ANKARA YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ASSESSMENT OF NATURAL LIGHTING LEVELS IN STUDIO CLASSROOMS OF ARCHITECTURAL DEPARTMENTS USING THE DIALUX EVO12 TOOL

M.Sc. Thesis by

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by

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M.Sc. THESIS EXAMINATION RESULT FORM

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ABSTRACT

Natural light plays a crucial role in shaping the ambiance and functionality of interior spaces in all types of buildings. The architecture studio buildings are where students practice their daily design activities. Lighting is more important for work and comfort than in regular educational classrooms because of the time taken and the particular focus this activity requires. This research discusses the effects of natural light on architecture studios in AYBU, Amasya, and Samsun universities. The study examines how natural light achieves users' comfort levels in the three universities. DIALux tool is used to model the building in a 3D model and run a simulation on working days during the educational year. This simulation aims to obtain the levels of lighting and illumination and compare them with the design standards between universities. In addition, the research explores the improvements that can reduce the amount of light entering rooms, namely breakers. The results show that natural lighting levels at Amasya University are very high, which causes glare and thus hinders the educational process. This is due to the location of the rooms in the east of the building and the large size of the windows. At AYBU, laboratory buildings have been reused as studios for the Department of Architecture. Samsun University, a tobacco factory, was converted into an educational building, and part of it was allocated to the Department of Architecture. These studios suffer from a lack of light entering the rooms during certain times of the year, particularly in the winter months. In this study, sun breakers have been proposed as a solution to improve lighting levels. The tests conducted at Amasya University and AYBU yielded acceptable results. This indicates the potential feasibility of using this solution.

Keywords: Natural light, Educational Classroom, DIALux, Architectural studio

MIMARLIK BÖLÜMLERININ STÜDYO SINIFLARINDAKI DOĞAL AYDINLATMA DÜZEYLERININ DIALUX EVO12 ARACI KULLANILARAK DEĞERLENDIRILMESI

ÖZ

Doğal ışık, tüm bina türlerinde iç mekanların ambiyansını ve işlevselliğini şekillendirmede kritik bir rol oynamaktadır. Mimarlık stüdyosu binaları, öğrencilerin günlük tasarım faaliyetlerini gerçekleştirdikleri yerlerdir. Bu etkinliğin gerektirdiği zaman ve özel odaklanma nedeniyle aydınlatma, sıradan eğitim sınıflarından daha fazla iş ve konfor açısından önemlidir. Bu araştırma, AYBÜ, Amasya ve Samsun üniversitelerindeki mimarlık stüdyolarında doğal ışığın etkilerini tartışmaktadır. Çalışma, üç üniversitede kullanıcıların konfor seviyelerine nasıl ulaşıldığını incelemektedir. Eğitim yılı boyunca iş günlerinde simülasyon yapmak ve binayı 3D modellemek için DIALux aracı kullanılmıştır. Bu simülasyon, aydınlatma seviyelerini elde etmeyi ve bunları üniversiteler arasındaki tasarım standartlarıyla karşılaştırmayı amaçlamaktadır. Ayrıca, odalara giren ışık miktarını azaltabilecek iyileştirmeler, yani kırıcılar araştırılmaktadır. Sonuçlar, Amasya Üniversitesi'ndeki doğal aydınlatma seviyelerinin çok yüksek olduğunu, bunun da parlama nedeniyle eğitim sürecini engellediğini göstermektedir. Bu durum, odaların binanın doğusunda yer alması ve pencerelerin büyük boyutu nedeniyle oluşmaktadır. AYBÜ'de laboratuvar binaları, Mimarlık Bölümü için stüdyo olarak yeniden kullanılmıştır. Samsun Üniversitesi'nde ise bir tütün fabrikası eğitim binasına dönüştürülmüş ve bir kısmı Mimarlık Bölümü'ne tahsis edilmiştir. Bu stüdyolar, özellikle kış aylarında, yılın belirli dönemlerinde odalara giren ışık eksikliğinden muzdarip olmaktadır. Bu çalışmada, aydınlatma seviyelerini iyileştirmek amacıyla güneş kırıcıları çözüm olarak önerilmiştir. Amasya Üniversitesi ve AYBÜ'de uygulanan testler kabul edilebilir sonuçlar vermiştir. Bu, çözüm olarak kullanılma potansiyeline dair bir gösterge sunmaktadır.

Anahtar Kelimeler: Naturallight, Eğitim Sınıfı, DIALux, AYBÜ, Samsun Üniversitesi, Amasya Üniversitesi

CONTENTS

NOMENCLATURE

Roman Letter Symbols

H	Height from the ground

Acronyms

AHP	Analytic Hierarchy Process
AY	Amasya University
AYBU	Ankara Yildirim Beyazit University
BAU	Bahçeşehir Üniversitesi
BEM	Building Energy Modeling
BIM	Building Information Modeling
CS	Circadian Stimuli
DGP	Daylight Glare Probability
DIAL	German Institute for Applied Lighting Technology
IF	Image-Forming
IoT	Internet of Things
ITU	Istanbul Technical University
NIF	Non-Image-Forming
SNI	Indonesian National Standard
SU	Samsun University
UTHM	University Tun Hussein Onn Malaysia
UV	Reduce Ultraviolet
Dim	Dimensions
TMY	Typical Meteorological Year

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CHAPTER 1

INTRODUCTION

1.1 General

Light is electromagnetic radiation within the wavelength range of 380 nm to 770 nm, stimulating the human visual system and enabling the perception of vision. On the other hand, optical radiation encompasses a broader range of electromagnetic radiation from 1 nm to 1 mm, impacting various aspects of human physiology beyond vision. Lighting serves as the means to deliver both light and optical radiation, utilizing similar techniques for their effective implementation. By understanding light and optical radiation's distinct characteristics and functions, we can optimize lighting practices to promote visual comfort and individuals' overall well-being. Further research in this field is warranted to enhance our understanding of the physiological effects of optical radiation and refine lighting standards accordingly[1].

Light, the visible part of the electromagnetic spectrum, possesses distinctive properties that enable its transmission through space. While light rays can travel limitless distances, they can also undergo interactions with objects, leading to reflection, transmission, or absorption. The sun is the source of natural lighting, while artificial lighting is produced by electrical lighting devices [2].

Different types of light have distinct characteristics and applications. Natural daylight, for example, provides a balanced spectrum of light that benefits human health and well-being. On the other hand, incandescent lamps, produced by heated filaments, emit a different spectrum with specific color temperatures and applications in various lighting contexts.

Understanding the dual nature of light is essential for comprehending its energy properties and physiological effects on living organisms. By exploring the particle-like nature of light through photons and its wave-like properties, it is possible to unravel the complex interactions between light and biological systems. This knowledge is crucial for diverse fields, including optics, agriculture, medicine, and technology, as we continue to harness and utilize light energy for various applications. [3]

The amount of natural light and its spread during different times of the day and the year are important factors in evaluating the efficiency of the interior spaces of various buildings. Its effects go beyond just lighting, affecting users' mood, productivity, and general well-being [4]. Welfare, happiness, and good mood directly affect a person's physical and mental health. Architects, designers, and researchers have long recognized the importance of harnessing natural light to enhance the aesthetics and performance of buildings.

Adequate lighting is indispensable to countless human endeavors and dramatically affects the quality of the indoor environment, especially in workplaces. The European standard EN 12464-1 is adopted internationally for lighting workplace regulations. It presents a detailed description of the necessary illumination (both natural and artificial) for various activities such as industrial, offices, public assembly, and educational places [5].

The contemporary milieu has engendered profound transformations in our living and working patterns, engendering an extraordinary reliance on artificial illumination. Regrettably, this dependency has incurred harmful consequences for our physical and psychological well-being and overall productivity. The advent of artificial lighting represents a significant departure from the erstwhile dependence on natural illumination sources. Electric lighting, in particular, introduced a paradigm shift by affording humanity unprecedented control over illumination. This transition extended the hours during which individuals could engage in productive activities and fundamentally restructured the fabric of daily existence. Consequently, the utilization of artificial light has become deeply ingrained in the fabric of our modern society. The ramifications of this transformation on physical health are deserving of meticulous scrutiny. Artificial lighting perturbs our intrinsic circadian rhythm, an internal biological mechanism regulating various physiological processes. Disruptions to this intricate temporal framework can engender sleep disturbances, fatigue, and impaired cognitive functioning [6].

Lighting in educational places is essential to provide a well-lit environment conducive to comfortable and efficient task execution by students and faculty [7]. The atmosphere inside an academic building significantly impacts the satisfaction and effectiveness of its occupants by achieving physical and psychological comfort for both teachers and learners, as lighting plays a pivotal role in this regard. A wisely designed interior environment gives educational buildings a spacious and inviting feel, enhancing vitality, receptivity to information, and overall satisfaction.

Daylighting has been an age-old aspect of architectural design, aligning the built environment with the sun's natural rhythms. It involves strategically placing and designing windows, skylights, and other transparent elements, allowing natural light to permeate indoor spaces. The integration of daylighting not only enhances the aesthetic quality of a building but also fosters profound effects on occupants' well-being [8]. Despite the numerous advantages of natural light, it can also pose some problems:

a) Glare and Temperature Imbalances can cause distracting glare, mainly when it reflects off shiny surfaces or directly enters the workspace.

b) Fading and Damage: Excessive exposure to natural light over time can cause premature fading or damage to furniture, fixtures, and other materials.

c) Glare on Shiny Surfaces When direct sunlight falls on shiny surfaces like glass, mirrors, or polished surfaces, it can create intense glare. This glare can be visually discomforting and hinder visibility.

d) Heat and Cooling Costs: if the natural lighting design is not planned correctly, excessive sunlight can lead to unwanted heat gain within a space. This increase in temperature may require additional cooling measures, such as air conditioning, to maintain a comfortable environment. Consequently, this can result in higher energy consumption and increased cooling costs. Various strategies can be employed, including using window treatments like blinds or shades to control glare, installing window films or tinted glass to reduce ultraviolet (UV) exposure, and implementing proper insulation and shading techniques to minimize heat gain. Additionally, well-designed lighting systems that integrate natural and artificial light can balance the benefits of natural light and control potential drawbacks [9].

Illuminance is a crucial parameter in lighting design, reflecting the light flux per unit area incident on a specific space. By understanding the relationship between illuminance, space characteristics, and human behavior, designers can create lighting environments that align with the needs and well-being of occupants. Appropriate illuminance levels in lighting design are imperative for achieving healthy lighting and fostering optimal human performance in various spaces. Further research and advancements in lighting technology can contribute to continuously improving lighting design practices and the overall well-being of individuals in built environments [4].

Adequate lighting is crucial for promoting visual performance, safety, and the regulation of bodily functions. Light plays a significant role in synchronizing the circadian rhythm and influencing the secretion of melatonin, which is essential for healthy sleep patterns and overall well-being. Disruptions to these natural rhythms caused by improper light exposure can adversely affect human health. Recognizing the importance of appropriate lighting conditions and implementing strategies to ensure proper light exposure are therefore essential for promoting optimal visual performance, safety, and overall health. Further research in this area is warranted to understand better the complex interplay between light, human physiology, and well-being [10].

The lighting quality is determined by a combination of factors, including illuminance, uniformity, correlated color temperature, color rendering index, perceived brightness, and sufficiency. Understanding the interrelationships and implications of these factors is crucial for achieving high-quality lighting design and implementation. Professionals can create visually comfortable, efficient, and productive environments by considering and addressing these factors. Continued research, technological advancements, adherence to regulations and standards, user feedback, and innovative design approaches will enhance lighting quality and positively impact human well-being and productivity [11].

Lighting facilitates the execution of visual tasks safely and comfortably. Furthermore, lighting influences individuals' biological clocks, fosters alertness, affects emotions, and contributes to overall well-being. Lighting is essential to the built environment, significantly impacting individuals' ability to navigate and interact with their surroundings. Highlights how lighting contributes to human well-being by examining its effects on visual perception, circadian rhythms, cognitive processes, emotional states, and overall quality of life. Lighting is a crucial environmental element that significantly impacts human lives. Its effects extend beyond mere visibility, encompassing circadian rhythms, cognitive processes, emotional well-being, and overall quality of life. Recognizing the importance of lighting in design and planning processes can lead to environments conducive to human well-being, promoting safety, comfort, and improved psychological states. Further research and interdisciplinary collaboration are necessary to fully understand and harness the potential of lighting in enhancing human health and thriving [12].

An educational building refers to a structure dedicated solely to the functions of a school or Department that the relevant board, university, or competent authority accredits. These functions primarily involve gathering for instruction, education, or related activities. Additionally, an educational building includes facilities such as libraries or research institutions that support these educational activities. It also contains provisions for essential staff members to live on-site and in hostels associated with academic institutions, whether situated on their campus or elsewhere [13].

Daylighting plays a crucial role in improving both students' academic performance and their health. Moreover, when implemented correctly without causing excessive glare, it also boosts the overall energy efficiency of buildings [14].

In recent years, there has been a surge in the development of new methods for assessing and designing lighting. The discovery of previously unidentified photoreceptor cells in the eye, called photosensitive retinal ganglion cells, has prompted lighting researchers to focus on understanding the impacts of light on both image-forming (IF) and non-image-forming (NIF) functions. It has prompted a reassessment and redefinition of the lighting needs of occupants, presenting a challenge in implementing innovative lighting concepts into practical applications [15].

An analysis of existing lighting simulation tools has identified illuminance-based metrics, luminance-based metrics, daylight availability metrics, and glare indexes as commonly utilized performance indicators. Following considerations such as usability, acceptability, availability, and scholarly references, six software applications (Radiance, DAYSIM, Evalglare, Dialux, VELUX, and VISSLA) were chosen for comparison. It was noted that no single tool could meet all designer requirements, necessitating the selection or combination of simulation tools based on project objectives and design phase. Various applications of lighting simulation were identified and categorized into different groups. These include performance metrics, design phases, optimization, model integration, Building Information Modeling (BIM), and parametric modeling [16].

1.2 Problem Definition

Adequate lighting within university educational buildings, especially in architecture departments, is essential for creating conducive learning and creative environments. Architectural studio rooms require abundant natural light to facilitate various activities and tasks. Given the specific design requirements of buildings intended for architectural functions, there is a need to assess the suitability of existing structures in meeting the lighting needs of the Department of Architecture. In architectural education, spaces initially designed for different purposes and later repurposed for architectural education pose a research problem when designers overlook the requirements and conditions for adequate natural lighting in designing architectural studio classrooms and the educational process. It is why educational buildings not initially intended for this purpose were chosen, such as the Department of Architecture at Ankara Yildirim Beyazit University (AYBU), which was transformed into a laboratory and now serves as a focal point. Concurrently, the Department of Architecture at Samsun University, originally a tobacco manufacturing facility, has been repurposed and redesigned for educational purposes. The outcomes from these two institutions will be compared with those from Amasya University, serving as a reference point. These universities are selected based on their geographical proximity and shared latitude. These limitations define the scope of the study, emphasizing its focus on the Turkish context and the field of architecture.

1.3 Research Questions

What are the implications of repurposing completed buildings as educational facilities?

What is the quantity of natural light entering the studio's room for Architecture Faculty, and does it suffice to achieve visual comfort?

What are the optimal hours and days for effective studying within these spaces?

To address these inquiries, we will consider the parameters for assessing natural lighting adequacy and strategies for maximizing illumination in architectural studio education classrooms.

1.4 Scope and Objectives of the Study

The scope of this study encompasses an investigation into the attainment of visual comfort within architectural studio rooms situated across university buildings, with a specific focus on the influence of natural light on furniture, walls, and ceilings. The study aims to identify deficiencies in natural light penetration and propose viable solutions to enhance illumination levels within these spaces, specifically in AYBU, the building of the Department of Architecture. The objectives of the study are delineated as follows:

- Determine how many architectural studio rooms conform to European Code Certification standards in Türkiye regarding visual comfort.
- Conduct a comprehensive evaluation of the current impact of natural lighting throughout the day and across all seasons, analyzing its effectiveness in fostering conducive learning environments.
- Propose strategies for optimizing natural lighting within educational buildings to maximize illumination levels during instructional periods.

By addressing these objectives, the study aims to enhance visual comfort and illumination quality within architectural studio rooms in university buildings in Türkiye, ultimately fostering improved learning experiences for students and faculty members alike.

1.5 Research Methodology

The methodology employed in this study comprises the following steps :

- A comprehensive literature review was conducted about natural lighting in educational buildings globally and within the Türkish context. This review will encompass strategies for analyzing natural lighting in architectural settings.
- Collect relevant files and information related to university educational buildings in Turkey (one of them was already designed as the Faculty of Architecture (Amasya University), one was redesigned as the Faculty of Architecture (Samsun University), and the other was converted from educational laboratories to Architecture studios (AYBU).
- After collecting the plans of AYBU, Amasya University, and Samsun University, they were visited, and the necessary information for the building was taken from the building materials used for the walls, ceilings, and existing furniture.
- Using Dialux Evo12 software, 2D architectural drawings will be converted into 3D models, facilitating a more immersive and detailed inspection of buildings.
- Using Dialux Evo12 software, simulations will be generated to assess various factors influencing natural lighting within the educational buildings under scrutiny. These simulations will incorporate parameters relevant to the study objectives.
- Investigate the effects of natural light on study tables, walls, and ceilings within architectural studio rooms, exploring its influence on the overall study environment.
- The outcomes derived from the simulations will be analyzed comprehensively. A comparative analysis will be undertaken to juxtapose the results against each other, aiming to discern patterns and variations. The reasons underlying deviations from requisite lighting standards will also be explored and discussed. Subsequently, comparisons will be drawn with analogous facilities in other universities.

This research methodology is structured to facilitate a systematic investigation into the natural lighting in educational buildings within Türkiye.

1.6 Study Limitations

This research is limited to three universities in Türkiye, focusing on the Architecture studios. The primary emphasis lies in investigating these buildings' lighting levels and associated factors. The study examines lighting intensity within architectural studio education classes and explores lighting's impact on various surfaces such as walls, ceilings, and furniture.

1.7 Scientific Contribution

This study aims to enrich the literature concerning natural lighting within educational buildings, particularly emphasizing architectural contexts. Investigating recently constructed buildings in Türkiye endeavors to advance knowledge and understanding. Using the Dialux Evo12 Program as a tool for lighting calculation demonstrates to architects the feasibility of preemptively assessing lighting conditions before implementation. This approach empowers architects to make evidence-based decisions, fostering transparency and accountability in the natural lighting investment process, thereby ensuring alignment with community needs. Moreover, the study seeks to quantify the natural lighting requirements of the universities under examination and proposes strategies to augment its intensity, thereby enhancing educational environments.

1.8 Organization of the Thesis

The thesis is structured into five chapters, outlined as follows:

- Chapter 1: Introduction: This chapter serves as an introductory section, providing an overview of the study's background, delineating its scope and limitations, elucidating the methodology employed, and articulating the problem statement under investigation.
- Chapter 2, Literature Review, delves into previous research endeavors within the subject area, offering a comprehensive review of relevant literature. Topics covered include natural light utilization in educational buildings, global practices concerning natural lighting in architectural contexts, analytical

methodologies applied in assessing natural lighting, and simulation techniques for lighting analysis in buildings and architectural institutions, explicitly focusing on Türkiye.

- Chapter 3, Research Methodology and Results, delineates the research methodology employed for the lighting analysis and presents the findings derived from the conducted study.
- Chapter 4: Discussion of Simulation Results. In this chapter, the outcomes obtained from simulations performed using the Dialux Evo12 program are discussed in detail, and their implications within the context of the research objectives are analyzed.
- Chapter 5: Conclusion and Recommendations The final chapter synthesizes the research findings and their implications, drawing conclusions based on the observations. Additionally, recommendations for future research endeavors are highlighted.

CHAPTER 2

LITERATURE REVIEW

Natural lighting analysis is essential in architectural design, especially in educational environments like studio classrooms. Proper natural lighting can elevate the academic experience, enhance student well-being, and reduce energy use.

Today, various software tools exist for efficient lighting analysis, such as EnergyPlus, ClimateStudio, AGi32, HoloArch, Velux Daylight Visualiar, and DIALux. The DIALux Evo 12 was chosen for lighting analysis in this research due to its simplicity, efficiency, and reliability, which gave accurate results. DIALux Evo 12 software is a cutting-edge technology tool that enables the simulation and evaluation of lighting conditions, making it an indispensable resource for evaluating natural lighting in studio classrooms.

2.1 Analysis Techniques for Natural Lighting

Quantitative and qualitative techniques are used to evaluate and optimize daylight performance analysis in a building. These approaches complement each other, providing a comprehensive understanding of how daylight interacts with a space.

2.1.1 Quantitative Techniques

Quantitative techniques aim to enhance natural illuminance and reduce energy consumption by analyzing peak daylight levels and incident solar radiation. Additionally, the integration of thermal and daylight performance assessments is essential for achieving optimal building design [17]. Studies suggest that kinetic architecture, utilizing dynamic façades, can significantly improve daylight efficiency and visual comfort through computational models and parametric analyses [18]. Moreover, parametric workflows might be used to manage the perceived quality of artificial lighting in urban climatic conditions characterized by high solar radiation levels, enhance comfort, and reduce energy consumption [19]. These numerical approaches help architects optimize the design of spaces with the necessary illumination level and low energy consumption [20]. Figure 2-1 gives a detailed presentation of quantitative methods for natural lighting analysis.

2.1.2 Qualitative Techniques:

While the quantitative analysis techniques are focused on providing satisfactory lighting levels, qualitative analysis is concerned with the aesthetic aspect, ensuring the excellent ambiance within a building. Qualitative analysis uses descriptive information such as text documents, audio, images, and videos. Unlike quantitative analysis, which centers on numerical data analysis, qualitative tools are relied upon to facilitate the complexities resulting from qualitative data and its interpretation [21] [22].

Qualitative methods include computer simulations, parametric modeling, and optimization. They allow researchers to find the appropriate building envelope configuration and exterior shading devices. This improves the natural light's quality with satisfactory thermal comfort and energy efficiency in school and office buildings. Various qualitative analysis tools such as Rhinoceros, Grasshopper, and Honeybee Plus [23] are available. Using the Grasshopper and Rhino plugin tools, parametric modeling has been of essence for developing models for daylight and thermal comfort analysis [24]. Furthermore, applying artificial intelligence methods in combination with numerical models facilitates accurate assessments of the zenith daylight levels and the incidence of solar radiation in indoor spaces [17]. A detailed presentation of qualitative techniques used for lighting analysis is presented in Figure 2.2.

DIALux, a popular quantitative analysis tool, has been selected for the present research due to its wide use in recent papers. DIALux also supports qualitative analysis, which makes it suitable for analyzing data in mixed methods, combining qualitative and quantitative data [25].

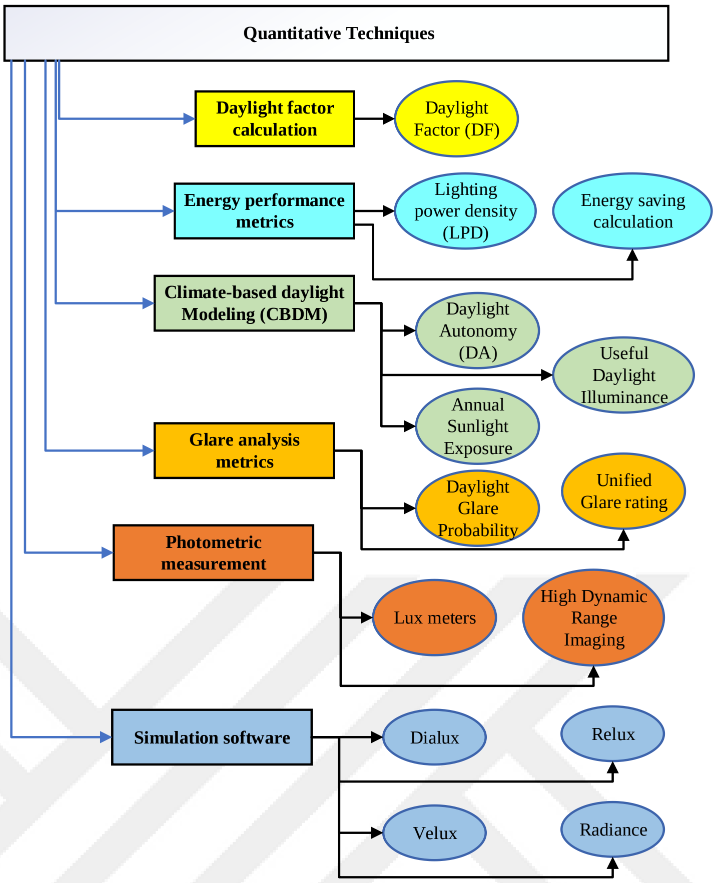

Figure 2.1 Quantitative techniques

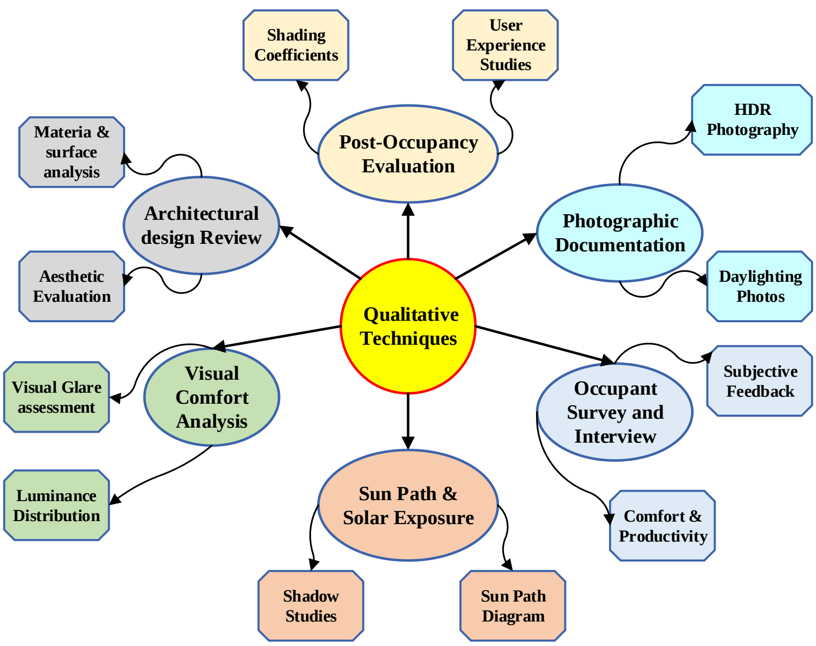

Figure 2.2 Qualitative Techniques.

2.2 Influential Elements on Natural Light

Some factors influence how much natural light enters a building and the quality of that light. Our research concerns the quantity and quality of natural lighting and highlights several factors. These factors include:

- Building Geographical Location: The geographical location of the building is connected to the daylight duration. For example, a building in the south of Türkiye receives more lighting than a similar building in the north.

- Building Orientation: The orientation of a building is essential for receiving daylighting quantity. The orientation describes the timing for direct daylight's impact on a building.

- Window Size and Placement: Daylight reaches the inside of the building through windows. The position and orientation of windows relative to the direction of the sun rays, the size of the opening, and the glass types have a logical and direct effect on lighting quantity and quality.

- Interior design and material: Inside, things like wall colors, materials, and how furniture is arranged all affect how much natural light is present.

- Climate and Weather Conditions: The weather conditions impact the lighting in general, especially inside buildings. A cloudy day yields less daylight than a clear day.

- Seasons/Weeks and Days: The weather is connected directly to the seasons.

- Building floor height and interior space: The building dimensions impact the daylight entering. Increasing floor height logically Increases the exposure of buildings to natural lighting.

- Barriers, like buildings, trees, and other constructions: These objects can block the flow of sunlight into areas. This site environment plays a role in determining the amount of daylight in architectural or city planning attempts [26].

Many research studies are focused on the impact of various elements on the quality and quantity of daylighting. Some deal with the design of multiple buildings, while others focus on academic buildings, including architectural departments in various universities. Most of the research is performed in the building design stage, giving total freedom to designers to change window size and position, materials, building dimensional characteristics, and building orientation.

[26] Analysis of the impact of window orientation, interior occupant's location and seating position, and artificial lighting support on circadian Stimuli (CS). Numerical techniques are used to model the Daylight Glare Probability (DGP) and CS. It is mainly a qualitative analysis of the comfort of interior space within a living building. An optimization objective function is formulated based on CS modeling. Vertical eye illuminance is used for the linear modeling of DGP. Many results are the output of this research, including the effect of uniform illuminance and the occupant's seating position inside the region affected by daylighting. Thermal comfort and its contribution to the optimal artificial daylighting system were also investigated. The nonlinear modeling of DGP could be examined for more realistic lighting situations. Also, exploring adaptive façade systems that allow alteration of the façade performance and appearance to the changing daylight conditions and users' likings can improve results. Some new leading techniques, like machine learning and artificial intelligence approaches, enhance lighting control for more comfortable buildings based on their typology and user needs [27].

The weather changes in the European climatic conditions, and their impact on window selection is investigated in [28]. The classic architectural design of the modern European building on glass elements faces a real challenge due to climate change and rising temperatures. Continuing the current architectural style will cause adverse effects from the escalating use of air conditioning devices in the summer, contributing to increased energy consumption and its accompanying adverse effects. In addition to the energy balance, windows affect the natural lighting of the building, affecting visual comfort and light consumption. The research proposes a parametric analysis with the objective of the evaluation of various window designs on comfort and energy cost. All parameters of the window design are investigated, including the total window area, glass type, window frame, shaping, orientation, and shading systems. This research is focused on the negative impact of excessive daylighting on energy consumption, especially in summer. It must consider positive and negative effects during the year and not be limited to a specific period.

Many research studies are focused on windowing and façade design optimization using various techniques for better lighting strategy [29], [30], and [31]. The quantity and quality of research related to this topic outline the importance of window and façade design strategy on the amount and quality of daylighting.

The latitude and orientation of the building directly affect the indoor lighting. In [32], the latitude and orientation effects on the total absorbed daylighting are investigated. Building Information Modeling (BIM) and Building Energy Modeling (BEM) are used to analyze many case studies in various locations in Europe, South America, the Middle East, and Australia. Results show that most daylight enters houses from their rear side, where the most occupied rooms are located. The illuminance levels are above 300 lux, varying according to the season.

2.3 Evaluation Tools for Natural Light

Many tools and applications have been designed to increase the awareness of architects and engineers for the efficiency of incorporating daylight within buildings and cities. These tools typically refer to embedding a geometric 3D model of the building or urban setting in a simulation program. Tools calculate various daylighting factors such as daylight factor, useful daylight illuminance, and dynamic daylight performance indices. These methods can increase productivity and reliability by reducing mathematical computations and improving design efficiency.

Many natural lighting analysis tools are available for architectural design. Each tool has its advantages and disadvantages. A designer must focus on his (or her) objectives for tool selection. Among the most used lighting tools are DIALux, Relux [33], Lumicept [34], Ecotect [35], AGi32 [26], HoloArch [36], Radiance [37], EnergyPlus [38], DianaX [39], ClimateStudio [40], and Velux Daylight Visualizer [41]. Some tools are free, and others require a license underpayment. Some tools are used for 2-dimensional simulation, and others are used for 3-dimensional plans.

DIALux evo 12.1 is selected as a daylighting analysis tool for our thesis. This selection is justified by the widespread use of this free-of-charge version in the literature. DIALux is the world's leading lighting design software where customers can design, calculate, or even imagine indoor or outdoor lighting. This software is employed by lighting designers around the globe and is beneficial for its capacity to establish models and simulate lighting, thus improving the amelioration of issues and the design of light. Implementation of such tools in the learning processes of architecture can contribute to the development of a generation of architects that is knowledgeable in sustainable and people-oriented designing; the tools help provide helpful information and assist in optimizing the conditions of the light in the educational context, thus developing the learning and the students in an overall manner. Regarding technology's influence on education and lighting design simulation, Darlington believes that 'Applications such as DIALux Evo will likely become more common[42].

Table 2.1 The advantages and disadvantages of DIALux are presented in several previous research studies related to our field. This table outlines that the principal use of DIALux is for daylight analysis, which is the main objective of the present research.

2.4 Natural Lighting in Educational Buildings

Many studies have extensively examined the advantages of natural lighting in educational environments. Findings indicate that adequate natural lighting can enhance student focus, alleviate eye discomfort, and elevate emotional state and general health. Integrating natural light is essential in educational environments, as it improves learning, energy efficiency, health and well-being, and aesthetic and design advantages [51]. It is critical in studio classrooms for architect departments in various universities, where students engage in prolonged complex tasks [52].

An analysis of the current status of the lighting quality at Escuela Técnica Superior de Ingeniería Aeronáutica y del Espacio de la Universidad Politécnica de Madrid (ETSIAE-UPM) (Spain) is conducted in [47] using empirical data and DIALux simulations. The research is trying to propose adequate solutions to improve the lighting within the classrooms of various faculties. Buildings under consideration have existed for more than 65 years with old artificial lighting systems. The ultimate goal of the study is to meet the European standard for illumination in classrooms (i.e., 500 lux) from the initial situation with much lower illumination values.

The study focuses on shedding light on how the lighting conditions can be best made to provide increased comfort and efficiency by introducing changes and modifications that can be made to the currently existing classroom. Settings can be made by measuring and comparing the illuminance levels in the classrooms and simulating certain advancements to improve the given conditions. The research enlightens ways to improve the academic lighting environment with authentic findings of the problem and unveils a novel approach to enhancing the established analysis and simulation studies. Based on the findings obtained from the sampled classrooms, it is evident that the average illumination levels over desks can be substantially enhanced by implementing LED technology.

The proposed improvement tries to solve the problem of low lighting in some classrooms where the existing artificial lighting fails to increase the illumination to an acceptable level. This work shows a suitable method for improving lighting in old academic establishments using the DIALux tool as the leading simulation software. The same procedure can be followed in our research for improving lighting without making large-scale physical modifications and analyzing potential glare problems during different times to achieve visual comfort in educational buildings.

DIALux Evo 9.0 tool is also used to evaluate lighting performance in the hall of the Faculty of Engineering, State University of Gorontalo [46]**.** DIALux simulator is used to compare the lighting level of the existing building with an improved engineering design model, the latter of which results from adding windows and light shelves and changing some materials to transparent ones. Simulations are conducted on September 21 for a clear sky. Research results show that **e**ngineering design interventions can effectively optimize the direction of light toward designated points of interest while concurrently mitigating glare. However, further engineering refinements are a prerequisite to fully addressing the prevailing challenges. This research is very limited in time, focusing only on one date and one weather situation. A multi-objective approach optimization for a classroom is presented in [53]. It includes architectural design features like lighting (natural and artificial). The objectives of this research are centered on the student's educational experience, which increases productivity,

Table 2.1 Advantages and disadvantages of the DIALux tool

Ref.	Year	Advantages	Disadvantages
[43]	2023	Parameters for energy planning can be entered within the usual workflow, enhancing the user experience.	Some DIALux versions are only considered one point in time for luminous intensity distribution curves.
[44]	2022	The program provides detailed insights into the lighting conditions, allowing adjustments to enhance natural lighting usage and reduce dependency on artificial lighting.	The discrepancy was found between the DIALux simulated results and measured lighting levels.
[45]	2019	The DIALux tool helped to optimize natural and artificial lighting design, ensuring optimal visual performance with low energy consumption.	-
[46]	2021	offers improved visual rendering capabilities, allowing for a more realistic representation of the lighting conditions within the studied space.	The accuracy of the simulation results heavily relies on the input parameters and assumptions made during the modeling process.
[47]	2020	DIALux tool analyzes and fine-tunes the attenuation of luminaires to match the measured data, helping to improve the lighting quality in the classrooms.	Research indicates that the software may have limitations in fully addressing the lighting deficiencies in some cases.
[48]	2021	It provided the ability to assess the suitability of the lighting levels in the studio room according to the SNI 03-6197-2011 standard.	-
[49]	2021	Can analyze the performance of lighting systems in specific locations and environments, presenting results through numbers, graphs, and pictures.	It is essential to validate the results obtained from DIALux simulations with on-site measurements to ensure accuracy and reliability.
[50]	2021	The software facilitated the evaluation of different scenarios, enabling the researchers to make informed decisions to improve lighting conditions effectively.	-.
[19]	2022	DIALux allows for the representation of lighting distribution in rooms using false colors and models, making it easier to visualize the intensity of daylighting in different areas.	DIALux capabilities are specific to daylighting simulations, requiring additional software for other analyses.
[38]	2017	DIALux provides a comprehensive analysis of daylighting levels during different periods.	The processing time for running simulations in DIALux is lengthy,

improves human performance, and optimizes energy consumption. The optimization performed in this paper focuses on daylight and energy in the context of three standard school building models, emphasizing occupants' comfort. The evaluation of natural light in the classroom design considers factors such as the amount of light entering the room to ensure it enhances health and productivity without causing discomfort to occupants. The research methodology used custom Radiance materials to simulate daylighting, assigning different properties to interior and exterior walls to optimize natural light within the classroom environment. One proposed method is partitioning the classroom into multiple zones to optimize the lighting strategy. The results show that the proposed methodology can provide designers with a guideline for designing a sustainable classroom that fulfills their preferences. The minimization of discomfort glare with various shading systems has not been studied in this research and is proposed in future work. Also, problems related to acoustic comfort are critical aspects of users' comfort and should be considered in future design procedures.

[54] focuses on the impact of design characteristics related to daylight elements in creating healthy internal environments for Mosul City, Iraq, school buildings. Design properties related to factors of daylight play a crucial role in enhancing the healthiness of interiors and increasing educational productivity within school buildings. The study evaluated three types of school buildings in Mosul City using the Velux Daylight Visualizer -2012 as part of the research methodology. The research emphasized two main daylight factors contributing to achieving a healthy spatial environment in educational buildings. First, the solarization average for the building as a whole, and second, the homogeneity of daylight at the work surface in the classroom spaces.

DIALux Evo version 9.2 software is used as a quantitative method [44] to evaluate lighting systems in educational facilities. The case study in this research is the academic building in Universitas Indonesia. The main objective is to minimize artificial lighting by optimizing the quantity of daylight entering the building. Two variables are under consideration: the building orientation and lighting position. Collected data about illumination is performed by a Lux meter in the clear sky and modeling with DIALux. The analysis for this research concludes that the lighting planning has fulfilled the 350 lux standards for working space and the 500-lux minimum for laboratories.

Another study that focuses on optimizing library lighting systems for comfort, energy efficiency, and cost-effectiveness is presented in [45]. DIALux Evo 8.1 tool is used for lighting quantity/ quality evaluation. The variables under study are illumination values, lamp selection, and lighting scenarios of the library in the Learning Center Building at Universitas Gadjah Mada, Indonesia. The developed lighting scenario ensures comfort, energy efficiency, and cost reduction. Results show that some areas in the library have higher levels of illumination, which enhances the user experience. Proper lighting optimization leads to cost savings, meeting standards, and improving energy efficiency. Suggestions for further research include maximizing natural lighting and choosing furniture with higher reflectance values to enhance building efficiency.

Research is conducted with its case study within the School of Engineering at the University of Pisa [55]. The lighting quality in single and six classrooms within the educational institution was analyzed. Aim to evaluate various aspects of lighting conditions and identify critical areas for improvement. The proposed lighting quality assessment method was utilized during the case study to assess the lighting in the selected classrooms. Criteria, sub-criteria, and indicators were carefully chosen and applied to evaluate the lighting quality effectively. The researchers used the Analytic Hierarchy Process (AHP) to assign weights to different criteria based on their significance in determining lighting quality. This systematic approach ensured a comprehensive analysis and prioritization of factors influencing classroom visual comfort. Following the assessment, a subjective survey was carried out to validate the results obtained through the proposed method. The feedback from 420 questionnaires provided insights into users' perceptions of lighting quality, confirming the effectiveness and validity of the process. This alignment validated the accuracy and reliability of the technique in effectively gauging lighting quality and user comfort levels.

[50] is surrounded by the enhancement of the daylighting impact and artificial lighting in the UPGRIS lecturer's environment at Semarang City, Central Java, by controlling

the electrical use of both forms of lighting. DIALux Evo 9.0 is a simulation tool for lighting quality & quantity analysis. The evaluation of existing buildings reveals insufficient natural lighting, requiring the support of artificial lighting. From the study, it can be extracted that the focus is placed on near window areas to disuse artificial light during daylight. It results in energy optimization and improves the levels of lighting or illumination. Regarding possible retrofitting measures, changing lamp types and using lux sensors for automatic light control were discussed to increase lighting levels higher than the standard stated in SNI, namely 350 lux. The study illustrated that the tested retrofit interventions can improve workspace illumination. A quantitative approach was adopted in the research whereby simulation analyses using DIALux were done with compliance to modeling based on CAD drawings concerning lighting standards to enhance lighting conditions in the lecturer workspace.

2.5 Natural Lighting in Architectural Education Buildings

According to the European standard, EN 12464-1 (2002), adopted by Türkiye and most countries, educational classrooms require lighting equal to 300 lux, while 500 lux is the minimum illuminance for laboratories. Architectural buildings, especially studios, require at least 500 lux. As part of education and academic buildings, architectural studios attracted researchers as case studies for evaluation regarding the quantity and quality of lighting. A good analysis must occur at the design stage, but given that most of the University buildings have already been constructed for a long time, an evaluation can contribute to increasing the lighting efficiency with minimum energy cost. A selected number of papers published on architectural studios have been surveyed in this section.

[56] presents an architectural study of studios at Catholic University (Indonesia) using qualitative and quantitative methods. It is performed using qualitative and quantitative analysis through student questionnaires and DIALux simulations. Factors such as lighting techniques, lighting levels, color temperature, room reflectance, and daylight contribution stand out as the most influential determinants in shaping the quality of a studio environment. Although the lighting level is below standard, participants rate the lighting quality positively in the studio space. Visual comfort perception is higher than

the perception of the room atmosphere. Lighting techniques, illumination levels, light colors, room reflection factors, and daylighting contribution are the factors that affect room quality the most.

The need for daylight is also one of the aspects assessed by respondents as necessary to improve work productivity. Sun glare reflects many students' complaints, especially the morning near windows, but the research did not propose any solution.

[57] focuses on the impact of artificial light on the overall lighting quality/quantity for architectural studios of the University Tun Hussein Onn Malaysia (UTHM). These studios were initially designed as laboratories and then converted to architectural studios later. Data about illuminance quantity is collected using a lux meter. Sigmaplot and DIALux evaluate illuminance intensity and compare it to the adopted standard. Also, a quality analysis is conducted using a questionnaire for students to assess the learning experience. The outcome of this study can be considered for future architectural studio lighting design to improve the students' learning experience. The research did not propose any solution to improve the actual lighting situation.

Daylight is critical for energy conservation and enhancing the overall quality of life. Moreover, there is a growing emphasis on acknowledging and leveraging naturally provided energy sources as an initial stride toward achieving optimal energy efficiency and diminishing reliance on fossil fuels. [58] Analysis of the indoor daylight conditions and the energy performance of the library within the Faculty of Architecture, Design, and Built Environment at Beirut Arab University. The investigation analyses various architectural elements, including spatial depth, window dimensions, external obstruction angles, and glazing visible transmittance. The research is performed using different software, including Autocad Ecotect for actual daylight situations, DIALux for artificial lighting analysis, and the behavior of the users throughout the day using Hobo loggers. The objectives are to improve the students' comfort and other environmental, technological, and energy saving as well as sustainable and green building designs. The research proposes daylight designs based on hollow prismatic light to improve the actual state.

Using research tools, luminance measurements conducted at the UNISA Workshop building in Yogyakarta showed inadequate lighting levels for the architecture studio room [48]. Concerning this problem, particular recommendations have been made regarding the lighting planning during compliance with the data, reflected in SNI 03-6197-2011. All the non-exempt areas require alternative lighting designs with 12 No's Philips TCS260 2xTL5-80W HFP C6 lamps to meet the standards. Such investigations highlighted the importance for architects to properly and explicitly strategize about the lighting systems to raise efficiency during the usage of studios for intended users. It stressed how to use lighting with the correct intensity for extended periods and how proper lighting controls and designs enhance usage comfort and efficiency. Furthermore, studies conducted by Tanjitri, Damanik & Abdullah at the Architecture Sumatra Institute of Technology revealed that the lighting conditions in the architectural studio are insufficient to meet the Indonesian National Standard (SNI) while highlighting the importance of user comfort in studio environments.

Natural lighting plays a crucial role in the energy dynamics of buildings, as insufficient natural light often leads to heightened electricity consumption for artificial lighting. From this perspective, it is evident that the arrangement of lighting fixtures should consider daylighting illuminance levels to realize energy-efficient lighting [49]. The studio classrooms at the Department of Architecture, Universitas Trisakti, require sufficient illumination for the students to do hand/ digital drawing. This study is performed in the design stage of next-built studios. The research aims to design the appropriate lighting for an architectural studio classroom to minimize wasted energy while increasing the comfort of seeing. It seeks to meet lighting standards by utilizing natural lighting and presents a new lamp grouping design using DIALux Evo 9 to enhance lighting efficiency.

The Negeri Manado University Hall, the venue used for formal meetings, was studied [59]. The hall was analyzed using data from AutoCAD and the DIALux tool. Based on Indonesian national standards, the simulation process resulted in a scarcity of light intensity and a dark radiation distribution, which is considered non-compliant. Several methods have been proposed for modifying illumination, including extending exposure by replacing the glass material and adjusting it to match incoming sunlight, modifying reflection equipment in the vicinity, applying light, and spotting light.

We noticed that the DIALux tool is the most frequently used software for lighting analysis in general, especially in educational buildings. Given that the working hours for students are usually during the day, the Clear sky is always used for research on buildings, especially using the DIALux tool; this is why most of the simulated scenarios in our study are based on the same assumption.

2.6 Lighting for Educational, and Architecture Department Buildings in Türkiye

In Türkiye, lighting analysis through digital simulation plays a crucial role in assessing energy efficiency and visual comfort in buildings, especially in educational institutions like architectural Departments. Research emphasizes the significance of Building Energy Performance (BEP-TR) tools for evaluating energy efficiency in public structures [60]. While architectural technology education in Türkiye is diverse and incorporates different approaches, focusing on lighting design and energy efficiency remains essential in architectural curricula [61]. Further, daily monitoring of building usage through wireless sensor networks helps investors make post-retrofit predictions when applying financial choices for efficient energy solutions that would be most effective [62].

Sustainable architecture deals with the basic concepts underlying the creation of sustainable structures and the fundamental goals of sustainable architecture; based on these data, the work provides a framework for integrating sustainability considerations into school construction programs. It highlights necessary elements that need to be considered during the early stages of the building design to enhance sustainability by considering features like environment, topography, climate, and orientation. Structural and aesthetic concepts such as the all-embracing analysis, the financial review, and the dynamic design approaches should be embraced if buildings' ambitious sustainability goals are to be met [63].

[41] conducts an assessment of daylighting performances of classrooms in kırklarelı University (Türkiye) using the Velux Daylight Visualizer simulation program. It focused on assessing natural lighting concerns at the school using a classroom at the Kayali Campus and two at the Kavakli Campus of Kirklareli University. The observer quantified illuminance in the identified classes and examined established standards and design specifications. Research has demonstrated that daylight illuminance levels within such environments exhibit directional variation. Accordingly, architectural considerations such as building orientation, fenestration patterns on building facades, and the incorporation of shading elements should be meticulously designed by proficient experts in natural lighting to optimize these conditions. Some ideas mentioned regarding the improvement of daylighting included the integration of laser-cut panels, concave acrylic material, and anabolic ceiling systems, which help facilitate lighting.

A study of the visual and thermal/ energy performances of buildings in Istanbul that have been transformed into Architecture schools is presented in [38]. Because of the particular requirement of studios and considering the green building strategy, architecture schools should satisfy several kinds of performances, including lighting, ventilation, and heating. Therefore, efficient energy utilization is vital for environmental conservation and minimizing Türkiye's energy expenditures. The study analyses the performance of envelope systems using the examples of two architectural faculties at Istanbul Technical University (ITU) and Bahçeşehir Üniversitesi (BAU). Other elements used in the analysis are U-values of external walls and windows in the buildings of ITU and BAU and comparison with the standardized thermal performance indicators. DIALux Evo simulation analysis is employed to analyze visual and thermal comfort provisions in the teaching studios of the mentioned architecture schools. This study reveals that ITU and BAU's general daylight levels are mostly satisfactory on specific days of the year, but glare is noticed in the afternoons, mainly at ITU. One of the possible solutions to control the amount of sunlight by having a positive attitude and decreasing the level of glare is movable sun devices.

The optimization of window configuration plays a pivotal role in enhancing both visual and thermal comfort within built environments. This improvement is achieved by mitigating glare, effectively distributing natural light, and regulating solar energy influx. To improve students' performance and reduce energy consumption, [7] focuses on the case study of a school in Eskisehir by evaluating the effect of natural lighting on the building design. It investigates the influence of varying transparency ratios (Window-to-Wall Ratio, WWR) and different combinations of windows in two cardinal orientations (west and east) on both occupants' comfort levels and the energy requirements of a classroom setting. Analysis of the different transparency ratios and the window combinations on the comfort of the occupants, as well as the energy requisite for the classrooms, were done with special computer simulation software including DIALux Evo 6. 0 and EnergyPlus 8. 9. The simulation results using DIALux show a reduction of 15% in artificial lighting and an improvement in comfort by using a glazing ratio of 50%.

The specifics of lighting energy performance are observed at the selected site, the Faculty of Architecture of Erciyes University (ERU) [33]. Energy consumption patterns of the lighting were analyzed to examine the energy efficiency of the educational building considering visual comfort necessities. The BEP-TR approach was used to assess the existing case data on which the study was based. As concerns the study of lighting energy consumption values using new simulation methods in comparison with comfort visual criteria, it is possible to define new ways to improve the directions of lighting design to achieve the energy saving goals considering the requirements of the defined comfort visual standards. It also provides a cost calculation to calculate the payback of the initial investment cost made towards the lighting system control and comfort, consumption, and price.

Daylighting performance measures have been evaluated in educational buildings, especially in Türkiye, to enhance lighting conditions for many users in these facilities. [64] used the analysis of daylighting standards and international regulations related to educational buildings to develop a set of rules adaptable to educational infrastructure and climatic conditions in Türkiye to improve user well-being and energy efficiency in educational spaces. The research results showed the need to re-evaluate standardized educational projects in Türkiye to meet diverse user needs, architecturally flexible uses, and energy efficiency standards across different climate zones. The primary benefit of this paper is its ability to guide policymakers, architects, and designers in developing educational buildings that prioritize user comfort, energy efficiency, and well-being in line with global best practices, thus contributing to a more sustainable and suitable environment. An educational environment for students and teachers alike. This assessment also helped bridge the gap between international standards and local requirements, allowing the development of guidelines specific to educational buildings in Türkiye. They conclude that it is necessary to analyze daylighting standards and international regulations related to educational buildings to create a comprehensive set of rules that can be customized to suit the educational infrastructure and climatic conditions in Türkiye to enhance user well-being and energy efficiency in educational spaces.

The importance of orienting the building based on the sun's path and prevailing winds is outlined in [65]. In Türkiye, south-facing rooms are preferred as they are exposed to prolonged sunlight in winter and shade in summer, bringing users energy efficiency and comfort. Understanding the dynamic nature of the sun and its impact on building design is significant. Designers in different latitudes should consider strategies to reduce daylight penetration based on seasonal variation to achieve designs that save energy and improve human health. Calculating the roof slope according to the sun angle in architectural structures improves efficiency in various aspects. Good orientation helps maximize energy efficiency and comfort, even in existing structures, with proper shading and exposure adjustments.

Natural light patterns significantly influence building design in Türkiye. Studies emphasize the importance of considering the intensity of natural light for optimal lighting conditions in residential houses [66]. Furthermore, in architectural structures like libraries, controlled daylight intake plays a crucial role in user adaptation, psychological comfort, and space performance [67]. It is pertinent to note that natural lighting performance in buildings depends on factors, including the angle between the focal façade and the surface reflectance, as evidenced by the simulations. Further, creative architectural concepts such as collimator lenses employing total internal reflection provide better solutions for the assemblies that exploit natural light in buildings [68]. Finally, Türkiye can adapt these insights into building design processes to enhance the spaces' efficiency before using artificial light by prioritizing natural light to improve comfort, energy use, and user experience [69] [70].

2.7 Literature Survey Summary

The wide literature survey served to clarify the research method and how to meet objectives. This research is mainly concerned with the evaluation of daylighting in the case studies of three existing University buildings in Amasra, Samsun, and Ankara. A designer can use a few freedom actions to improve daylighting impact. Our main objective is to compare the three case studies conducted in various weather conditions and during the educational period. So, the elements under investigation are Seasonal/Week and Day, climate and weather conditions, façade, and windows.

The selected technique is quantitative evaluation but with some impact on the lighting quality. DIALux is selected as a simulation tool for lighting due to its approval efficiency, time cost, and accuracy. It offers many features that make it a viral tool. DIALux EVO is the most used lighting design tool by users as noticed from the literature survey, and it can generate practical and professional lighting calculations efficiently.

CHAPTER 3

METHODOLOGY AND CASE STUDIES

3.1 Introduction

This chapter presents the research method and evaluates the case studies under consideration. The main objective is to study natural lighting levels in the architectural studios of three universities in Türkiye. Information about the universities is collected using basic plans and by inspecting buildings through a visit to each location. The architectural department plans for three universities have been provided in 2-D files. Some plans have been received directly from universities; others have been downloaded from the Ekap website [71] (under İhale No. 2021/58288). All plans were taken in AutoCAD format, including plans, sections, and facades.

3.2 Case Study

The research is conducted in the studio rooms of the Architecture Department of three universities in Türkiye, namely Amasya, Samsun, and AYBU. The idea is to compare AYBU Architecture Studios with other universities in Türkiye. AYBU was designed as different laboratories and reused for the Department of Architecture. Amasya University Architecture Department Studios were chosen because they were designed and implemented as architecture studios. Samsun University used to be a tobacco factory and was reused as an education building for the Department of Architecture. The building adaptation project of the Faculty of Architecture and Design was deemed worthy of the "Necip Fazil Architecture Award". The selected case studies aimed to evaluate the effect of adaptation and design of the studios on the amount of light.

Among the many elements in the indoor environment, lighting impacts the human body significantly. Light has been shown to have both visual and non-visual effects on people. Among the various light sources, sunlight is the most important and cannot be easily replaced by electric light due to its dynamic quality and spectral features. In addition, it is the most important source of vitamin D, which is essential for human bone strength and overall health. Daylighting is a passive strategy to improve energy performance and visual comfort for students without expensive installation and operation costs. The daylighting mechanism improves student performance by increasing vision, mood, and overall health.

Information was collected for the simulation using the DIALux tool to evaluate the amount of natural lighting at the three universities. The data required in the DIALux program is a general plan of the buildings, in addition to a detailed plan of the architectural studio and the height of the floor. The building plan is entered into the program in AutoCAD dwg. Then, the file unit is set, the coordinates are determined, and the 3D model is drawn. After drawing the studio rooms, the windows are placed according to the existing dimensions in the chart. Ready-made windows and doors within the program were used after the dimensions were modified. The ceiling is placed after selecting it from the ceilings in the program based on its compatibility with the type present in the building. After that, the material for the walls and ceilings is determined, in addition to the existing furniture consisting of a study table, chair, and whiteboard. After completing the 3D model building, the north for each university is determined. When choosing the university location in the location options, AYBU was present, but for Amasya and Samsun, it was not present, so the latitude and longitude were entered for both. The simulation began as the months, days, and hours that fall during the study season were chosen, starting from 9:00 in September and ending at 17:00 in June. For the academic year 2023-2024, the simulation results and images in PDF format are obtained from the program. The desired perspective can be selected, and its image can be downloaded from the program. The flow of the method is described in Figure 3.1.

3.2.1 Amasya University

Amasya University is a state university in Amasya – Türkiye. Founded on March 17, 2006, the institution offers various undergraduate and postgraduate courses. Amasya University Faculty of Architecture was established with the establishment of the University due to the enactment of the law numbered 26111 dated 17.03.2006, as shown in Figure 3.2. Three years after its establishment, the Departments of Architecture, City, and Regional Planning were established in 2009, and the

Departments and Staff of the Departments of Architecture, City and Regional Planning of the Faculty were established. "The purpose of documenting the faculty in Amasya is to train a professional staff who is sensitive to the historical and cultural characteristics of Amasya, the city of Princes, due to its historical urban structure and the historical characteristics of the nearby provinces and the absence of a Faculty of Architecture in the Central Black Sea region.

The city of Amasya is located at latitude 40.8333 and longitude 35.5167. The city of Amasya is located at latitude 40.8333 and longitude 35.5167. The Department of Architecture at Amasya University is located in the northwest direction as shown in Figure 3.3. The building is designed in three parts parallel to each other at different heights. The part containing the architectural studio rooms consists of 3 floors with a height of 5.4 m on the ground and first floors, while the third floor has a height of 5.4 m and 4.4 m. The building contains seven architectural studio rooms: a studio on the ground floor, a studio on the first floor, and five studio rooms on the third floor, as shown in Figures 3.4, 3.5, and 3.6, respectively.

The pictures were taken during a field visit to the building, and Figure 3.7 showed Studio room Z01 after the Construction building located in the east direction of the building. Information was collected from the AutoCAD file regarding the dimensions of the windows, their orientation, and the area of each studio, as shown in Table 3.1.

During a visit to Amasya University, it was discovered that the building was changed after implementation, as Studio Z01 and Studio 101 were divided into rooms with a change in function. Figure 3.8 shows one of the rooms of Studio Z01 after its division. Figure 3.9 shows Studio 101 before the change, and Figure 3.10 shows one of the parts of Studio 101 that was used as an architectural studio, while Studio 301, 302, and 303 were made into one studio, as shown in Figure 3.11.

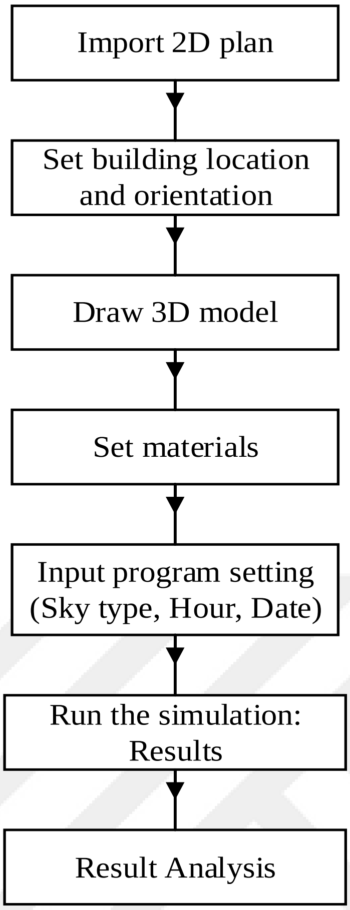

Figure 3.1 Simulation method steps

Figure 3.2 Architecture Department of Amasya University

Figure 3.3 Amasya University site topographic location

Figure 3.4 Plan of studio room Z01

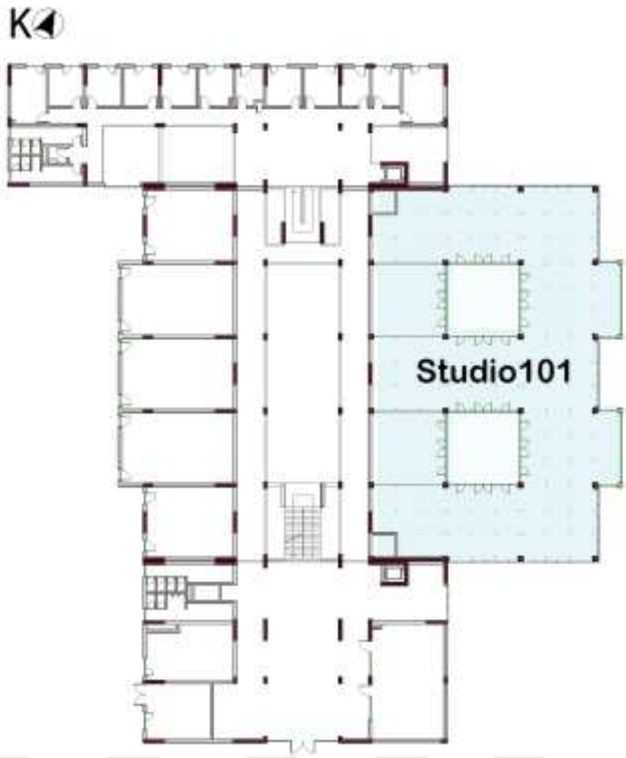

Figure 3.5 Plan of Studio Room 101

Figure 3.6 Plan of studio rooms 301-305

Figure 3.7 Studio room Z01 in Amasya University

Table 3.1 Information on Studio rooms at Amasya University

Room Studio	Area (m^2)	window	direction of windows	Windows Dimensions (Dim)/ (m) Height from the ground (H)/ (m)
Z01	738.55	2	Northwest	Dim = 3.4 × 7, H = 1.25
		5	Northeast	
		2	Southeast	
101	621.02	4	Northwest	Dim =3.4 × 7, H=1.25 (7 windows)
		5	Northeast	Dim =2.25 × 7, H = 4.20 (2 windows)
		4	Southeast	Dim =2.25 × 1.9, H = 4.20 (4 windows)
301	45.96	1	Northeast	Dim =3.45 × 4.80, H = 1.20
302	52.34	1	Northeast	Dim =3.45 × 4.80, H = 1.20
303	52.34	1	Northeast	Dim =3.45 × 4.80, H = 1.20
304	52.34	1	Northeast	Dim =3.45 × 4.80, H = 1.20
305	45.96	1	Northeast	Dim =3.45 × 4.80, H = 1.20

Figure 3.8 Studio Z01 after the change in Amasya University

Figure 3.9 Studio 101 Before the change in Amasya University

Figure 3.10 Studio 101 After the change in Amasya University

Figure 3.11 Studios 303,304 and 305 after the change in Amasya University

Table 3.2 presents the input information on walls, roofs, and furniture, while Figure 3.12 shows the furniture material in studio rooms at Amasya University.

Table 3.2 Material elements of studio rooms in Amasya University

Room studio	**Wall**	**Roof**	**Furniture**
Z01	Matte White Print	Waffle slab ceiling Light white color, not polished	Wood and Metal/ Glass and Metal
101			Glass and Metal
301, 302, 303, 304, and 305			Wood and Metal

Figure 3.12 The materials and furniture at Amasya Studios

3.2.2 Samsun University

Samsun University is in the Turkish city of Samsun and was officially established in 2018. Samsun University's Ballıca campus was transformed from a tobacco barn into the Faculty of Architecture. The university opened in 2020 and began receiving students. Figures 3.13 and 3.14 show the buildings of the Architecture Department and the site's topographic location.

Figure 3.13 Architecture Department of Samsun University

Figure 3.14 Samsun Architecture Department site topographic location

The Architectural Department consists of 2 hangars, and work is underway on the third hangar, as shown in Figure 3.15. On the ground floor of the first hangar, there is Studio 1, to the east of the building, and to the west are the staff rooms, while in the second hangar, Studio 2 is present, as shown in Figure 3.16. Studio 2 represents three-quarters of the hangar's area and is open from both sides to the ceiling, making Studio 3 on the first floor open to Studio 2. Due to its large dimensions, Studio 2 includes two separate sub-studios within the same space. In our analysis, we assume it is a single room for one studio as in its original design. The first floor in Hangar 1 contains rooms for the department's teaching staff, while Hangar 2 contains Studio 3. Hangar 1 is connected to Hangar 2 by a glass-covered bridge.

Table 3.3 lists the studio room's area and the window's direction and dimensions, while Table 3.4 presents materials used for walls, ceilings, and furniture. Images of the building were collected during the field visit to Samsun University. Figure 3.17 shows the room of Studio 1, which is still not in use. A photo taken from the first floor of Hangar 2 illustrates the furniture in Studio 2, as shown in Figure 3.18.

The furniture of Studio 3 is depicted in Figures 3.19 and 3.20. Figure 3.21 shows the ceiling of Studio 1, while the elements used to increase the percentage of incoming light are the ceiling openings shown in Figures 3.22 and 3.23.

Figure 3.15 ground floor plan of Samsun University

Figure 3.16 First-floor plan of Samsun University

Table 3.3 Information on Studio rooms at Samsun University.

Room Studio	Area (m^2)	window	direction window	Window Dimensions (Dim)/ (m) Height from the ground (H)/ (m)
1	480.94	5	East	Dim = 2.6× 2.1, H = 0.12
2	786.95	8	East	Dim = 2.6× 2.1, H = 0.12
		8	West	
3	341.32	8	East	Dim = 2.6× 2.1, H = 0.12
		8	West	

Table 3.4 Material Elements of Studio Room In Samsun University.

Room studio	Wall	Roof	Furniture
1	Matte White Print	Plaster	Wood and Metal
2			
3		Aluminum	

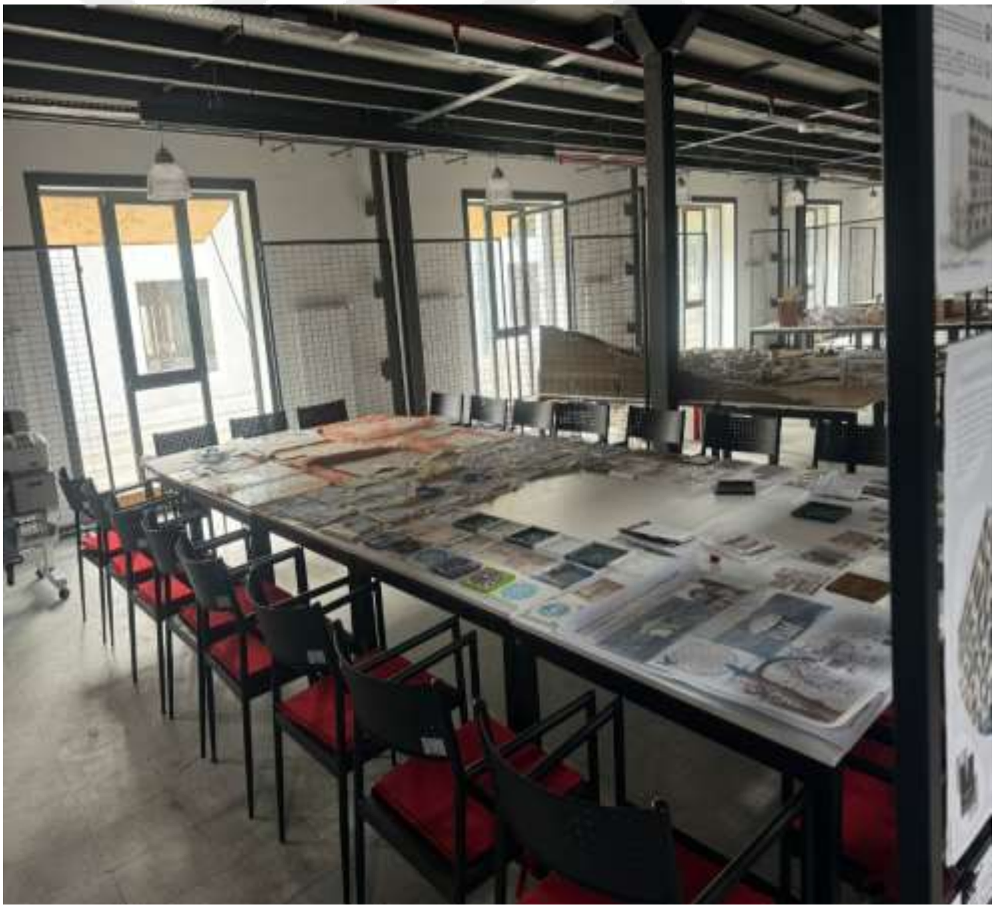

Figure 3.17 Studio 1 of Samsun University

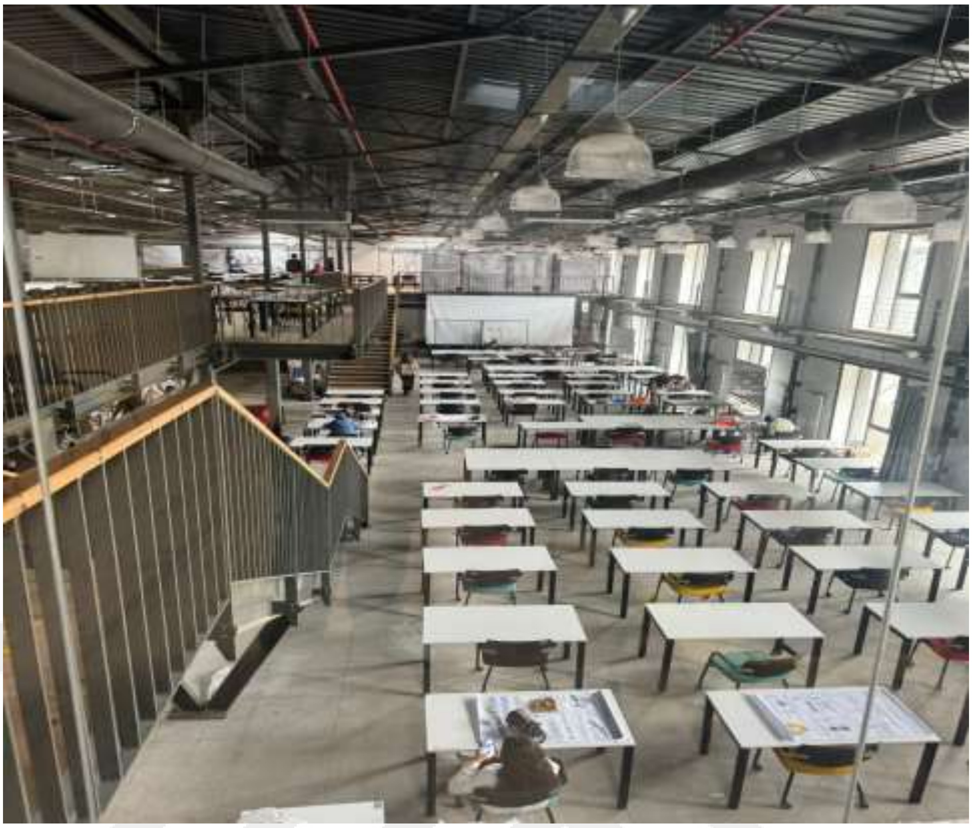

Figure 3.18 Furniture in Studio Room 2 of Samsun University

3.2.3 AYBU

Ankara Yildirim Beyazit University was established on June 21, 2010, and began its educational activity on November 3, 2011. Faculty of Architecture was established in 2013 in Ankara Esenboğa campus in Latitude 40.1281, Longitude 32.995. Figures 3.24 and 3.25 show the buildings of the Architecture Department and the site's topographic location. As mentioned, the building was designed as an educational building for the Laboratory Department. Still, the design was modified, and its function was transferred to the building of the Architectural Engineering Department. The building contains five architectural studio rooms within the D-block, 2nd, and 3rd floors of the Faculty of Architecture and Fine Arts as presented in Figure 3.26 and 3.27 Studio room plan.

Information is collected from the AutoCAD file regarding the dimensions of the windows, their orientation, and the area of each studio, as shown in Table 3.5.

Figure 3.19 Furniture in Studio 3 of Samsun University.

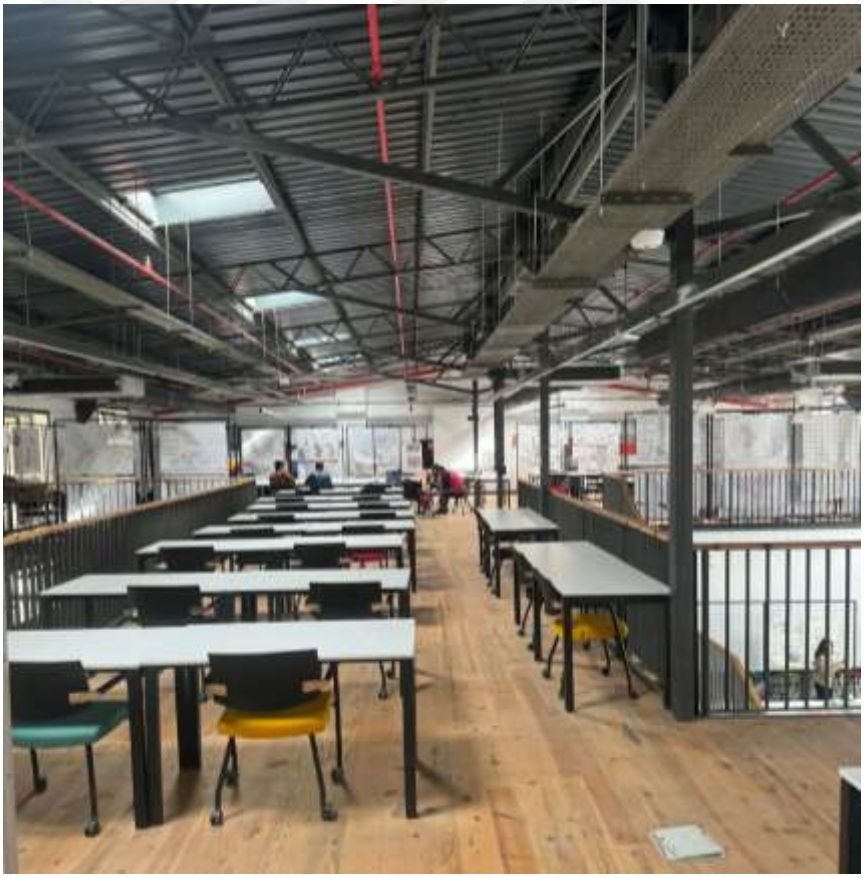

Figure 3.20 Furniture of Studio 3

Figure 3.21 The roof of Studio Room 1 of Samsun University.

Figure 3.22 The skylight in Hanger 1 of Samsun University.

Figure 3.23 The skylight in Hanger 2 Studio 3 of Samsun University.

Figure 3.24 Architecture Department of AYBU

Figure 3.25 AYBU Architecture Department site topographic location

Figure 3.26 Second floor plan of AYBU block D

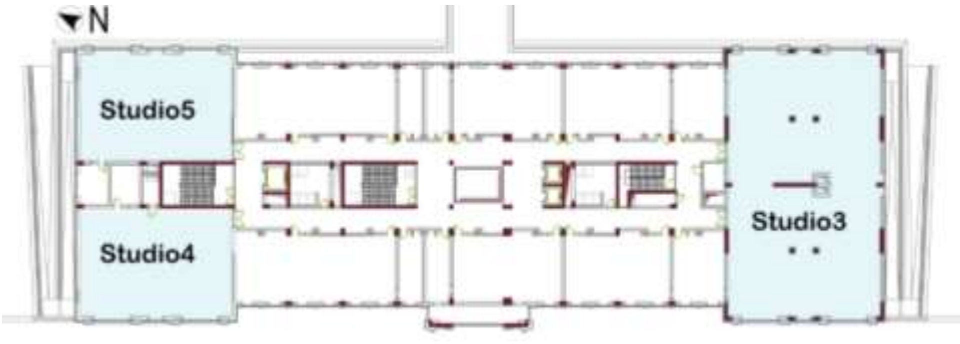

Figure 3.27 Third floor plan of AYBU block D

The pictures were taken during a field visit to the building, and Figure 3.28 showed the windows located in the southeast direction of the building and the curtains used to block the light entering the room. The materials used in the wall, ceiling, and furniture, which consisted of an engineering drawing table and a chair, were identified by visiting the building as in Table 3.6.

Table 3.5 Information on Studio rooms at AYBU.

Room Studio	Area (m^2)	window	direction window	Dimensions (Dim)/ (m)
1	261.73	2	East	Dim = 4× 4
		1	East	Dim = 4× 1.6
		1	South	Dim = 4× 1
2	261.54	2	South	Dim = 4× 4
		1	South	Dim = 4× 1.6
		1	South	Dim = 4× 1
3	519.47	4	2 East / 2 South	Dim = 2.85× 4
		2	1 East / 1 South	Dim = 2.85× 1.6
		1	South	Dim = 2.85× 2.5
4	217.39	2	North	Dim = 2.85× 4
		1	North	Dim = 2.85× 1.6
5	217.22	2	North	Dim = 2.85× 4
		1	North	Dim = 2.85× 1.6

Figure 3.28 Studio 3 in AYBU

Figure 3.29 in Studio 1 shows the window locations and dimensions, ceiling engineering drawing tables, and chairs, while Figure 3.30 represents the furniture in AYBU studios.

Table 3.6 Material elements of studio room in AYBU

Room studio	Wall	Roof	Furniture
1, 2, 3, 4, and 5	Matte White Print	Metal	Glass, Wood, and Metal

Figure 3.29 Studio 1 in AYBU

Figure 3.30 Furniture in the AYBU studios

3.3 Method: DIALux Evo12 Tool

The ability to quantify access to daylight is a significant component of energy usage in building designs to enhance occupant experience. Previous works highlight that the lighting and thermal environment assessment should be performed with the help of simulation tools for dynamic solar and daylight conditions. These tools prove effective in achieving near-optimal designs of the buildings by factoring in wall-to-window ratios, shading, and positioning. Furthermore, with the help of daylight simulations, it is highlighted how using semantic 3D city models aids in assessing daylight accessibility in the context of urban densifications. This leads to the necessity of defining the geodata and the specifications of the 3D models as accurately as possible. In addition, the specification of luminous and thermal environments is crucial in optimizing daylight use in building designs. This underlines the generation of a more enhanced Typical Meteorological Year (TMY) for energy simulation that incorporates daylight needs to be carried out.

3.3.1 What is DIALux?

The German Institute for Applied Lighting Technology (DIAL) was established in 1989 and stands behind the DIALux tool. DIAL encompassed a varied range of services relating to the branch of lighting design and building automation. The DIALux has been its core business since 1994, and it is the first and the only lighting design software in the world. The layout is a well-known program that is used in Indoor/Outdoor lighting control designs, Street lighting, LED lighting, Stadium, area lighting, etc. It is to display all values and to display better quality images. You can also walk around the project, observe its construction, and even film a movie about it for free without entering the activation code. Supported by cross-sectional work of over 120 international corporations.

DIALux also calculates daylight illuminance based on three typical sky conditions: Clear sky, average sky, and overcast sky according to CIE 110–1994 standard. DIALux offers various catalogs concerning commercial electric lighting products, electric light control systems, products connected with daylight, and so forth [72]. Figure 3.31 outlines the advantages of the DIALux tool.

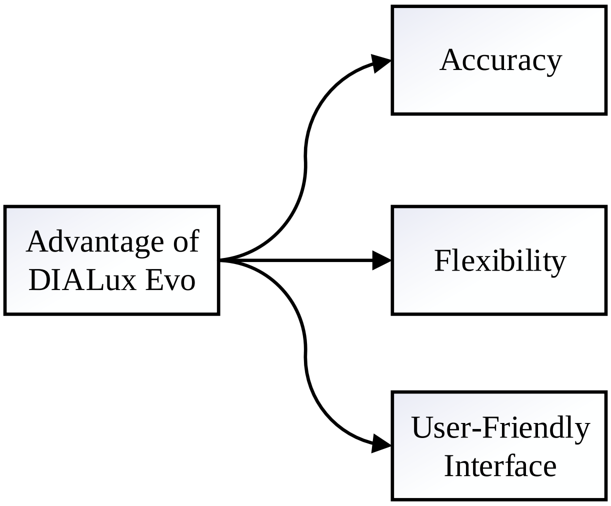

Figure 3.31 Advantages of DIALux Evo [73].

3.3.2 Why DIALux Evo12?

DIALux is used for lighting design and analysis tools due to its approval efficiency, time cost, and accuracy [73]. It offers many features that make it a viral tool. DIALux Evo12 is the new version of DIALux Evo, available free of charge from the official website. Its user-friendly interface includes features like Increased Productivity, Comprehensive Lighting Product Library, Accurate Lighting Calculations, 3D Visualization, and Interactive Simulations. In addition, DIALux Evo has other factors considered, including room conditions, supporting equipment, and surface color, which affect the results [74]. We believe that the accessible version of DIALux Evo 12 used in this research is an excellent simulation tool characterized by its simplicity in design, which makes designing work easier.

DIALux EVO is the most used lighting design tool by users worldwide, and it can generate practical and professional lighting calculations easily [75]. Figure 3.32 presents some essential points for using DIALux Evo in architectural education. It optimizes design solutions, enhances learning, and improves students’ practical skills.

DIALux users face many challenges, such as data accuracy, learning methods, and software limitations. Accuracy is directly related to the input data for simulation, which requires carefully inspecting the materials used within a building. DIALux is considered a high-level tool requiring high competence.

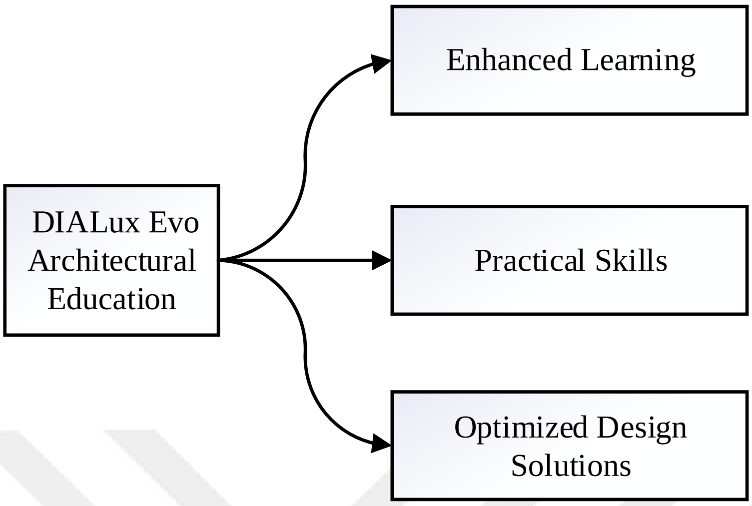

Figure 3.32 Benefits of DIALux Evo in Architectural Education

CHAPTER 4

SIMULATION RESULTS AND DISCUSSION

4.1 Introduction

Simulations of the proposed case study include the three universities in Türkiye: Amasya, Samson, and AYBU Universities. The simulation focuses on the architect's studio rooms in every University. The simulation is conducted for ten (10) months, from September to June, where lectures occur during the educational period. Simulations are performed in clear-sky weather situations, which could be more realistic in the three university locations. Although the weather in the three cities hosting the universities is radically different, this selection of clear sky can serve as a comparison as used in most of the previous research. Additionally, every University simulates the average weather and overcast conditions for one month. Each month, a specific day is chosen, and data is collected at two-hour intervals at 9:00, 11:00, 13:00, 15:00, and 17:00. Table 4.1 gives all the simulated scenarios in a total of 36 scenarios, 12 for every University.

4.2 Amasya University Data

Amasya University/ Architect Department studio rooms are explained in the previous chapter as part of our case study. There are seven studio rooms in Amasya for the architectural department, as shown in Figures 4.1, 4.2, and 4.3.

Table 4.2 presents the collected result of the simulation of the case study Amasya for six scenarios, namely, AMASYA-1, AMASYA-2, AMASYA-3, AMASYA-4, AMASYA-5, and AMASYA-6. Table 4.3 is data collected for the other six scenarios, which are AMASYA-7, AMASYA-8, AMASYA-9, AMASYA-10, AMASYA-11, and AMASYA-12. While the pink color indicates the illuminate’s values superior to 1000 lux, the green color indicates the illuminate’s values ranging between 500 to 1000 lux, and finally, the blue indicates the illuminate’s levels under 500 lux. The European standard states that for comfort in the studio, the lighting should be between

500 and 1000 lux, while when it becomes higher than 1000, this will cause glare. Under the level of 500, the support of artificial lighting is needed.

Table 4.1 Simulated Scenarios

Day	Scenario			
	Amasya	**Samsun**	**AYBU**	**Weather condition**
21-9-2023	AMASYA-1	SAMSUN-1	AYBU-1	Clear Sky
16-10-2023	AMASYA-2	SAMSUN-2	AYBU-2	Clear Sky
21-11-2023	AMASYA-3	SAMSUN-3	AYBU-3	Clear Sky
21-12-2023	AMASYA-4	SAMSUN-4	AYBU-4	Clear Sky
22-1-2024	AMASYA-5	SAMSUN-5	AYBU-5	Clear Sky
21-2-2024	AMASYA-6	SAMSUN-6	AYBU-6	Clear Sky
21-3-2024	AMASYA-7	SAMSUN-7	AYBU-7	Clear Sky
22-4-2024	AMASYA-8	SAMSUN-8	AYBU-8	Clear Sky
22-5-2024	AMASYA-9	SAMSUN-9	AYBU-9	Clear Sky
21-6-2024	AMASYA-10	SAMSUN-10	AYBU-10	Clear Sky
22-1-2024	AMASYA-11	SAMSUN-11	AYBU-11	Average Sky
22-1-2024	AMASYA-12	SAMSUN-12	AYBU-12	Overcast

Figure 4.1 Modeling of Studio Z01

Figure 4.2 Modeling of Studio 101

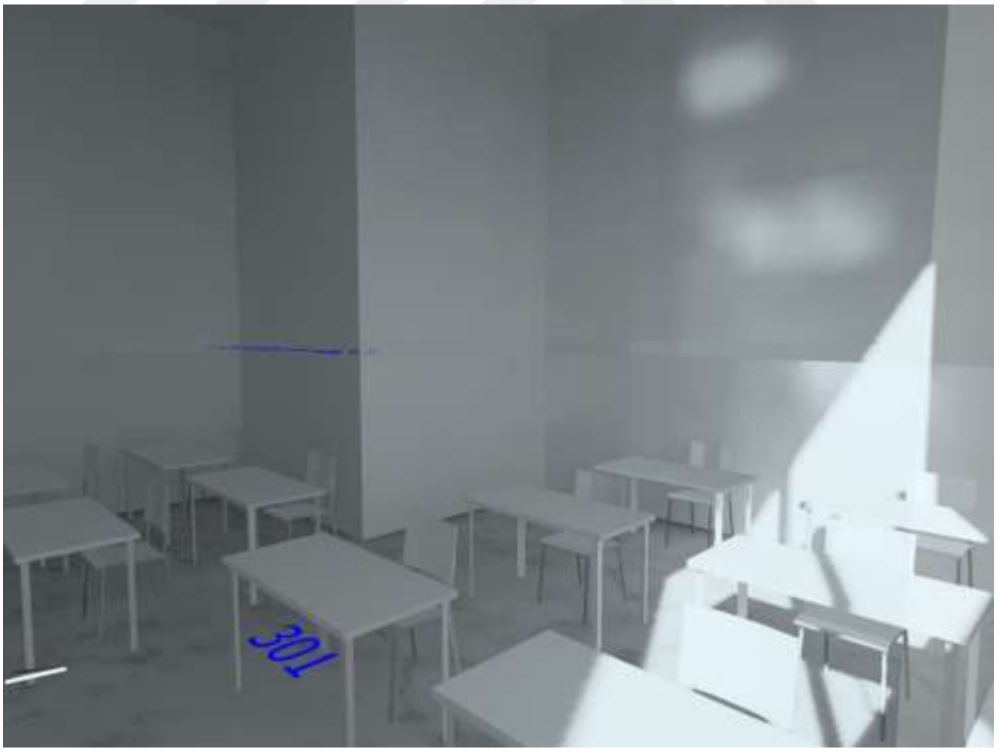

Figure 4.3 Modeling of Studios 301-305

Table 4.2 Scenarios AMASYA-1 to AMASYA-6 simulation results

Scenario	AMASYA-1					AMASYA-2				
Time / Room	9:00	11:00	13:00	15:00	17:00	9:00	11:00	13:00	15:00	17:00
Studio Z01	6263	4222	2207	860	569	5045	4259	1942	761	1207
Studio 101	6113	5325	3129	1119	567	1300	5437	3061	1032	350
Studio 301	9981	1957	1226	1063	747	5901	1528	1153	971	487
Studio 302	8183	1817	1135	1000	706	4886	1392	1068	914	460
Studio 303	8877	1840	1138	996	700	5182	1415	1074	909	458
Studio 304	8751	1824	1128	979	690	5269	1432	1067	895	451
Studio 305	9444	2003	1227	1065	750	5577	1535	1154	972	489
Scenario	AMASYA-3					AMASYA-4				
Studio Z01	2487	3549	1322	622	122	1213	3218	1237	592	105
Studio 101	2078	4426	2531	674	117	1051	3757	2430	645	99.9
Studio 301	1804	1232	1016	786	167	1203	1124	965	741	143
Studio 302	1666	1126	947	740	158	1046	1030	898	700	135
Studio 303	1648	1147	948	736	157	1073	1046	901	694	134
Studio 304	1619	1182	946	725	154	1099	1091	905	683	132
Studio 305	1821	1238	1018	790	167	1191	1127	970	741	143
Scenario	AMASYA-5					AMASYA-6				
Studio Z01	1549	3629	1844	696	263	3922	4384	2403	813	463
Studio 101	1237	4252	3074	911	253	3115	5403	3634	1355	450
Studio 301	1590	1316	1060	856	355	4342	1989	1194	1000	619
Studio 302	1378	1213	984	806	336	3704	1742	1105	940	585
Studio 303	1422	1231	988	802	333	3892	1780	1107	935	581
Studio 304	1466	1275	988	790	328	3968	1788	1108	923	572
Studio 305	1581	1340	1061	858	356	4226	1985	1197	503	621

4.2.1 General Observation

The results show that in the timing period from 9:00 to 13:00, daylighting values are higher than 1000 for most scenarios. This is due to:

- The high window dimensions (total aperture area) cause more irradiation to enter into the buildings,
- The building's orientation to the east allows sunlight to enter through the windows all day,

- The existence of a skylight in studio Z01, and studio 101,
- The high lux level in studios 301, 302, 303, 304, and 305 can be attributed to their tiny room size. Compared to the larger studios such as Z01 and 101, the compact dimensions ensure a more concentrated light distribution, leading to higher lux levels.

Table 4.3 Scenarios AMASYA-7 to AMASYA-12 simulation results

Scenario	**AMASYA-7**					**AMASYA-8**				
Time / Room	9:00	11:00	13:00	15:00	17:00	9:00	11:00	13:00	15:00	17:00
Z01	6321	4427	2472	925	618	7071	3815	1987	887	740
101	5873	5615	3448	1286	623	6922	4900	2573	945	904
301	9468	2777	1257	1078	809	15007	3409	1280	1107	933
302	8002	2219	1161	1012	763	12635	2539	1185	1039	883
303	8528	2251	1164	1007	758	13181	2588	1183	1032	875
304	8746	2259	1157	992	746	13283	2592	1170	1016	862
305	9179	2765	1263	1080	813	14385	3418	1286	1111	939
Scenario	**AMASYA-9**					**AMASYA-10**				
Z01	7023	3279	1598	899	816	6983	3207	1456	901	868
101	7013	4240	1923	933	1281	6944	4140	1716	948	1456
301	17425	4301	1305	1122	1000	18275	5354	1337	1132	1033
302	14760	3199	1210	1054	946	15809	4172	1235	1062	975
303	15341	3268	1205	1043	936	16293	4246	1233	1051	968
304	15437	3252	1190	1029	921	16350	4174	1217	1037	951
305	16751	4309	1310	1130	1005	17834	5369	1343	1139	1041
Scenario	**AMASYA-11**					**AMASYA-12**				
Z01	677	2306	1546	607	95.2	224				
101	562	2624	2210	788	107	241				
301	753	1473	1351	737	119	334				
302	655	1354	1230	676	111	309				
303	670	1370	1243	674	110	305				
304	686	1381	1239	668	108	300				
305	745	1491	1360	743	121	337				

4.2.2 Comparison of Various Weather Conditions

Two specific scenarios to evaluate the lighting in the case of average sky (AMASYA-11) and overcast (AMASYA-12) are under focus. The AMASYA-11 scenario is compared with AMASYA-5 and AMASYA-12 because all three are simulated for the same date (22 January) but with different weather conditions. Figures 4.4 and 4.5 show that the lighting inside the two studios is higher in the case of clear weather compared to other cases.

The overcast resulting minimum natural lighting equals 224 lux for studio Z01 and 241 lux for studio 101, under the 500-lux level. Given that the quantity of natural lighting is higher in clear-sky situations than in the average sky, the curve of the average is always under that of the clear sky. Both weather conditions yield a daylighting level higher than the maximum accepted level (1000 Lux).

4.3 Samsun University Data

The Samsun University's Architect Department studio rooms, a significant part of our case study, were detailed in the previous chapter. Three studio rooms in Samsun, each unique in its architectural design and lighting conditions, are depicted in Figures 4.6, 4.7, and 4.8.

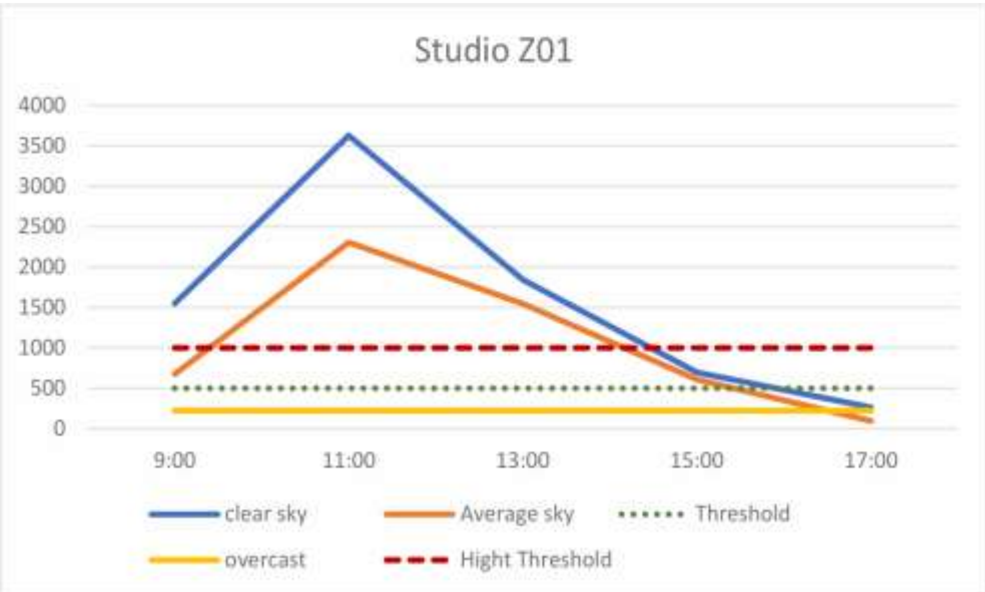

Figure 4.4 Results of AMASYA-5, 11, and 12 for studio Z01

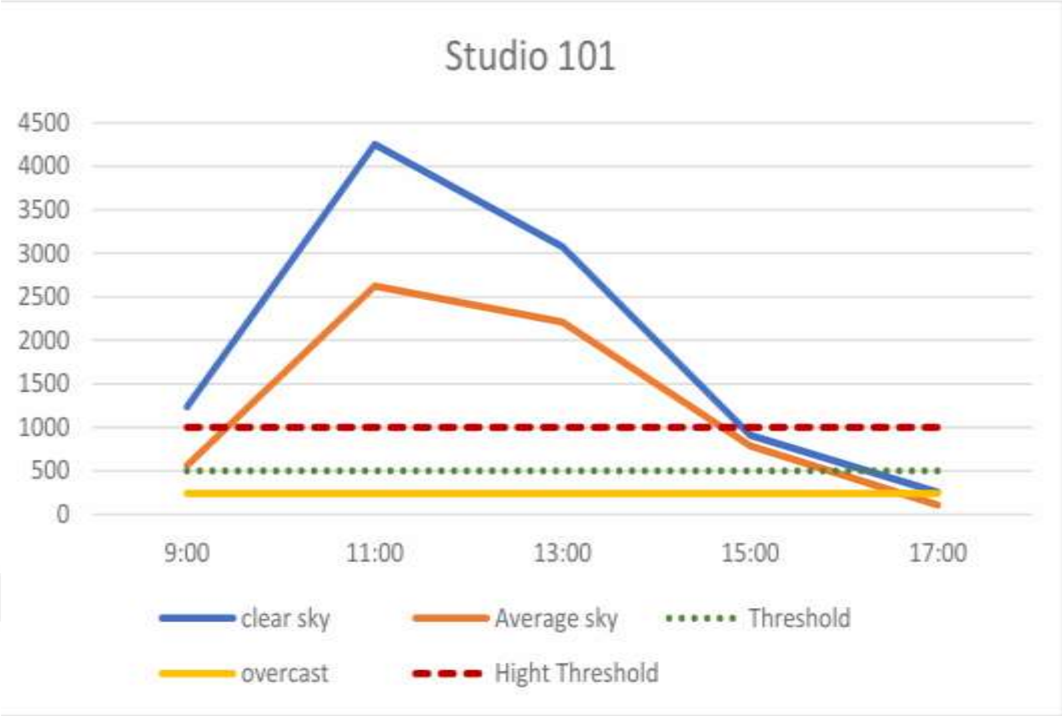

Figure 4.5 Results of AMASYA-5, 11, and 12 for Studio 101

Table 4.4 presents the comprehensive simulation results of the Samsun University case study. It covers all possible scenarios (12) from SAMSUN-1 to SAMSUN-12. The data in Table 4.4 is meticulously collected and organized, with scenarios of similar conditions color-coded for easy reference.

4.3.1 General Observations

The results show that many remarks can be deduced:

- The daylighting has values less than 500 Lux for most of the scenarios for studio one because this room is open to the sun from one side while many administration offices are placed on the other.
- The existence of breakers placed at window facades decreases the lighting entering the building, so there are few cases with lighting levels superior to 1000 Lux,
- The existence of a skylight in Studio 2 and Studio 3,

- The results show that October, November, December, and January usually have low illumined values, while September, February, March, April, June, and July have illumined values mostly superior to 500 Lux. It took us a while to solve the problem of low illumined values.

4.3.2 Comparison of Various Weather Conditions

The lighting in the case of average sky (SAMSUN-11) and overcast (SAMSUN-12) are compared with SAMSUN-5 because all three are simulated for the same date (22 January) but with different weather conditions. Figures 4.9, 4.10, and 4.11 show that the lighting inside the three studios is higher in the case of clear weather compared to other cases. The overcast resulting minimum natural lighting equals 26.8, 49.2, and 52.8 Lux for studios 1, 2, and 3. Although the quantity of natural lighting is higher in explicit sky situations than in the average sky, both curves are under 500 Lux except for small periods for studio two and studio 3.

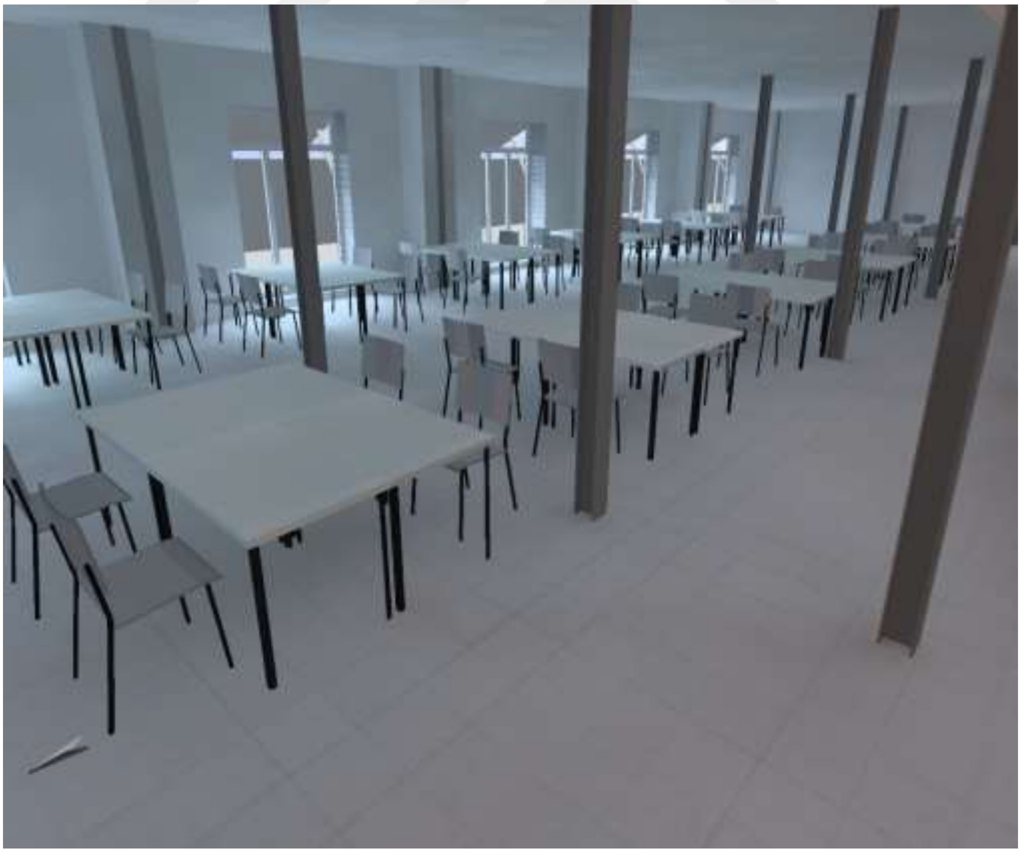

Figure 4.6 Modeling of Studio 1

Figure 4.7 Modeling of Studio 2

Figure 4.8 Modeling of Studio 3

Table 4.4 Scenarios SAMSUN-1 to SAMSUN-12 simulation results

Scenario	SAMSUN-1					SAMSUN-2				
Time / Room	9:00	11:00	13:00	15:00	17:00	9:00	11:00	13:00	15:00	17:00
Studio 1	850	359	344	295	91.2	763	356	376	142	50.0
Studio 2	1286	632	356	785	1139	1192	608	355	973	426
Studio 3	901	702	716	805	798	761	626	600	760	307
Scenario	**SAMSUN-3**					**SAMSUN-4**				
Studio 1	442	315	259	101	13.2	234	316	196	94.3	10.7
Studio 2	686	513	314	741	50.5	351	507	271	637	39.4
Studio 3	445	473	410	535	38.9	248	430	328	456	30.5
Scenario	**SAMSUN-5**					**SAMSUN-6**				
Studio 1	304	400	187	118	33.4	702	455	211	219	68.6
Studio 2	432	632	287	718	170	1043	717	326	785	698
Studio 3	308	532	391	555	130	661	661	538	717	495
Scenario	**SAMSUN-7**					**SAMSUN-8**				
Studio 1	921	404	266	400	103	767	308	304	476	132
Studio 2	1390	694	350	727	1262	1167	642	360	612	1548
Studio 3	905	722	702	850	846	915	771	866	932	1018
Scenario	**SAMSUN-9**					**SAMSUN-10**				
Studio 1	614	267	356	680	148	592	257	324	804	157
Studio 2	935	590	359	500	1538	874	586	358	433	1434
Studio 3	893	813	951	928	1029	894	822	979	906	1027
Scenario	**SAMSUN-11**					**SAMSUN-12**				
Studio 1	130	261	176	91.7	10.6	26.8				
Studio 2	179	415	305	424	50.1	49.2				
Studio 3	134	368	355	350	42.3	52.8				

Figure 4.9 Results of SAMSUN-5, 11, and 12 for Studio 1

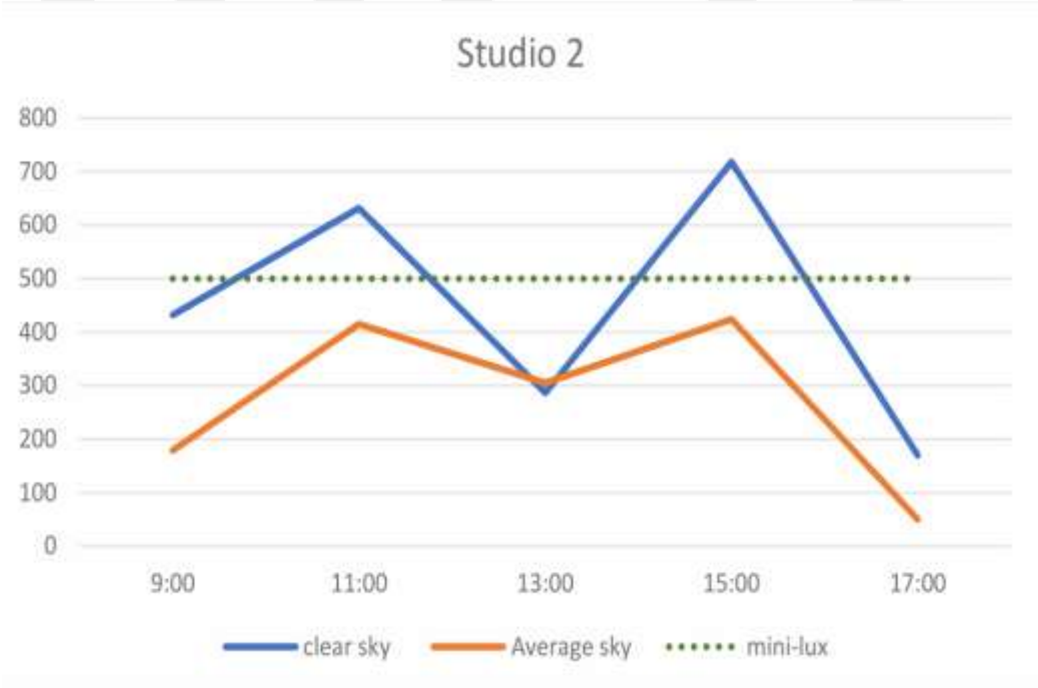

Figure 4.10 Results of SAMSUN-5, 11, and 12 for Studio 2

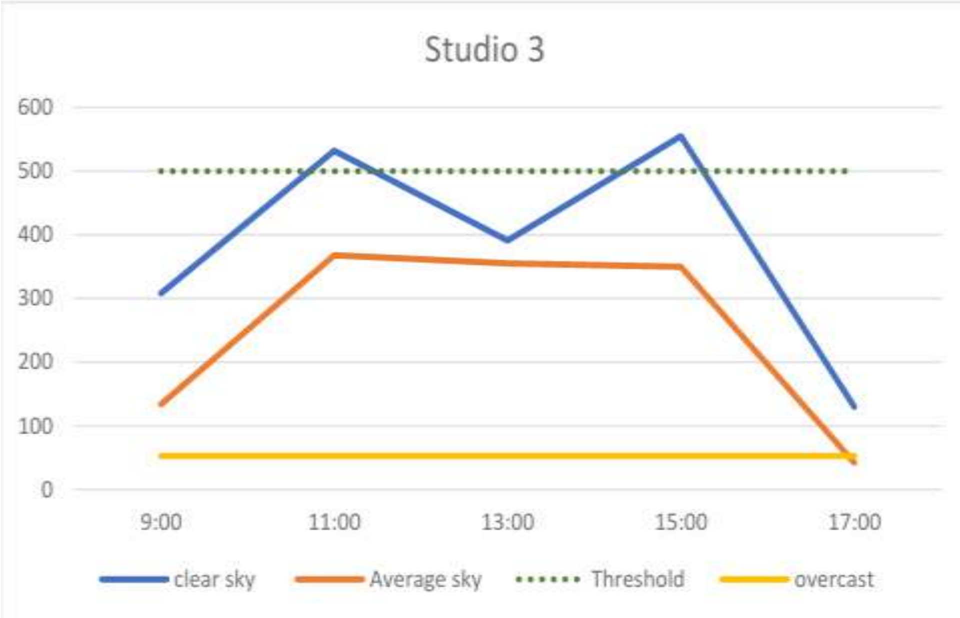

Figure 4.11 Results of SAMSUN-5, 11, and 12 for Studio 3

4.4 AYBU Data

AYBU/ Architect Department studio rooms are the third group of studios under study. There are five studio rooms in AYBU for the architectural department, namely Studios 1, 2, 3, 4, and 5, as shown in Figures 4.12, 4.13, and 4.14, three of which are shown.

Table 4.5 presents data collected by DIALux simulation of the case study AYBU for all scenarios (12 scenarios) from AYBU-1 to AYBU-12, where pink, green, and blue colors have the same meaning as previous university results.

4.4.1 General Observation

The results show that

- Since 500 lux is the lowest acceptable level, while 1000 lux is the highest permissible level, daylight values are almost evenly distributed between the lowest and highest levels and between these two levels with little increase in those above the highest level

- The results show that January and February usually have lower illumined values than other months, while April, June, and July have the highest daylighting values.
- From the point of view of the quantity of daylight, studios 1, 2, and 3 are better than studios 4, and 5.
- The most noticeable increase in daylight occurs in the afternoon. It is undoubtedly related to the position and orientation of studios.
- The lighting quantity is calculated by DIALux as an average of the illuminance on some predefined points inside every studio. As an example of a more detailed analysis, Figure 4.15 shows the daylighting result in simulated points of S3 for scenario AYBU-5.

4.4.2 Comparison of Various Weather Conditions

The lighting in the case of the average sky (AYBU-11) and overcast (AYBU-12) are compared with AYBU-5 because all three are simulated for the same date (22 January) but with different weather conditions. The lighting inside the studios behaves according to the location and orientation of rooms, as shown in Figures 4.16, 4.17, 4.18, and 4.19. Studio 1 is located in the direction of sunrise, so daylight is highest before noon, decreasing rapidly in the afternoon, reaching the minimum level near 15:00. The situation is the opposite in the case of Studio 2, as it faces the setting sun, which makes the lighting more intense in the afternoon as in Figure 4.17. The same conclusion for the latter can be generalized to studio three and studio four, as in Figure. 4.18. and Figure 4.19. Studio 5 windows face the North, so daylight is less than in the four previous studios, as presented in Figure 4.20. The overcast resulting minimum natural lighting equals 85, 45, 67, 69, and 70 Lux for studios 1, 2, 3, 4, and 5.

Figure 4.12 Modeling of Studio 1

Figure 4.13 Modeling of Studio 3

Figure 4.14 Modeling of Studio 5

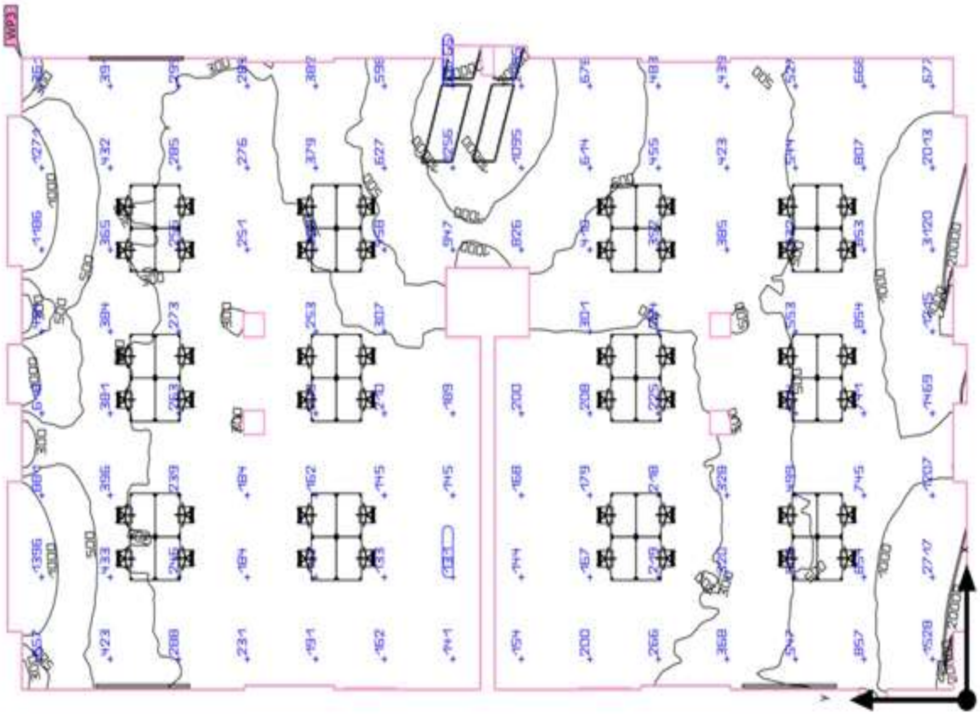

Figure 4.15 Distribution of lighting inside Studio S3

Table 4.5 Scenarios AYBU-1 to AYBU-12 simulation results

Scenario	AYBU-1					AYBU-2				
Time	9:00	11:00	13:00	15:00	17:00	9:00	11:00	13:00	15:00	17:00
Studio 1	3105	1585	803	455	268	2169	1199	828	466	192
Studio 2	339	612	955	2261	1761	367	688	1437	2045	907
Studio 3	1470	1048	1015	1779	1349	1127	906	1133	1688	690
Studio 4	255	341	1288	3405	2769	224	341	1502	3274	1362
Studio 5	2668	1258	346	294	220	1961	812	329	273	155
Scenario	AYBU-3					AYBU-4				
Studio 1	966	904	791	423	89.3	459	832	777	443	81.7
Studio 2	227	651	976	2205	146	123	577	834	3500	123
Studio 3	553	726	1063	1301	147	278	671	940	1159	127
Studio 4	156	306	1361	2439	232	110	270	1090	2089	196
Studio 5	860	481	295	228	72.1	404	491	284	216	65.3
Scenario	AYBU-5					AYBU-6				
Studio 1	580	1137	855	529	157	1563	1684	911	557	245
Studio 2	132	587	1225	1477	627	234	630	993	4612	1322
Studio 3	338	807	922	1362	417	824	1038	945	1625	1026
Studio 4	117	275	941	2448	739	176	308	930	2960	2046
Studio 5	517	785	311	246	120	1404	1225	346	282	188
Scenario	AYBU-7					AYBU-8				
Studio 1	3044	1864	851	496	287	4162	1986	709	415	319
Studio 2	302	595	846	5427	6236	277	488	1454	5518	3721
Studio 4	240	329	1007	3254	3190	279	332	987	3326	3829
Studio 5	2628	1524	358	298	235	3375	1665	355	302	265
Scenario	AYBU-9					AYBU-10				
Studio 1	4681	2106	614	385	335	6429	2288	591	378	342
Studio 2	246	387	1211	3231	3714	233	339	505	4581	3840
Studio 3	1812	1110	673	1550	1749	1828	1138	575	1444	1747
Studio 4	289	327	825	3135	3832	290	322	643	2932	3723
Studio 5	3573	1778	357	304	280	3653	1915	364	306	286
Scenario	AYBU-11					AYBU-12				
Studio 1	243	807	725	388	59.1	85.1				
Studio 2	55.5	394	833	875	269	45.8				
Studio 3	140	571	739	827	166	67.6				
Studio 4	50.7	288	789	1425	296	69.7				
Studio 5	213	584	385	216	43.6	69.9				

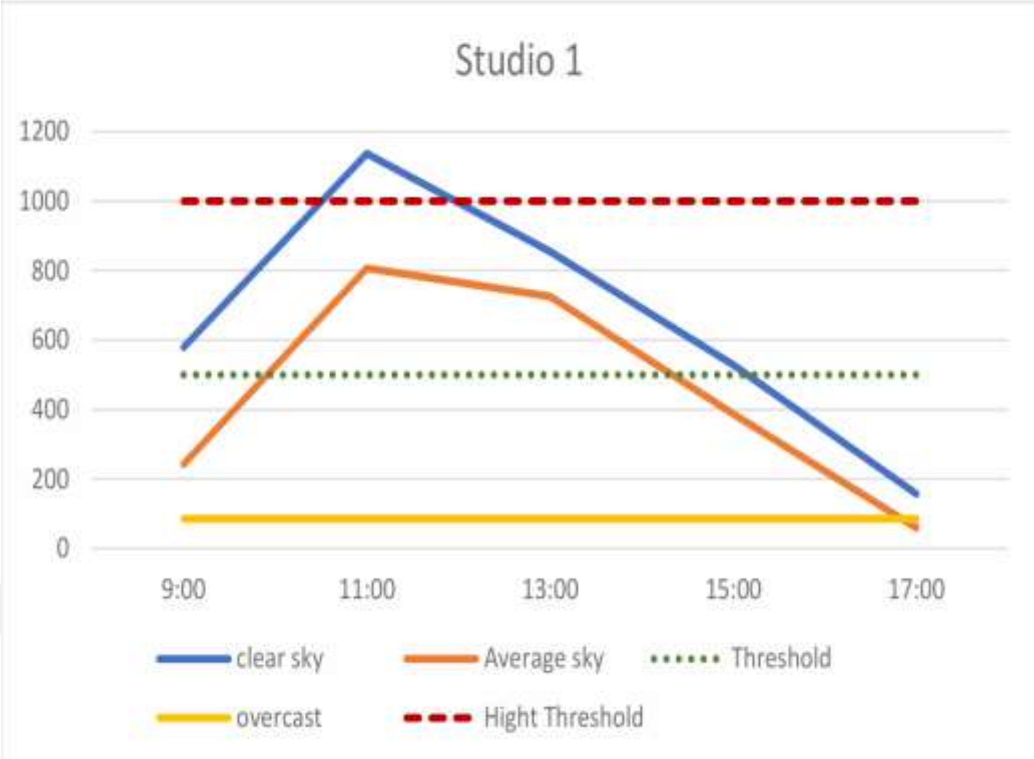

Figure 4.16 Results of AYBU-5, 11, and 12 for Studio 1

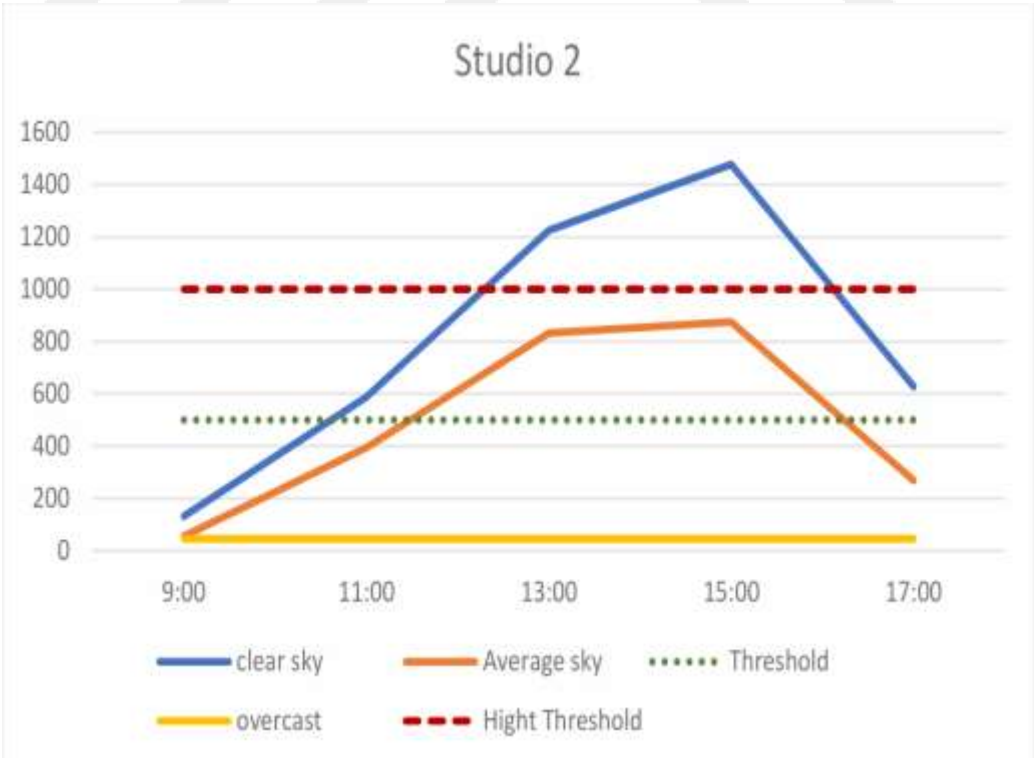

Figure 4.17 Results of AYBU-5, 11, and 12 for Studio 2

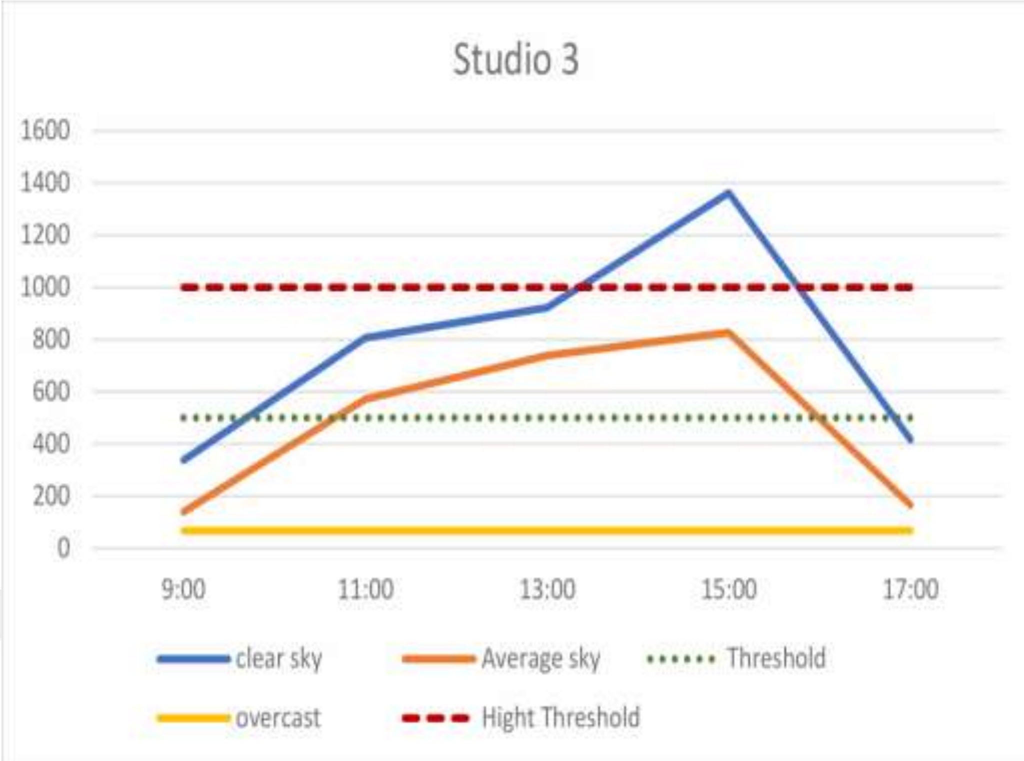

Figure 4.18 Results of AYBU-5, 11, and 12 for Studio 3

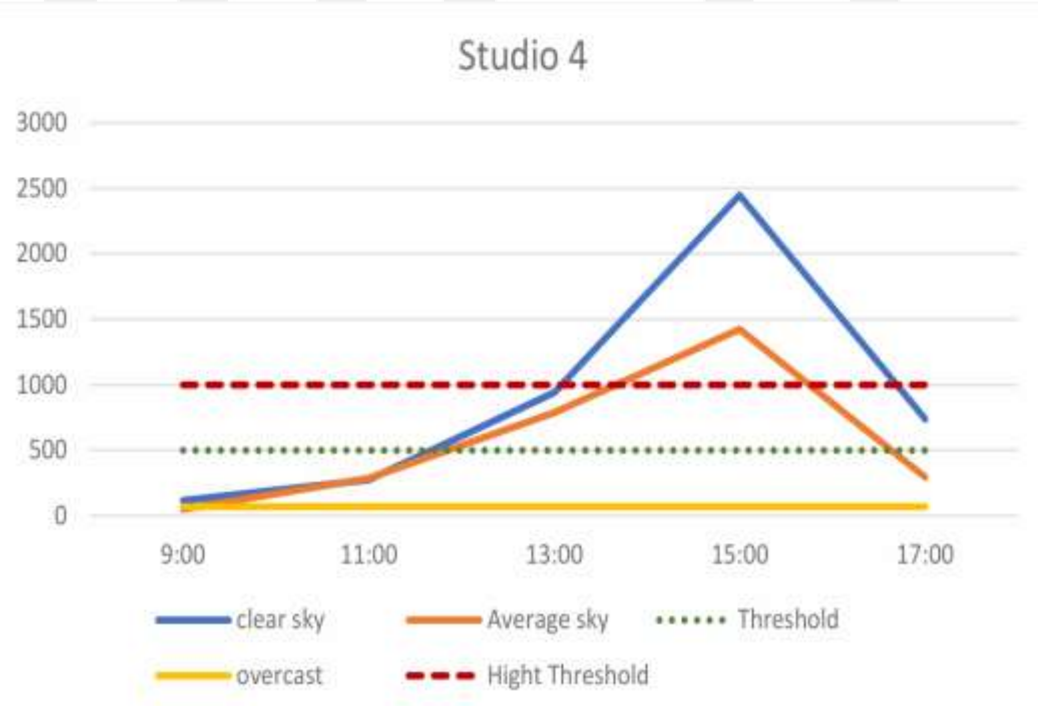

Figure 4.19 Results of AYBU-5, 11, and 12 for Studio 4

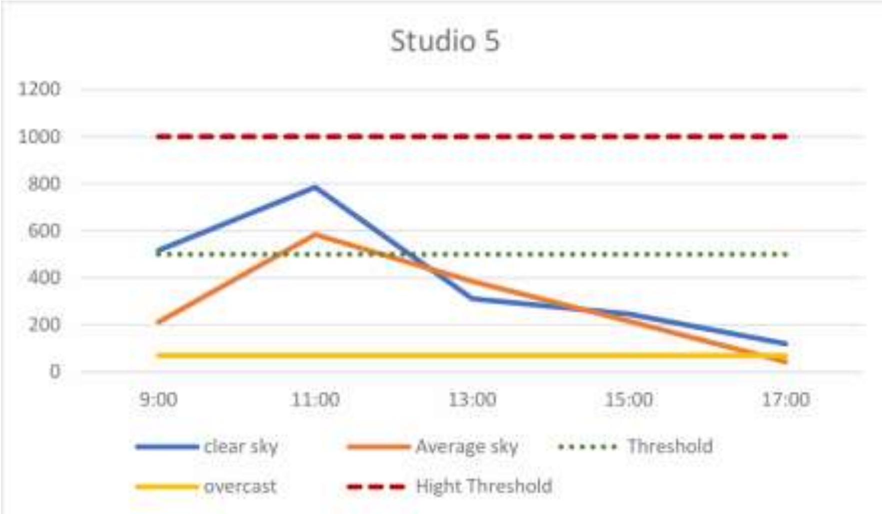

Figure 4.20 Results of AYBU-5, 11, and 12 for Studio 5

4.5 Comparison of the Results of the Three Universities

To compare the results collected from the three universities, Tables 4.6, 4.7, and 4.8 summarize the total results. The tables show the percentage of each studio room's conditions (acceptable, high, and low lighting). These results can be used to compare studios at one university or between different universities. Tables represent the data collected in (10) months for clear sky weather conditions. Since there are five points to collect information daily, there will be 50 points for every studio, while the total points for one university will depend on the studio number.

4.5.1 Comparison Between Studios at Amasya University

Table 4.6 shows a correlation between results from various studios at Amasya University. The percentage of accepted lighting results is around 30% for all studios. This result is confirmed for the total number of measured points, where this percentage equals 32%. The rate of over-lighting is higher than in under and accepted lighting situations. Around 60% of the situations are over-lighting, while only 8% is the percentage of points of under-lighting. While the percentage of under-lighting is practically equal for all studios, Studios 302, 303, and 304 perform better in terms of accepted-lighting. This is due to their small size and orientation. After our physical inspection of these buildings, the nature of windows with higher dimensions causes these results.

Table 4.6 Percentage of lighting levels for Amasya University

Studio	Over Lighting	% Over Lighting	Under lighting	% Under lighting	Accepted lighting	%Accepted lighting
Z01	31	62%	4	8%	15	30%
101	34	68%	5	10%	11	22%
301	30	60%	4	8%	16	32%
302	28	56%	4	8%	18	36%
303	28	56%	4	8%	18	36%
304	28	56%	4	8%	18	36%
305	30	60%	4	8%	16	32%
Total	209	59.7 %	29	8.3%	112	32%

4.5.2 Comparison Between Studios at Samsun University

Results of Table 4.7 describe the daylighting situation at the University of Samsun. A significant difference between studios 1, 2, and 3 is noticed. Studio 2 and 3 have similar positions, orientations, and interior design, while in Studio 1, some offices are implemented inside. It is why, in the latter, most of the measurement points fell within the under-lighting situation; here, 82%. Results indicate no over-lighting in Studio 1 and 3, while the test points with under-lighting are 82% and 28% respectively. There are significant differences between the two studios concerning accepted lighting, equal to 18% and 72%, respectively. For Studio 2, over-lighting, under-lighting, and accepted lighting are 16%, 24%, and 50%, respectively. Studio 3 performs better than all the studios analyzed in this research with an acceptable illumination ratio of 72%.

Table 4.7 Percentage of lighting levels for Samsun University

Studio	Over Lighting	% Over Lighting	Under lighting	% Under lighting	Accepted lighting	%Accepted lighting
Studio 1	0	0%	41	82%	9	18%
Studio 2	8	16%	17	34%	25	50%
Studio 3	0	0%	14	28%	36	72%
Total	8	5.3%	72	48%	70	46.7%

4.5.3 Comparison Between Studios at AYBU

In the case of AYBU, the lighting inside the five studios depends significantly on the orientation and position of every studio. Over-lighting test points range from 56% to 26%, and the average over-lighting of the five studios is 39%. Studio 3 is the studio with the maximum over-lighting at 56%, while studio 5, due to its location, gives only 26% as over-lighting measurement points. Studio 3 has windows facing the east and the west, so sunrise enters practically all day inside the studio. This explains why this studio's underlighting percentage is minimal compared to the other rooms and equals 10%. Studios give a rate between 66% to 30% of under-lighting measurement points. The maximum value is 66% for studio five, which is oriented far from the sunrise and the sunset. The percentage of accepted lighting ranges from 8% in the case of studio 5 to 34% in the case of studio 3. So, studio 3 is better in overall lighting analysis.

Table 4.8 Percentage of lighting levels for AYBU

Studio	Over Lighting	% Over Lighting	Under lighting	% Under lighting	Accepted lighting	%Accepted lighting
Studio 1	15	30%	19	38%	16	32%
Studio 2	20	40%	15	30%	15	30%
Studio 3	28	56%	5	10%	17	34%
Studio 4	21	42%	22	44%	7	14%
Studio 5	13	26%	33	66%	4	8%
Total	97	38.8%	94	37.6%	59	23.65

4.5.4 Comparison Between the Three Universities

This comparison is based on data collected from the simulation of the three case studies. The percentage of over-lighting, under-lighting, and accepted-lighting in every case study is used as comparison criteria. Comparing the three universities, in the case of Amasya University, the excess lighting amounts to about 60% of the test points.

The studios in this university face the sunrise and sunset with big windows letting entering daylight. At Samsung University, only 5.3% of testing points are over-lighting. It can be explained by the fact that the Samsung building was not designed for educational purposes but was adopted for Architect Department studios after that. The architects then worked to improve the lighting in these three studios, resulting in better results in acceptable lighting, excessive lighting, and dim lighting compared to the other two universities. Around 39% of test points fall on end over-lighting situations in the case of AYBU. At the same time, accepted lighting is 30% at Amasya University, 46.7% at Samsung, and 23.6% at AYBU. This shows that Samsung is much better than the two other universities, followed by Amasya University.

Results show that University Studios suffer from over-lighting and require improvement measurements to daylighting in clear skies. Samsun University's situation is different because lighting needs to be improved to increase the quantity and quality of daylight entering studios. In the case of AYBU, the percentage of the three situations is close enough to require the proposal of both measurements to increase and decrease lighting according to the situation.

4.6 Improvement of the Daylight and Proposed Solutions

In most previous works, improving daylighting is related to changing materials or windows. It is noted that most of the improvements are associated with enhancing the window opening because it represents the path through which daylight passes. From this conclusion, it was suggested that some changes in the original plans of different universities be studied to collect data and compare them with the original plans. Adding a facade outside all windows in Amasya and AYBU and removing the existing facade at Samsun University are suggested.

4.6.1 Installation of Façade at Amasya Studios

Our previous case study simulations proved that the over lighting is the main problem at Amasya University. To solve this problem, a facade to decrease the lighting entering studios during working hours is proposed as a design solution. Figure 4.21 shows the implementation of the facade on the windows in Z01. Table 4.9 gives the simulation results for this case study. Results show that by implementing the new facade, daylight has decreased to a level ranging from 50% to 15% of its original values. It is a radical solution for the excess illumination during working days in architectural studies at

Amasya University. The simulation was conducted only for studio Z01, but the same method can be extended to all studios. Figure 4.22 compares lighting before and after breakers installation for studio Z01. Lighting after breaker installation is attenuated to be within or close to the accepted level.

Figure 4.21 Amasya University façade change

Table 4.9 Daylight proportion for Clear sky on 21/9/2023

Room	**9:00**	**11:00**	**13:00**	**15:00**	**17:00**
Studio Z01	838	1341	1242	428	278

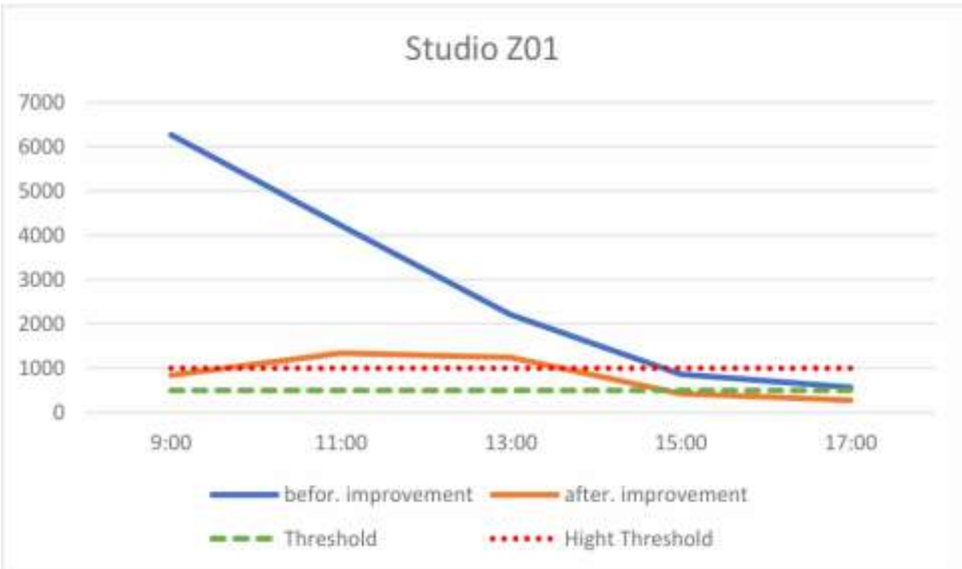

Figure 4.22 Results within Breakers in the Façade of Amasya Z01 studio

4.6.2 Façade Change at Samsun University Studios

Samsun University results in the previous section show a problem with under-lighting during working hours. A modification has been made to the existing plan of the University studios to solve this problem. This modification tries to improve the daylighting within these buildings. The existing plan at Samsun University has a fixed facade, as was noted during our visit to the buildings on all windows, as shown in Figure 4.23. This façade is removed from the initial plan to see how it affects daylighting inside the buildings. The simulation is performed in two cases. The first case is with a clear sky, and the second is with an average sky. Both simulations were performed on 22 January, which is analogous to the case studies of SAMSUN-5 and SAMSUN-11.

Table 4.10 shows an increase in daylighting for the average sky. This improvement tends to double the quantity of lighting during simulation hours. Before modification, all hours with the simulation scenario SAMSUN-11 were under illumination. After removing the facade, the results show six green simulation points, meaning the daylight level is between 500 and 1000 Lux. Simulation points, which are nine, are still under lighting, but the illumination quantity has doubled. The same conclusions can be drawn by inspecting Table 4.11, which gives the simulation of a case study analogous to SAMSUN-5 with a clear sky after modification. The original lighting values were all under lighting situations except 4 for them. After modification, there are 5 points for acceptable lighting, 2 points for over-lighting, and the rest for still underlighting. This modification can be very efficient by providing an automatic or adaptive facade technique using digital electronics and new sciences like the Internet of Things (IoT) so the façade will be adjusted according to the daylight quantity, resulting in optimal lighting inside the building during all days.

4.6.3 Installation of Façade at AYBU

AYBU sometimes requires decreasing daylight and increasing it at other times. To solve this problem, window breakers are added, as shown in Figure 4.24. Figure 4.25 presents an interior view of the studio for studio X2 as an example of the new design for all studios within AYBU. The simulation was conducted for AYBU on 21 September (similar to the AYBU-1 scenario), and the results are given in Table 4.12.

Figure 4.23 Existing Façade in Samsun University studios.

Table 4.10 Daylight for Average sky on 22/1/2024 for Samsun University.

Room Name	9:00	11:00	13:00	15:00	17:00
Studio1	192	423	264	136	16.5
Studio2	273	739	554	748	79.5
Studio3	208	604	541	582	66.4

Table 4.11 Daylight for clear sky on 22/1/2024 for Samsun University.

Room Name	9:00	11:00	13:00	15:00	17:00
Studio1	434	620	247	160	48.7
Studio2	625	1051	458	1197	251
Studio3	464	838	523	899	198

Figure 4.26 represents the original daylight situation in a clear sky compared to the same. Still, after the addition of breakers for studio 1, the improvement is evident as daylight is decreasing to be within the acceptable range between 9:00 and 14:00. In contrast, the daylight quantity decreases under 500 Lux. The same improvement is made in Figures 4.27, 4.28, 4.29, and 4.30 for studios 2, 3, 4, and 5, respectively. Daylighting is sometimes decreed by dividing it by a factor of five (5). This shows the efficiency of the method used to decrease daylight quantity. Studio 3 performs better

than all studios after the installation of breakers because the lighting in this scenario falls always within the acceptable range.

The introduction of adjustable breakers presents a promising solution to maintain optimal daylight levels in all AYBU studios, ensuring a comfortable student working environment. This enhances their learning experience and contributes significantly to energy conservation, a key concern for the university.

Figure 4.24 Change of the Façade at AYBU

Figure 4.25 Studio 4 within Breakers in the Façade of AYBU

Table 4.12 Daylight for Clear sky on 21/9/2023 after improvement

Room Name	9:00	11:00	13:00	15:00	17:00
Studio1	676	599	567	262	123
Studio2	259	498	430	723	775
Studio3	540	523	518	728	592
Studio4	107	133	342	1212	1178
Studio5	712	278	135	123	92.2

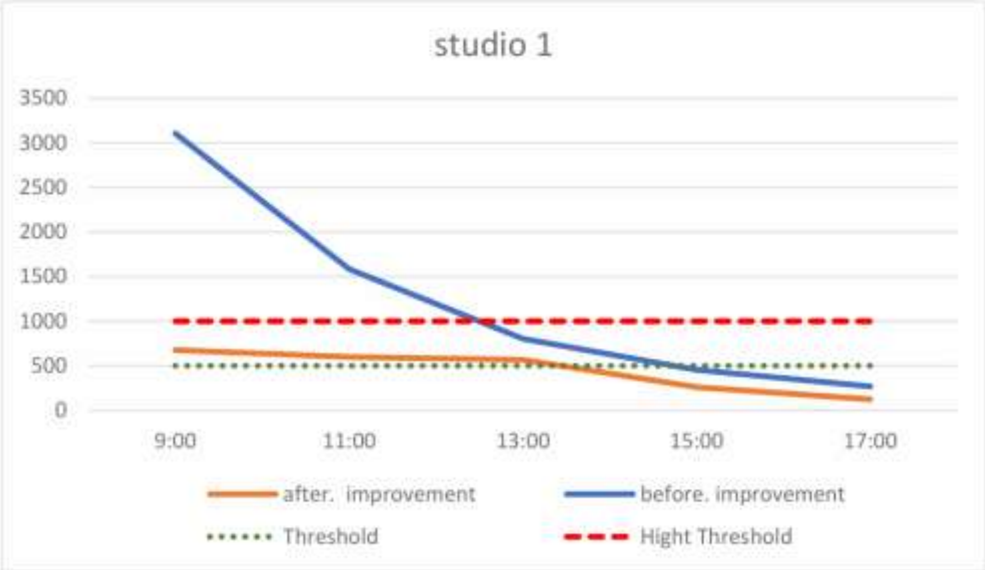

Figure 4.26 Improvement of lighting in Studio 1-AYBU

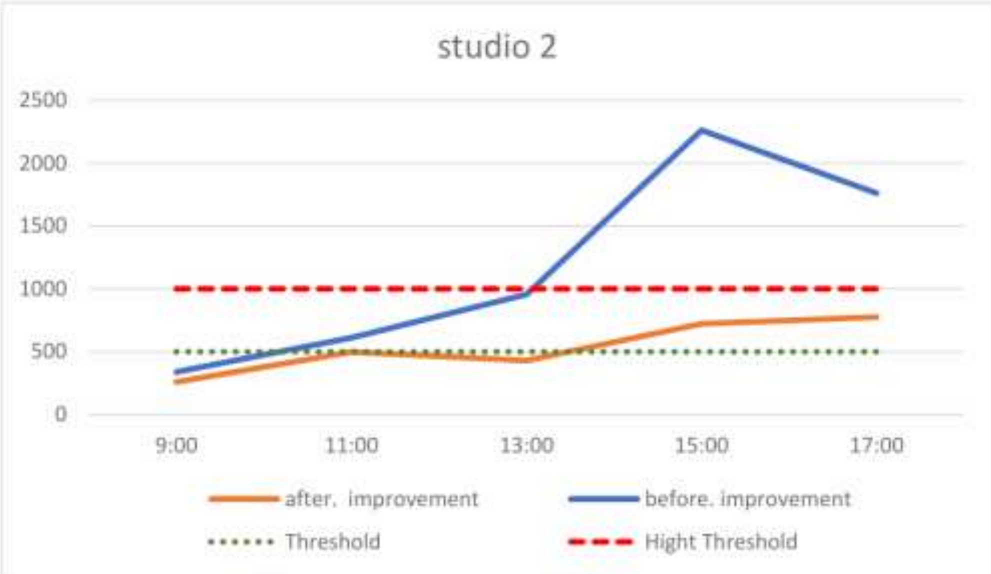

Figure 4.27 Improvement of lighting in Studio 2-AYBU

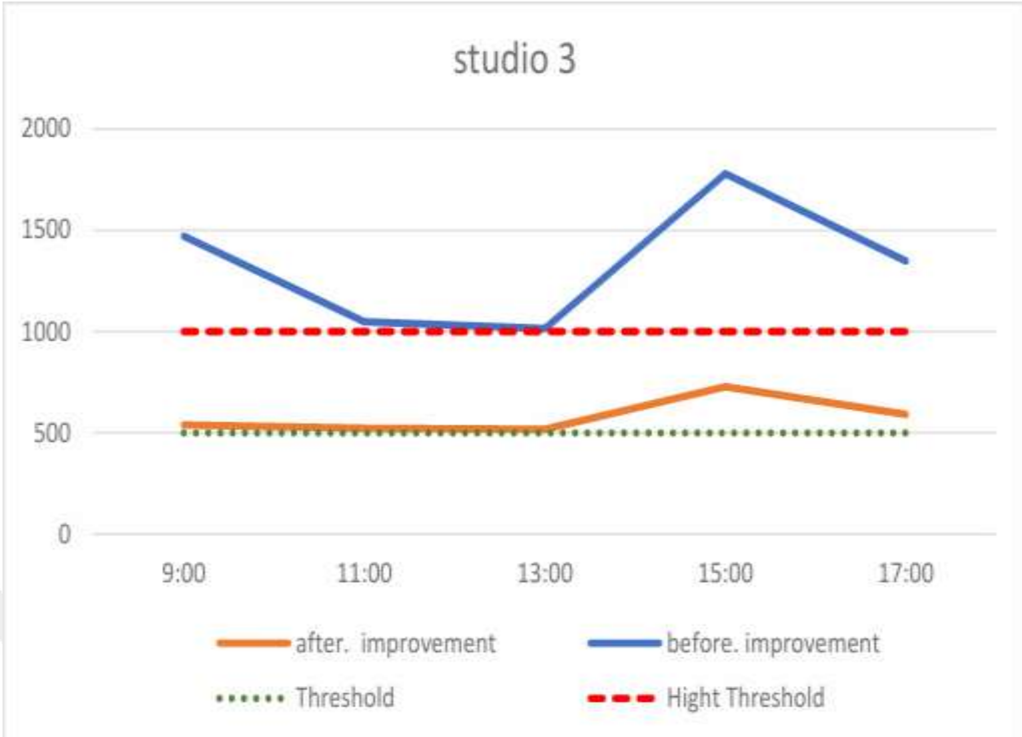

Figure 4.28 Improvement of lighting in Studio 3-AYBU

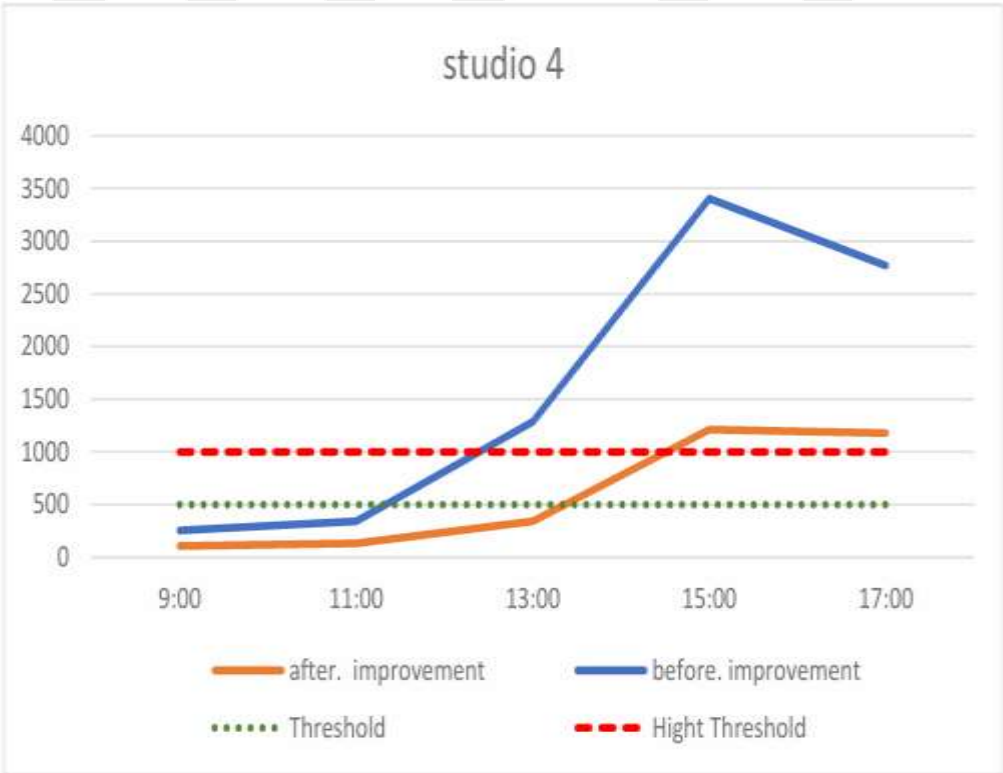

Figure 4.29 Improvement of lighting in Studio 4-AYBU

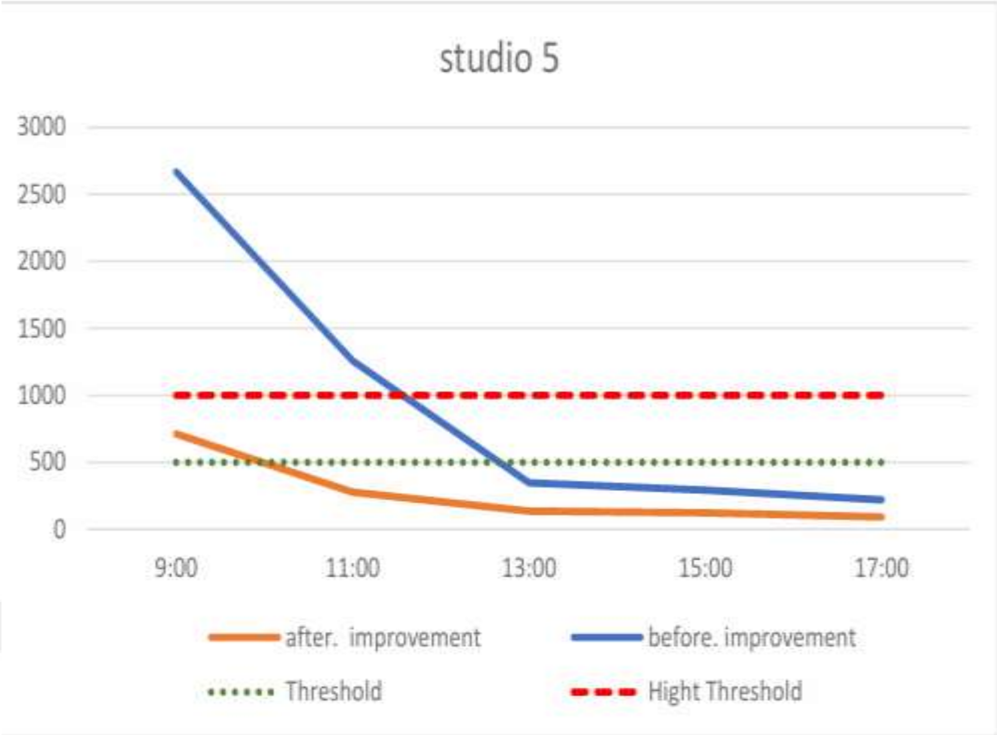

Figure 4.30 Improvement of lighting in Studio 5-AYBU

4.7 Impact of the Furniture and Materials on the Lighting

All case studies were simulated using the complete state of the building, including furniture and finishing materials. It is interesting to evaluate the influence of these two factors on lighting. This section presents the results of two simulations: one without furniture and one with furniture and materials removed.

4.7.1 Impact of the Furniture on the Lighting

Scenarios AYBU-5, and AYBU-11 are simulated without furniture as the results are presented in Tables 4.13, and 4.14 respectively**.** Table 4.13 presents the results of scenario AYBU-5 without and with furniture to clarify its impact on the lighting quantity. The results show a correlation between the two case studies in terms of lighting, but the effect is very small. The conclusions drawn are that furniture absorbs light, and thus, there is a slight increase in values in empty rooms. The lighting increase from furniture removal is between 3% and 4%. This result is confirmed for the average sky as in Table 4.14.

4.7.2 Impact of the Materials on the Lighting

The material effects on lighting are analyzed for the same scenarios AYBU-5 and AYBU-11.

Table 4.13 Clear sky daylight furniture impact

Studio	9:00	11:00	13:00	15:00	17:00	Furniture
Studio1	618	1179	874	536	165	Without
	580	1137	855	529	157	With
Studio2	138	598	1254	1515	697	Without
	132	587	1225	1477	627	With
Studio3	357	827	944	1403	454	Without
	338	807	922	1362	417	With
Studio4	129	301	991	2600	878	Without
	117	275	941	2448	739	With
Studio5	570	828	340	270	132	Without
	517	785	311	246	120	With

Table 4.14 Average sky daylight furniture impact

Studio	9:00	11:00	13:00	15:00	17:00	Furniture
Studio1	257	833	741	392	60.8	Without
	243	807	725	388	59.1	With
Studio2	57.4	401	853	897	301	Without
	55.5	394	833	875	269	With
Studio3	147	617	759	851	180	Without
	140	571	739	827	166	With
Studio4	54.4	309	835	1511	351	Without
	50.7	288	789	1425	296	With
Studio5	233	617	413	231	46.6	Without
	213	584	385	216	43.6	With

The materials used for walls, ceilings, and floors are removed, and simulations are made to see their effect on lighting. Tables 4.15, and 4.16 show results collected from simulations with and without materials for clear and average sky and without furniture. The results show a reduction in illumination due to the removal of materials compared to empty studios with materials. This reduction can reach values of up to about 75%

of the original illumination, which is significant. This can be explained by the reduction of the reflection factor from 80% to 20%.

Table 4.15 Clear sky daylight materials impact

Studio	9:00	11:00	13:00	15:00	17:00	Materials
Studio1	618	1179	874	536	165	With
	374	678	676	376	109	Without
Studio2	138	598	1254	1515	697	With
	86.5	464	768	1008	453	Without
Studio3	357	827	944	1403	454	With
	252	611	707	1103	347	Without
Studio4	129	301	991	2600	878	With
	92.6	216	691	2120	672	Without
Studio5	570	828	340	270	132	With
	403	554	245	194	95.7	Without

Table 4.16 Average sky daylight materials impact

Studio	9:00	11:00	13:00	15:00	17:00	Materials
Studio1	257	833	741	392	60.8	With
	166	538	572	289	43.3	Without
Studio2	57.4	401	853	897	301	With
	37.6	309	554	618	201	Without
Studio3	147	617	759	851	180	With
	108	448	585	677	141	Without
Studio4	54.4	309	835	1511	351	With
	42.2	239	622	1237	277	Without
Studio5	233	617	413	231	46.6	With
	172	447	320	179	36.1	Without

4.8 Discussion

The three universities used as case studies for this research are Samsun, Amasya, and AYBU. AYBU is located in Ankara, while Amasya is 330 km northeast of Ankara. Samsun University is a new university in the city of Samsun, 100 km north of Amasya.

While Architectural Studios in Amasya University were initially designed as architectural studios, Samsun was originally built as a factory. Before using the

Samsun University studios by students, many Architects studied the situation and adopted these buildings to be architectural studios after modification. AYBU Studios are designed as an Academy building but not for the Architect Department. Since architectural studios require special care about daylighting that must be included between 500 and 1000 Lux, transformation must be considered to optimize daylighting within these buildings.

Amasya University Studios faces the sunrise and sunset with huge windows, resulting in excess daylight during working hours. Being overlight can hurt students due to glare negatively affecting the educational experience in these classrooms. Redesigning according to the standards to decrease the quantity of lighting during the day must be considered. While over-lighting is the problem of Amasya University, under-lighting is the problem facing Samsun University. Samsun University Studios performs better than the two other university studios. This is due to the excellent work performed by the architect in adapting existing buildings as architectural studios.

At AYBU, the challenge is not just under-lighting or over-lighting, but a combination of both at different times and dates. This complex situation necessitates an innovative approach to building design that can effectively manage daylighting to meet the quantity and quality standards required for such buildings.

As per previous research, Clear Sky is adopted as a comparison situation for the three universities. Türkiye has many clouded days, which can negatively affect the daylight quantity/quality inside buildings. Also, within one University, different daylighting levels exist in other studios. This is because not all studios are oriented in the same manner. Some innovative solutions can be proposed to solve these problems, which will stated as part of the future work section, like the use of adaptive facades or new materials to improve the daylighting situation.

CHAPTER 5

CONCLUSION & FUTURE WORK

5.1 Conclusion

Natural lighting has a proven positive health effect on building occupants compared to artificial lighting. In addition, making the most of daylight reduces energy consumption, leading to many economic and environmental conservation benefits.

The lighting study is an essential stage in the architectural design of all types of buildings. Educational buildings are places used by students, academics, and administrators during daylight hours. Addressing these buildings' lighting is crucial to obtaining the most natural lighting during the lesson. In the case of studying lighting in already constructed buildings, there are improvement solutions to increase the benefit of natural lighting, including types of bright paint, modifying windows, adding windows in some places, and choosing the appropriate types of window coverings. It is also vital that artificial lighting be similar in quality and intensity to natural lighting.

The study of studio rooms at AYBU, Amasya, and Samsun University aims to evaluate the current status of the impact of natural lighting around working hours and in all seasons of the workıng ten months. The proposal of innovative solutions can improve and optimize the use of natural lighting. The study also gained a broad understanding of lighting in the Ankara, Amasya, and Samsun regions, which will help architects make better use of natural lighting in academic buildings that will be designed in the future.

Many scenarios in DIALux Evo 12 are implemented in the three universities' exact date and hour range. Two main comparisons have been conducted to evaluate the existing daylighting within architectural buildings during all time and date ranges and for clear skies. The first compares studios within every university, while the second is between the three universities.

The international standard about accepted lighting in architectural university studios states that it must be between 500 and 1000 Lux as minimum and maximum accepted lighting. Results are classified into three groups: acceptable lighting quantity, inferior to the minimum, and superior to the minimum.

Amasya University studio buildings show lighting levels that often fail on the superior to the maximum. The high dimensions of windows and their number contribute to this result. Samsun University performs better than the others in terms of lighting levels. This is explained by the architectural works conducted during the building adaptation stage, which yielded positive results. AYBU results show significant variations according to the location and orientation of studios.

Many solutions are proposed to improve the lighting situation in the three universities. The main proposal is to add breakers to the windows to limit the amount of daylight in various studios.

5.2 Future Works

Many future research ideas can be proposed to improve the lighting situation within the three universities:

- The University of Amasya building needs improvements to reduce the lighting entering the studio rooms, which causes a high percentage of glow that hinders the inside of the studio room. Therefore, in this study, we have made a preliminary improvement, which is to install window breakers, resulting in a decrease of 50% in lighting. Further progress must be suggested via extensive study to put lighting within the accepted boundary. For example, they could reduce the number of windows or change their design to be smaller than the current dimensions. It is also possible to focus on designing window breakers to reduce lighting effects.
- The Samson University building needs to increase the lighting entering the building at certain times, so we suggest changing the breakers' shape. An innovative adaptive breaker can contribute to adopting the lighting quantity

according to the hour and date so that its quantity fails within an acceptable range.

- AYBU suffers from increased lighting at times and decreased lighting at other times. Therefore, the best option is to install movable (adaptable) breakers to limit lighting when lighting increases. Also, the skylight is a solution for the leak of daylighting. Both measures can be installed and tested according to our collected data.
- All the proposed solutions can be part of a controlled system using the Internet of Things technology combined with sensors and Artificial Neural Networks (ANN). The system can adapt to the situation and then regulate breakers and skylights according to the lighting inside buildings.

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