	Autodesk Revit	Lighting Analysis Plug-in used
Location Coordinates	40° 59' 38" N, 28° 42' 4" E	Istanbul, Türkiye
Work Plane Height	30 inches (≈76.2 cm)	Typical desk height for illuminance analysis
Sky Model	Perez All-Weather	Supports both direct and diffuse irradiance
Time Periods Simulated	March 21, June 21, December 21	Spring Equinox, Summer Solstice, Winter Solstice
Daily Occupancy Schedule	08:00-18:00	Based on observed design studio use
Metrics Analyzed	DF, sDA, UDI	Covers both static and dynamic daylighting performance

The digital model was geolocated based on the actual project coordinates to ensure climate-accurate simulation inputs. The simulation grid was defined at a working plane height of 76 cm (30 inches), representing the typical desk height in a tertiary educational environment. Physical attributes such as glazing transmittance, material reflectance values and occupancy schedules were embedded into the model to increase realism and accuracy.

The analysis utilized three widely accepted daylight metrics: Daylight Factor (DF) for overcast sky conditions, Spatial Daylight Autonomy (sDA) for annual daylight performance under dynamic sky conditions and point-in-time illuminance levels to determine instantaneous lux values. These metrics allow comprehensive evaluation of daylight sufficiency and distribution across the studio space.

Due to the space's function as a design studio - which demands higher visual clarity and prolonged daily use - daylight performance was assessed using appropriately adjusted threshold values. The simulation parameters, including the selected sky models, analysis periods and illuminance thresholds, are detailed in the subsections below.

3.1.1. Sky models

In daylighting simulations, the selection of a sky model directly impacts the accuracy of light distribution predictions. The Perez All-Weather Sky Model, developed by Perez et al. (1993), has become a widely adopted method due to its ability to simulate a broad spectrum of sky conditions - from clear to overcast - by interpolating direct and diffuse irradiance data. Compared to simpler models such as the standard CIE Overcast Sky, the Perez model allows for a more nuanced and realistic luminance distribution, especially in dynamic daylight simulations (Andersen, 2015; Nazari & Matusiak, 2024; Perez *et al*., 1993; Reinhart & Walkenhorst, 2001).

The CIE General Sky Standard, which includes 15 sky types ranging from overcast to clear skies, is also used in many daylighting assessments (Li *et al*., 2023). However, it is more static in nature and may not accurately capture the variation in daylight found in diverse climates. The Perez model dynamically adjusts based on environmental inputs, offering more reliable results for annual daylight simulations and Useful Daylight Illuminance (UDI) metrics (Littlefair, 1991; Tregenza & Waters, 1983).

For this study, conducted in Istanbul, Turkey (Latitude 40° 59′ 53.5″ N, Longitude 28° 41′ 55.7″ E), the Perez all-weather model was selected to reflect the region's highly variable sky conditions throughout the year. Unlike in northern European countries, where overcast skies dominate for much of the year - making CIE Overcast Sky a reasonable assumption - Istanbul experiences a Mediterranean climate with significant seasonal and diurnal variation in solar radiation. According to Meteonorm climate data (Remund et al., 2010) and the Turkish State Meteorological Service, Istanbul typically has a balanced distribution of clear, intermediate and overcast days**,** especially between spring and autumn. Thus, employing a static overcast model would result in underestimating daylight availability in this context.

By using the Perez All-Weather Sky, this study ensures the simulation captures Istanbul's climatic diversity, yielding results that are not only more context-sensitive but also more representative of daylight conditions under which learning spaces operate throughout the academic calendar.

3.1.2. Time period

Occupancy schedules in educational buildings are critical to daylight simulation since daylight availability is inherently time-bound. Institutional calendars vary significantly depending on geographic location, academic level and curriculum structure. For instance, Chilean elementary schools typically operate from March through December, while Chinese schools observe academic breaks in February, July and August (Guan & Yan, 2016). In the United States, most schools follow a two-semester system, running from late August or early September through May or June, with a summer break in between (EducationIndex, n.d.). In Germany, universities follow a split semester system with a winter semester (October-February) and a summer semester (April-July), often accompanied by exam and preparation periods (DAAD, 2025). Similarly, in Japan, the academic year begins in April and is divided into spring and fall semesters, with short breaks in August and March (MEXT, n.d.). University design studios across all these contexts typically follow more flexible or extended timetables due to the iterative and project-based nature of studio learning.

In the Turkish higher education context, academic calendars are generally divided into three periods: fall semester (typically mid-September to mid-January), spring semester (mid-February to early June) and optional summer sessions (mid-June to August). Classroom and studio spaces in Turkish universities are predominantly used between 8:00 AM and 6:00 PM, although some design programs may extend later into the evening to accommodate critique sessions and deadlines (IGU, 2025). These schedules reflect a combination of structured lecture-based courses and more flexible studio-based formats, especially in architectural faculties.

In this case study, classroom occupancy was modeled from 8:00 AM to 6:00 PM, aligning with typical academic studio schedules in Turkish universities. Three representative dates were selected to capture seasonal variation in daylight conditions: the spring equinox (March 21), the summer solstice (June 21) and the winter solstice (December 21). These dates were chosen to represent the average, maximum and minimum daylight durations respectively. While summer sessions may see irregular or reduced usage, the summer solstice was included to examine peak daylight levels, particularly in relation to glare risk and potential over-illumination in studio spaces.

3.1.3. Targeted thresholds for illuminance levels for classrooms

The evaluation uses three major recognized simulation metrics: Daylight Factor (DF), Spatial Daylight Autonomy (sDA) and point-based illuminance measurements. The time period and illuminance values for each metric are provided in Table 3. Each analysis is performed separately, with the goal of evaluating and comparing the results. Given the mixed-use function of the classrooms as both lecture and design studio spaces, a minimum target threshold of 500 lux was adopted for this study, in accordance with lighting requirements for detailed visual tasks. For comparative purposes, two ranges were evaluated: 300-3000 lux for general classrooms and 500-3000 lux for design studios.

Table 3. Targeted analysis and value for case study

Analysis Type	Time Period	Illuminance Value
a. DF analysis	NA	2% ≤ DF ≤ 5%
b. Illuminance	March 21 (8am to 6pm)	300 – 3000 lux
		500 – 3000 lux
	June 21 (8am to 6pm)	300 – 3000 lux
		500 – 3000 lux
	Dec. 21 (8am to 6pm)	300 – 3000 lux
		500 – 3000 lux
c. sDA analysis	Jan 1 – Dec 31 (8am to 6pm)	sDA300 (%50)

Daylight Factor (DF) is a static ratio representing the indoor illuminance relative to the unobstructed outdoor illuminance under a standard overcast sky. In this study, a threshold range of 2% to 5% was adopted, meaning that areas where the DF falls within this range are classified as “within threshold”. The analysis evaluates the percentage of the floor area in the simulated space that meets this DF threshold, providing an indicator of baseline daylight accessibility independent of weather fluctuations.

Spatial Daylight Autonomy (sDA) is a dynamic metric that measures the percentage of the floor area receiving at least 300 lux of natural light for 50% or more of the occupied hours annually. This metric helps quantify the sufficiency of daylight throughout the year and its potential contribution to energy savings by reducing artificial lighting needs. The analysis focuses on how much of the space achieves this target illuminance threshold during typical usage periods.

For illuminance levels, two separate threshold ranges were considered to accommodate different functional requirements of spaces: 300-3000 lux and 500-3000 lux. Within these ranges, illuminance values below 300 lux (or 500 lux for the higher threshold) are classified as “below threshold”, indicating insufficient lighting for effective tasks. Values within 300-3000 lux (or 500-3000 lux) are classified as “within threshold”, representing an adequate and comfortable daylight range. Illuminance levels exceeding 3000 lux are labeled as “above threshold”, which may imply excessive daylight potentially causing glare or discomfort. This classification allows for a nuanced interpretation of daylight quality and visual comfort relative to the specific needs of the studied space.

3.1.4. Surface reflectance

Surface reflectance plays a critical role in daylight performance, as it determines how much light is reflected and redistributed within a space. Accurate input of material reflectivity values in daylighting simulations is essential to realistically assess interior illuminance and spatial brightness (Reinhart & Andersen, 2006; Wienold & Christoffersen, 2006).

In the adaptive reuse of the case study building, interior finishes on the floor, wall and ceiling surfaces remained unchanged. The design intervention focused primarily on spatial reconfiguration rather than altering surface materials. Specifically, the floor retains its original very dark carpeted textile material, the ceiling continues to feature the original suspended acoustic tiles and the wall finishes were preserved without modification. Partition walls introduced during the reuse phase were painted in a light neutral tone matching the existing original walls, maintaining visual consistency throughout the space.

These inherited materials significantly influence the reflectance characteristics of the space. Very dark carpeting typically has a reflectance value between 5% and 15%, while white acoustic ceiling tiles generally reflect 80% to 90% of incident light (IESNA, 2011). Wall surface reflectance for light-colored matte interior paints typically ranges from 60% to 80%, consistent with values reported in established lighting design guides (CIBSE, 2015; IESNA, 2011; Reinhart & Andersen, 2006). Field observations and architectural documentation confirm that these values remain valid in the current use of the studios.

It is important to note that unlike some lighting simulation software such as Dialux, which allows direct input of reflectance percentages, Autodesk Revit requires reflectance to be defined indirectly through RGB color values. Reflectance cannot be manually entered as a numerical value; instead, it is calculated based on luminance properties derived from RGB codes (Autodesk, 2024). This approach is consistent with Revit's material definition system and necessitates careful approximation to match reflectance targets. Reflectance values were calculated using the standard luminance formula, which maps RGB color input to photometric reflectance: $(0.2126R + 0.7152G + 0.0722B) / 255$. This widely accepted formula in computer graphics and lighting simulation connects RGB color codes with physical reflectance properties (Glassner, 1995; Ward, 1994). By this method, the software approximates the material's actual reflectivity from its color specification, enabling accurate daylight simulation within Autodesk Revit.

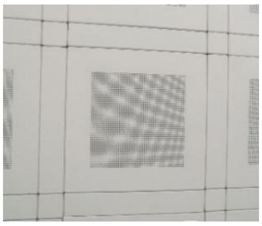
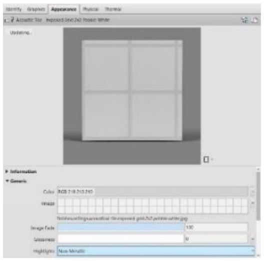
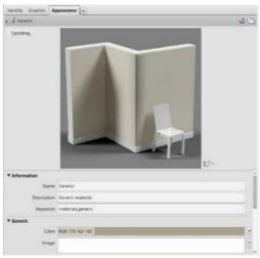
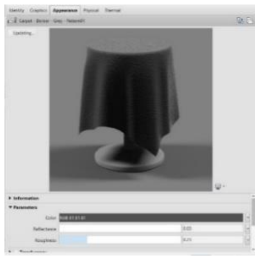
Table 4. Surface reflectance values

Surface Type	Material Description	Reflectance (%)	RGB Color Code (R, G, B)	Notes / Comments
Ceiling	White acoustic suspended ceiling	82	(209, 209, 209)	Original material, high reflectance
Wall	Light neutral matte paint	63	(161, 161, 161)	Original material, medium-high reflectance
Floor	Very dark carpet	12	(31, 31, 31)	Original carpet, low reflectance
Window Glazing	Blue-tinted curtain wall glass	50	-	Visible Light Transmittance (VLT), default Revit value

Based on this approach, RGB codes were assigned to each modeled surface to achieve target reflectance values: 82% for ceilings, 63% for walls and 12% for floors. The materials were subsequently applied to the building components within the Autodesk Revit model. Additionally, glazing properties were defined, with visible light transmittance (VLT) for the curtain wall system set at 50%, consistent with the default properties of the blue-tinted glass in the Revit library and standard commercial glazing (Koti & Munshi, 2009). By incorporating both retained and updated material finishes and adapting the material input strategy to Revit's requirements, the simulation achieves a balance between practical constraints and photometric fidelity. Surface reflectance values of the incorporated materials are detailed in Table 4.

The relationship between surface reflectance and true color is illustrated in Table 5. Based on the accepted surface reflectance values, the corresponding RGB codes are entered into the "material properties palette" of Autodesk Revit.

Table 5. Surface reflactance-true color relation in Autodesk Revit "material properties palette"

	Ceiling	Wall	Floor
True color			
Autodesk Revit color rendition			
RGB code	209 209 209	161 161 161	31 31 31
Reflectance	82 %	63 %	12 %

3.2. Simulation Results

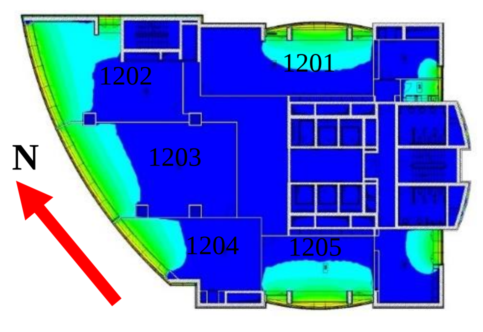
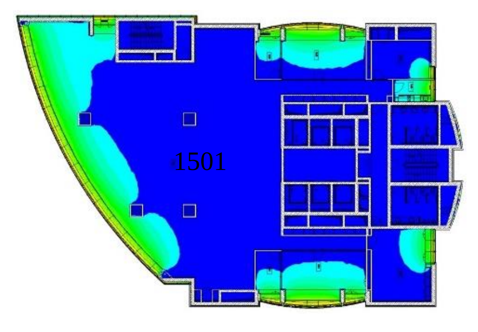
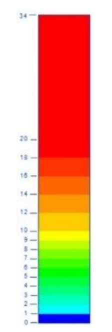
Autodesk's Revit software was utilized for the simulation and three distinct types of measurements were conducted using this software. The first measurement is Daylight Factor (DF) analysis, the second is Spatial Daylight Autonomy (sDA) analysis and the third is illuminance analysis. Each of these measurement methods provides different data. Since DF is a static metric, it does not yield climate-based results. Additionally, using the educational version of Autodesk Revit restricts the outcomes of sDA analysis. Therefore, more reliable results can be obtained through illuminance analysis when using this software.

3.2.1. DF analysis

Illuminance maps for the 12th and 15th floors, based on the results of daylight factor (DF) analysis, are presented in Table 6, which illustrates the percentage of floor area that meets the defined thresholds.

Evaluating within the threshold, in the classroom 1205 has the highest value at 19%, followed by classroom 1202 with a DF value of 17%. Classrooms 1201 and 1203 both have similar values of 12%. The lowest value in this category is classroom 1204, which has a value of 11%. Evaluating above the threshold, classroom 1205 has the highest percentage at 21%, while classroom 1201 has the lowest percentage at 14%. This variation can be attributed to the orientation of the facades; classroom 1201 faces northeast, whereas classroom 1205 faces southwest. The classroom that falls significantly below the required threshold is classroom 1201, with a value of 74%, which is also related to its facade orientation. On the 15th floor, only one space (classroom 1501) was included in the analysis and the results are summarized in the Table 6. The average daylighting factor (ADF) for the entire 12th floor is 1.5%, while the ADF for the 15th floor is 2%.

Table 6. Illuminance mapping with daylight factor (DF) analysis for the 12th and 15th floors (top) and the percentage of floor area meeting the defined thresholds on the 12th and 15th floors (bottom)

12th floor	15th floor	DF scale
		

Threshold (2% < DF < 5 %)	Percentage of floor area					
	1201	**1202**	**1203**	**1204**	**1205**	**1501**
Above threshold	14	20	16	17	21	14
Within threshold	12	17	12	11	19	10
Below threshold	74	63	72	73	60	76

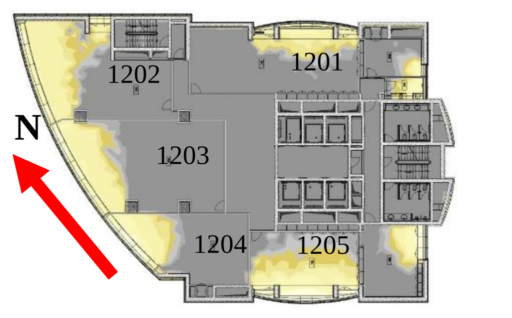
3.2.2. sDA analysis

The sDA (Spatial Daylight Autonomy) analysis provides valuable insight into daylight sufficiency across the studied design studio. By identifying the percentage and distribution of floor area receiving at least 300 lux of daylight for 50% or more of the occupied hours annually, the analysis offers a nuanced understanding of where daylighting is adequate and where it is deficient. In this case, simulation results indicate that while a substantial portion of the space meets the daylight autonomy threshold, certain peripheral zones - particularly those farthest from the glazed façade or shaded by structural elements - fall below the target. These underperforming areas highlight the need for supplementary electric lighting to ensure visual comfort and maintain appropriate illumination levels. Strategically integrating artificial lighting in these zones - through daylight-responsive controls or localized luminaires - can optimize energy efficiency while preserving lighting quality (Reinhart & Walkenhorst, 2001; IESNA, 2011). Thus, the sDA analysis not only evaluates passive daylight performance but also supports a targeted and energy-conscious approach to electric lighting design.

sDA analysis was conducted for the period from January 1 to December 31, between 8 AM and 6 PM, with a threshold of sDA300 (50%). Illuminance mapping for the 12th and 15th floors, along with the percentage of floor area meeting the defined thresholds, is presented in Table 7. It is evident that the areas near the building core do not achieve sufficient values due to their deeper space. The separated classrooms on the 12th floor tend to have higher percentages than the single classroom on the 15th floor, which has increased depth. Overall, the 12th floor exhibits higher percentages than the 15th floor. Only classroom 1201 has the same value as classroom 1501. Only two classrooms, 1202 with 52% and 1205 with 78%, exceed the targeted 50% threshold. Classroom 1205 may experience discomfort glare due to its higher value.

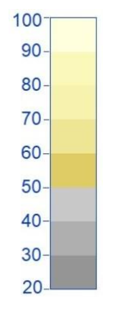
Table 7. Illuminance mapping of sDA analysis for the 12th and 15th floors (top) and the percentage of floor area that meets the defined thresholds on the 12th and 15th floors (bottom)

12th floor



15th floor

sDA scale



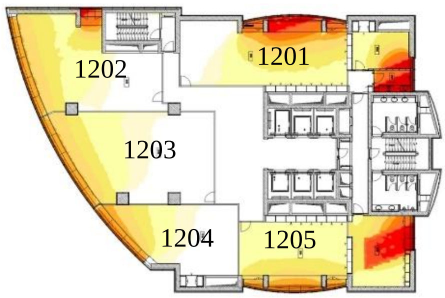
Threshold	**Percentage of floor area**					
	1201	**1202**	**1203**	**1204**	**1205**	**1501**
DA300 (50%)	32	52	35	34	78	32

3.2.3. Illuminance analysis

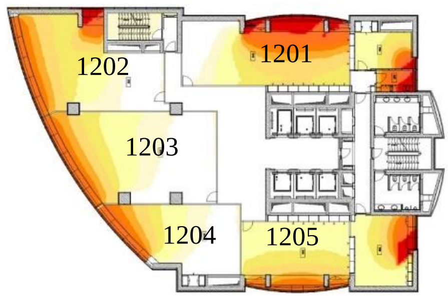
More data was obtained from the simulation involving illuminance analysis. Simulations were conducted based on the time period and other parameters outlined in Table 2. The simulations were repeated by applying the minimum threshold levels separately for both 300 lux and 500 lux. The illuminance mappings for the 12th floor, with a threshold range of 500 to 3000 lux, are presented in Table 8.

Table 8. Illuminance mapping for the 12th floor with a threshold of 500-3000 lux

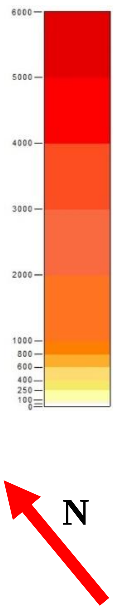
3/21 – 8am



6/21 – 8am



Lux scale



3/21– 3pm

6/21 – 3pm

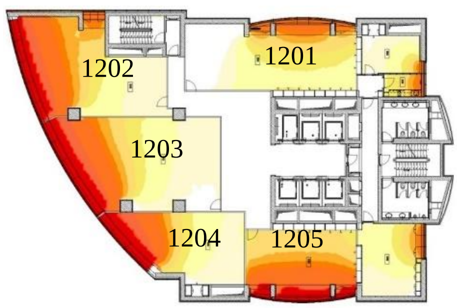


Figure 3 presents illuminance data based on the spring equinox, summer solstice and winter solstice, utilizing two different thresholds of 300 lux and 500 lux as minimum levels for the northeast-facing classroom 1201. The window on one side of the room allows natural light to enter from only two-thirds of the wall, rather than the entire wall. The highest threshold values are recorded on June 21, with a minimum threshold level of 300 lux (Figure 3c). Conversely, on December 21, the 500 lux minimum threshold level results in insufficient daylight (Figure 3f). The highest within the threshold value is achieved on June 21 at 8 AM, with 52% at the 300 lux minimum threshold level (Figure 3c). The above-threshold value is predominantly observed in the early morning for this classroom. It is beneficial to analyze the situations in which classroom 1201 meets within the threshold criteria separately and compare them with the entire 12th floor to evaluate the results. Therefore, a comparison of the illuminance values within the threshold between the 1201 design studio and the 12th floor is presented in Table 9. First, when the minimum illuminance level in the simulation is increased from 300 to 500 lux, a significant decrease is observed in the percentage of the area remaining within the threshold. Since this is the most intensively used time period, the analysis focuses on the midday hours between 12 noon and 3 PM.

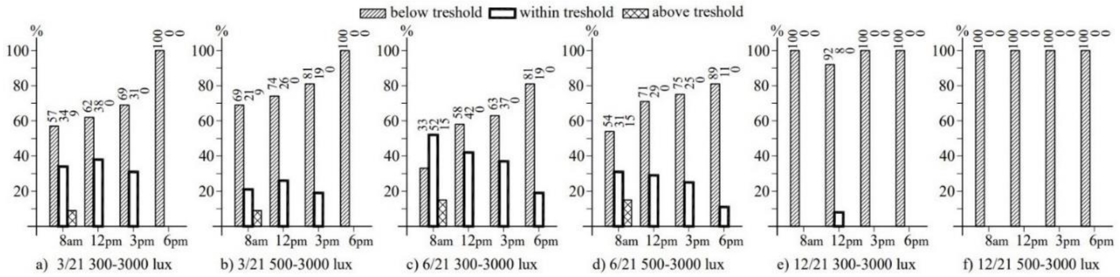


Figure 3. Illuminance analysis for the 12th floor design studio / classroom 1201

Table 9. Comparison of illuminance values within the threshold between 1201 design studio and the 12th floor

Date	Threshold (lux)	Time	1201 (%)	12th fl. (%)
March 21	300-3000	8:00 a.m.	34	24
		12:00 p.m.	38	34
		3:00 p.m.	31	26
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	21	14
		12:00 p.m.	26	24
		3:00 p.m.	19	20
		6:00 p.m.	0	0
June 21	300-3000	8:00 a.m.	52	31
		12:00 p.m.	42	34
		3:00 p.m.	37	30
		6:00 p.m.	19	19
	500-3000	8:00 a.m.	31	20
		12:00 p.m.	29	24
		3:00 p.m.	25	22
		6:00 p.m.	11	13
Dec. 21	300-3000	8:00 a.m.	0	0
		12:00 p.m.	8	15
		3:00 p.m.	0	18
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	0	0
		12:00 p.m.	0	6
		3:00 p.m.	0	15
		6:00 p.m.	0	0

Upon examining classroom 1201 and the entire 12th floor, it is evident that on March 21 and June 21, classroom 1201 consistently exceeds within the threshold value compared to the entire floor. However, on December 21, the entire 12th floor surpasses classroom 1201 in terms of the threshold value. The closest comparison occurs on March 21 at 3 PM, where the minimum value recorded is 500 lux. Conversely, the greatest disparity between the two is observed on December 21 at 3 PM, also with a minimum value of 500 lux.

The data collected for classroom 1202 is presented in Figure 4. Overall, classroom 1202 demonstrates superior values compared to classroom 1201. This improvement can be attributed to the presence of windows on two different facades: the northeast and northwest sides. Additionally, the depth of classroom 1202 is within standard limits, unlike classroom 1203, which has an excessive depth. The highest value recorded within the threshold occurs on June 21 at 12 PM, with a measurement of 59% at a minimum threshold level of 300 lux (Figure 4c). As is typical, December 21 shows the lowest value, although it is still better than that of classroom 1201. The above-threshold values are predominantly observed in the afternoon for this classroom. A comparison of the within-threshold values of classroom 1202 and the entire floor is illustrated in Table 10. Classroom 1202 has consistently recorded more within the threshold value compared to the entire floor on March 21 and June 21. In contrast, classroom 1201 shows values that are relatively close to the overall floor values on December 21. The closest recorded value in this comparison occurs on December 21 at 12 PM, with a minimum of 300 lux (Figure 4e). The greatest disparity between values is observed on June 21 at 12 PM, also with a minimum of 300 lux (Figure 4c).

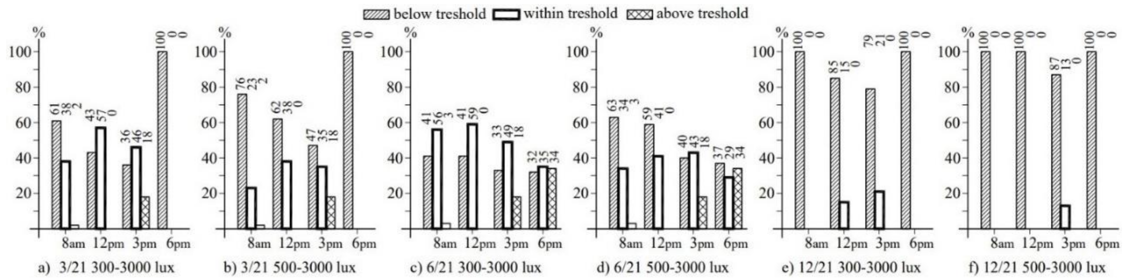


Figure 4. Illuminance analysis for the 12th floor design studio / classroom 1202

Table 10. Comparison of illuminance values within the threshold between 1202 design studio and the 12th floor

Date	Threshold (lux)	Time	1202 (%)	12th fl. (%)
March 21	300-3000	8:00 a.m.	38	24
		12:00 p.m.	57	34
		3:00 p.m.	46	26
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	23	14
		12:00 p.m.	38	24
		3:00 p.m.	35	20
		6:00 p.m.	0	0
June 21	300-3000	8:00 a.m.	56	31
		12:00 p.m.	59	34
		3:00 p.m.	49	30
		6:00 p.m.	35	19
	500-3000	8:00 a.m.	34	20
		12:00 p.m.	41	24
		3:00 p.m.	43	22
		6:00 p.m.	29	13
Dec. 21	300-3000	8:00 a.m.	0	0
		12:00 p.m.	15	15
		3:00 p.m.	21	18
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	0	0
		12:00 p.m.	0	6
		3:00 p.m.	13	15
		6:00 p.m.	0	0

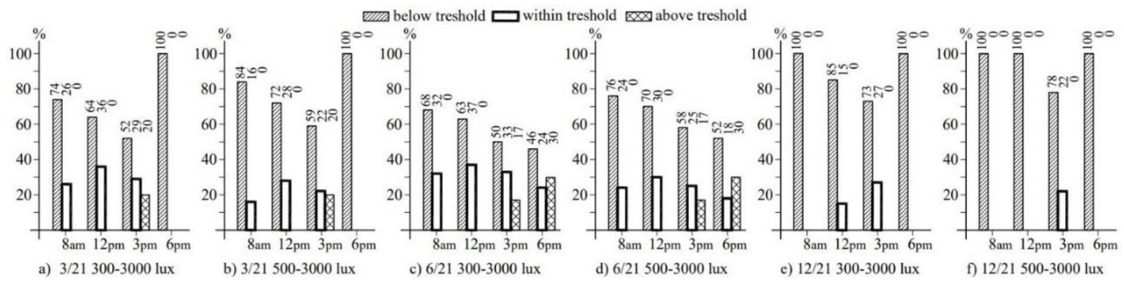


Figure 5. Illuminance analysis for 12th floor design studio / classroom 1203

Figure 5 illustrates the percentage of the area that meets the thresholds for classroom 1203. This classroom faces northwest and features a significant depth of space. It has a single window located on the short side of the room, which results in insufficient daylight reaching the back of the classroom. The highest within the threshold value is recorded on June 21 at 12 PM, with 37% at a minimum threshold level of 300 lux (Figure 5c). Conversely, December 21 shows the lowest value, although it is still better than that of classroom 1202. The above-threshold values are predominantly observed in the afternoon for this classroom. Table 11 presents a comparison of the within-threshold values of classroom 1203 and the entire floor. Classroom 1203 consistently exhibits a higher within-threshold value than the entire floor on March 21 and June 21. A similar trend is noted in the comparison on December 21 at 3 PM, when the minimum threshold is set at 300 lux (Figure 5e). The greatest disparity between the two values occurs on June 21 at 12 PM, with a minimum threshold of 500 lux (Figure 5d).

Table 11. Comparison of illuminance value within the threshold between 1203 design studio and the 12th floor

Date	Threshold (lux)	Time	1203 (%)	12th fl. (%)
March 21	300-3000	8:00 a.m.	26	24
		12:00 p.m.	36	34
		3:00 p.m.	29	26
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	16	14
		12:00 p.m.	28	24
		3:00 p.m.	22	20
		6:00 p.m.	0	0

Date	Threshold (lux)	Time	1203 (%)	12th fl. (%)
June 21	300-3000	8:00 a.m.	32	31
		12:00 p.m.	37	34
		3:00 p.m.	33	30
		6:00 p.m.	24	19
	500-3000	8:00 a.m.	24	20
		12:00 p.m.	30	24
		3:00 p.m.	25	22
		6:00 p.m.	22	13

Date	Threshold (lux)	Time	1203 (%)	12th fl. (%)
Dec. 21	300-3000	8:00 a.m.	0	0
		12:00 p.m.	15	15
		3:00 p.m.	27	18
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	0	0
		12:00 p.m.	0	6
		3:00 p.m.	22	15
		6:00 p.m.	0	0

Classroom 1204 faces the northwest and features a narrow side window. However, it is not as deep as classroom 1203. Figure 6 illustrates the illuminance data for classroom 1204. The highest value within the threshold is recorded on June 21 at 12 PM, reaching 35% at a minimum threshold level of 300 lux (Figure 6c). Conversely, December 21 shows the lowest value within the threshold among all conditions (Figure 6e and 6f). Overall, the values are quite similar to those of classroom 1203. The above-threshold values are predominantly observed in the afternoon for this classroom. Table 12 compares the within-threshold values of classroom 1204 with those of the entire floor. On March 21 and June 21, Classroom 1204 exhibits nearly the same within-threshold values as the entire floor. However, it shows a slightly higher value than the entire floor on December 21.

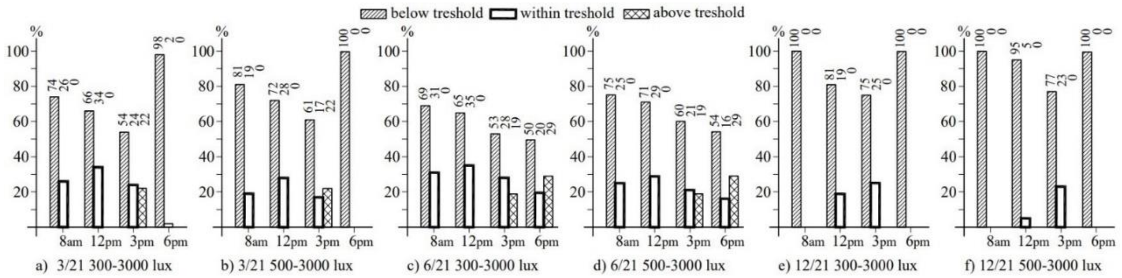


Figure 6. Illuminance analysis for the 12th floor design studio / classroom 1204

Table 12. Comparison of illuminance value within the threshold between 1204 design studio and the 12th floor

Date	Threshold (lux)	Time	1204 (%)	12th fl. (%)
March 21	300-3000	8:00 a.m.	26	24
		12:00 p.m.	34	34
		3:00 p.m.	24	26
		6:00 p.m.	2	0
	500-3000	8:00 a.m.	19	14
		12:00 p.m.	28	24
		3:00 p.m.	17	20
		6:00 p.m.	0	0

Date	Threshold (lux)	Time	1204 (%)	12th fl. (%)
June 21	300-3000	8:00 a.m.	31	31
		12:00 p.m.	35	34
		3:00 p.m.	28	30
		6:00 p.m.	20	19
	500-3000	8:00 a.m.	25	20
		12:00 p.m.	29	24
		3:00 p.m.	21	22
		6:00 p.m.	16	13

Date	Threshold (lux)	Time	1204 (%)	12th fl. (%)
Dec. 21	300-3000	8:00 a.m.	0	0
		12:00 p.m.	19	15
		3:00 p.m.	25	18
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	0	0
		12:00 p.m.	5	6
		3:00 p.m.	23	15
		6:00 p.m.	0	0

The data obtained for classroom 1205 is presented in Figure 7. This classroom has a southwest view from its side window, which provides an advantage similar to that of Classroom 1201, as the window is longitudinally positioned. However, due to its orientation, this classroom receives more sunlight than all other classrooms. On March 21, the sunlight exposure is 81% (Figure 7a), on June 21 it is 80% (Figure 7c) and on December 21 it is 59% (Figure 7e) at 12 PM, indicating strong performance. The highest value recorded is 91% (Figure 7e) on December 21 at 3 PM. These results suggest a potential for discomfort glare. The above-threshold values are predominantly observed in the afternoon for this classroom, making it the highest among all classrooms on the 12th floor. The comparison of within the threshold values for Classroom 1205 and the entire floor is presented in Table 13. Classroom 1205 consistently exhibits higher threshold values than the entire floor on March 21 and June 21. Additionally, it demonstrates the greatest difference compared to the other classrooms. The most significant disparity is observed on December 21 at 3 PM, with a minimum threshold value of 300 lux (Figure 7e). Conversely, the closest values in the comparison occur on June 21 at 12 PM, with a minimum value of 500 lux (Figure 7d).

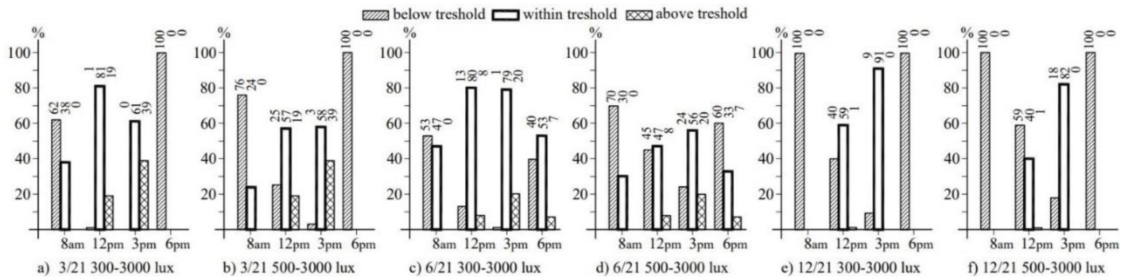


Figure 7. Illuminance analysis for the 12th floor design studio / classroom 1205

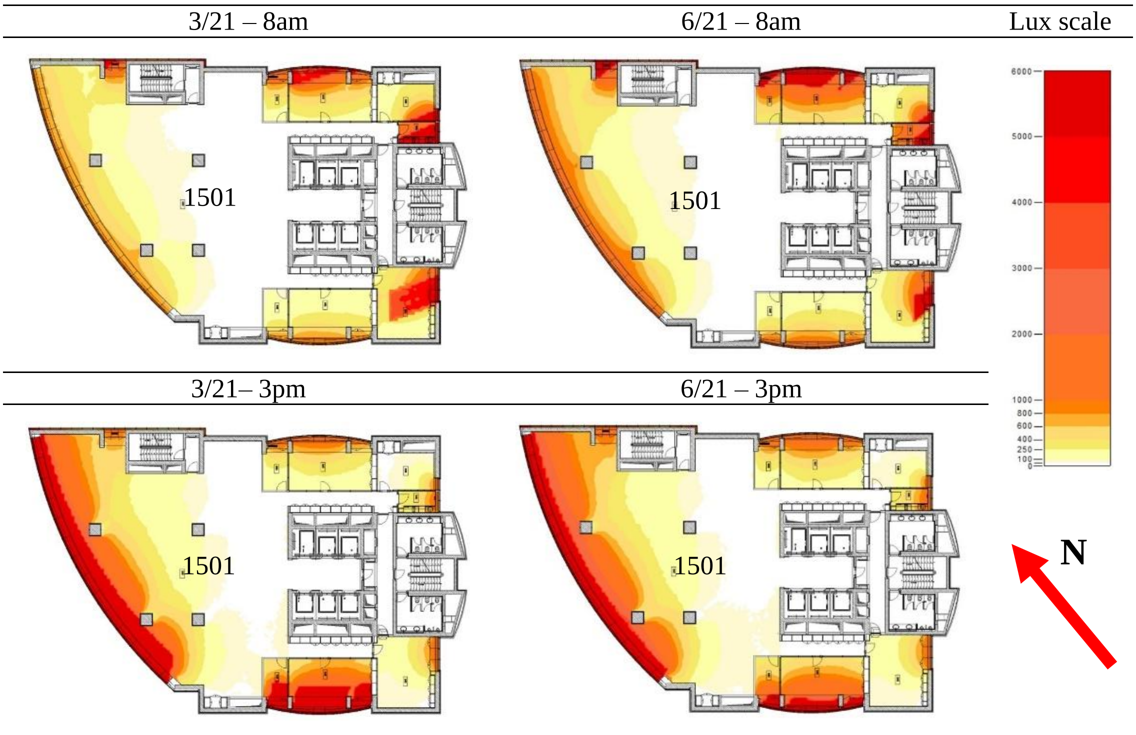
Table 13. Comparison of illuminance value within the threshold between 1205 design studio and the 12th floor

Date	Threshold (lux)	Time	1205 (%)	12th fl. (%)
March 21	300-3000	8:00 a.m.	38	24
		12:00 p.m.	81	34
		3:00 p.m.	61	26
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	24	14
		12:00 p.m.	57	24
		3:00 p.m.	58	20
		6:00 p.m.	0	0
June 21	300-3000	8:00 a.m.	47	31
		12:00 p.m.	80	34
		3:00 p.m.	79	30
		6:00 p.m.	53	19
	500-3000	8:00 a.m.	30	20
		12:00 p.m.	47	24
		3:00 p.m.	56	22
		6:00 p.m.	33	13
Dec. 21	300-3000	8:00 a.m.	0	0
		12:00 p.m.	59	15
		3:00 p.m.	91	18
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	0	0
		12:00 p.m.	40	6
		3:00 p.m.	82	15
		6:00 p.m.	0	0

Table 14 illustrates the illuminance mappings for the 15th floor, with a threshold range of 500 to 3000 lux. The simulation results are based on climate-based metrics and are presented on a lux scale. The 15th floor features a different layout compared to the 12th floor, as it is designed as an open space. This variation leads to distinct daylighting performance across the overall plan. The minimum threshold levels of 300 lux and 500 lux are applied separately in the simulation. According to the simulation results depicted in the illuminance mapping, the northeast facade receives more sunlight at 8 AM, while the southwest facade receives more sunlight at 3 PM.

Classroom 1501 is a single open space with a round-shaped side window that overlooks the southwest and northwest. Additionally, it features a small window in comparison to the primary window located on the northeast facade. Due to its shape and the orientation of the primary window, this classroom receives a significant amount of direct sunlight in the afternoon. Figure 8 illustrates the percentage of the area that meets the thresholds for classroom 1501. The highest value within the threshold is recorded on June 21 at 12 PM, reaching 34% at a minimum threshold level of 300 lux (Figure 8c). Conversely, the lowest value within the threshold is typically observed on December 21 (Figure 8f). Values above the threshold are predominantly noted after 3 PM during the equinox and the summer solstice. The comparison of the within-threshold values for classroom 1501 and the entire floor is presented in Table 15. Classroom 1501 exhibits a lower within-threshold value than the entire floor on all recorded dates. This discrepancy is attributed to the deeper space at the center of the classroom. The average value for the entire floor increases due to the inclusion of performance metrics from the typical office areas surrounding the core of the building. The greatest difference between the two values is observed on March 21, June 21 and December 21 at 12 PM, with a minimum threshold value of 300 lux (Figure 8a, 8c and 8e). The closest values in the comparison are typically recorded at 3 PM.

Table 14. Illuminance mapping for the 15th floor with a threshold of 500-3000 lux



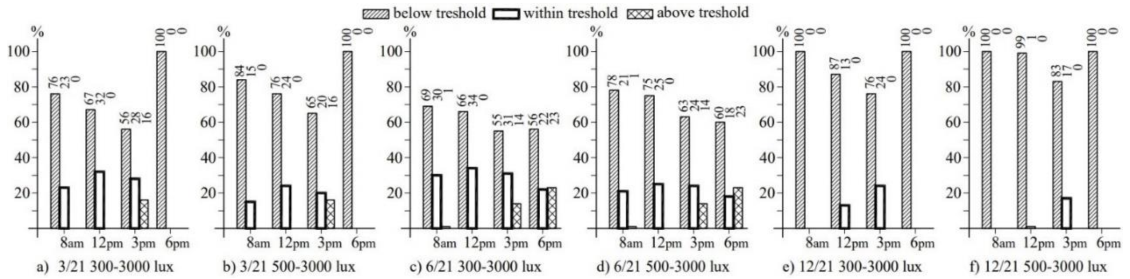


Figure 8. Illuminance analysis for the 15th floor design studio/classroom 1501

Table 15. Comparison of illuminance value within the threshold between 1501 design studio and the 15th floor

Date	Threshold (lux)	Time	1501 (%)	15th fl. (%)
March 21	300-3000	8:00 a.m.	23	30
		12:00 p.m.	32	41
		3:00 p.m.	28	32
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	15	19
		12:00 p.m.	24	30
		3:00 p.m.	20	23
		6:00 p.m.	0	0
June 21	300-3000	8:00 a.m.	30	37
		12:00 p.m.	34	41
		3:00 p.m.	31	38
		6:00 p.m.	22	25
	500-3000	8:00 a.m.	21	26
		12:00 p.m.	25	30
		3:00 p.m.	24	28
		6:00 p.m.	18	18
Dec. 21	300-3000	8:00 a.m.	0	0
		12:00 p.m.	13	20
		3:00 p.m.	24	25
		6:00 p.m.	0	0
	500-3000	8:00 a.m.	0	0
		12:00 p.m.	1	7
		3:00 p.m.	17	18
		6:00 p.m.	0	0

4. Evaluation of the Simulation Results and Discussion

In the evaluation of the simulations, we focus on illuminance analysis to provide more detailed results. This evaluation method allows for the acquisition of time-dependent results, enabling comparisons based on different time periods for various locations. Three primary questions arise in this section. First, regarding reuse, what are the differences between the results for the office with a threshold of 300 lux and the results for the design studio with a threshold of 500 lux? Secondly, if the building is utilized as a design studio with reuse, how are the results assessed when the threshold is set to 500 lux? Thirdly, if the building is utilized as a design studio, how do you interpret the results for the above-threshold when the threshold is set at 500 lux? According to the within-threshold, above-threshold and below-threshold values, it will be possible to determine which classrooms have sufficient natural lighting, which classrooms require additional artificial lighting for extended periods and which classrooms need to implement measures against discomfort glare. The analysis of natural lighting performance on the 12th and 15th floors yields different results due to the distinct layouts of the spaces. The 12th floor features divided independent classrooms, while the 15th floor is designed as a single open studio, similar to an open office environment.

4.1. Differences Between Minimum Threshold Values of 300 lux and 500 lux

When the building was initially used as an office, the minimum accepted illuminance value for the office space was 300 lux. However, when the building was converted into a design studio, the minimum illuminance value was increased to 500 lux. Computer simulations were conducted for both scenarios, with one simulation assuming a range of 300 lux to 3000 lux and the other ranging from 500 lux to 3000 lux. The simulation results focus on the within-threshold range, clearly indicating a decrease in the within-threshold value when the minimum lower value is set at 500 lux. This raises the question of the extent of the reduction in the within-threshold value resulting from the change in usage. Upon reviewing the final analysis, the difference attributable to the change in the minimum lower value is illustrated in Figures 9. For the interpretation of the results, the research was focused on a specific time period as an example. The equinox represents a seasonal period during which the duration of day and night is nearly equal. In this context, March 21 is considered the spring equinox, with 12 noon providing values that are closest to the average. As illustrated in Figure 9, the highest difference, recorded at 19%, is observed in classroom 1202 (Figure 9b), while the lowest difference, at 6%, is found in classroom 1204 (Figure 9d). When examining the entire 12th floor without concentrating on a specific time interval, the results for classrooms 1203 and 1204 are largely similar (Figure 9c and 9d). On the 12th floor, the most significant difference occurs on June 21 at 12 o'clock, with a value of 33% (Figure 9e). On the 15th floor, the largest difference measured is 12% at 12 o'clock on December 21 (Figure 9f).

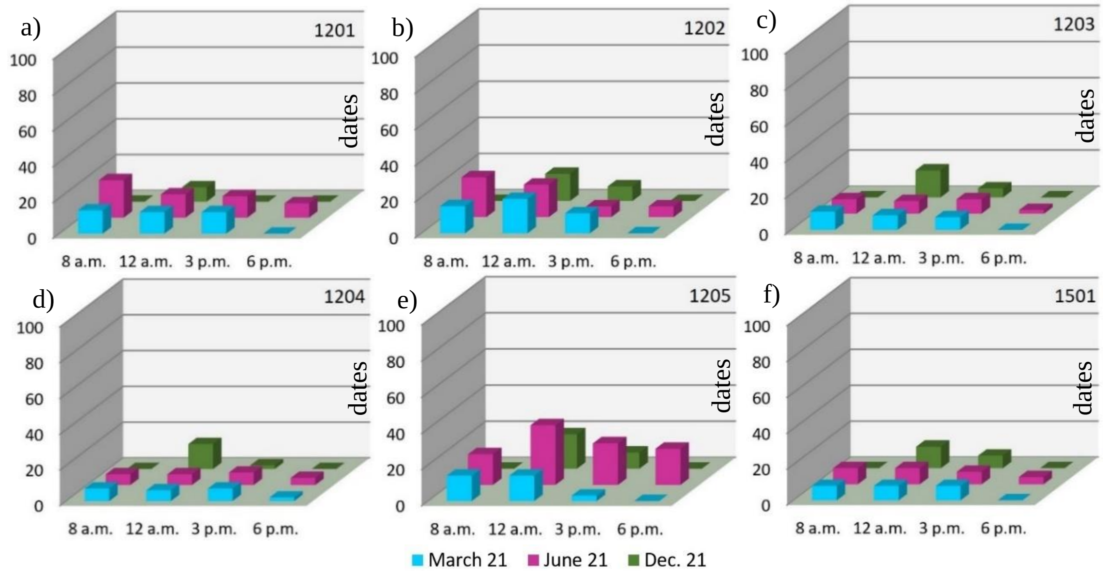


Figure 9. Differences (in percentage) between the within threshold values of 300 lux and 500 lux for classrooms 1201 - 1205 and 1501

4.2. The Percentage of Illuminance Values Within the Threshold of 500 lux to 3000 lux

In cases where the minimum threshold value is set at 500 lux instead of 300 lux, a general decrease in the within-threshold values is observed. As in the previous section, a specific time interval is again emphasized in the interpretation of the findings. The values for March 21, the spring equinox, at noon (12 PM) are analyzed here. As illustrated in Figure 10, the space with the highest within-threshold range is classroom 1205, which has a value of 57% (Figure 10e). The second space that meets the within-threshold criteria is classroom 1202, with a value of 38% (Figure 10b). Classrooms 1203 and 1204 have similar values, both at 28% (Figure 10c and 10d). Among the spaces on the 12th floor, classroom 1201 exhibits the lowest value (Figure 10a). When considering all the spaces across both floors, the lowest value is recorded in classroom 1501, at 24% (Figure 10f). When evaluated across all time periods among the compared classrooms, the highest values are observed in classroom 1205 (Figure 10e). This can be attributed to its southwest orientation, with the long side of the room parallel to the facade. Classroom 1202 ranks second; although its main window faces northwest, the additional window on the north side enhances its lighting values. Conversely, classroom 1501 exhibits the lowest values (Figure 10f). The excessive depth of this space limits the amount of natural light reaching the room's interior. Consequently, it is evident that to meet minimum lighting conditions, classrooms 1201, 1203, 1204 and 1501 will require extended durations of artificial lighting.

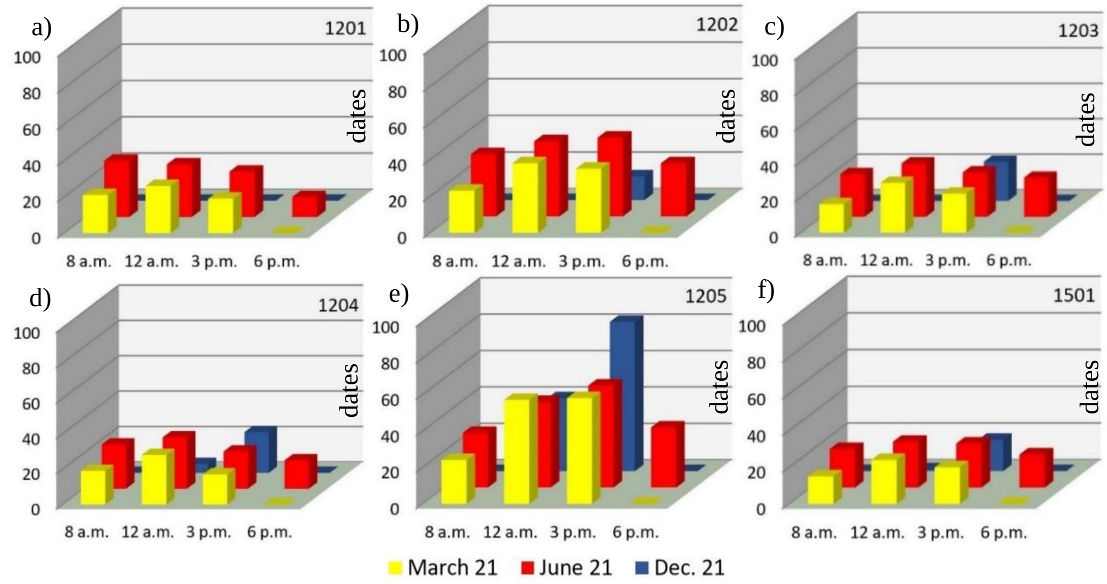


Figure 10. The percentage of illuminance values within the threshold range of 500 to 3000 lux for classrooms 1201 - 1205 and 1501

4.3. Results of the Above-Threshold Range of 500 lux to 3000 lux

As a result of the analysis conducted on light levels ranging from 500 lux to 3000 lux, the focus shifts primarily to the afternoon when examining values exceeding 3000 lux. Among the results for March 21, June 21 and December 21, classroom 1205 exhibits the highest value at 3 PM, reaching 39%. Classrooms 1202, 1203 and 1204 show very similar results at the same time. In contrast, classroom 1201 does not display any values above the threshold in the afternoon. However, due to its northeast orientation, this room does show a low above-threshold value in the morning at 8 AM. Based on the findings, it is evident that the most significant disturbing glare disturbance will occur in classroom 1205, with a potential for some level of glare disturbance in the other classrooms as well. When classroom 1501, located on the 15th floor, was examined at 3 PM, a glare potential of 16% was observed on March 21 and 14% on June 21. Similarly, a comparable level of disturbing glare potential was noted in classrooms 1202, 1203 and 1204.

5. Conclusion

At the beginning of the study, it was noted that the natural lighting performance values would be impacted by the conversion of the office building into an educational facility, necessitating a thorough analysis. The literature review, conducted to identify the problem, revealed that the minimum lighting requirements for specialized classrooms, such as design studios, are significantly higher than those defined for office spaces. While a minimum of 300 lux is recommended for offices, design studios require a minimum of 500 lux. Consequently, the primary objective of the study was to investigate the implications of these differing threshold values and their effect on the lighting performance of the space. To achieve this, performance evaluations were conducted using computer simulations. The analysis required for performance evaluation depends on several parameters, including the sky model, time period, targeted illuminance thresholds for classrooms and the surface reflectance of interior materials.

Due to its widespread adoption, Autodesk Revit software has been employed and daylighting metrics such as DF, sDA and illuminance analysis have been conducted. When quantitatively examining the data obtained from these metrics, DF provides limited information as it is a static metric and sDA offers restricted data due to the use of the educational version of Autodesk Revit. In contrast, illuminance analysis yields detailed, climate-based data. Consequently, this metric has been prioritized and the findings derived from it have been thoroughly examined.

In this case study, the 12th and 15th floors of the tower building, which house design studios, have been analyzed. The 12th floor has been converted into a separate design studio, while the 15th floor functions as a single open design studio, maintaining the building's original layout. This variation in usage significantly impacts the natural lighting performance of the spaces. The findings are evaluated in three stages, which are presented under the following headings: differences between minimum threshold values, the percentage of illuminance values within-threshold ranging from 500 lux to 3000 lux and results of above-threshold between 500 lux and 3000 lux.

As the initial analysis conducted, the results of the daylight factor (DF) analysis revealed a data value of 1.5% for the 12th floor and 2% for the 15th floor. This indicates that, overall, the level of natural lighting is insufficient due to the floor plan. Additionally, the spatial daylight autonomy (sDA) analysis was performed according to the sDA300 (50%) parameter and the results showed that only classrooms 1202 and 1205 met this target value. Consequently, it is evident that achieving the minimum threshold value of 750 lux in the illuminance analysis will be quite challenging. Therefore, considering the mixed use of the examined spaces, it has been determined that a minimum threshold value of 500 lux is more appropriate.

Upon examining the illuminance mapping results derived from the daylight factor (DF) analysis, it is evident that classrooms 1201 and 1205 exhibit significant similarities. However, classroom 1201 faces northeast, while classroom 1205 faces southwest. Consequently, classroom 1201 receives more sunlight in the morning, whereas classroom 1205 benefits from increased sunlight in the afternoon. From this perspective, the DF analysis offers only a general percentage and does not provide time-dependent results. In contrast, the illuminance mapping obtained from the spatial daylight autonomy (sDA) analysis yields more detailed insights for the aforementioned classrooms. At the very least, it captures clues regarding the building's orientation.

The limitations encountered in this study stem from the use of the educational version of Autodesk Revit, which restricts the modification of sDA parameters. Specifically, it automatically sets the minimum threshold value to 300 lux and does not allow for analysis at 500 lux. Additionally, while surface reflectance can be entered by inputting RGB (red, green, blue) values, direct input as a percentage is not permitted.

According to the findings from the illuminance analysis, when the minimum threshold is set at 500 lux instead of 300 lux, the most significant decrease in illuminance is observed in classroom 1205, while the least decrease occurs in classroom 1204. When the minimum threshold value is established at 500 lux, classroom 1205 is the most successful in achieving values within the threshold. However, this classroom also has the highest proportion of above-threshold values, making it the most likely to experience disturbing glare. Due to the spatial depth of classroom 1501 on the 15th floor, sufficient natural light cannot adequately reach the center of this space. Consequently, it is evident that the periods requiring artificial lighting will be considerably prolonged. In general, classrooms that fail to meet the accepted threshold values necessitate support from artificial lighting, which increases the overall lighting load.

As future work, a more detailed examination can be conducted by focusing on one of the classroom studied here. In this study, it is essential to perform a glare probability analysis using different software.

Acknowledgment

The author would like to thank Byan A. Jetto (M.Sc. Architect) for contributing to the production of various materials for this article and for assisting in conducting the research.

Information notes

The lighting analysis for the case study discussed in the article was conducted by the author. Revit® is a trademark of Autodesk, Inc. The software mentioned is legally used by the author for educational purposes.

Declaration of competing interest

The author declare no conflict of interest.

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