University of Mohammed Kheider- Biskra
Faculty of architecture, urbanism, civil engineering and hydraulic
Department of Architecture

Academic Master's Dissertation

Complementary within the Framework of Ministerial Decision No. 1275 for the Acquisition of a University Degree – Economic Enterprise Project

Domain: **Architecture, urbanism and city professions**
Field: **Architecture**
Specialization: **Architecture**
Theme: **Architecture, Environment, and Technologies**

Presented and defended by:
Hanine SATTAFI

On: November, 2025

Theme:

Designing an Integrated Daylighting System for Glare Mitigation, Thermal Comfort Element, and Energy Consumption Optimization

The project:

School of Architecture

Examiner's committee

Dr.	MAHAYA Chafik	MCB	University Of Biskra	President
Dr.	MERAD Yacine	MCA	University Of Biskra	Examinator
Dr.	DAICH Safa	MCA	University Of Biskra	Advisor
Dr.	SAADI Mohamed Yacin	MCA	University Of Biskra	Co-advisor

Academic year: 2024 - 2025

SUMMARY

This thesis investigates the design of an integrated daylighting system that mitigates glare, enhances thermal comfort, and optimizes energy consumption in architectural educational spaces. The study, which focuses on the typology of schools of architecture, highlights how important daylight is for sustainability, learning effectiveness, and visual comfort.

With the help of a thorough literature review, the study starts with a theoretical investigation of daylighting principles, thermal and visual comfort metrics, and their relationship to energy performance. In order to determine environmental and spatial design criteria, the analytical phase looks at site conditions, chosen case studies -recent architecture school projects-, and architectural school requirements. These conclusions led to the development of an architectural project that combined environmental responsiveness, comfort, and functionality.

The project's implementation of the suggested daylighting system, specifically in the workshop façade, was examined using simulation models. Better light distribution and less glare were shown in the results, and the optimized daylighting performance naturally led to increased thermal comfort and decreased energy consumption.

Overall, the study demonstrates that well-thought-out daylighting systems can lower energy consumption and greatly enhance indoor environmental quality, which supports sustainable architectural design, particularly in hot and dry climates.

Key words:

Daylighting- Integrated Daylighting System- Glare Mitigation- Visual Comfort- Thermal Comfort- Energy Optimization- School of Architecture- Hot and Arid Climate.

الملخص:

تبحث هذه الأطروحة في تصميم نظام إضاءة نهارية متكامل يخفف من الوهج، ويعزز الراحة الحرارية، ويحسن استهلاك الطاقة في المساحات التعليمية في مشروع مدرسة الهندسة المعمارية. تُركز الدراسة على تصنيف مدارس العمارة، وتُبرز أهمية ضوء النهار للاستدامة، وفعالية التعلم، والراحة البصرية.

بفضل مراجعة شاملة للأدبيات، تبدأ الدراسة ببحث نظري لمبادئ الإضاءة النهارية، ومقاييس الراحة الحرارية والبصرية، وعلاقتها بأداء الطاقة. ولتحديد معايير التصميم البيئي والمكاني، تتناول المرحلة التحليلية ظروف الموقع، ودراسات الحالة المختارة للمشاريع المعمارية السابقة، ومتطلبات المدارس المعمارية. وقد أدت هذه الاستنتاجات إلى تطوير مشروع معماري يجمع بين الاستجابة البيئية والراحة والوظائف العملية.

تم فحص تطبيق المشروع لنظام الإضاءة النهارية المقترح، وتحديدًا في واجهة ورشة العمل الموجهة نحو الجنوب، باستخدام نماذج المحاكاة. وقد أظهرت النتائج توزيعًا أفضل للضوء ووهجًا أقل، وأدى الأداء الأمثل للإضاءة النهارية، بطبيعة الحال، إلى الراحة الحرارية وتقليل استهلاك الطاقة.

وبشكل عام، أظهرت الدراسة أن أنظمة الإضاءة الطبيعية المدروسة جيدًا يمكن أن تعمل على خفض استهلاك الطاقة وتعزيز جودة البيئة الداخلية بشكل كبير، وهو ما يدعم التصميم المعماري المستدام، وخاصة في المناخات الحارة والجافة.

الكلمات المفتاحية:

الإضاءة الطبيعية - نظام إضاءة طبيعية متكامل - تخفيف الوهج - الراحة البصرية - الراحة الحرارية - تحسين الطاقة - كلية الهندسة المعمارية - المناخ الحار والجاف

Acknowledgments

In the name of Allah, the Most Gracious, the Most Merciful.

All praise is due to Allah for granting me the strength and guidance to complete this work.

I would like to express my sincere gratitude to my two supervisors for their continuous support, valuable guidance, and encouragement throughout this research:

Dr. Safa DAICH

Dr. Mohamed Yacin SAADI

Special thanks to my supervisor at POLITECNICO DI MILANO for the enriching academic experience and kind mentorship during my mobility period:

Dr. Rajendra SINGH ADHIKARI

I also extend my appreciation to the esteemed jury members for their time, insightful remarks, and evaluation of this thesis:

Dr. Chafik MAHAYA

Dr. Yacin Mirad

I am equally grateful to all my professors at THE DEPARTMENT OF ARCHITECTURE, UNIVERSITY OF BISKRA, whose knowledge, dedication, and support have contributed greatly to my personal and academic growth over the years. Their teachings laid the foundation upon which this thesis was built.

Dedication

To my determined and ever-aspiring self — may you always chase the light, no matter how distant it seems. Your resilience and passion are the compass guiding this journey.

To my beloved father, Lakhdar — my unwavering support, my strength, my first hero, and the living example of perseverance and ambition.

To my beloved mother, Salima — the heart of my world, the anchor in every storm, the one who listens in silence and speaks to my soul. Your love is my sanctuary.

To my dear aunt Aisha — my second refuge, whose warmth has often mirrored that of a mother's.

To Souhaib, Aroua, and Anas, my siblings, my truest companions, and the greatest treasures of my life.

To my two grandmothers — your prayers were the invisible hands that lifted me higher.

To my cherished aunts — your pride in me has lifted my spirit more than words could ever express. Thank you for your constant encouragement.

To my extended family — every word of support, every smile, every prayer, has been a part of this path.

To my dear friends — the companions of my growth, laughter, and challenges:

Khadija, Bouthaina, and Marwa the keepers of my earliest steps.

To my dearest souls Noura, Aridj, Roumaissa, Abir, the loyal souls who walked with me through the befor final chapters.

To my beloved friends Fatima, Meriem, Rima, Malak, Emmy, Ines, Khouloud

To my fellow colleagues— it was an honor to share this academic voyage with you.

To everyone who has ever believed in me, prayed for me, or wished me well — your kindness is etched in my heart.

To every soul who, in any small way, contributed to this milestone — this achievement is as much yours as it is mine.

With gratitude, hope, and love.

The one behind this journey: Hanine SATTAFI

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

INTRODUCTORY CHAPTER

I.General Introduction

Daylighting is a fundamental aspect of sustainable architectural design, particularly in educational institutions such as Schools of Architecture. Effective daylighting enhances visual comfort, reduces reliance on artificial lighting, and contributes to overall energy efficiency. However, the challenge lies in optimizing daylight to prevent issues such as glare and excessive heat gain, which can compromise indoor comfort and building performance (Cheryan et al., 2014).

In the context of a School of Architecture—where students spend extended hours engaged in design work, model-making, and theoretical studies—a well-lit and thermally comfortable environment is essential for productivity, concentration, and well-being. Studies such as Designing Classrooms to Maximize Student Achievement (Cheryan et al., 2014) emphasize that environmental factors like daylight quality, air temperature, and acoustic comfort have a measurable impact on cognitive performance and learning outcomes. Therefore, achieving controlled, balanced daylighting in spaces such as studios, lecture halls, and workshops is vital for maintaining optimal visual and thermal conditions.

At the same time, research such as Design Optimization of the Skylight for Daylighting and Energy Performance Using NSGA-II demonstrates the potential of advanced simulation and optimization techniques in achieving energy-efficient daylighting solutions. These studies highlight that integrating daylighting and energy analysis can yield systems capable of adapting to dynamic environmental conditions, thereby reducing glare, moderating thermal gain, and improving overall energy performance (Fakhr et al., 2023).

Building on these insights, this research explores the design of an integrated daylighting system tailored for architectural schools, aiming to mitigate glare, enhance thermal comfort, and optimize energy consumption. The proposed system will be tested and evaluated through digital simulations to determine its performance across varying climatic conditions. By aligning architectural design with environmental control, this study aspires to contribute innovative, evidence-based strategies for sustainable daylighting—creating educational spaces that foster both comfort and academic excellence.

II.Problematic

Designing educational spaces, especially architecture schools, poses special daylighting challenges. Students' comfort and performance are adversely affected by traditional daylighting solutions, which frequently result in excessive glare, thermal discomfort, or insufficient illumination levels. When incorporating daylighting into such areas, the following are the main issues to consider:

Glare Control: The usability of learning and working environments can be negatively impacted by excessive daylight penetration, which can cause visual discomfort.

Thermal Regulation: Heat gain from poorly designed daylighting systems can raise cooling loads and energy usage.

Energy Efficiency: While daylighting reduces the need for artificial lighting, ineffective integration may result in higher HVAC demands, offsetting energy savings.

To address these issues, this study seeks to answer the following research questions:

- How can an integrated daylighting system effectively reduce glare while maintaining optimal illumination levels in architectural education spaces?

- What are the most efficient strategies for regulating indoor temperatures using daylighting techniques?
- To what extent can the proposed daylighting system contribute to energy savings in educational buildings?
- How can simulation models and experimental validation be used to assess the effectiveness of the proposed system?

An integrated strategy that strikes a balance between thermal performance, energy efficiency, visual comfort, and natural light distribution is required to address these issues. In order to effectively manage these factors and support the sustainable design of educational spaces, this research suggests a façade-integrated daylighting system.

III. Hypothesis

This research is based on the following hypotheses:

H1: The integration of a well-designed daylighting system can simultaneously mitigate glare and enhance thermal comfort by optimizing the distribution and control of natural light within architectural educational spaces.

H2: The application of the proposed integrated daylighting system will result in a measurable reduction in overall energy consumption, as verified through simulation models assessing visual, thermal, and energy performance parameters.

IV.Objectives

In order to accomplish the objectives of this study, a well-defined framework outlining the core objectives and anticipated contributions must be established. The study's goals are to address the daylighting issues that have been identified in architectural education settings. The goal of this research is to lower energy consumption and improve indoor environmental quality by installing an integrated daylighting system.

The primary objectives of this research are:

- To design an integrated daylighting system that mitigates glare while maintaining adequate indoor illumination levels.
- To explore strategies to regulate indoor temperatures efficiently.
- To evaluate the energy savings potential of the proposed daylighting system.
- To develop and validate a prototype of the system using experimental setups and simulation models.

V.Research Methodology

- Introductory chapter: The research's general framework is presented in this chapter. The problem statement, background, study objectives, hypotheses, and methodology are all presented. It also describes the thesis's organization, giving a synopsis of the subject matter and goal of each succeeding chapter. The conceptual and methodological foundation for the remainder of the study is established in the introductory chapter.

- Theoretical chapter: The study's key concepts—daylighting systems, thermal comfort, visual comfort, and energy consumption optimization—are defined and examined in the theoretical chapter. Through a literature review, it investigates their relationships and implications for architectural design. The scientific basis for comprehending the environmental and design principles that direct the study is formed by this chapter's synthesis of earlier research and theoretical viewpoints.

- Analytical chapter: The theoretical framework is translated into analytical investigation in this chapter. It is separated into two main sections:

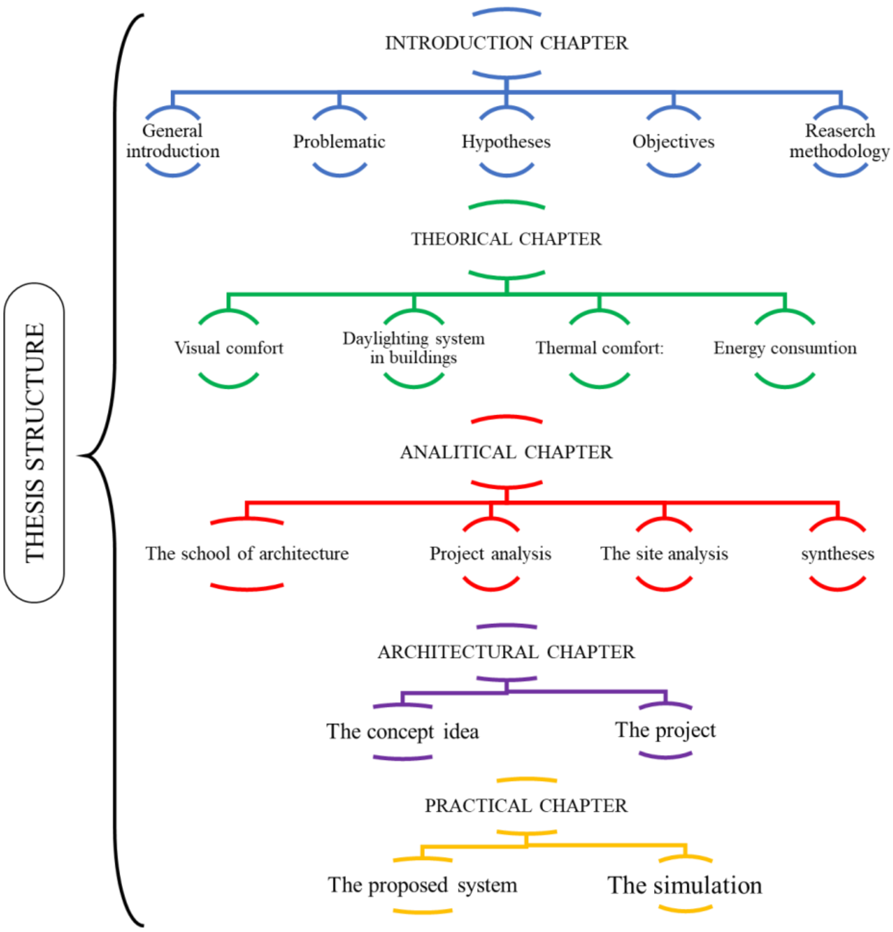
The School of Architecture typology is the main topic of Part I, which also identifies functional requirements, spatial organization, and environmental design needs pertaining to comfort, ventilation, and lighting.

In Part II, the chosen site and reference projects are analyzed, along with site conditions, climatic data interpretation, and a programmatic definition of spaces. The contextual and design parameters required to develop the suggested architectural project are provided by this analysis.

- Architectural chapter: The architectural chapter presents the design development of the School of Architecture project. It presents the primary idea, design concept, and architectural expression that are based on the results of the analysis. The chapter contains design views, architectural renderings, and graphical documents that show how the project reflects the values of environmental responsiveness, comfort, and functionality.

- Practical chapter: The suggested integrated daylighting system and its use in the planned project are the main topics of the last chapter. It describes the idea behind the system, how it is integrated into the building envelope, especially the workshop façade, and how it should perform environmentally. The simulation and performance evaluation are also presented in this chapter, evaluating how well the system reduces glare. The findings are examined in order to support the theories and show how the suggested system advances sustainable architectural design.

VI.The thesis structure:



CHAPTER I:

THEORETICAL FOUNDATIONS OF DAYLIGHTING, COMFORT, AND ENERGY EFFICIENCY IN BUILDINGS

I.INTRODUCTION:

In architectural design, daylighting is crucial because it affects energy efficiency, thermal balance, and visual comfort. It presents chances to lower energy consumption and artificial lighting in sustainable buildings while enhancing occupants' quality of life. By looking at daylighting systems, the concepts of thermal and visual comfort, and their relationship to energy use, this chapter offers a theoretical framework. Additionally, it examines pertinent literature to highlight contemporary methods and resources, which serve as the foundation for creating an integrated system that strikes a balance between efficiency, comfort, and glare control**.**

II.VISUAL COMFORT

II.1.Daylighting in buildings

The dynamic nature of daylighting, both the day and the year, creates significant obstacles when designing structures that strive to use this plentiful natural resource to satisfy the illumination requirements of architectural spaces (AHMED et al., 2023).

II.2.The daylighting strategy:

The goal is to better catch and penetrate natural light, which will then be distributed and focused. To avoid visual discomfort, the light should be carefully controlled. The intelligent utilization of natural light minimizes power usage for lights(Liébard & Herde, 2005).

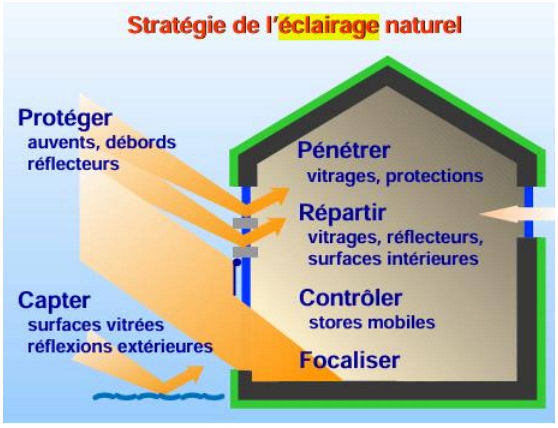


Figure 1 daylighting strategy. The source: Alain Liébard, 1996, treatise on bioclimatic architecture and urban planning, p125

II.3.Architecture of Daylighting:

Conceptually, daylighting can be supplied to interior spaces by apertures on the side, top, or both. Building type, height, massing, prevalent climatic conditions, site impediments, and building functions are frequently used to guide strategy decisions. Innovative daylight solutions can also help to maximise the use of daylight. These harness the physical rules of reflection and refraction to precisely light spaces while avoiding excessive warmth. The selection of tactics and equipment for optimal daylighting is consequently determined by the purposes of the structures and the light requirements of each architectural area. The solutions include side lights, top lights, shedding devices, and building orientation ways of daylighting. (Zarewa et al., 2023).

II.4.The visual comfort:

Visual comfort is a subjective assessment of the amount, distribution, and quality of light (Liébard & Herde, 2005).

- The Haute Qualité Environnementale54 (HQE) group states that "visual comfort" is the tenth goal of the construction project. The following are its main lighting needs or requirements:

-An enough visual connection with the outside world;

-Optimal natural lighting in terms of energy efficiency and comfort;

-Artificial lighting that is only meant to be used as a supplement to natural lighting when it is available.

II.4.1.**Comfort parameters:**

The interventions connected to the parameters of visual comfort are:

-the level of illumination of the visual task

-the distribution of light in the room

-the luminance ratios

-the lack of distracting shadows

-the improvement of object relief and modeling

-the view outside

-the rendering of colors

-the shade of light

-the absence of glare (Liébard & Herde, 2005).

II.5.The visual performance:

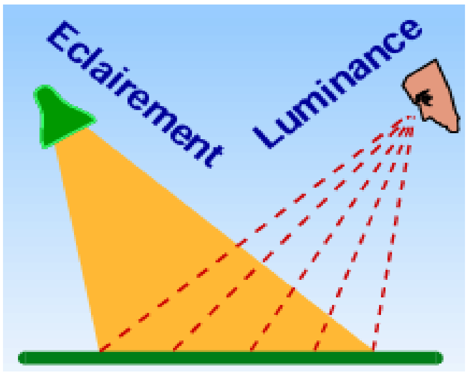
The desired visual performance is decided by the task to be done and depends on the following parameters:

- the level of illumination of the work surface

- the luminance contrast between the observed object and its support.

Illuminance is the effect caused by luminous flux descending from a natural or artificial light source onto a specific surface. He expresses himself in Lux.

Luminance describes the amount of light that leaves a surface and enters the observer's sight. It is measured in candelas per m² (Liébard & Herde, 2005).



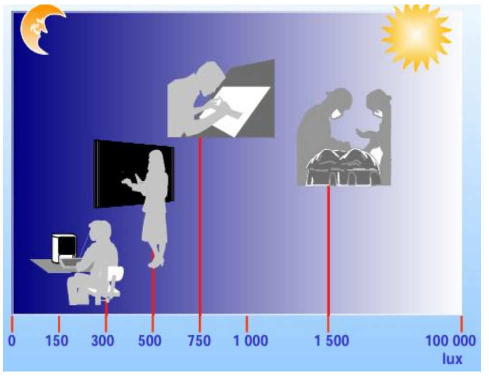


Figure 2 (a)Eclairement et luminance The source: Alain Liébard, 1996, treatise on bioclimatic architecture and urban planning, p113, (b) Le niveau d'éclairement de référence est selon l'activité. The source: Alain Liébard, 1996, treatise on bioclimati

(a) *(b)*

II.6.Perception visual field:

The visual area viewed by a person gazing straight ahead must be separated into monocular and binocular sections. The monocular field is commonly thought to extend around 90° temporally, 60° nasally (depending on the prominence of the nose), 70° inferiorly (limited by the cheek), and 50 to 60° superiorly (bound by the brow). The monocular visual fields overlap to produce a combined binocular field, the middle 120° of which is visible to both eyes.

Even if the visual field extends almost 180° horizontally and 120° vertically, the component which has a importance for visual comfort ratings is a band of 40° centred at normal eye height. It may be seen that there are frequently no constraints in the horizontal plane, resulting in an almost panoramic picture of around 180° view angle.

The field of vision is also divided into central (foveal) and peripheral (foveal surround) vision. Foveal vision, which exists in a 2° cone around the center of the retina, gives the human eye its awareness and focus. Furthermore, the cones that are abundant in the fovea offer information on details and hues. Peripheral vision (30° cone) provides quite high awareness and discrimination of brightness differences between an object and its background or foreground via the rods (Marty et al., 2003).

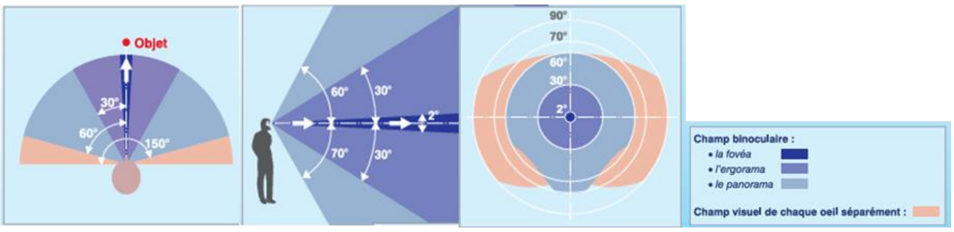


Figure 3 Perception visual field The source: Alain Liébard, 1996, treatise on bioclimatic architecture and urban planning, p285.

II.7.Lighting in classrooms:

Students who receive more natural light (daylight) in their classroom outperforms those who receive less natural light.

In a study of almost 2,000 classrooms in California, Washington, and Colorado, students who were exposed to more amount of daylight had better math and reading test scores than students who were exposed to less daylight (2%-26% higher, depending on school district), even after statistically correcting for student demographic variables such as socioeconomic status and race.

According to the National Center for Education Statistics, 16% of schools with permanent structures and 28% of schools with temporary (portable) facilities have inadequate natural illumination. Although adding additional daylight to classrooms might be advantageous, it must be done cautiously to minimize visual irritation and temperature rises (Cheryan et al., 2014).

II.8.Contraste:

The light distribution in a area must be studied so that excessive brightness differences are reduced, allow users to see properly. Extremely dark or brilliant fields should be avoided because they result in an unstudied contrast. Contrast is the brightness difference between an object and its surroundings, or between various components of an object, which causes it to stand out. The contrast balance is vital for both comfort and detail perception. When there are considerable brightness changes in the field of vision, the eye must adjust to the new gaze direction. During acclimation, visual acuity reduces (Daich, 2019).

II.9.Glare:

1-Glare is defined as a visual disturbance caused by high luminance or luminance contrast. Glare can be caused by direct natural light, light reflection on reflective surfaces (floor, computer screens, surrounding buildings, etc.), excessive artificial light, or an excessive light contrast between direct or indirect light and neighboring surfaces.

2- Glare is the sensation caused by luminance in the visual field that is so high that the eye cannot adjust to it. As a result, discomfort or failure in visual performance and visibility have occurred.

It is typically classified into two categories:

- Disability glare and Discomfort glare.

  1. Disability glare prevents individuals from seeing specific objects in their field of view, while

  2.Discomfort glare causes discomfort without affecting visual performance or visibility.

This phenomenon can occur either when there is an excessive amount of light reaching the viewer's eyes or when the viewer experiences a large range of luminance in a visual field. The intense contrast among both illuminated and dark areas of the visual field leads to a gradual decline in visual performance. As a result, it causes premature eye fatigue, which can be accompanied by discomfort or other symptoms such as migraine.

Figure 4 Glare in different situations The source: the author

II.9.1.**Glare metrics:**

The majority of glare research has focused on glare from different electric sources of light, but because of its patterns and variations in luminance, daylight glare has been particularly studied. For example, in daylight conditions, the window creates glare because the luminance is frequently uneven and high, particularly when direct sunlight is present, and it usually covers a significant portion of the visual field. because windows and computer screens are often close together and in vertical planes. A significant luminance contrast between the window and the computer screen is caused by the direct beam illuminance, reflections, and luminance in the sky-dominated portion of the window area, which are frequently very high. There are various existing indices:

• British Glare index (BGI).

• Discomfort Glare Index (DGI); to focus on contrast rather than brightness.

• CIE Glare Index (CGI).

• Unified Glare Rating (UGR).

•Discomfort Glare Probability DGP.

• DGPs; to emphasis on brightness.

• Predicted Glare Sensation Vote (PGSV).

• DGP considers most parameters that affect the glare sensation (AHMED et al., 2023).

The following five indices are used for evaluating discomfort glare:

Visual Comfort Probability (VCP), CIE Glare Index (CGI), Daylight Glare Index (DGI), Unified Glare Index, and Discomfort Glare Probability (DGP) .

1.Visual Comfort Probability (VCP): This index initially was introduced in order to evaluate discomfort glare probability and then it was edited for use in various lighting systems. VCP was only developed to evaluate typical sizes, such as ceiling

mounted lights with uniform illumination. Therefore, it is not suitable for evaluating non-uniform illuminance or for predicting daylight glare.

2. CIE Glare Index (CGI): To correct the mathematical inconsistencies of the British Glare Index (BGI) for multiple glare sources, a new index was introduced, which was later accepted by the International Commission on Illumination (CIE), and called the CIE glare index.

3. Discomfort Glare Index (DGI): This index is derived from the CGI and its purpose is to predict the glare caused by large glare sources such as a window . The metric is based on subjective ratings from human subjects in a daylit office space. The DGI value is associated with different levels of discomfort glare. A value of 22 is considered a logically acceptable threshold.

4. Unified Glare Rating (UGR): The value of this index varies between 10 (just imperceptible) and 34 (just intolerable). Similarly to the CGI, a value of 19 is usually considered the borderline between comfortable and discomfort glare.

5. Daylight Glare Probability (DGP): To determine glare, DGP combines vertical eye illuminance with elements of existing glare indices. In comparison with the existing glare indices, DGP shows a very strong correlation with occupants' glare perception. A comparison between glare metrics values is tabulated in the table (Faraji et al., 2023).

Level of Discomfort Glare	VCP	CGI	DGI	UGR	DGP [35,42]
Just imperceptible	>80	<13	<18	<13	<0.35
Just acceptable	60–80	13–22	18–24	13–22	0.35–0.4
Just disturbing	40–60	22–28	24–31	22–28	0.4–0.45
Just intolerable	<40	>28	>31	>28	>0.45

Table 1 Table 1 Glare indices, source : (Faraji et al., 2023).

II.10.Indoor visual comfort in educational spaces:

Visual comfort in the indoor environment has been shown to improve learning outcomes. Furthermore, the positive impact of the quality of view on wellbeing and eye health is discussed.

Reading rooms are frequently used during the day. Thus, the challenges posed by sunlight must be addressed in the design. To maximize the benefits of using natural light sources in buildings, discomfort glare should be avoided when designing daylighting systems. Because people must be present in these areas for extended periods of time, a lack of glare control has a negative impact on them.

II.11.Outdoor visual comfort in educational spaces:

The effects of shading devices on outdoor thermal comfort have been extensively studied. However, the effects of shading devices on outdoor illuminance and visual comfort have largely gone unexplored.

Visual comfort is defined as "a subjective state of visual well-being caused by the visual environment." Several studies have found that translucent artificial shade can reduce illuminance by 16% to 81% when compared to outdoor open space.

The reduction in illuminance is determined by the solar angle, cloud cover, and season. While these studies focus on objective measures of illuminance, few have investigated the effects of illuminance on subjective outdoor visual comfort in outdoor environments (Lam et al., 2023).

Previous research found a multisensory interaction between both the thermal and visual sensations in outdoor urban areas. For example, plant shade can decrease illuminance and sun sensation vote, thereby trying to improve outdoor thermal comfort. It is unclear whether this phenomenon applies to artificial shading (Lam et al., 2023).

II.12.The color rendering index:

The color rendering index of a light source is defined as the quantitative evaluation of the agreement level of between the psycho - physical color of an object illuminated by the illumination under test and that of the same object illuminated by the reference illumination (CIE, 1987). The index varies between 50 and 100. In other sayings, the CRI color rendering index, stated as a percentage, a represents the capacity of a source to truthfully render the different colours of an object.

The CRI of 100 demonstrates that the light in question includes 100% of the original colors (Daich, 2019).

II.13.Daylighting systems in buildings

A daylighting system is made up of systems, technologies, and architecture; while not all of the components listed by Ander, Reinhart, and Wienold are considered necessary for every daylighting system or prototype, at least one of them is usually present (Zarewa et al., 2023).

Types- schemas:

II.13.1.**Light tubes**

Sun scoops (also known as tubular skylights, light pipes, and solar pipes) are tubes or pipelines that collect natural light into an internal environment, as illustrated in the figure. Light tubes offer the opportunity to bring natural light into the dark deepest level of a building or underground structure. Light tubes consist of three major components: the trying to collect head unit, the duct unit, and the diffuser unit. The access to the tube is generally a dome, which serves to reflect as much light as possible into the tube. Reflectors and heliostats can also be used to reflect light into the tube, improving performance. The the inside of the pipe is highly reflective, allowing light to move downward into the space with minimal loss. Some light pipes have up to a 90-98 reflection ability within in the tube (Zarewa et al., 2023).

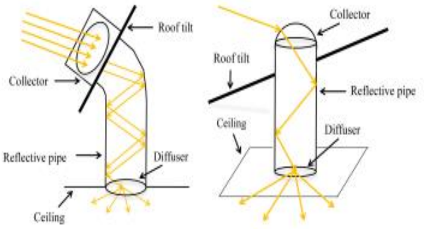


Figure 5 light pipe sections (Von Wachenfelt et al., 2015)

II.13.2.**Light shelf**

Light shelves play a significant role in improving and attempting to control interior daylight performance, thereby increasing occupants' visual comfort. Its performance is determined by a variety of parameters, including geometry, materials, dimensions, the inclination angle of the device's external portion, and external climatic conditions (overcast or clear sky, with or without the sun). The outer portion of the system can shade the glass surface, while the inner portion reflects sunlight, directing illuminance away from the window and resulting in a uniform distribution of light on the workpiece surface.

However, the light shelf faces the challenge of changing sun orientations and altitudes, as well as constantly changing sky environmental factors and climate. Nonetheless, the light shelf can help to improve consistency and distribution at the back of deep space. Further to that, it can safeguard occupants from bright sunlight in forwarding zones while also providing visual access to the outdoors (Bahdad et al., 2020).

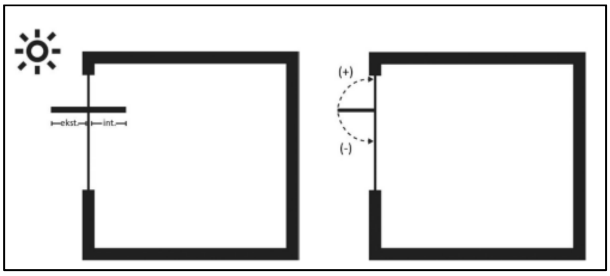


Figure 6 Illustration of elevation view of a light shelf in a building

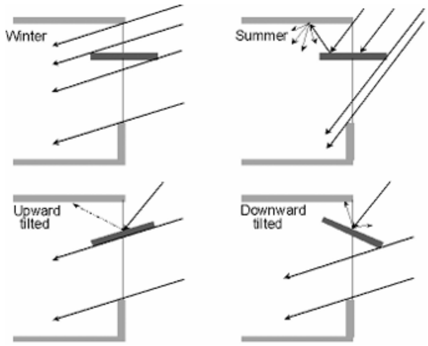


Figure 7 Section of a light shelf with the path of sunlight rays (Ruck et al., 2000)

II.13.3.Louvers and Blind Systems

Louvers and blinds are vintage daylighting structures that can be used for solar shading, glare reduction, and daylight redirection. Louvers and window shades are made up of several horizontal, vertical, or sloping slats. There are several types of louver and blind systems, some of which feature technically advanced shapes and surface finishes. Blinds or louvers can be installed between two panes of glass or on the outside or inside of any window or skylight. Blinds are installed inside or between windows, while louvers are typically located on the facade's exterior. It has two types:

1) The "Fish" system uses fixed horizontal louvers with triangular sections that are precisely aligned through special connections. The system, designed only for longitudinal windows, is designed to reduce glare and reroute diffuse light; additional shading is recommended (e.g., a roller blind) to heat gains and admission of sunlight. The louvers are designed to direct light from the upper quarter of the sky into the upper quarter of the room (roof). In theory, the system without glazing transmits 60% of diffuse light for an aluminum surface with 85% reflectance.

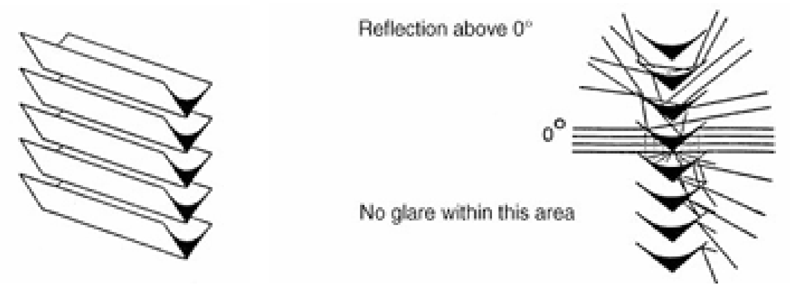


Figure 8 "Fish" system consisting of fixed horizontal louvers(Ruck et al., 2000)

2) The "Okasolar" system, also a static system, consists of multiple evenly spaced, three-sided, reflective louvers inside a double-glazed unit. In the winter, the structure reflects light up to the roof, while in the summer, it shades. These louvers are made to cater the latitude at which they will be used (Ruck et al., 2000).

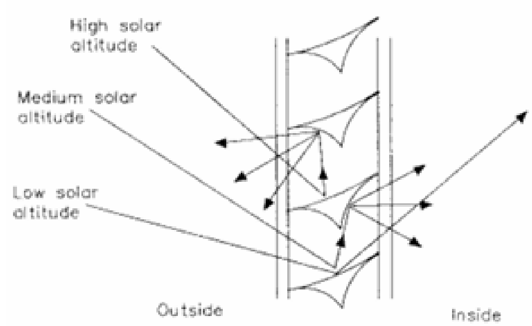


Figure 9 The Okasolar system consists of fixed, equally spaced, reflective louvers (Ruck et al., 2000)

II.13.4.**Prismatic Panels**

Prismatic panels are fine, sawtooth, two dimensional, clear acrylic instruments used to refract or redirect sunlight in temperate climates. They transmit diffuse skylight but refract direct sunlight when used as a shading device. They can be used for the skylights and facades in a variety of ways, including fixed or sun-tracking configurations. An array of acrylic prisms makes up a linear prismatic panel, with the prism backing being the plane surface formed by one of the prisms. Two refracting angles exist. These prismatic systems are commonly decided to install in double-glazed devices to avoid the necessity for maintenance (Ruck et al., 2000).

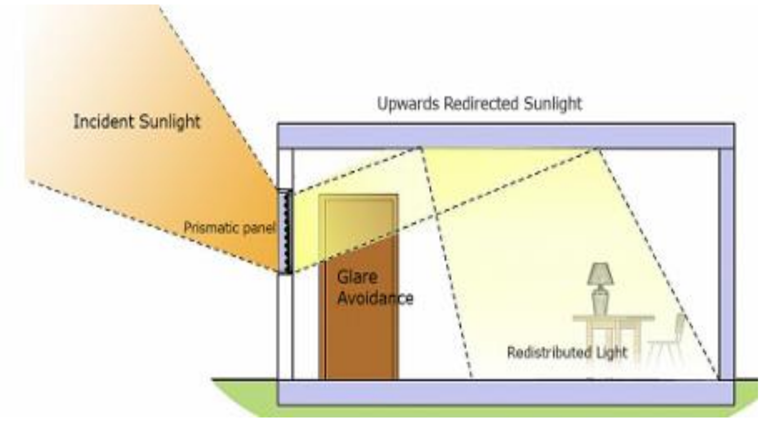


Figure 10 The use of prismatic panel as a redirector system (Eltaweel et al., 2020)

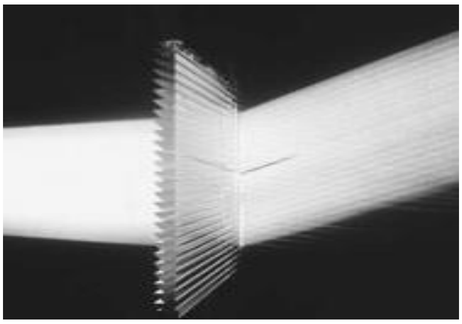


Figure 11 Visualization of the light redirection achieved by the panel (Ruck et al., 2000)

II.13.5. Heliostats Daylighting Devices:

As seen in the figures, heliostats are stationary mechanisms that follow the sun in order to direct light toward a receiver of some sort. They can focus strong light onto photovoltaic panels, light telescopes, and light transferring systems, among several other applications (Zarewa et al., 2023).

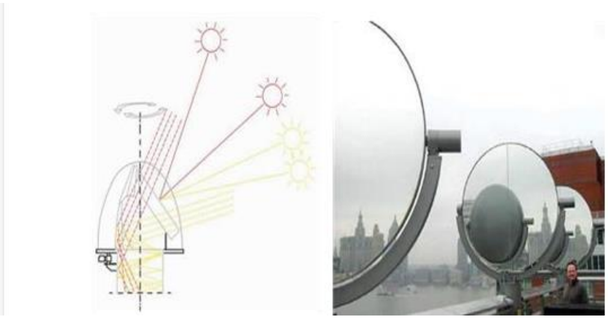


Figure 12 Diagram of Heliostats (Zarewa et al., 2023)

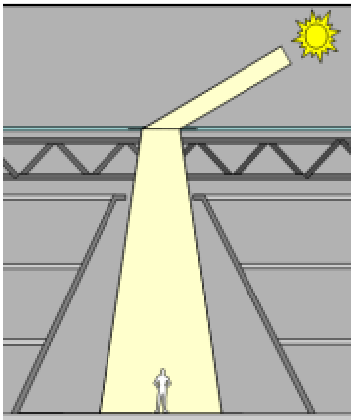


Figure 13 How holo-lux works (Daich, 2019)

II.13.6. Fiber Optics Daylighting System

A rooftop collector (which is made up of heliostats or lenses) is used to collect fiber optic light, which is then fed into the ends of fiber optic cables that can distribute the light throughout the building. Research indicates that, in full sun, the cable can emit 1,180 lumens, which is equivalent to the output of a 100-watt incandescent lightbulb.

The cable allows only the recognizable spectrum of light to transmit through; ultraviolet and most infrared are filtered out. Some products lose only 4% of light for every 10m cable length. It is noted that the high cost of glass cable production renders this current technology impractical, but research is being conducted on using a less efficient but significantly cheaper plastic cable. Other research is being conducted to reduce various costs associated with fibre optic lighting.

The ongoing dimension limit is approximately 15m (Zarewa et al., 2023).

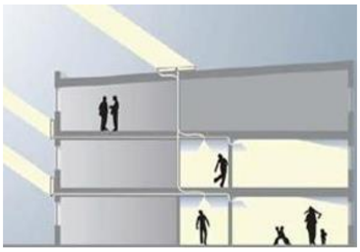


Figure 14 Fibre optics lighting technology (Zarewa et al., 2023)

II.13.7.**The anidolic ceiling:**

is an extensive natural light distribution system that works well in overcast conditions of sky. It is actually a light conduit built into a suspended ceiling in the center of the space. The anidolic ceiling is a zenithal lighting system made up of two parabolic mirrors that serve as concentrators, capturing the incoming light flow and redistributing it over a larger area. The anidolic elements are installed at both extremes of the light conduit: on the outside to capture light from the sky, and on the inside to control the direction of light emitted into the space. This system is supposed to enhance light levels in deeper parts of the space and create a more balanced distribution all through the the room while occupying the limited space of the false ceiling. Consequently, it leads to significant energy efficiency by lowering the use of artificial light in spaces with a large depth (Daich, 2019).

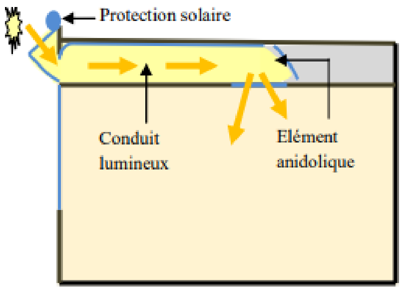


Figure 15 How the anidolic ceiling works (Daich, 2019)

II.13.8.**skylight**

A skylight is an architectural element implemented over an opening in a top of the building to permit daylight into the skylights come in a variety of styles, including individual roof lights, dome lights, ridge roof or curved continuous roof lights, and shed lights. A skylight's glass can be oriented in various directions, which are used to enhance daylight performance, reduce glare, and enhance both of visual and thermal comfort within a building (Fakhr et al., 2023).

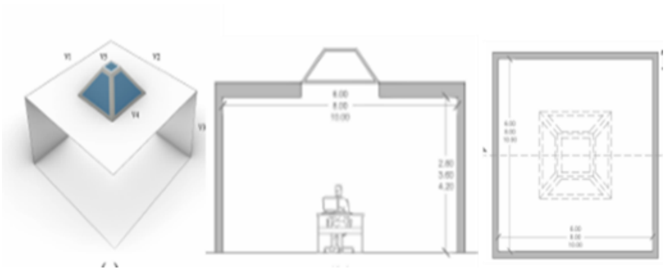


Figure 16 specific case of skylight (Fakhr et al., 2023)

II.13.9.**Laser-Cut Panel**

The laser-cut panel is a daylight-redirecting system created by laser cutting a thin panel of clear acrylic material. A laser-cut screen is a fine that has been laser cut into a series of rectangular elements. Each laser cut surface acts as a small internal mirror, attempting to deflect light that passes through the panel. A laser-cut panel does have the the following characteristics:

(a) a very high proportion of light deflected through a large angle (>120°),

(b) a clear view through the panel, and,

(c) a flexible production process perfect for small or large quantities (Ruck et al., 2000).

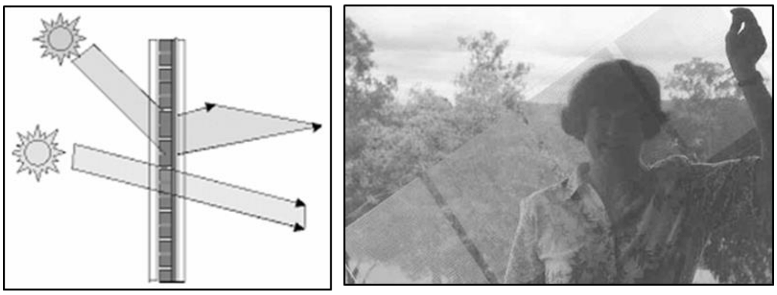


Figure 17 (left) section (right) view through a laser-cut panel (Ruck et al., 2000)

II.14.Key Design Parameters for Optimizing an Integrated Daylighting System:

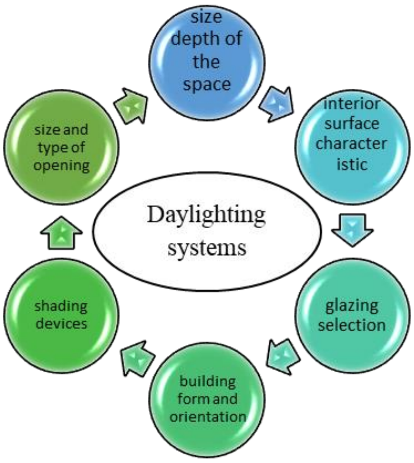


Figure 18 Key design of daylighting system

II.15.Assessment of visual comfort:

II.15.1.**Quantitative Evaluation in Daylighting**

Quantitative evaluation measures the performance of daylight using numerical metrics and data. Common metrics include:

- Daylight Illuminance (DI): Measures the amount of light (in lux) reaching a surface.
- Daylight Factor (DF): The ratio of internal illuminance to external illuminance under overcast sky conditions.
- Useful Daylight Illuminance (UDI): The percentage of time daylight levels fall within a desirable range (typically 100-2000 lux).
- Daylight Autonomy (DA): The percentage of occupied hours a space meets a specific illuminance level using natural light.

- Spatial Daylight Autonomy (sDA): The percentage of a space receiving at least 300 lux for 50% of the annual occupied hours.
- Annual Sunlight Exposure (ASE): Evaluates the potential for glare by measuring the percentage of space receiving more than 1000 lux for more than 250 occupied hours per year.
- Daylight Glare Probability (DGP): A measure of visual comfort evaluating the likelihood of glare based on brightness and angle of light sources.

II.15.2. Qualitative Evaluation in Daylighting

Qualitative evaluation assesses the subjective aspects of daylight in a space, focusing on human experience and comfort. Key factors include:

- Visual Comfort: Evaluating how well daylight reduces glare, provides balanced brightness, and avoids discomfort.
- Aesthetic Quality: How daylight enhances the perception of space, materials, and architecture.
- Color Rendering: The ability of daylight to accurately reveal colors in the environment.
- Psychological Impact: The influence of daylight on mood, productivity, and well-being of occupants.
- View and Connection to the Outdoors: How daylighting systems provide visual access to the outside, enhancing user experience.

III. Thermal comfort:

III.1. Definition

Thermal comfort can be defined as a feeling of satisfaction with the thermal sensation. It is identified by between both the dynamic equilibrium defined by thermal exchange between both body and its surroundings (Liébard & Herde, 2005). It represents also 'the state of mind, which express satisfaction with thermal environment' by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE 2004). Hensen (1991) also define it as "a state in which there are no driving impulses to correct the environment by the behavior"; which has the similarities with Givoni's (1976) opinion that thermal comfort is ' the absence of irritation and discomfort due to heat or cold, and as a state involving pleasantness'. Alternatively, it is the state that the person is entirely unaware of thermal condition of surroundings, neither considering whether the space they stay in is too hot or too cold (Strathclyde 2007). There is one concept all of these and other definitions of thermal comfort represent and emphasis: thermal comfort is the condition that individual feels neither too cold nor too warm while wearing an amount of clothing suitable to the task they need to perform. Thermal comfort is influenced by personal difference, such as mood, culture and other individual, organization and social factors. As such, the definition of thermal comfort is not a state condition, but rather a state of mind. The definition of thermal comfort is meant by the condition of mind, which correctly emphasizes that, the judgment of comfort or not is a cognitive process involving many inputs influenced by physical, physiological, and other factors (Hou, 2016).

III.2. Parameters of thermal comfort:

- Metabolism: the human body generates heat through metabolism, maintaining a temperature of around 36.7°C. A working metabolism that corresponds to a specific activity is added to the body's basal metabolism at rest.
- Clothing: signifies thermal resistance to heat interaction between both the the skin's surface and the surrounding environment.
- The ambient air temperature Ta.
- The walls' temperature (Tp). In a simplified manner, we define a felt comfort temperature (also known as the resulting dry temperature): Trs corresponds = (Ta + Tp) / 2.
- Relative humidity (RH) is the percentage difference between the amount of water in the air at a given temperature (Ta) and the maximum amount of water at the same temperature.

- Air velocity affects convective heat exchange. Inside the home, velocity field rarely exceed 0.2 m/s (Liébard & Herde, 2005).

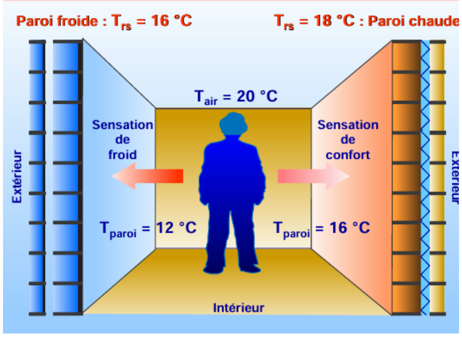


Figure 19 The comfort temperature depends on the air temperature and the wall temperature. The source: Alain Liébard, 1996, treatise on bioclimatic architecture and urban planning, p83

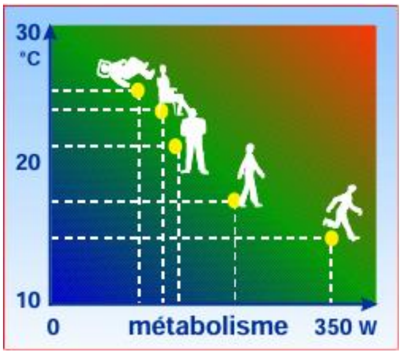


Figure 20 Comfort temperatures for different activities. The source: Alain Liébard, 1996, treatise on bioclimatic architecture and urban planning, p83

III.3.Ranges of temperatures:

Thermal comfort refers to the temperature's ranges, airflow velocities, and humidity levels that residents do not find uncomfortable. It is primarily a result of the heat exchange between the human body and its surroundings. These exchanges are caused by the following mechanisms: heating or cooling of the skin by convection with the air, depending on whether the ambient temperature is higher or lower than the skin's temperature; cooling of the skin by sweating the body in the air; and heating of the skin by direct or indirect radiation from the sun. This radiation has a short wavelength; it heats or cools the skin based on whether the walls' temperature is higher or lower than the skin's. This radiation has a long wavelength, and the presence of machinery or people in the room can generate heat. The increase in temperature causes the skin to heat up through convection (Liébard & Herde, 2005).

In hot, dry climates: The air temperature is frequently higher than the body temp. It is necessary to favor constructions with high thermal inertia in order to store coolness in the walls at night and restore it during the day. The low humidity level means allowing water to evaporate and cool the air. The existence of plants and trees helps to fulfill the comfort requirements (Liébard & Herde, 2005).

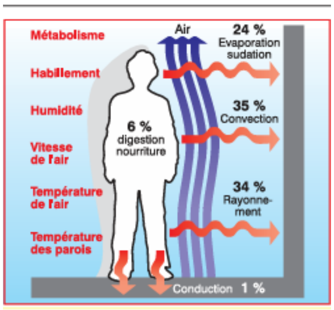


Figure 21 Physical parameters of heat loss of the human body, The source: Alain Liébard, 1996, treatise on bioclimatic architecture and urban planning, p81

III.4.The heat-balance approach

Cold discomfort is significantly highly related to mean skin temperature, while warmth discomfort is highly related to skin wetness. Dissatisfaction can also result from whole-body discomfort or local discomfort (unwanted heating or cooling of a specific body part). These relationships serve as the foundation for scholars' methods in developing the thermal comfort research model, which includes comfort model of Fanger (Hou, 2016).

III.5.Thermal comfort standards types

- European Standards ISO 7730
- ASHRAE Standards 55
- Chartered Institution of Building Services Engineers (CIBSE, UK Guideline)
- EN15251 (Hou, 2016).

IV.Energy Efficiency

IV.1. Energy efficiency in Buildings:

Building Construction industry consumes 40% of the entire of the world's primary energy and it is the responsible of 24% of CO2 of world's emissions. According to a report from the Intergovernmental Panel on Climate Change (IPCC), CO2 emissions from buildings have increased to the double from 4 gigatonnes (Gt) per year in 1971 to approximately 8 Gt per year in 2004, and are expected to reach 14 Gt per year in 2030, owing primarily to rising energy consumption in developing countries. By 2030, buildings will account for one-third of global CO2 emissions.

As a result, improving building energy efficiency is becoming a highest priority on the policy priorities among several countries and the global world community. The International Energy Agency, the IPCC (is Intergovernmental Panel on Climate Change), and the United Nations Environment Program recently released recommendations to mitigate greenhouse gas emissions and reduce energy consumption of buildings.

Some of these recommendations include tightening regulatory energy standards for new buildings, monitoring the quality and maintenance of existing buildings, encouraging energy-saving behavior among homeowners, and stimulating the diffusion and innovation of energy-efficient technologies. Technological innovation in particular has the potential to significantly reduce building energy consumption. The energy efficiency of insulation materials, heating systems, and other appliances has greatly improved over the last few decades, and recent developments in solar boilers, geothermal energy, or lighting technologies have also been very promising (Noailly, 2012).

IV.2.Impact of Daylighting on Building Energy Performance:

Because of the contemporary environmental and energy crises, as well as CO2 emissions, many scientific disciplines have shifted their focus to the use of clean energy sources. One of the most important sources of renewable energy in recent years have been the sun, which has been used in a number of different ways, of one of which has received less attention than others: the use of sunlight to illuminate the interior areas of buildings. Natural daylight and its efficient use are two variables that reduce the energy consumption and contribute to the sustainable architecture design. Natural light has played an important role in the advancement of architecture. Temperature, location, and natural light exposure have always been important and fundamental architectural considerations for architects. Existing records in the domain on how to use daylight in diverse environments and climates and building styles are diverse. After evaluating and comparing how different skylights disperse light in rooms, it appears that the space with a skylight implemented in the ceiling has better conditions in terms of brightness and daylong light homogeneity (Bashir et al., 2024).

V.Literature review on daylighting systems:

V.1.Visual performance

article	objective	Tools/methods	Climate and location of case study	Data collection	System discription/ location facades	Space dimention s	Orientat-ion	componants	limits
(Daich et al., 2016)	capture, channel and distribute day lighting to the interior space.	model ceiling system -simulation -scale model of 1/4 -HDR digital image - fish-eye lens - luxmeter.	Hot aride clomate, Biskra; Algeria	The illuminance values were taken using a luxmeter.	integrated ceili ng	12m deep room	the nort h façad e	a collector on façade, mirrored light duct, distribution element	/
(Choi et al., 2017)	Algorithm with three shading control modes (glare protection; illuminance satisfaction; energy conservation)	-Energy simulation -Glare simulation -Illuminance simulation -Real-scale mock-up	Korea Hot and humid in summer, cold and dry in winter	-local weather, - Illuminance data Sun positionf, Solar radiation, -shade design information	shading device algorithm using a shaded fraction that can be utilized in conjunction with an external movable shading device	4.2m x 5m x 4.2m	the south east	The shaded fraction , temperature sensors, illuminomet ers, a pyranometer, and a watt-hour meter	/

(Kim et al., 2019)	Devising a multi-objective exterior movable shading system and an algorithm to generate appropriate shapes	Rhino 3D Grasshopper 3D Octopus Ladybug	Korea Hot and humid in summer, cold and dry in winter	-DGP -solar radiation -the position of the sun -weather data -material properties -the solar shielding rate	the shading device can move and adjust its form around the window adapting to solar position. Its length from 200mm to 1000mm	window size(2700mm x 1800 mm)		composed of a driving part composed of four iron frames and a flexible fabric material connected to the frames	complexity of the system and the algorithm and the optimization
Abdelhakim Mesloub, 2020	assess the optimum performance of light shelves to facilitate the appropriate distribution of daylight and optimize energy savings,	Diva for Rhino as the tool to simulate daylight performance		-illuminance values: The simulations at the summer and winter solstices and during the mid-season	Light shelves are placed above eye-level and have highly reflective upper surfaces that reflect daylight onto the ceiling and deeper into a space.	4.6mx8m x3m	South orientation	combination of external and internal light shelves using integrated solar panels in several places	provides uniform daylight except the winter.
(Do & Chan, 2021)	evaluate daylight redirecting film's effectiveness when combined with automatically controlled roller shades	Simulation Radiance(three phase method) Energy Plus weather BSDF viewer	in Taipei Taiwan, humid subtropical and tropical monsoon climate	climate data, room *data (geometry and Radiance materials), sensor points, and the facade's BSDF files and shading states -illuminance levels		12 m × 15 m × 3.3 m	different orientations	multi-sectional façade(daylight redirecting film, roller shades, glazing)	multi-sectional facade concept has not been fully explored.

(Özdemir & Çakmak, 2022)	create an approach to evaluating daylight performance with a flat and dynamic shading system facade	Grasshopper ClimateStudio tools in Rhino	Hot aride clomate, Mardin, Turkey	the weather and precipitation data -Initial data and parameters -An algorithmic mechanism	the south facade	5m x 7m x 3m ;		single-glazed glasses, metal in triangular cell shells,	
(AHMED et al., 2023)	simulation-based study for an adaptive solar screen design driven by daylight and glare performance	using Rhino software, algorithmic modelling by Grasshopper and Diva with Galapagos interface		- Annual glare evaluation: weather file - monthly Simulations -series of commands; dimensions of the module	the Southwest facade	6m x 5,8 x 3.45m	the Southwest direction(south-western oriented window)	an adaptive solar screen was developed that consisted of a modular grid of hollow boxes,	
(Zarewa et al., 2023)	Optimising indoor lighting condition for visual comfort via light pipes	Ecotect, Radiance and Daysim; Revit	Kaduna; Nigeria tropical climates	climate data (qualitative research,) Annual weather data	300mm light pipe diameter is optimum to adequate lighting of shopping malls			the collecting head unit, the duct unit, and the diffuser unit	light pipe Performance (climate changes , modifications in installation)

Table 2 literature review of visual performance daylighting systems, source: the author

V.2.Thermal performance

article	objective	Tools/methods	Climate and location	Data collection	System facades	Space and dimentions	Orientat-ion	componants	limits
(Huang et al., 2015)	buoyancy driven exterior dynamic shading system to improve the energy performance and the thermal comfort	EnergyPlus Firefly	hot and humid climate of Taiwanese	-TMY3 of Taipei and Kaohsiung -temperature -solar radiation		office 6.0 m x 5.0 m x 3.0 m; with one 6.0	Various orientatioons	the outline frame, drive device ؛ floating-provided liquid compartment	Complexity of buoyancy mechanism
(Ahmed et al., 2016)	experimental results of thermal performance of residential building coupled with smart kinetic shading system	Rhino and Grasshopper	Egypt hot and arid climate	Temperature solar radiation Humidity data	central part moved vertically, the minor move from 0 to 180°	Living room 6.65m x 3.25m x 2.70m	south facade.	-temperature sensor -Arduino board -aluminum and panel -links -Servo motor -DC motor	
(Evola et al., 2017)	evaluating the effectiveness of shading devices to improve thermal comfort and illuminance level indoors, glazed buildings	-Ecotect -Energy Plus	Hot climate of the city of Catania, Southern Italy.	-operative temperature -occupancy period -ITD		Office building 27.5m x 11.5m	The main facade is South oriented and is almost entirely glazed	external roller blinds solar control film internal venetian blinds	It’s not easy to draw general conclusion

(Sheikh & Asghar, 2019)	present a biomimetic adaptive facade that reduces solar heat gain and hence the energy consumption	-Revit 2016 -Insight 360 -Ecotect 2011 -numerical valuation	hot and humid climate of Lahore, Pakistan	the building orientation, sun angles, solar radiance levels, indoor light ing levels, thermal performance of materials	panels moving on x and y axis on a steel frame structure The whole system is controlled by sensor feedback system	- commercial building for offices with twenty story - height in each floor:9 feet and 1 inch	the North-East facade is not exposed to direct sunlight, the other three facades are receiving direct solar gain during daytime	primary unit:shading module; made up of four shading panels, steel frame structure, hinges, guide rails and electric motors	

Table 3 literature review of thermal performance daylighting systems, source: the author

V.3.Energy consumption performance

article	objective	Tools/methods	Climate and location of case study	Data collection	System facades	Space and dimentions	Orientat-ion	componants	limits
(Giovannini et al., 2015)	Examine the effects of the SVM system on global primary energy performance and annual daylight performance.	DIVA-for-Rhino EnergyPlus	Abu Dhabi, United Arab Emirates. Hot desert climate	climate-based data, metrics as: Daylight Autonomy, Energy demand for lighting, cooling, heating	Closed mode: blocking direct sunlight. Open mode: allows skylight and view out.	Office scale: 3.52 m by 5 m by 3.04 m. Building scale: five-story, 10 offices	façades facing east and west	Three overlapping patterned shields Phase-change actuator Clear glazing Reflective materials	In a desert, venetian blinds are not practical. No use of the ASE (Annual Sunlight Exposure) metric; no north/south analysis.
(Attia, 2017)	evaluates the Al Bahr Towers adaptive façade. Energy control.	Site visits. Interviews. Review of standards and codes. occupant survey.	Abu Dhabi, United Arab Emirates. Hot desert climate	/	1,049 units :triangular origami shading device, open/ close with sun position	/	towers are round, there are differences in orientation.	Steel & aluminum frames for structural support. sun-tracking software; Sensors	complex manufacturing, Maintenance challenge, Managers didn't share actual energy data,
(Elzeyadi, 2017)	evaluate and compare the performance of different dynamic shading systems in Energy savings	-Simulation tools; Field testing; Full-scale prototypes	/	Full-scale experimental testing at the Façade	Dynamic shading systems adapt to external conditions using sensors	The study used a typical office space standard for commercial use.	The space was likely designed to simulate orientations that receive significant solar exposure	-Dynamic shadings - Sensors or control systems	-No single shading typology optimized all performance criteria

(Yi et al., 2019)	Initiate and evaluate an algorithm for adaptive façades to enhance building energy efficiency and daylighting.	Rhino, Grasshopper, DIVA; (TAPSSA) algorithm, intelligent Hardware; Case study testing: real façade in a lab	Miami, Florida International University, Hot and humid with strong sunlight exposure	Actual environmental data (hot, sunny hours) fed into the simulation model. On-site: illuminance and solar radiation.	Adaptive external shading devices adjust to sun's angle and intensity	Double-glazing façade facing a large courtyard.	East-facing façade receives strong morning sunlight, causing overheating and glare issues.	Shading elements, sensors, Arduino microcontroller , wireless communication modules	Complexity of simulations, existing tools (BIM plug-ins) can't handle dynamic responsive forms well, cannot be generalized to other climates/ buildings.

Table 4 literature review of energy performance systems, source: the author

CONCLUSION

The intricate yet crucial role that natural light plays in influencing indoor environmental quality and building performance is revealed by the theoretical investigation of daylighting systems. Functionality and well-being in occupied spaces depend heavily on visual comfort, especially the management of glare. In a similar vein, thermal comfort becomes an important factor that is directly impacted by solar gains and daylight penetration. Simultaneously, the potential of combining environmental design with sustainability goals is highlighted by the optimization of energy consumption through clever daylighting techniques.

Numerous tools, techniques, and adaptive systems have been developed to achieve a balanced integration of daylighting, comfort, and energy efficiency across a variety of climates and building types, as the reviewed literature makes clear. Conciliating daylight's dynamic nature with users' shifting needs and the built environment's architectural limitations is still difficult, though. In order to guide the design of an integrated daylighting system that aims to concurrently mitigate glare, enhance thermal comfort, and reduce energy consumption, this chapter thus offers the conceptual and scientific foundation required for the ensuing analytical and practical investigations in this thesis.

CHAPTER II:

ANALYTICAL STUDY OF SCHOOLS OF ARCHITECTURE: CASE EXAMPLES AND SITE CONTEXT ANALYSIS

I.INTRODUCTION

This Analytical Chapter (02) lays out the research framework for designing an architecture school. It is separated into two primary sections. While Part II concentrates on projects analysis, program, and site analysis, Part I offers a theoretical analysis of the School of Architecture typology, detailing its spatial and environmental requirements. The projects were picked as part of a larger selection process that also includes case studies from the modern era as well as other historical periods of architecture. One example of modern architecture, for example, was specifically chosen to guarantee diversity and demonstrate the evolution of environmental design responses. After identifying opportunities and challenges, the site analysis looks at contextual and climatic data to provide the performance criteria required for the design phase.

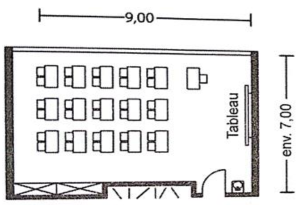
II.The School of Architecture:

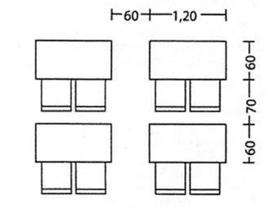
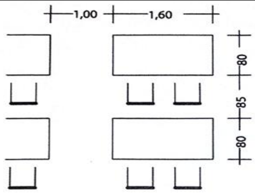
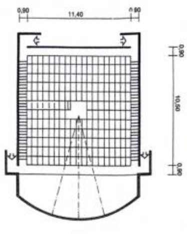
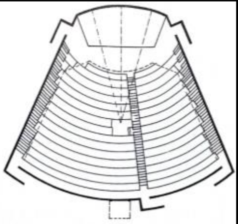
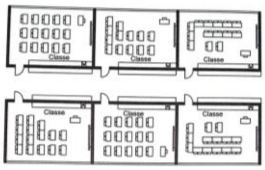
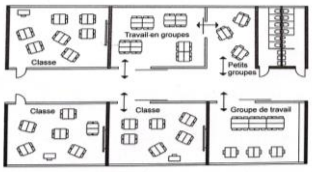
In architectural terms, can be defined as a physical and conceptual space where the process of architectural education and exploration takes place. It is a designed environment that embodies the principles of functionality, spatial organization, and aesthetic expression to facilitate the learning and creation of architecture. The school's layout typically integrates lecture halls, design studios, workshops, libraries, exhibition spaces, and collaborative areas, reflecting the dynamic interplay between theory, practice, and innovation. Architecturally, it serves as a living laboratory, showcasing design principles, materiality, and sustainable practices, often acting as a microcosm of the broader architectural field it represents.

II.1.The spaces types of the school of architecture:

Educational sector	Teaching, research and documentation
Administrative sector	Administration
Relaxing	Cafeteria, store ...

II.2.Architectural standards relating to spaces. The source: neufert:

Space	standards
 Profondeur maximale d'une salle de classe mono-orientée	This figure shows a typical mono-oriented classroom layout with a width of 9 meters and a maximum depth of approximately 7 meters. The limited depth ensures good visibility and acoustics for all students, while supporting efficient use of space. Architecturally, such proportions help maintain functional clarity and simplify environmental control by reducing the distance between the occupied zone and external walls.

 ⑥ Dimensions minimales pour l'organisation traditionnelle avec pupitres	This diagram outlines the minimum spatial requirements for organizing desks in a traditional classroom layout. Each pair of desks is spaced at 1.20 meters laterally and 70 centimeters longitudinally, with 60 centimeters allocated per student. These dimensions ensure adequate circulation, comfort, and accessibility within a compact footprint. From an architectural standpoint, adhering to these minimum standards supports functional density while maintaining usability and movement efficiency in educational spaces.
 ① Espace min. pour agencement des tables en rang dans salle de cours	This diagram shows the minimum recommended dimensions for organizing tables in a row-based classroom layout. A lateral spacing of 1.60 meters and a depth of 80 to 85 centimeters between rows allow for comfortable seating and circulation. From an architectural perspective, these dimensions help ensure a functional and accessible learning environment, balancing spatial efficiency with user comfort.
 ① Amphithéâtre rectangulaire de 200 places	Rectangular amphitheater: This amphitheater is designed in a rectangular format measuring approximately 11.40 meters in width and 10.50 meters in depth, offering seating for 200 individuals. The seating is arranged in a compact grid, emphasizing a frontal teaching approach ideal for lectures. Two side aisles, each 0.90 meters wide, facilitate circulation and ensure accessibility. The structure prioritizes clarity in sound and visibility but offers limited interaction, reflecting a traditional and passive learning model.
 ② Amphithéâtre trapézoïdal de 400 places	Trapezoidal amphitheater: With a layout estimated to be 20 to 22 meters wide at the rear and around 16 to 18 meters deep, this trapezoidal amphitheater supports a larger audience of 400 seats. Its shape optimizes sightlines and acoustic focus toward the speaker's area. A central aisle enhances circulation and organization. The widening geometry enhances engagement and spatial comfort, making it suitable for large lectures while remaining visually and acoustically effective.
 ① Double rangée de classes alignées le long d'un corridor, système distributif en face à face existant	This educational layout consists of multiple classrooms, each approximately 7 to 8 meters long and 6 to 7 meters wide, arranged on both sides of a central corridor. It represents a conventional school model that enables easy monitoring and standardized access. The internal configurations favor individual work and frontal instruction but lack flexibility and do not encourage inter-class collaboration.
 ② Reconversion d'une double rangée de classes en « cluster » avec plusieurs espaces de classes et des anciennes classes transformées en espaces pour travail en groupes, avec de nouveaux équipements sanitaires	In this extended cluster model, the total spatial arrangement spans approximately 25 to 28 meters in length and 6 to 7 meters in depth. It includes multiple classroom areas along with designated zones for group and small-group work. The diversity of learning setups supports different teaching styles, enhancing student autonomy and group engagement.

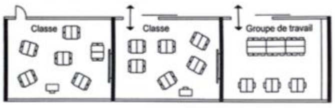
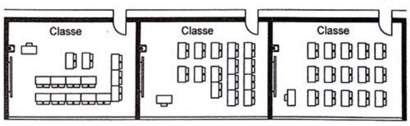
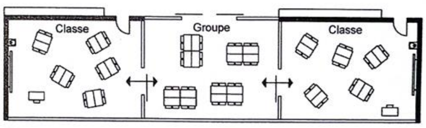
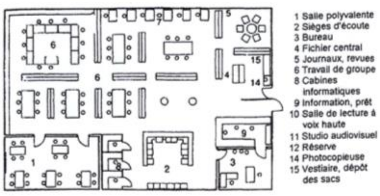
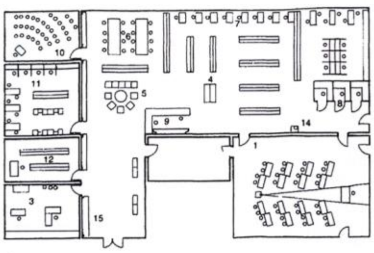
	Internal transparency and easy transitions between zones promote a more open and communicative environment.
 ② Reconversion d'une double rangée de classes en « cluster » avec plusieurs espaces de classes et des anciennes classes transformées en espaces pour travail en groupes, avec de nouveaux équipements sanitaires	This layout transforms standard classrooms into a clustered configuration extending approximately 20 meters across and 6 to 7 meters in depth. The reorganization introduces internal flexibility, with varied desk arrangements and group zones. This approach promotes collaborative and interactive learning, moving away from strict compartmentalization toward shared, dynamic spaces that better reflect current educational philosophies.
 ④ Rangée de classes sur un corridor distributif dans un plan existant	Here, classrooms measuring around 7 meters by 6.5 meters are aligned in a single row along a corridor, maintaining a rigid, traditional spatial organization. The desks are arranged in varied but mostly linear formats, emphasizing teacher-centered instruction. This configuration is efficient but spatially isolated, reinforcing conventional pedagogical methods.
 ⑤ Reconversion de l'espace fig. 4 en un système ouvert à la fois sur le corridor et les anciens espaces de classes	This open-concept layout converts classroom boundaries into flexible zones that connect to the corridor. The combined area covers around 20 meters in length and 6 to 7 meters in width. Central group spaces are shared by adjoining classes, reinforcing collaborative learning while maintaining visual openness. This layout promotes spatial fluidity, though it may require acoustic treatments to manage sound levels in such an open environment.
 ① Exemple pour une bibliothèque scolaire / médiathèque	This school media library is organized into functional sections within a compact area. It includes multipurpose rooms, IT stations, reading zones, and service desks. Each space is clearly defined to support both individual study and group activities. The space is efficiently used, allowing simultaneous use by multiple user types while maintaining order and accessibility.
 ② Exemple pour une bibliothèque scolaire / médiathèque	Spanning an estimated 28 to 30 meters in length and 16 to 18 meters in depth, this larger media library integrates traditional reading areas, audiovisual spaces, work zones, and a lecture hall. The spatial zoning is deliberate, allowing a smooth flow from quiet reading sections to more interactive or digital zones. The layout supports varied learning modalities, reinforcing the library's role as both an academic and social learning environment.

Table 5 standards of the spaces of school of architecture, source: neufert

II.3.Illuminance levels of spaces of the school of architecture:

Task or Activity	M I	UGR	CRI	Reference Plan
Filing, Transcription	300	19	80	
Writing, typing, reading, data processing drawing	500	19	80	Working area or 0.85m from the ground
Industrial Design	750	16	80	
Computer-aided design workstations	500	19	80	
Conference room	500	19	80	

Table 6 illuminance of the spaces of school of architecture

III.Project analysis

III.1.The list of examples:

III.1.1.Book examples

School of Architecture - University of Miami	Austin E. Knowlton School of Architecture	Bordeaux School of Architecture	BAUHAUS School
			

III.1.2.Existing examples

EPAU Algeirs	Biskra Depatement of Achitecture
	

III.2.The elements to be analyzed

Project Data	Urban Aspects	Architectural Aspects	Technical and Functional Aspect	Environmental Aspects
-Technical Sheet - Situation -Motivation of Choice	-Distant Environment -Immediate Environment -The Project Plot -Roads and Accessibility	-Design Concept -Volumetry -Entries	-Circulation - Spatial and Functional Organization	-Lighting -Thermal -Energy Consumption

III.2.1.The analysis of book examples:

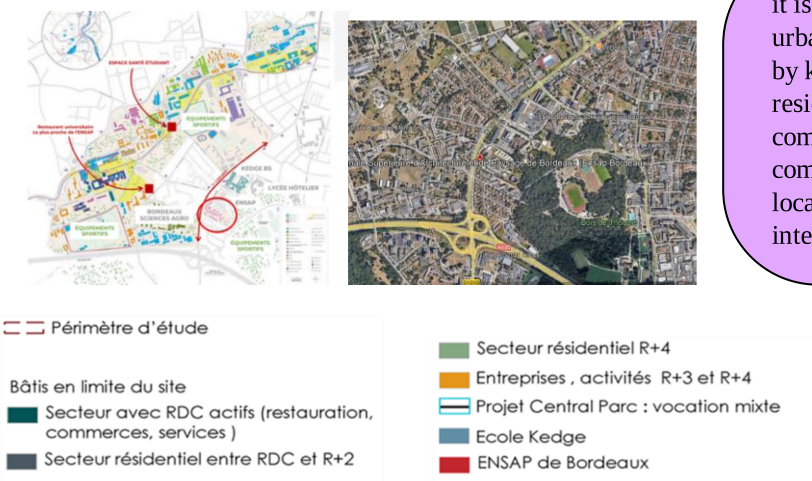
III.2.1.1.Project data

The project	Technical sheet	situation	Motivation of Choice
 School of Architecture - University of Miami	**Architect:** Arquitectonica (Bernardo Fort-Brescia, Raymond Fort, Sherri Gutierrez) **Year of Completion**: 2018 **Surface Area**: 13,125 square feet (1,220 m²) **Number of Floors**: One level	Coral Gables, Florida, United States	The project was chosen because of its unique form and small scale, and it shares the same context as the location of this thesis project. It also helps to address projects of various sizes rather than just large-scale.
 Austin E. Knowlton School of Architecture	**Architect**: Arquitectonica **Year of Completion**: 2004 **Surface Area**: **Number of Floors**: five-story structure	The Ohio State University in Columbus, Ohio, USA.	The project presents a volumetry rich and simple. its design concept is appropriate for our climate due to facades and using vegetation. It belongs to contemporary architecture.
 Bordeaux School of Architecture	**Architects** : Lacaton & Vassal **Year of Completion**: 2009 **Surface Area**: 19 570 m²	Talence, France, close to the Bordeaux University campus	the project's symbolism and the way its building elements are fragmented into various geometries set it apart from the other cases that were chosen and assist in ensuring variety within the thesis and avoiding a focus on a single project type.
 BAUHAUS School	**Architect**: Walter Gropius **Year of Realization**: 1925–1926 **Architectural style**: Modernist **Surface Area**: Approximately 7,500 m² **Number of Floors**: 3 main floors	Dessau, Germany	The project is selected because it maintains the coherence of the urban fabric while introducing architectural interventions, reinforces urban continuity, and is recognized, ensuring the availability of data for analysis. In architecture, it is widely known.

III.2.1.2.Urban aspects

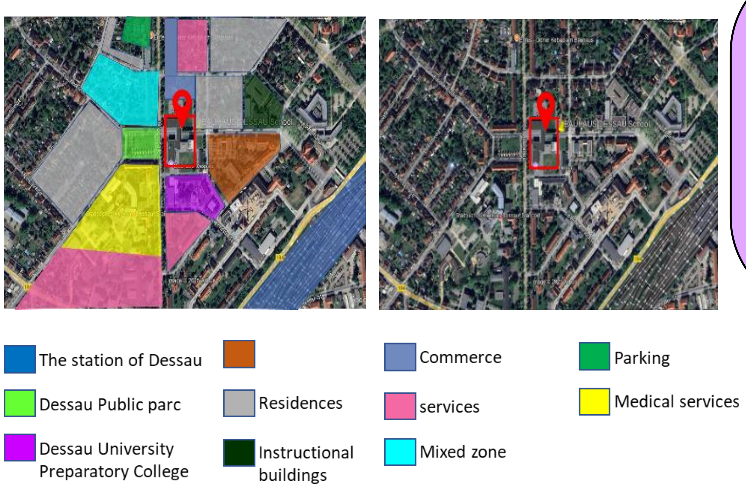
The project	Distant environment
School of Architecture - University of Miami	  The project is located in the University campus of Miami and it is surrounded by many types of projects: residential, commercial U. of Miami administration; Funcamps/Magicamp; Music Library Center; Mahoney Residential College Eaton Residential College; Lakeside Village; Intramural Fields; Commercial Lake Osceola; Lowe Art Museum; Mahoney-Pearson Parking Garage; UC Pool U. of Miami
Austin E. Knowlton School of Architecture	  Its location on the Ohio State University campus, close to important landmarks, academic buildings, residence halls, and recreational areas, facilitates students' everyday lives. University residences; Parking lots; Ohio Stadium; Instructional buildings Public parc; University halls; Ohio State Ice Rink; Pedagogical departements Commercial building; The oval place; St. John Arena

Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux

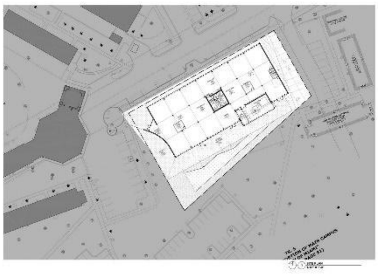
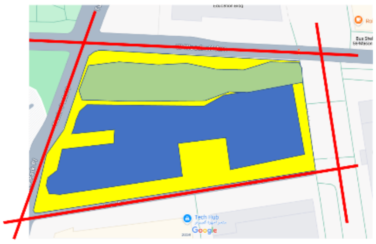
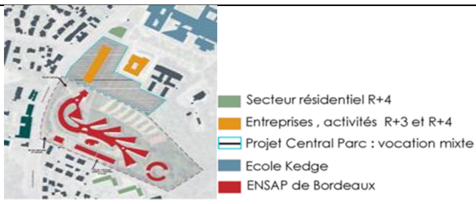
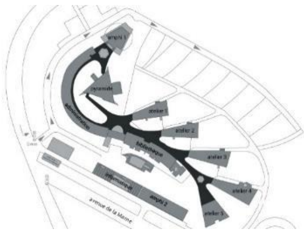


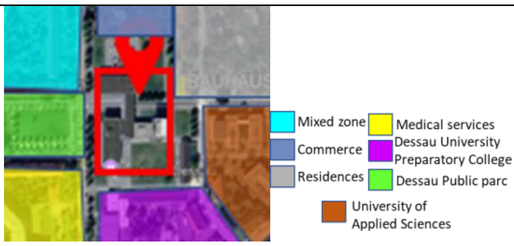
it is situated in an urban area, bordered by kedge School, a residential area, commercial area. The compus, where it is well located, is well integrated into the city.

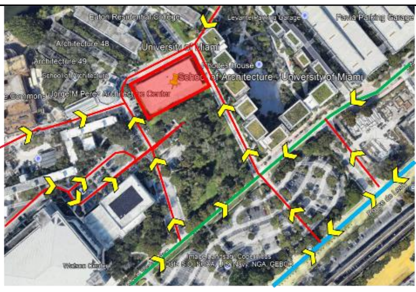
BAUHAUS School



Surrounded by a variety of building types, the Bauhaus on the outskirts of Dessau creates an urban continuity by forming the city's extensions

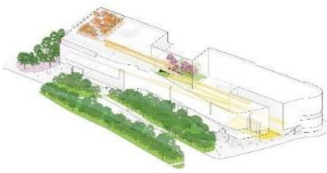
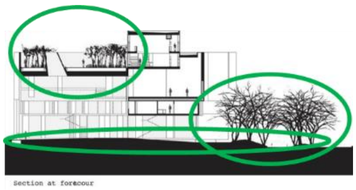
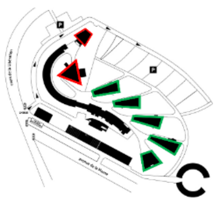
The project	immediate environment	the project plot
School of Architecture - University of Miami	 The immediate area is pedestrian-friendly, academic, and well-integrated into the campus landscape; the project continues to have a unique architectural	 The project occupies 100% of the plot.
Austin E. Knowlton School of Architecture	 The immediate surroundings are educational in nature, with departments and instructional buildings all around, and nearby residences adding continuity, vibrancy, and ease of use.	 The project takes up about 60% of the plot, with the remaining unbuilt area being used for circulation, vegetation, and greenery and the design itself
Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux	 Open green spaces and pedestrian walkways encourage interaction and integration with nearby faculties, because it is surrounded by other higher education facilities.	 Roughly 70% of the plot is devoted to the project, with the remaining portion being used for circulation and green spaces.

BAUHAUS School	 Open green areas and a different types of buildings encircle the Bauhaus School, which is positioned to highlight continuity, openness, and strong links to	 The project spans two plots separated by a road, connecting them to restore urban continuity, each part occupies only 10–20% of its plot to ensure openness and

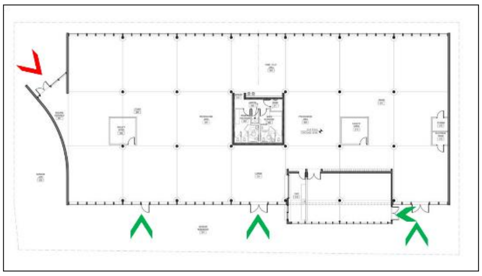
The project	roads and accessibility	
School of Architecture - University of Miami		National Street principal Street secondary Street directions
Austin E. Knowlton School of Architecture		National Street principal Street secondary Street pedestrian roads & directions
Ecole Nationale Supérieure		National Street principal Street secondary Street bus route & directions

BAUHAUS School		National Street principal Street secondary Street directions

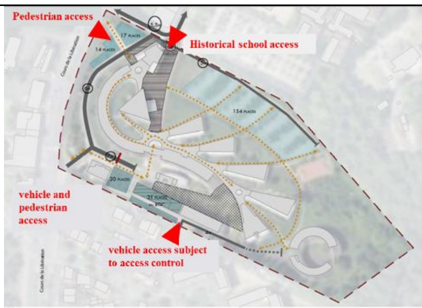
III.2.1.3.Architectural aspects

The project	-design concept
School of Architecture - University of Miami	   The project is deisghned to be at the center of an intersection, the building creates a plaza and adjoining pathway that links the campus to the Miami Metrorail.The roof slab warps slightly, seemingly melting in the Miami heat. The exposed structure of glass and concrete serves as a teaching tool by illustrating some of the basic tenets of modern architecture, construction, and sustainability.
Austin E. Knowlton School of Architecture	the building was designed to improve the natural light quality of the Interiors and to create useful outdoor spaces so for that two deep Courtyards where carve it from the unrelating perimeter walls. Thus, ways were found to increase the presence and power of the landscape in a tightly constrained site and as a striking complement to the contemporary architecture.   
Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux	From the initial 1973 master plan emerge two forms of apparent geometric simplicity affectionately nicknamed the “eye” and the “pyramid”. The first, an obvious reference to the Modern Movement and Oscar Niemeyer, serves as an amphitheater with effective acoustics. The building is inspired by powerful architectural forms, such as triangles and fan-shaped volumes, symbolizing both the dynamics of progress and an innovative approach to teaching.  

BAUHAUS School	Form follows function: functional and pure volumes, innovative use of new materials, (glass curtain walls, horizontal windows, absence of ornamentation, the overall design of all the elements and, through the glass wall, a relationship is created between the interior and the exterior.   

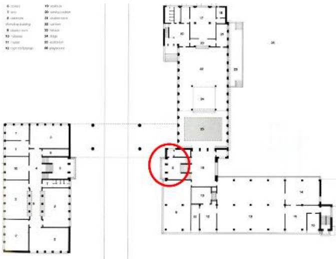
The project	-volumetry	-entries
School of Architecture - University of Miami	The volumetry of the project aligns with the goals of the interaction with the environment, Miami climate and the sustainability. Minimalist Form so that the strength of the design lies in its simplicity and clean lines (rectangular form and melt roof), Thoughtfully designed to mitigate Miami's heat and glare (the glass quality and the project orientation).   	 the project has one principle excess which is located at the intersection of two streets and 3 secondary entrances with one indirect access leads to a space then to the project
Austin E. Knowlton School of Architecture	The building is composed of rectangular and cuboidal volumes, The large overhang above the entrance enhance the sense of scale and create a welcoming gesture.The columns supporting the overhanging volume introduce a sense of openness at the ground level.The circular cut-out in the ceiling of the overhanging volume adds dynamic element that breaks the strict rectilinear geometry.   	 main entrance cafeteria entrance Administration entrance basement entrance emergency exit

<table>
<tr>
<td>Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux</td>
<td>
What is different in this project is that the distribution of spaces is fragmented:
-The pyramid in the center dominates the site, creating a visual and symbolic focal point. -The workshops are organized in a radial manner, which favors a functional distribution and interaction between the spaces. -The semi-circular structure connects the pavilions and offers meeting and exchange spaces for students and teachers. -The project is inserted in a green setting, with open spaces around it that reinforce its integration into the site. The pyramid in the center dominates the site, creating a visual and symbolic focal point. -The workshops are organized in a radial manner, which favors a functional distribution and interaction between the spaces. The semi-circular structure connects the pavilions and offers meeting and exchange spaces for students and teachers. -The project is inserted in a green setting, with open spaces around it that reinforce its integration into the site.

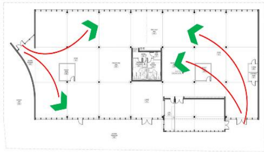
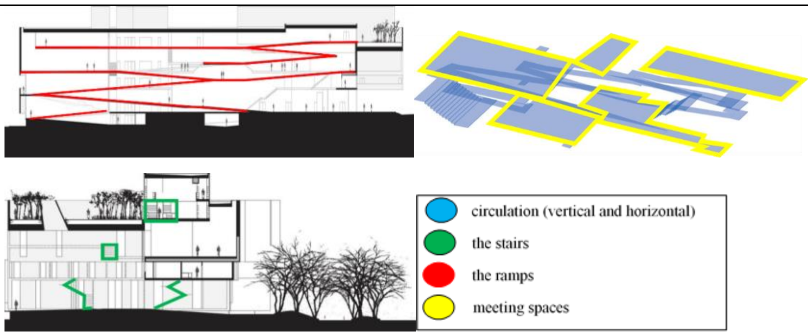
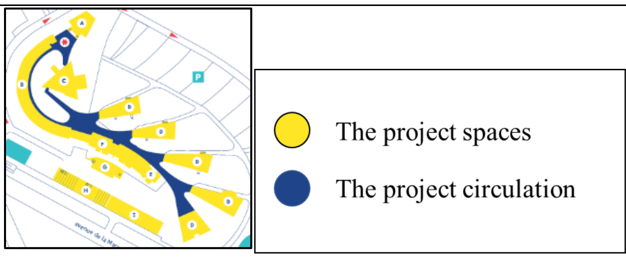
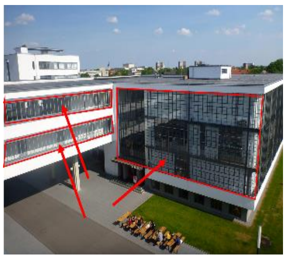

</td>
<td>


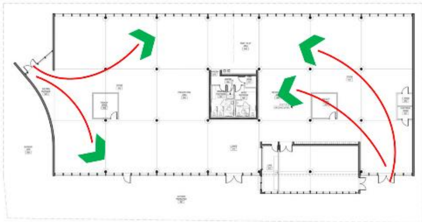
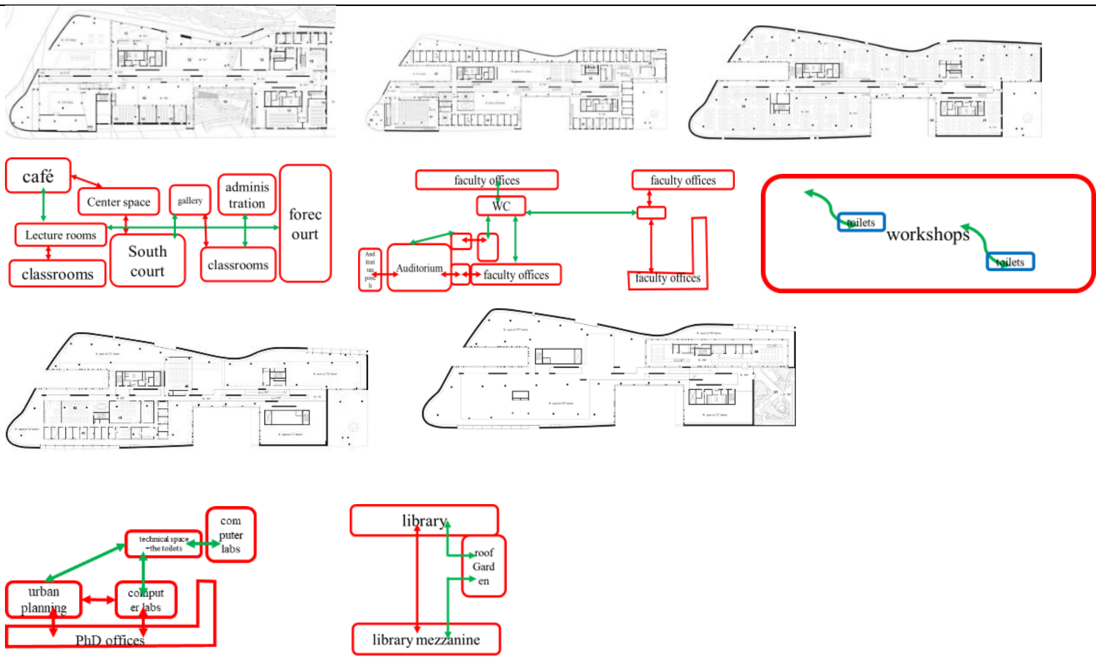
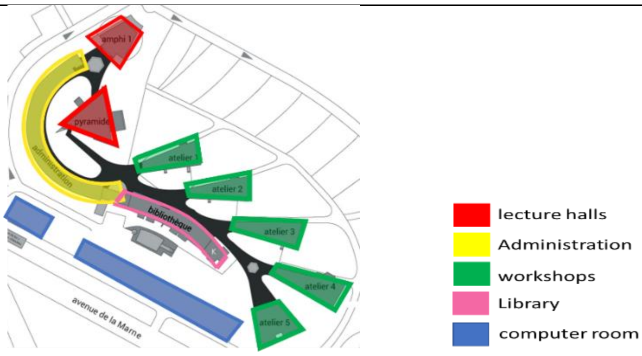
Lack of qualified pedestrian access (historical access to the north of the condemned site). A Light Vehicle access to the southwest: which serves 233 light vehicle parking spaces. A logistics/ firefighter’s access to the south. Roads organized around the periphery of the site.
</td>
</tr>
<tr>
<td>BAUHAUS School</td>
<td>
The building is composed of three wings, they're all connected by bridges. large two-story bridge associates the school and workshop spaces, which creates the roof of the administration located on the underside of the bridge. monumental entrance It separates the different buildings according to their function. architectural treatment and connects everything by an "interior" circulation. It is impossible to have a single vision of the building. You have to go around the Bauhaus to understand its shape.

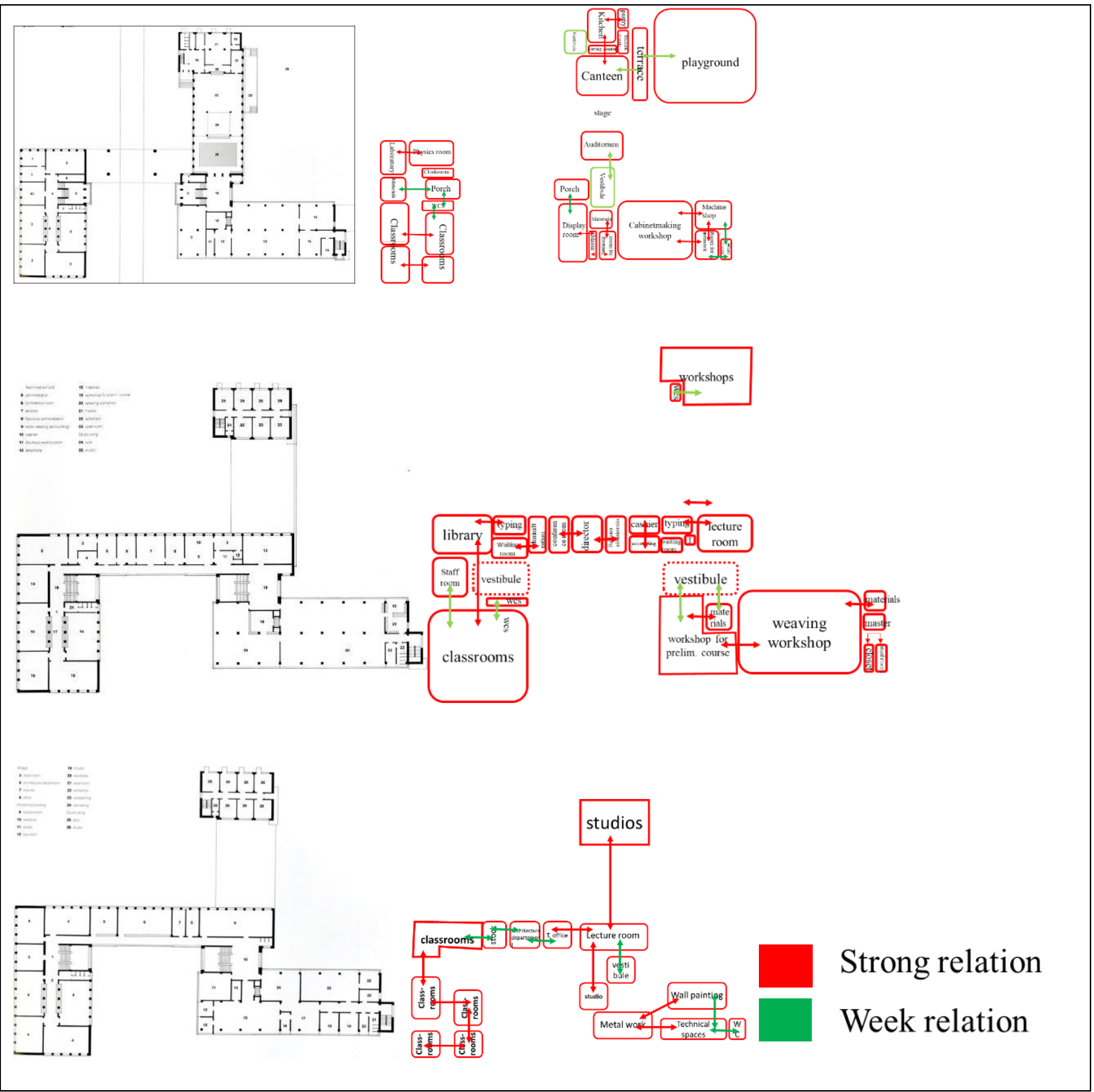
</td>
<td>


To ensure clear accessibility within the plan, the main entrance is positioned strategically at the intersection of the wings and is emphasized by a large red door that is reinforced by stairs that draw attention to it.
</td>
</tr>
</table>

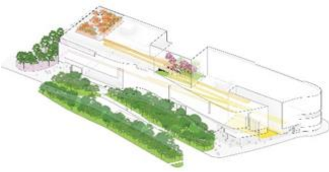
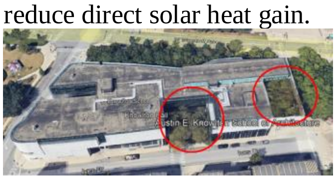
III.2.1.4.Functional aspect

The project	-circulation
School of Architecture – University of Miami	the project consists of a single level with a free plan so the circulation is really fluid and easy 
Austin E. Knowlton School of Architecture	 the vertical circulation path begins At the main entrance, the vertical circulation path begins.The inclined plane system moves up and through the building, passing through studios and review spaces along the way. The library's roof garden extends outward and onto the forecourt below, bringing the inclined plane to its end above the starting point.
Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux	
BAUHAUS School	The Bauhaus School's circulation is efficient and clear, with glazed bridges and corridors connecting the wings to guarantee seamless movement and spatial coherence and visual transparency. 

<table>
<tr><th>The project</th><th>Spatial and functional organization</th></tr>
<tr><td>School of Architecture - University of Miami</td><td></td></tr>
<tr><td>Austin E. Knowlton School of Architecture</td><td>
</td></tr>
<tr><td>Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux</td><td>
</td></tr>
</table>

BAUHAUS School	

III.2.1.5.Environmental aspects

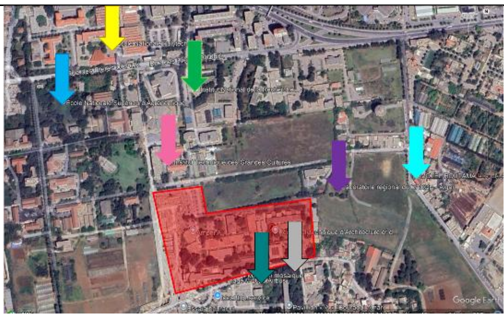
The project	lighting	thermal	Energy consumption
School of Architecture - University of Miami	the artificial light is not needed during the daytime while featuring the first ever use of 18 ft High hurricane resistant glass panels 	the openable windows sanctions as insulator and eliminate the total dependence on the air conditioning during the summer 	a sustainable work environment is insured by the orientation of the building and the Strategic elements 
Austin E. Knowlton School of Architecture	The building's large glass panels and strategic placement of windows ensure the penetration of ample daylight, reducing dependency on artificial lighting and lowering energy consumption. The central courtyard and open spaces contribute to interior lighting and airflow. 	For optimal thermal insulation, one of the passive techniques used is the green terrace. The overhang above the main entrance provides shading, The design allows for cross-ventilation. The vertical windows slits reduce direct solar heat gain. 	The well-insulated façade likely minimizes energy loss, optimizing the building's energy efficiency during extreme weather conditions in Ohio.
Ecole Nationale Supérieure d'Architecture et de Paysage de Bordeaux	 Utilizing large windows and open facades, positioning to let in and to capture the natural light as much as possible.	Fragmented shape in order to enable Integrate green spaces into the project to create a specific microclimate for the project and achieve a better atmosphere. 	/
BAUHAUS School	The workshops have a large glass facade, which allows maximum light and a view from the inside to the outside 	/	/

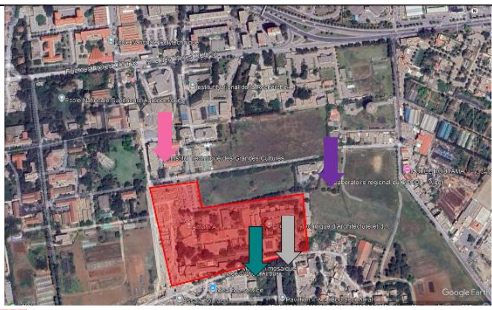
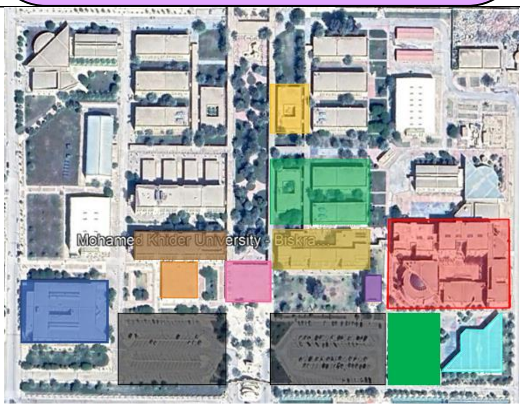
III.2.2.The analysis of Existing exemples:

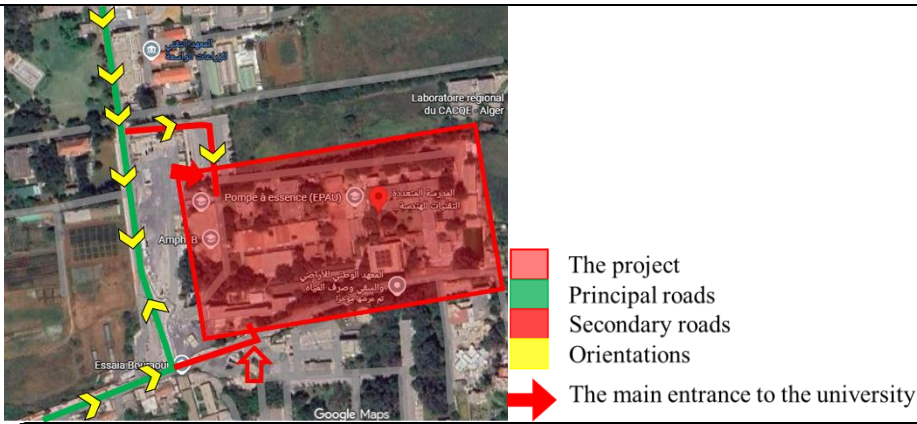
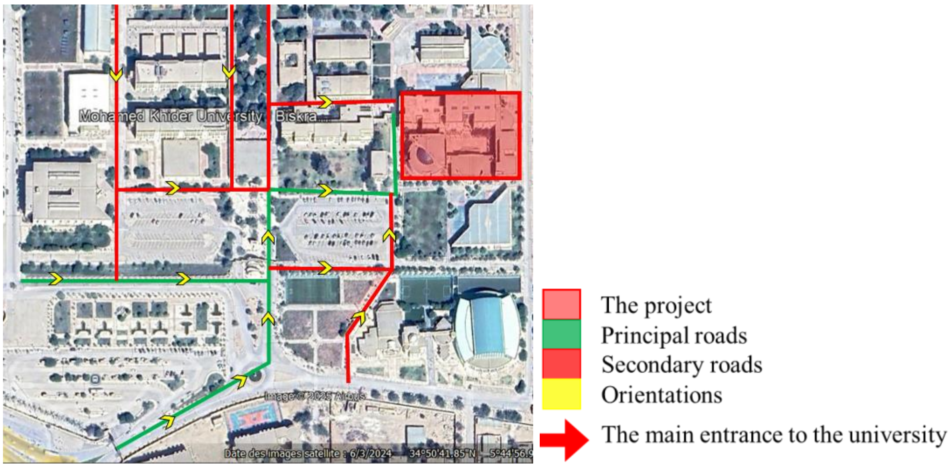
III.2.2.1.Project Data

Project data	Technical sheet	situation	Motivation of Choice
Polytechnic School of Architecture and Urban Planning: EPAU 	Architect : Oscar Niemeyer/ Jean-Jacques Deluz/ BEREG Year of Completion: 1968/1980/1999/2004/2006 Surface Area: 3.75 ha Number of Floors: four levels	The university campus is situated in the capital, Algiers, between the communes of El Huarache and Oued-Smar.	Choosing to analyze an existing project by famous architects which is visited helps to understand the space, its context, and user interactions. It allows for critical assessment and offers the chance to explore the principles and impact of renowned architects.
The department of architecture of Mohamed Kheidher Biskra university 	Architect: OUMANE Abd Karim /ARIOUET Brahim Year of Completion: 2004 Surface Area: 7.000 m² Number of Floors: four levels	Mohamed Kheidher Biskra university, Biskra city, Algeria. 2 Km far from the city center.	I chose this department for project analysis because I have experienced the space myself, having studied and lived it. This direct exposure allows me to observe every detail, and gain deep insights into its strengths and weaknesses. I can inspire from its positive aspects while identifying areas for improvement, making my analysis both practical and meaningful.

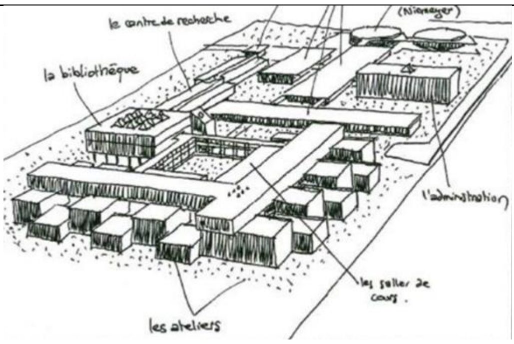
III.2.2.2.Urban aspects

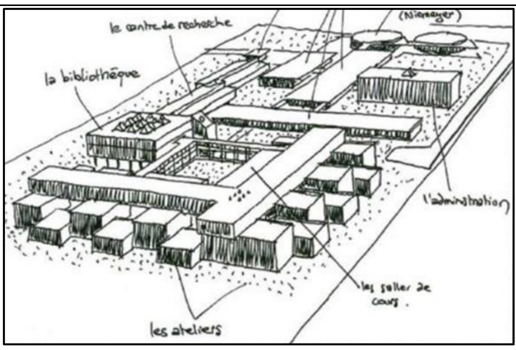
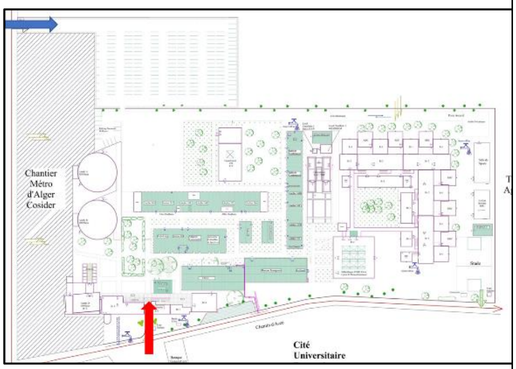
The project	Distant environment
Polytechnic School of Architecture and Urban Planning	 The project (epau) CACQE-Algiers regional laboratory- National research institute Motel ROUTAMA National Polytechnic School Technical Institute for Large-Scale culture National Higher School of Agronomy National Institute of Land, Irrigation and Drainage Mosaic store The school campus is situated in the capital, Algiers, between the communes of El Huarache and Oued-Smar, in an academic area
The department of architecture of Biskra University	 The project Military police The university central campus Residential buildings Public garden The valley Multi-sports stadium The project in located in Biskra Univ on the Eastern side of the city, an accessible urban area, near to 18 February Stadium and it reinforces the City Identity and development.

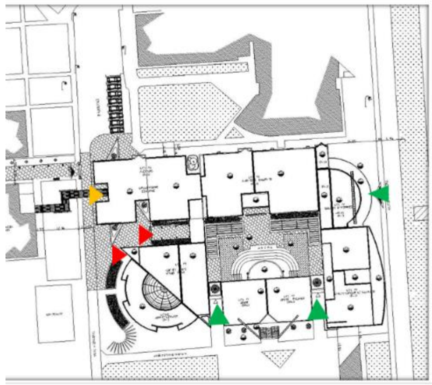
The project	immediate environnement	the project plot
Polytechnic School of Architecture and Urban Planning	 The project (epau) CACQE-Algiers regional laboratory- Technical Institute for Large-Scale culture National Institute of Land, Irrigation and Drainage Mosaic store the project is surrounded by educational buildings such as institutes and Laboratories and higher schools and Residences which gives it a vibrant	 The project occupies 60% of the plot as depicted in the illustration, where the rest is dedicated to the parking.
The department of architecture of Biskra University	 The project Administration -univ- The central club Amphitheatres Computer science department The central library Parkings Green space Administration offices The large conference room The old part of the architecture department and department of earth and universe science The project is located on the Biskra University campus, close to other academic departments. Its strategic location allows it to be seen from the entrance of the	 The project utilizes 90% of the plot, as depicted in the illustration.

The project	roads and accessibility
Polytechnic School of Architecture and Urban Planning	 The Bouraoui metro station and two major nearby roads provide convenient access to the Polytechnic School of Architecture and Urbanism. The university is easier to get to thanks to the pedestrian pathways around it.
The department of architecture of Biskra University	 The university is well-connected by mechanical accessibility, ensuring ease of access to the campus. Additionally, within the university, multiple roads provide convenient routes to the department.

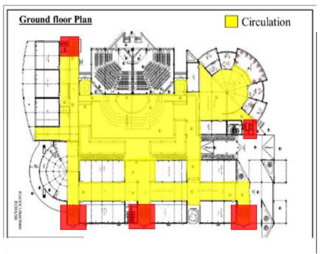
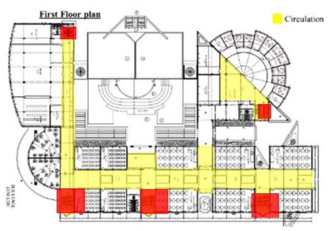
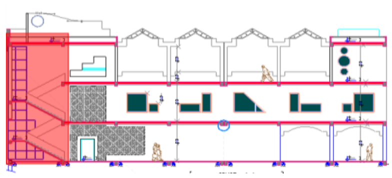
III.2.2.3.Architectural aspects

The project	-Design concept	
Polytechnic School of Architecture and Urban Planning		Inspired by Brasília's CEPLAN project, Oscar Niemeyer emphasized simple, economical design with patios for interaction and privacy, while Deluz proposed a functional alternative to his fluid volumes, preserving visual harmony.
The department of architecture of Biskra University		Integrate several styles into the project by using a Greek agora, Roman columns, ...and mix different architectural forms , materials was the concept idea

The project	-Volumetry	-Entries
Polytechnic School of Architecture and Urban Planning	 The school volume is composed of simple shapes (parallelepiped) organized around internal outdoor spaces and patios in a perpendicular way under the goal of simple and economical design.	 mechanical entrance pedestrian entrance

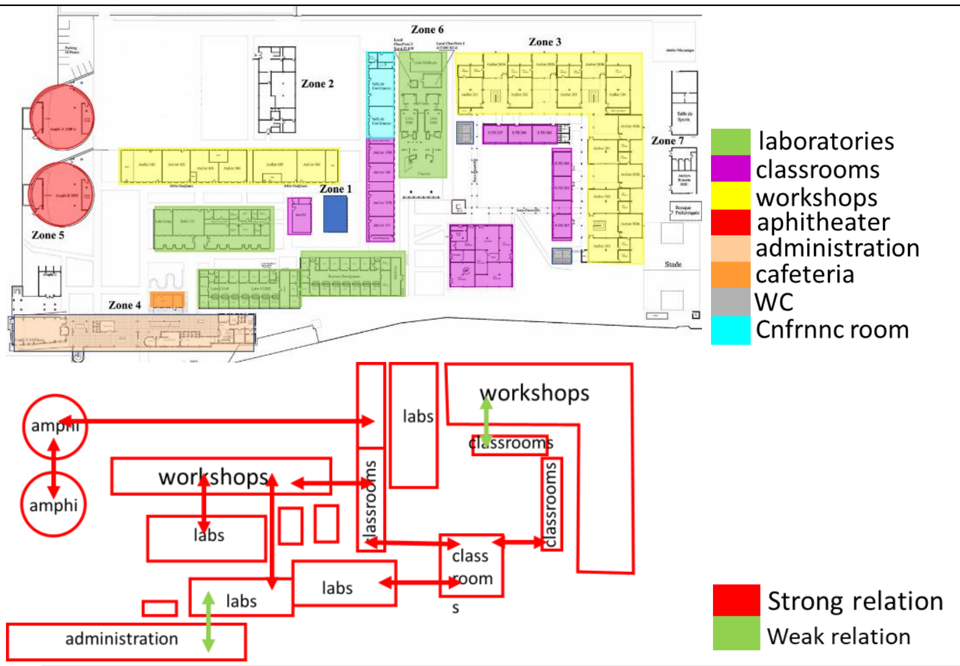
The department of architecture of Biskra University	 The project consists of a composition of organized geometric forms such as parallelepiped, triangular prism, cylinder, dome...	 Administrative access; teachers … Main access Secondary access

III.2.2.4.Functional aspect

The project	-circulation
Polytechnic School of Architecture and Urban Planning	 The circulation is practical and simple thanks to linear, open, and covered corridors that correspond to the project's volumes; vertical circulation focused in the articulations between the shapes, which ensure fluidity and interaction horizontal circulation vertical circulation
The department of architecture of Biskra University	   horizontal circulation vertical circulation Three main locations on the plan have vertical circulation, while a corridor connecting the classrooms and workshops as horizontal circulation.

III.2.2.5.Spatial and functional organization

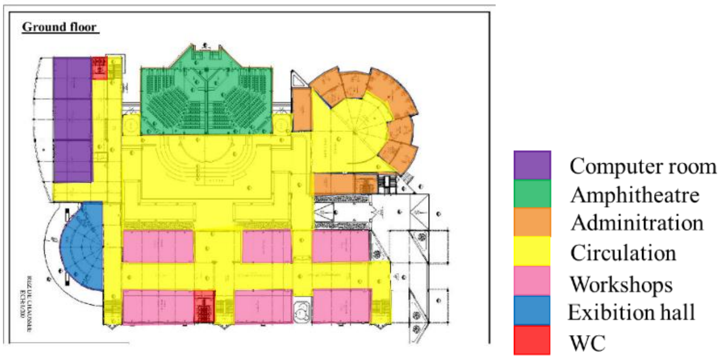
<table>
<tr><td>The project</td><td>Spatial and functional organization</td></tr>
<tr><td>Polytechnic School of Architecture and Urban Planning</td><td>

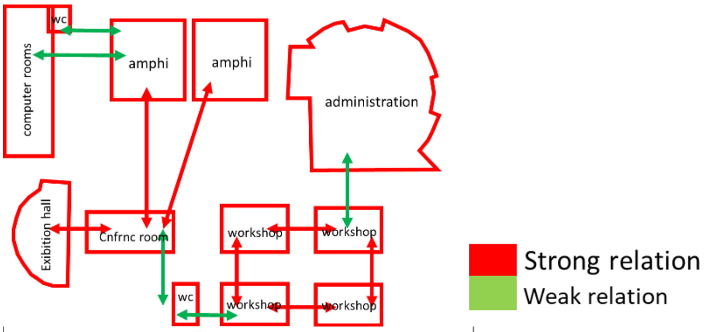


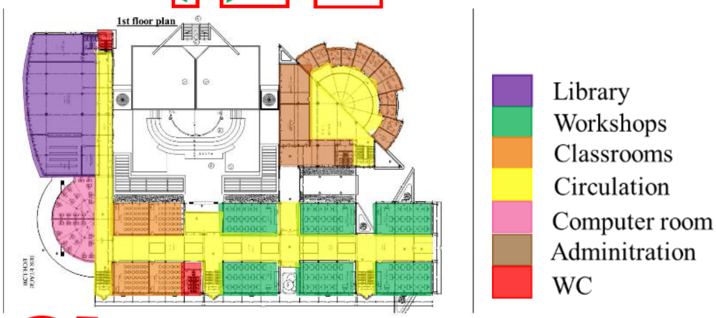
With strong and cohesive functional relationships, the project exhibits a functional organization characterized by distinct spatial division and separation.

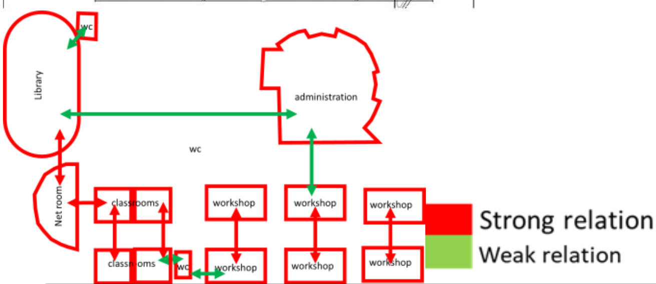
</td></tr>
</table>

The department of architecture of Biskra University









Clarity and usability in the functional and spatial organization are made possible by the administration area's clear separation and distinct expression from the educational portion, which are made up of various volumes.

III.2.2.6.Environmental aspects

The project	lighting	thermal	Energy consumption
Polytechnic School of Architecture and Urban Planning	Large windows overlooking the open spaces allow daylight penetration into the workshops and classrooms. 	The project's patios and courtyards with the vegetation produce a microclimate that improves the users' temperature. 	/
The department of architecture of Biskra University	the workshops and the classrooms which are the the main spaces in the project are oriented to north south to benefit from the natural Lighting in the better way. And the stairs are well lighted thanks to the curtain wall in there  	the orientation helps to minimize the Heat gain, either the light colors of the spaces also 	/

IV.The syntheses:

IV.1.The analysis syntheses

Element	**Synthesis**
Situation	the projects are situated in an urban fabric within various contexts with projects with different services to benefit from interaction and integration to the city.
Immediate Environment	The immediate environment of the projects is an academic environment in an urban fabric area to benefits from the interaction and to get an academic and vibrant life.
Design Concept	the design concepts take in consideration the site and the climate challenges, either the function. so, in our climate it's better to have open spaces, vegetation, and Courtyards, passive solutions... to create microclimate and design a sustainable project
Volumetry	the volume mixes between simplicity and richness and serve the function of the project and takes in consideration the climate, and balance between void and blocks and built and unbuilt.
Accessibility	the project is preferable to be in an urban area and connected to roads to guarantee the accessibility and the social life

Entrances	Schools of Architecture must have many main strategic entrances mechanical and pedestrian to guarantee easy accessibility and easy
Circulation	fluid and functional circulation that connects different parts of the project, and uses patios and open spaces, ensuring both functionality and interaction.
Spatial and Functional Organization	different functional parts such as educational, administrative, with strong functional relationship that's insure overall coherence.
Environmental aspects	natural lighting, minimize heat gain, through the passive strategies and creating project microclimate through the natural elements and the design.

Table 7 the syntheses of the projects analysis

IV.2.The requirements of each space

space	lighting	acoustics	ventilation	orientation	dimensions
workshop	From 500 [lux] to 850 [lux]	≤ 50 dB(A	Strong hybrid ventilation to effectively remove dust and fumes.	South/North to capture uniform light	almost 8 m² per student
classroom	325 [lux]	≤ 35 dB(A).	natural or mixed ventilation	South/ north	almost 3 m² per student
amphitheater	600 [lux]	≤ 35 dB(A)	mechanical ventilation for air quality control and dense occupancy,	Not specified	1 m² for each student
library	500 [lux]	≤ 30-35 dB(A)	mild natural or mixed ventilation.	Southeast to capture uniform light	/
laboratory	500 lux	40-50 dB(A)	Full mechanical ventilation with controlled exhaust and negative pressure		/

Table 8 the requirements of the spaces of school of architecture

IV.3.The proposed program

The space	The surface m²	The number	The space	The surface m²	The number
RECEPTION					
EXIBITION					
EDUCATION					
library	130	1	3D Printer and Laser Room	80	1
Reception Hall	230	1	Printing and Production Room	80	1
Main Circulation	520	1	Workshops	130	25
Permanent Exhibition		1	Classrooms	60	20

Temporary Exhibition	110	1	3D Models Workshops	130 open	1
Virtual Reality	110	1	Club Room		
Workshop	70	1	Conference Room	100	1
Bookstore	50	1	Materials Library	150	1
Admn offices	89	1	Laboratory CMT	70	1
Storage		1	Laboratory	200	1
outdoor Laboratory for Local Plants		1	lecture hall	250 places	2
			SERVICES		
ADMINISTRATION			Microwave Room	30	2
Administration Office	20	5	Medical Unit	80	1
Consultation Office	25	15	Cafeteria	100	1
Teachers' Room	60	1	Prayer Room	60	2
			Technical spaces		

Table 9 the proposed program of the project

V.SITE ANALYSIS:

V.1.Site location in relation to the city

the project site is located in the university compus of Mohamed Kheidher Biskra, in the eastern part of biskra city.

Figure 22 The location of the site. the source: the author

V.2.Motivation of choice

A key factor in this selection is the absence of an architecture school within this campus pole. The selected site is strategically located within a university campus, ensuring a dynamic academic environment that fosters collaboration and interdisciplinary exchange. Its proximity to university residences enhances accessibility for students and faculty. Additionally, its easy access via key circulation routes makes it a practical and well-connected choice.

V.3.The nature and morphology of the terrain

The terrain is mostly flat, with a slight level difference of approximately two meters. Its shape is geometrically organized, forming an almost rectangular layout.

Figure 23 The morphology of the site. the source: the author

V.4.The immediate environment

Figure 24 The immediate environment of the site. the source: the author

V.5.Accessibility

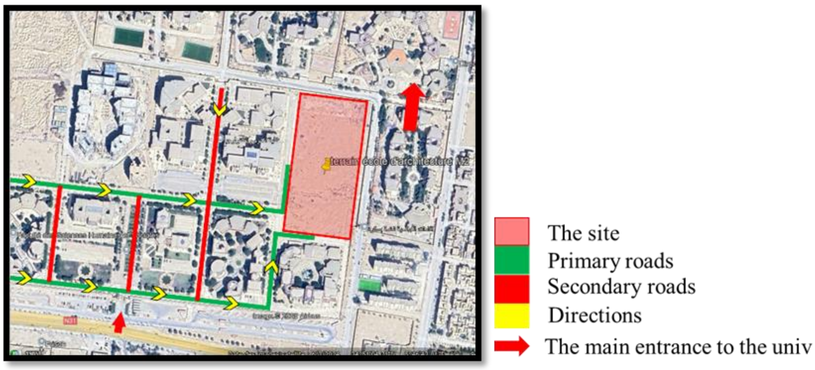


Figure 25 The accessibility of the site. the source: the author

all the primary and secondary roads within the university provide easy access to the site as shown in the image.

V.6.The surrounding buildings (shadow and light):

the maximum height of the surrounding buildings is ground floor + 3 so they do cast shadows directly onto the site at only specific times of the day.

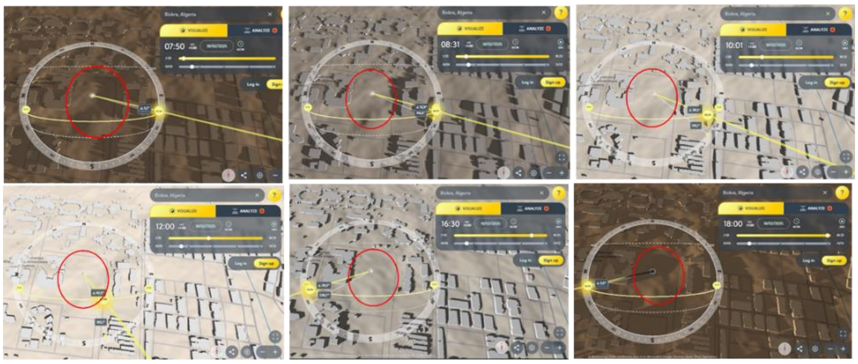
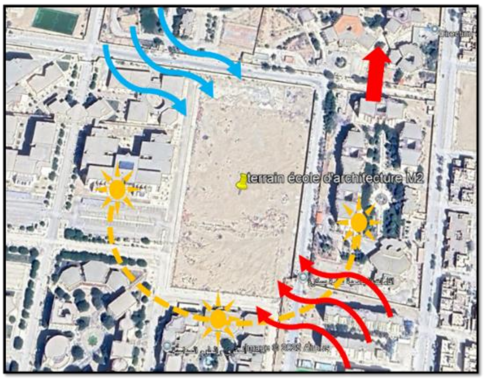


Figure 26 Surrounding buildings shadow. the source: shadow web site

V.7. Winds and sunshine:



The predominant warm winds originate from the southeast, while the predominant cold winds originate from the northwest.

The site is exposed to the sun all day long.

Figure 27The wind orientation and sunshine

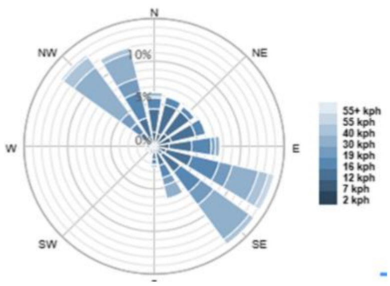


Figure 28 Annual windrose

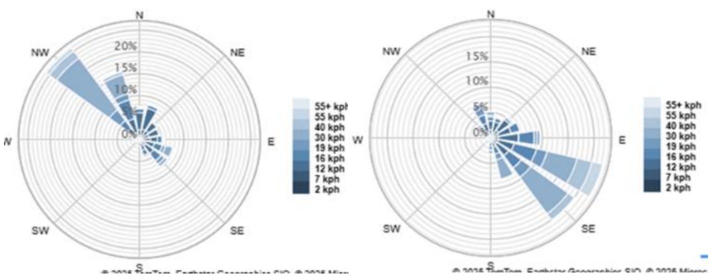


Figure 29 (left) windrose speed (Dec-Feb), (right) windrose speed (Jun-Aug)

V.8.Syntheses:

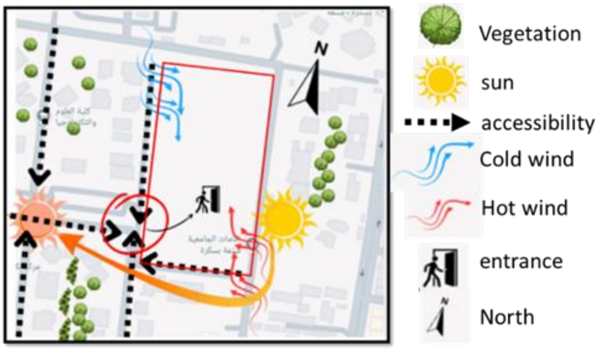


Figure 30 Synthesis of site analysis

Strength	Weakness
Situated in an academic setting that facilitates research and teaching. There are numerous main roads on campus that provide easy access. Good orientation (possibility of natural ventilation and lighting). Quiet environment because of the location on the campus (less noise disruption).	the absence of shading from nearby buildings leads to overheating and glare. exposure to environmental factors (heat gain, direct sunlight).
Opportunities	**Threats**
Incorporating cutting-edge comfort systems and microclimate solutions (pergolas, solar devices, green areas). The potential to establish a landmark that enhances the campus's edge identity. Possibility of taking advantage of the orientation for sustainable tactics (daily optimization, solar panels). Given the peaceful setting, there is a chance to improve outdoor areas for student interaction.	Exposure to too much sunlight, which causes discomfort and increases the need for cooling. Reliance on self-generated shading options because nearby buildings don't offer any.

Table 10 the s.w.o.t. of the site

CONCLUSION

The theoretical and contextual underpinnings required for the design process have been established in this analytical chapter. The environmental and functional requirements of the School of Architecture typology were explained in Part I, with a focus on the value of thermal comfort, balanced daylighting, and spatial adaptability in facilitating administrative, collaborative, and educational activities.

Through site analysis and case studies, Part II offered useful insights into how various architectural eras handled these issues where the projects were chosen as part of a larger plan that includes case studies from various architectural eras, including the modern era, and how site-specific factors influence design possibilities and limitations. The combination of these analyses emphasizes that a school of architecture's design needs to incorporate environmental performance, user experience, and spatial quality into a cohesive architectural response, going beyond technical systems.

The results demonstrate that future designs must produce a learning environment that is innovative in architecture, pedagogically supportive, and environmentally sensitive. Thus, the School of Architecture is defined as a model of sustainable academic design by a larger framework that includes the integration of daylighting, thermal comfort techniques, and energy efficiency.

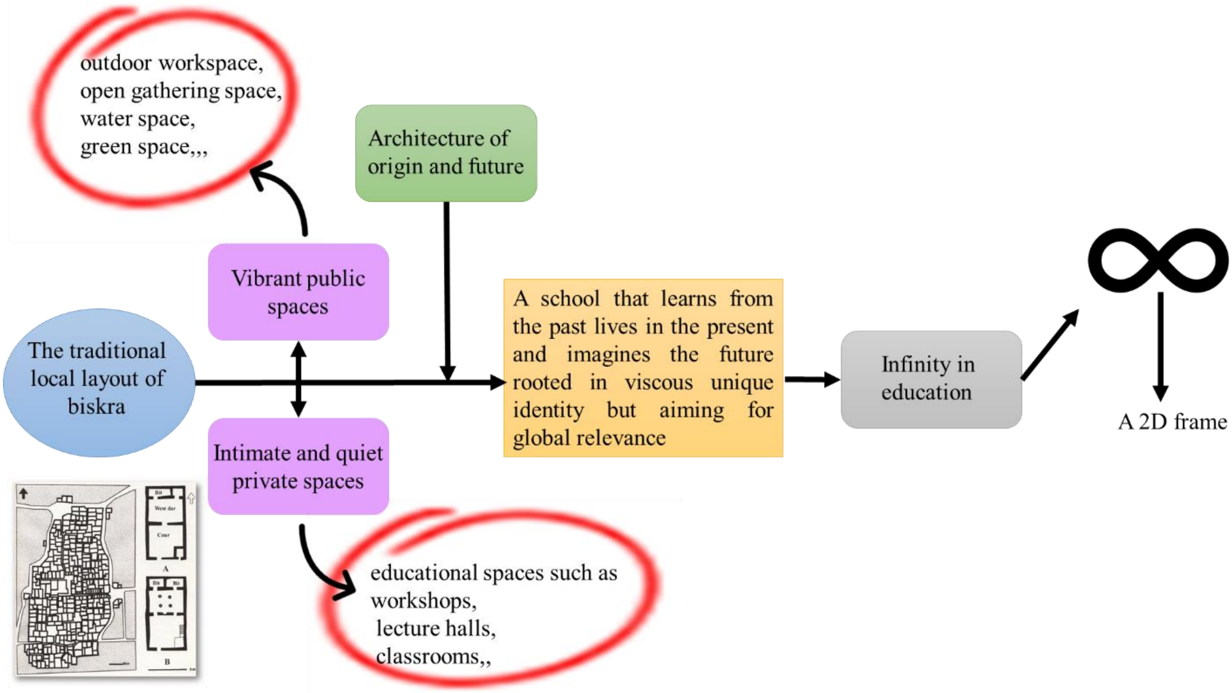
CHAPTER III:

ARCHITECTURAL PROJECT DEVELOPMENT

I.Introduction:

This Architectural Chapter presents the design development of the proposed School of Architecture project. With both the help of architectural renderings and other illustrations that demonstrate the project's formal and spatial identity, it presents the design concept and guiding idea. In order to demonstrate the relationship between form, function, and space, the chapter also highlights the key architectural views and drawings. After that, it displays how the integrated daylighting system is used, with special attention to how it is applied in the workshop façade, where it serves as a practical and aesthetically pleasing component of the overall design.

II.The concept idea:



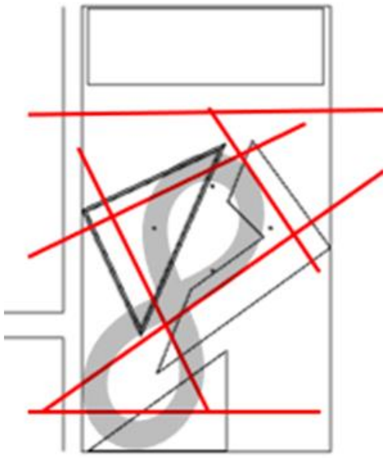


Figure 31 The initial pattern of the project, The source : the author

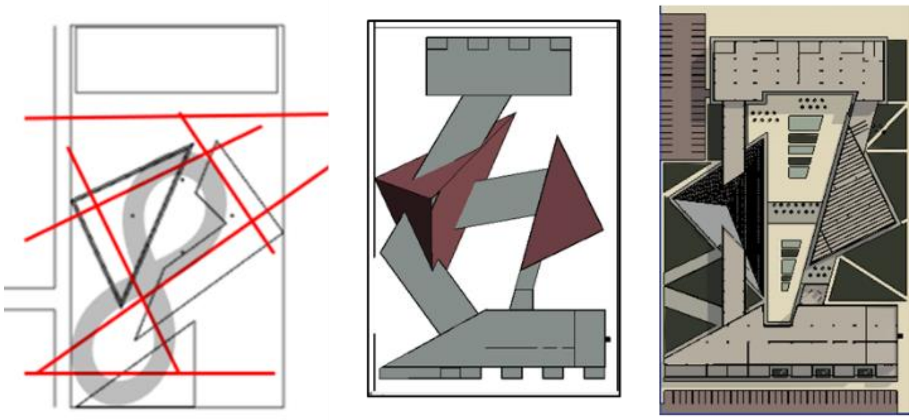


Figure 32 The 3D design process

III.Functional organization chart:

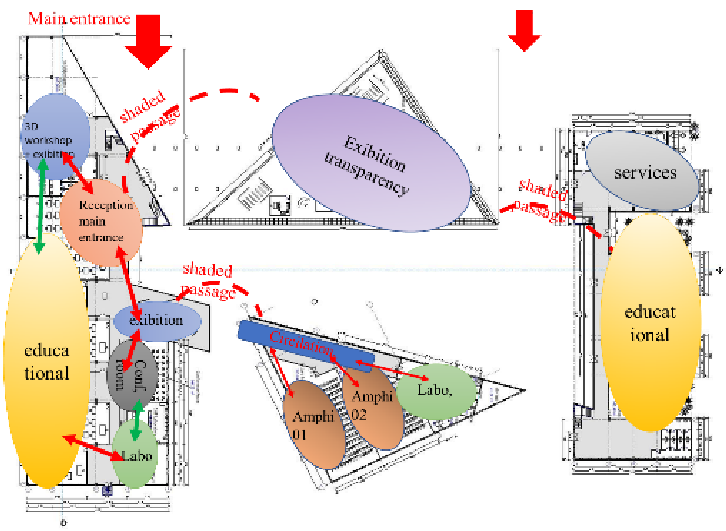


Figure 33 Level 0 Functional organization chart The source : the author

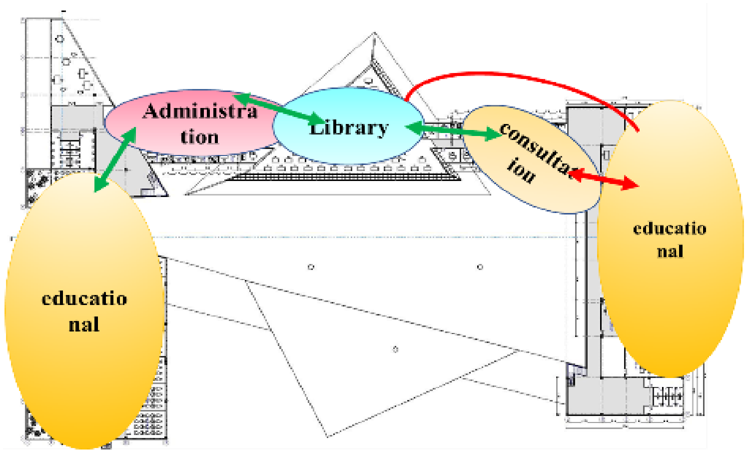


Figure 34 Level 1 Functional organization chart The source : the author

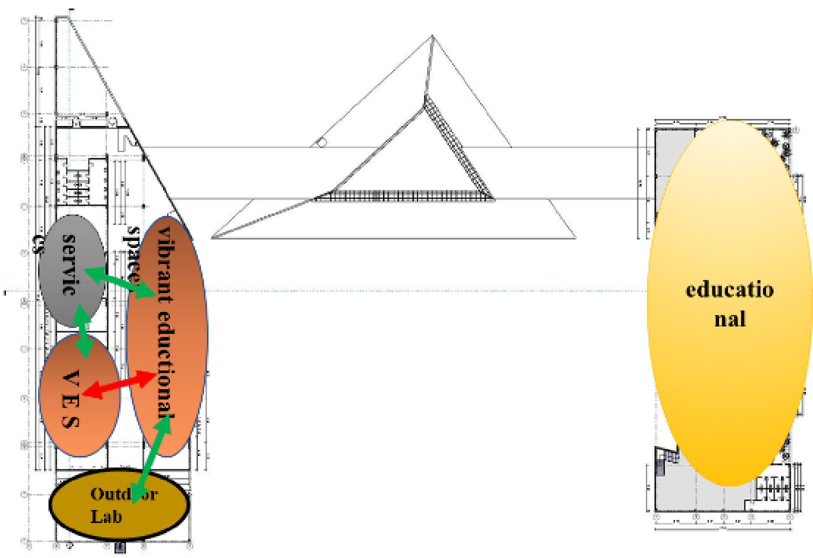


Figure 35 Level 2 Functional organization chart The source : the author

IV.Project presentation

IV.1.Plans

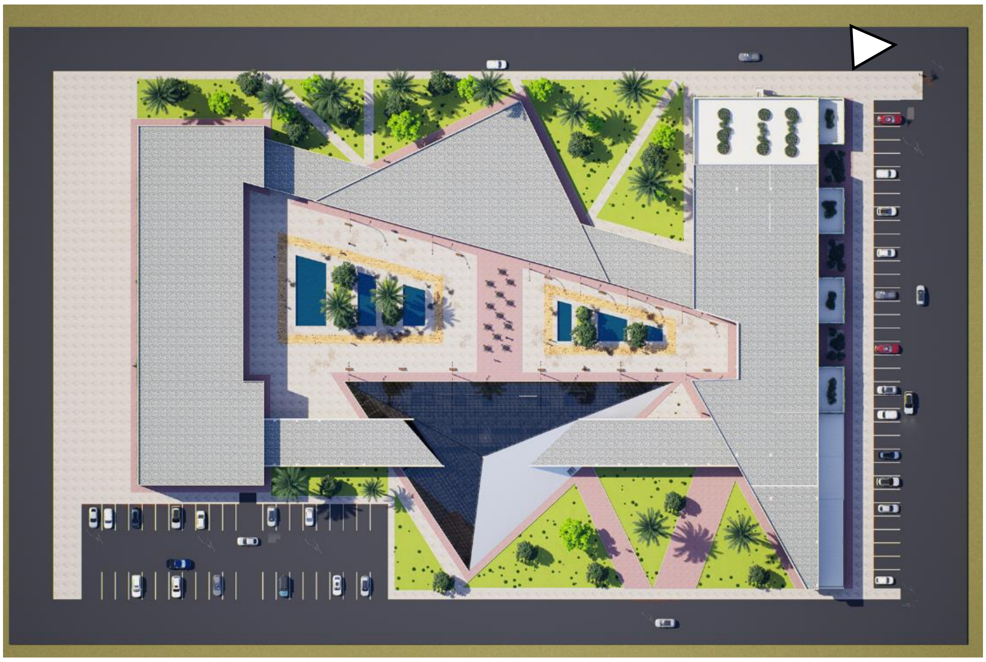


Figure 36 Ground plan, The source: the author

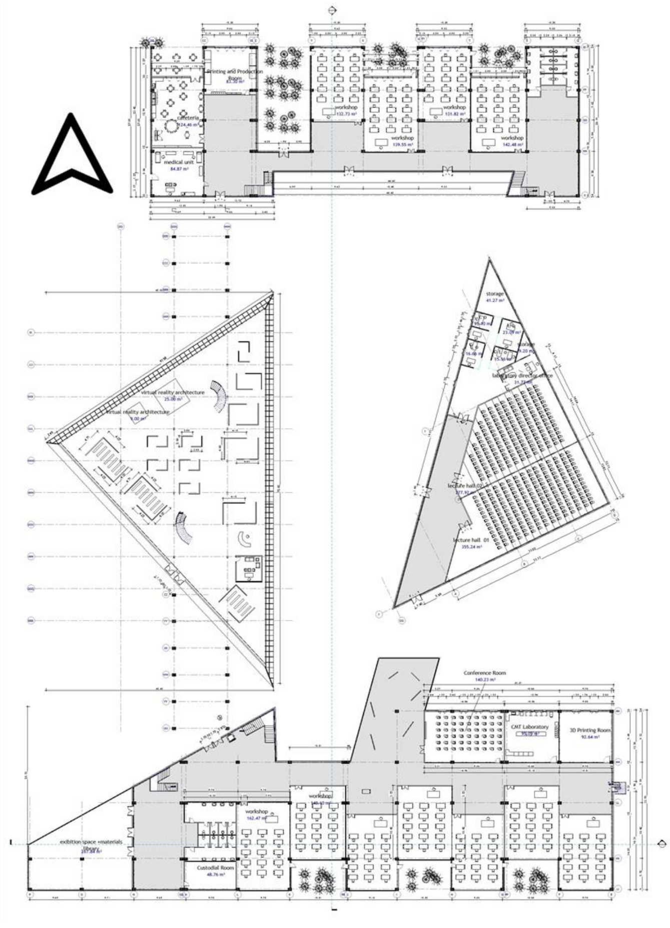


Figure 37 Level 0 plan, The source: the author

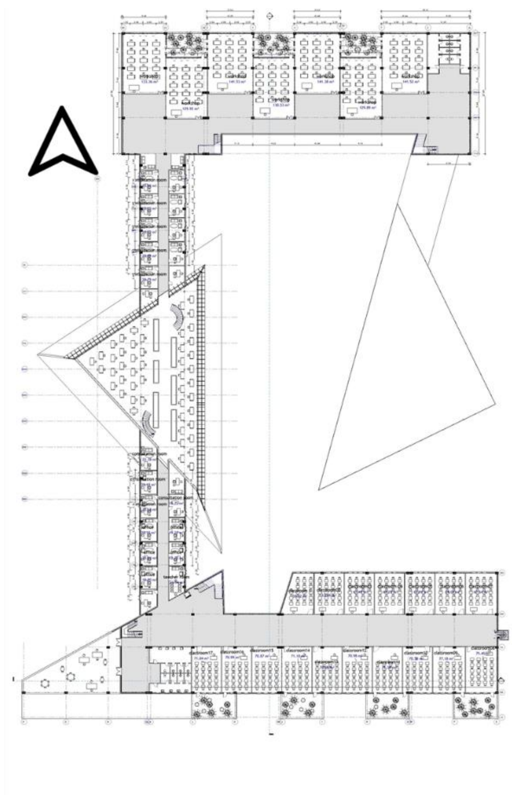


Figure 38 Level 1 plan, The source: the author

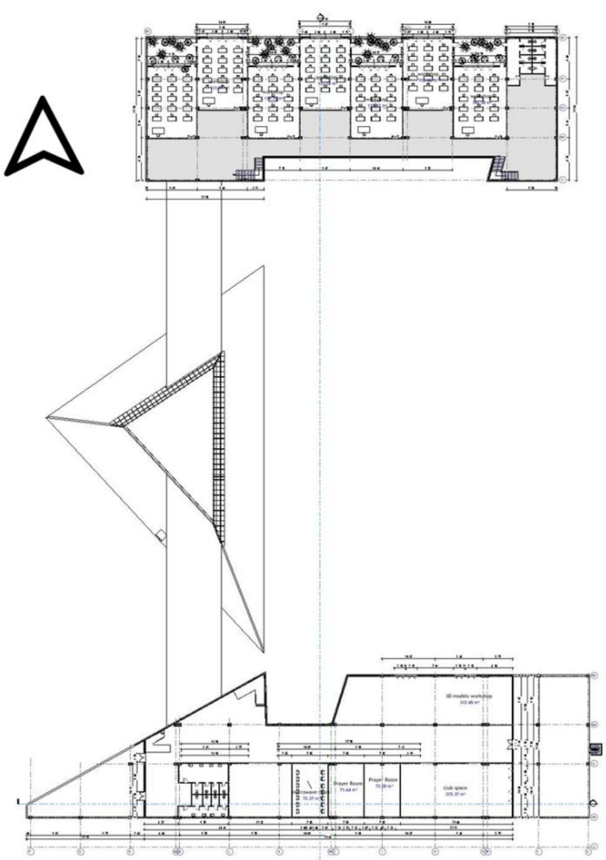


Figure 39 Level 2 plan, The source: the author

IV.2.Elevations

Figure 40 North elevation, The source: the author

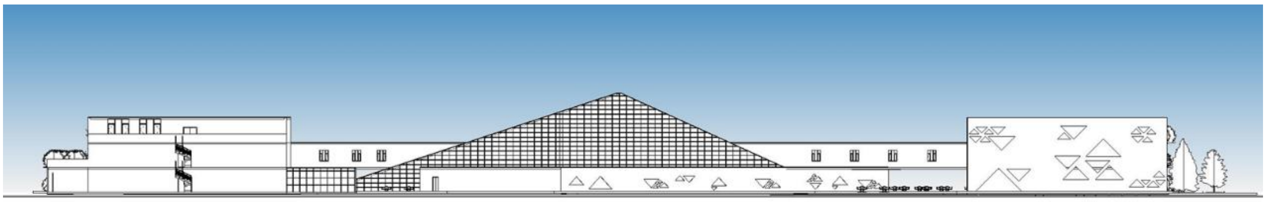


Figure 41 East elevation, The source: the author

Figure 42 South elevation, The source: the author

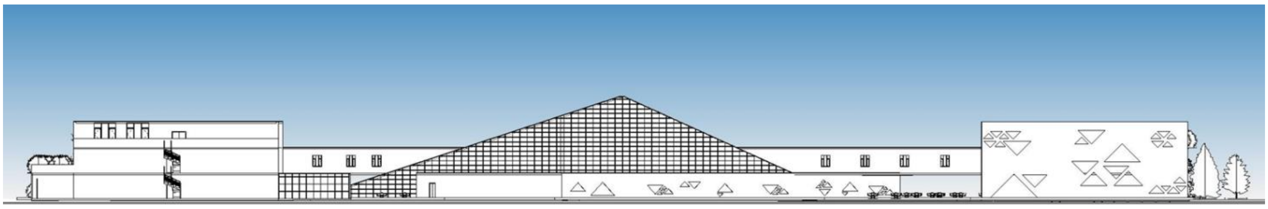


Figure 43 East elevation, The source: the author

IV.3.Sections

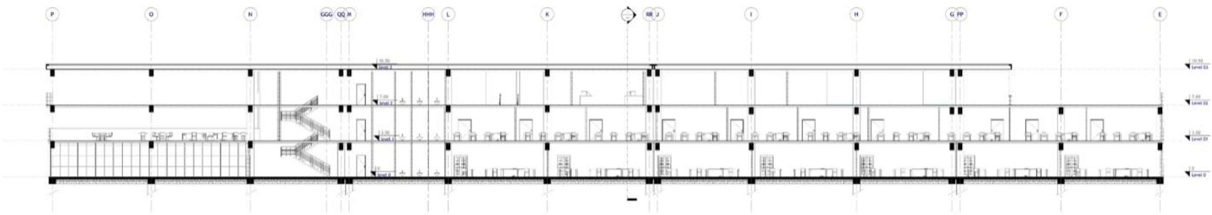


Figure 44 Section AA, The source: the author

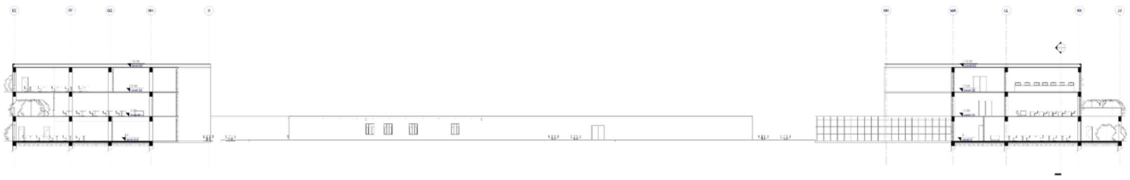


Figure 45 Section BB, The source: the author

CHAPTER IV:

PRACTICAL APPLICATION OF DEVELOPED DAYLIGHTING SYSTEM

I.Introduction

The research's practical implementation phase is presented in this chapter, with an emphasis on turning the theoretical and conceptual framework into a workable architectural solution. The subsequent sections seek to validate the suggested Integrated Climate-Responsive Architectural Facade system through simulation, prototyping, and performance evaluation, following the establishment of the scientific underpinnings and design principles in the preceding chapters. In buildings situated in hot and arid regions, the applied phase aims to show how the incorporation of intelligent, climate-responsive façade systems can improve environmental performance and user comfort. It emphasizes the steps involved in planning, building, and testing the suggested system in practical settings in order to evaluate its technical viability, environmental effectiveness, and economic feasibility.

II.Overview of the system:

TriLux, the suggested Integrated Climate-Responsive Architectural Facade System, is an integrated intelligent façade solution made to adapt to the outdoor climate in hot, dry environments. TriLux integrates low-power actuators, environmental sensors, and embedded control algorithms with a three-layer panel assembly (an internal plywood backing, an external aluminum skin, and an air cavity between them). The system's objective is to optimize daylight harvesting while limiting direct glare, to improve indoor thermal comfort and to reduce cooling and lighting energy demand**.**

Scientific name: Integrated Climate-Responsive Architectural Facade System

The name of the system: TriLux

III.Objectives:

The Integrated Climate-Responsive Architectural Facade system is designed to achieve a balance between visual comfort, thermal efficiency, and energy optimization within architectural spaces located in hot and arid climates such as Biskra. Its main goal is to combine intelligent heat and light control with a dynamic façade made of local available materials. Combining low-energy actuation, adaptive shading, and real-time environmental monitoring, the system aims to:

-Reduce the amount of glare in interior spaces and control daylight levels to improve visual comfort.

-Reducing solar heat gain while maintaining proper ventilation and light transmission will maintain thermal comfort.

-Reduce the need for mechanical cooling systems and artificial lighting to maximize energy efficiency.

-Maintain architectural aesthetic with a simple, adaptable design that works for different kinds of buildings.

-Reduce production and maintenance costs by using locally sourced materials and components to promote sustainability.

-TriLux's ultimate goal is to bridge the gap between contemporary façade design and environmental responsiveness by acting as a scalable and replicable architectural innovation.

IV.Performance Objectives

In addition to maintaining energy efficiency, the suggested system is made to maintain ideal indoor environmental conditions that improve thermal and visual comfort. These goals are in line with global norms that specify acceptable comfort levels for educational and professional settings, like ISO 8995 and ASHRAE 55.

<u>The system specifically seeks to achieve the following performance metrics:</u>

-Illuminance level: About 500 lux is the ideal amount of illumination for offices, studios, workshops and classrooms. To ensure consistent light distribution throughout the room, the system continuously modifies the façade elements to balance daylight penetration and reduce glare.

-Thermal comfort: By combining natural ventilation with shading control, a temperature range of 24°C to 28°C is maintained. By adjusting their position in response to indoor heat gains and solar radiation, the system's responsive panels lessen the need for mechanical cooling.

-Relative humidity: kept between 40% and 60% to promote the comfort and health of the occupants and avoid condensation or too much dryness.

-The system guarantees a comprehensive environmental balance by integrating these three factors: light, temperature, and humidity. This enhances user productivity and well-being while lowering overall energy usage.

V.System Components and Structure:

The proposed climate-adaptive façade system is composed of integrated physical and digital components that work together to ensure real-time environmental regulation and user comfort. The design creates a responsive, user-friendly, and energy-efficient solution by fusing smart technology with architectural functionality.

V.1.Physical Components:

The three primary layers of the façade unit are arranged in a deliberate manner to balance functionality, aesthetics, and insulation:

1) Outer aluminum layer: The outer layer of aluminum reflects too much sunlight and offers resilience and durability against severe weather conditions.
2) Air cavity: By serving as a natural thermal buffer, the air cavity enhances insulation and lessens heat transfer between indoor and outdoor spaces.
3) Inner plywood layer: provides a natural look that is appropriate for architectural integration, lightweight performance, and ease of installation.

The structure also has a supporting metallic frame that was locally designed and fabricated to guarantee stability and reduce costs.

V.2.Electronic and Control Components:

The system incorporates a number of intelligent components for adaptive control and real-time monitoring, such as:

-Sensors for humidity and temperature to gather environmental data.

-Light sensors to gauge the amount of daylight and identify glare.

-A low-power electric motor that automatically modifies the angle of the façade panels in response to changes in the surroundings.

-The system's movements are controlled by a microcontroller and control algorithm that process sensor data.

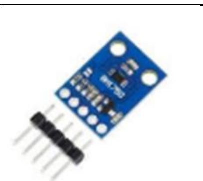
VI.User Interface and Control Modes:

The system incorporates a digital display screen that provides real-time temperature (°C), humidity (%), and illumination (lux) readings. This guarantees openness and makes it simple for residents to keep an eye on the surroundings. The system operates under two modes:

1) Automatic Mode: To maintain ideal comfort levels, the control algorithm automatically modifies the panels in response to sensor feedback.
2) Manual Mode: Using an easy-to-use interface, users can override automatic settings and make personal adjustments as needed.

When combined, these elements create a clever and interactive façade system that can achieve excellent environmental performance while preserving usability and aesthetic coherence.

VII.Components of the prototype hardware:

Component	Quantity	Role	Image
Light Intensity Sensor (BH1750)	2	Measures light intensity (lux) to adjust panels automatically.	
Servo Motor (MG996R)	2	Moves the panels between open/closed angles (180° control).	

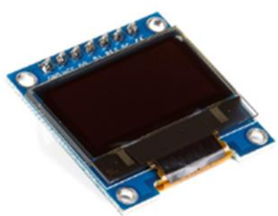
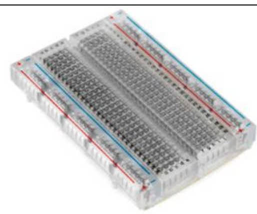
Temperature, Pressure, and Humidity Sensor (BME280)	4	Measures temperature, humidity, and pressure for climate feedback.	
DC-DC Buck Converter (LM2596)	8	Regulates and stabilizes voltage for the components.	
Dupont Jumper Wires (Male–Male, 20 cm)	1	Controls the whole system and processes sensor data.	
Microcontroller (ESP32, 38 Pins)	1	Displays real-time values (light, temp, humidity).	
OLED Display (0.96 inch)	4	Connects electronic components in the prototype.	
Breadboard	1	Used to assemble and test the circuit without soldering.	

Table 11 the components of the prototype hardware, source: the author.

VIII.Prototype hardware:

Figure 46 the prototype hardware, source: the author

Figure 47 the display screen with (left) auto mode, (right) manual mode, source: the author

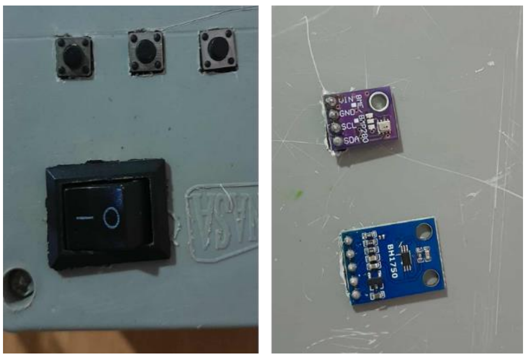


Figure 48 (left) Power button, (right) lighting and temperature sensors

IX.System Working Principle and Operation Process:

The suggested adaptive façade system uses to maintain the best possible indoor comfort, automated mechanical response and real-time environmental data analysis. Its operation depends on the sensors, control unit, and movable façade panels interacting continuously.

Data Collection and Monitoring

The operation begins with the sensors continuously recording the surrounding environmental parameters:

Illuminance (lux): measured by the light sensors to detect glare intensity and daylight availability.

Temperature (°C) and relative humidity (%): monitored by thermal and humidity sensors to evaluate indoor and outdoor comfort conditions.

The recorded data is displayed in real time on the integrated digital screen, allowing users to track variations and system responses at any moment.

Data Processing and Decision-Making

All collected data is transmitted to the microcontroller, where it is processed by an embedded control algorithm. The algorithm compares the recorded values with target comfort thresholds, defined as:

Illuminance: 500 lux

Temperature: between 24°C and 28°C

Relative humidity: between 40% and 60%

When deviations from these target ranges are detected, the control system automatically determines the necessary adjustments to restore balance.

Mechanical Adjustment and Actuation

The low-energy electric motor receives signals from the control unit and activates the movement of the façade panels. Depending on the detected conditions:

- When glare levels are high, the panels rotate or tilt to reduce direct solar penetration.
- When illumination drops below the target, the system reopens gradually to enhance daylight access.

This dynamic adjustment ensures that the indoor environment remains within the desired comfort parameters with minimal energy consumption. In addition to the automatic operation, users can switch to manual control mode when specific preferences or experimental settings are needed.

Feedback and Optimization

The system operates on a closed-loop feedback mechanism, meaning that each adjustment is followed by new sensor readings. This continuous process allows the façade to self-correct and adapt in real time, ensuring optimal performance and long-term efficiency.

X.Simulation and Performance Evaluation

After the design and digital modeling of the adaptive façade system, a simulation-based evaluation was conducted to assess its daylighting performance and the extent of illuminance improvement achieved within the workshop spaces.

X.1.1. Digital Tools and Simulation Workflow

The system was first modeled and parametrically built in Autodesk Revit 2023.1, where its geometry, materials, and motion parameters were defined according to the proposed design specifications.

Once the system was finalized, it was integrated into the architectural project, specifically in the workshops oriented to the South. This orientation was intentionally selected, as south-facing façades receive the highest solar exposure in hot-arid climates such as Biskra, making them more susceptible to glare and overheating.

After that, daylight and energy simulations were carried out using the Insight plugin, which allowed evaluation of energy efficiency and illumination levels in connection to the system's different opening configurations (0.1, 0.2, 0.3, and 0.4). Cloud rendering was used to visualize the results, giving accurate depictions of the lighting behavior and general façade aesthetics. Ultimately, Dynamo was used to automate parametric control and expedite façade opening adjustment, guaranteeing a responsive and dynamic design.

X.2.Simulation Scenarios

To understand the system's impact under different configurations, the façade was tested with four distinct opening ratios, defined as:

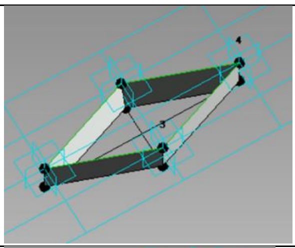
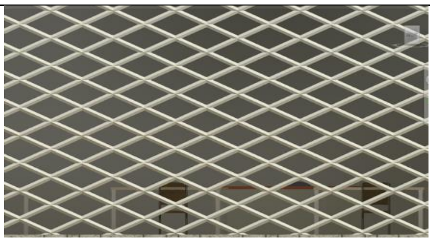
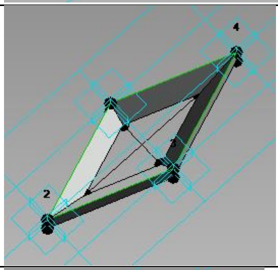
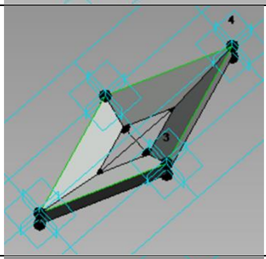
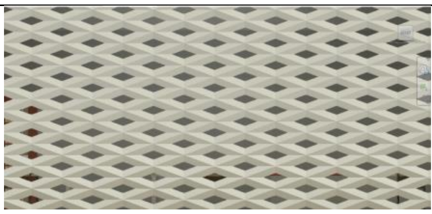
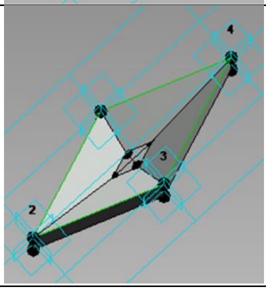
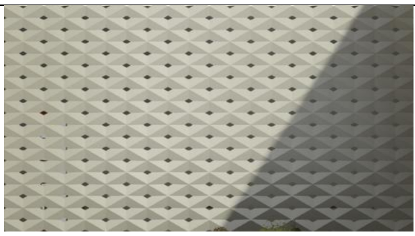
The opening ratio	The system unit	The façade system
0.1		
0.2		
0.3		
0.4		

Table 12 the opening ratios of the system

X.3.Daylighting Simulation:

The daylighting analysis was carried out using the Insight plugin integrated within Revit, which enables accurate simulation of illuminance levels (lux) based on geographic location, climate data, and material reflectance.

The target performance level was set at 500 lux, corresponding to the recommended illumination for educational workshops according to international lighting standards.

Simulations were performed under typical sky conditions, at representative times of the year, especially during summer and winter solstices, to evaluate seasonal differences in daylight availability.

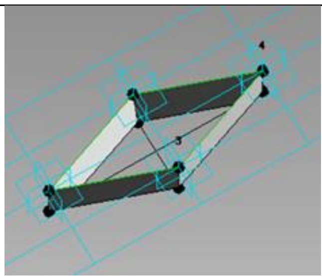
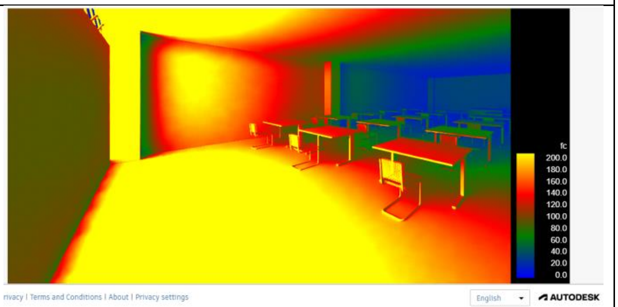
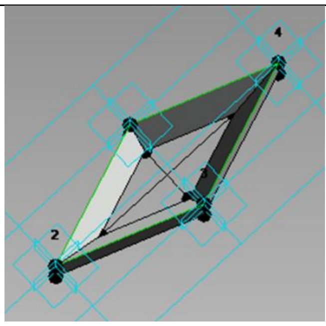
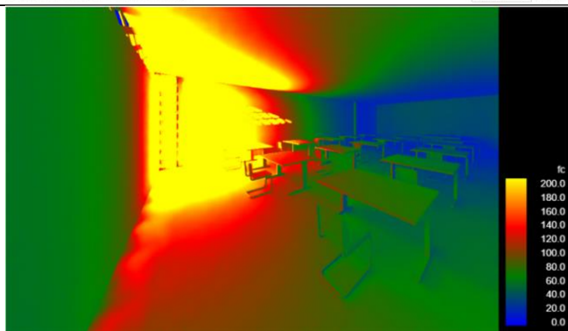
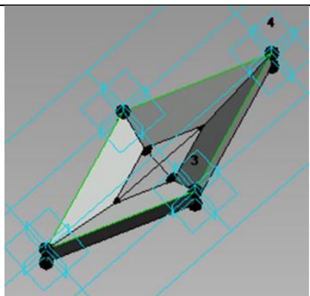
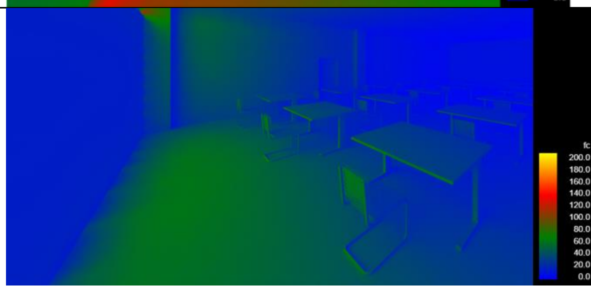
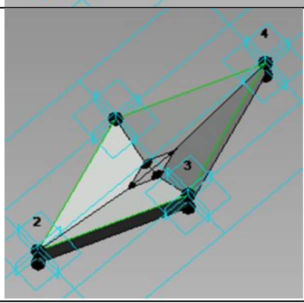
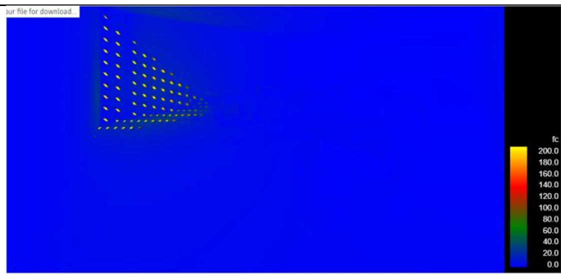
The date	The timing	The opening ratio	The system unit	The simulation
21/06/2025	9:00 am	0.1		
21/12/ 2024	9:00 am	0.2		
21/06/2025	9:00 am	0.3		
21/03/2025	9:00 am	0.4		

Table 13 simulation of diffrent openings

X.3.1. Simulation of the opening ratio 0.2:

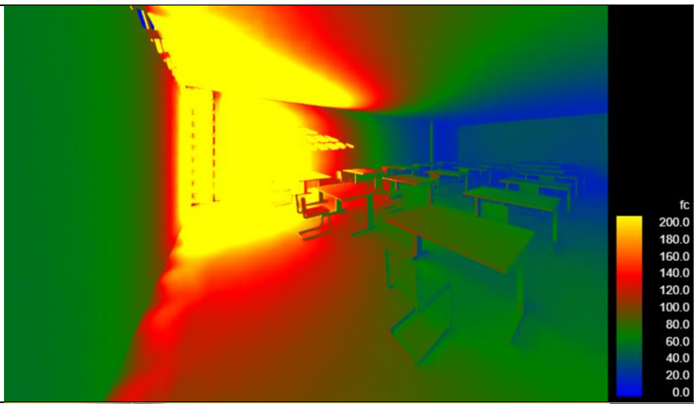
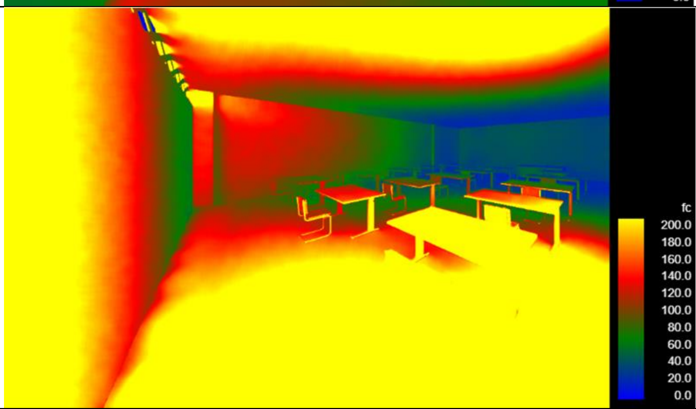
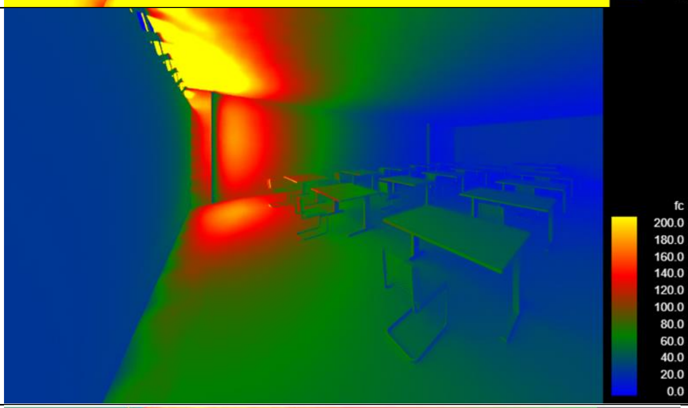
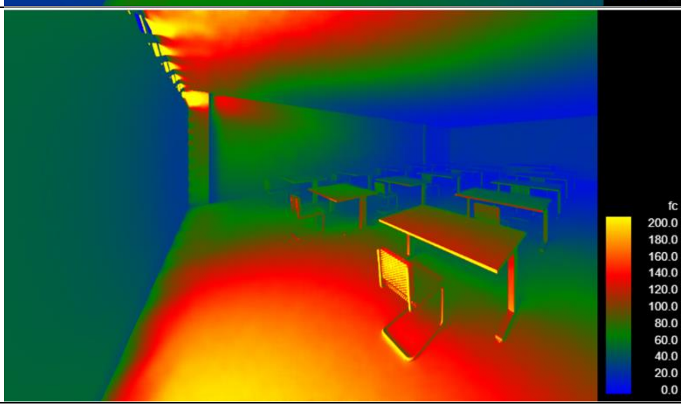
The date	The timing	Simulation
21/12/2024	9:00 am	
	4:00 pm	
21/06/2025	9:00 am	
	4:00 pm	

Table 14 simulation of the 0.2 opening ratio

X.4.Expected Performance:

The main objective of the simulation phase was to evaluate whether the adaptive system maintains the indoor illuminance close to 500 lux while reducing glare and controlling solar gain. It was also expected that smaller openings (0.3 and 0.4) would perform better in glare reduction, while larger openings (0.1 and 0.2) would ensure sufficient daylight penetration under lower external brightness. This step provided quantitative data to validate the efficiency and adaptability of the proposed system, guiding further refinement and optimization.

X.5.Results and Discussion:

The daylighting simulations revealed a clear improvement in natural light distribution within the workshops with the integrating of the adaptive façade system. Among the four configurations tested, the 0.2 opening ratio achieved the most balanced performance, maintaining an average illuminance close to 500 lux across the working plane. This level ensured sufficient daylight without excessive brightness or glare, aligning with international standards for visual comfort in educational environments.

GENERAL CONCLUSION

GENERAL CONCLUSION

The goal of this study was to develop and assess an integrated daylighting system that could reduce glare, improve thermal comfort, and optimize energy use in architectural learning environments. The study examined how controlled natural lighting can be used as an architectural and environmental driver to create learning environments that are efficient, comfortable, and healthy. It was based on the ideas of sustainable design.

The theoretical investigation established the scientific and conceptual foundation of the work, highlighting the intricate relationship between daylight availability, visual comfort, indoor temperature regulation, and energy performance. It became clear from a critical analysis of earlier research that incorporating daylighting techniques effectively not only improves thermal and visual comfort but also considerably lowers building energy consumption.

By analyzing the typology of the School of Architecture and its functional requirements, the analytical phase expanded on this understanding. The research determined the environmental, climatic, and spatial limitations that affect daylighting performance by examining and analysing projects case studies from various architectural eras and carrying out an extensive site investigation. The following chapters' strategic orientations and design parameters were influenced by these findings.

The architectural development translated these insights into a coherent design proposal for a School of Architecture that embodies environmental awareness through spatial organization, orientation, and form. the idea aims to design a school that learns from the past lives in the present and imagines the future rooted in viscous unique identity but aiming for a global relevance starting from the traditional layout of Biskra city.

The practical component showed how the suggested daylighting system, which is mainly integrated into the south-facing workshop façades that receive the most solar exposure, could be used. The system diffuses natural light, controls solar penetration, and restricts heat gain through a multi-layered adaptive façade.

Simulation analyses were performed under four different façade configurations to evaluate daylight distribution, glare levels, and energy performance. The results revealed a marked improvement in daylight uniformity within the workshops following the system's integration. Among all tested configurations, the 0.2 opening ratio achieved the most balanced outcome, maintaining average illuminance levels around 500 lux across the working plane—consistent with international standards for educational visual comfort. This configuration provided ample natural light while preventing excessive brightness and glare, proving most effective in maintaining optimal indoor conditions.

The discussion of these results emphasizes that achieving optimal daylight performance depends not only on geometry and orientation but also on the ability of façade systems to adapt dynamically to external conditions. The study demonstrates that integrating system can transform direct sunlight into a diffuse, stable, and comfortable light environment, while simultaneously minimizing energy use.

Based on these outcomes, several recommendations are proposed for designing effective daylighting systems in educational settings:

Employ adaptive and modular façades that adjust to seasonal and daily solar variations.

Combine passive design principles with simulation-based optimization early in the design process.

Integrate visual, thermal, and energy evaluations holistically rather than as separate stages.

Ensure that daylighting solutions are context-sensitive, reflecting both climatic and functional characteristics.

In conclusion, this thesis presents a comprehensive approach that unites daylighting, comfort, and energy efficiency within a single integrated design framework. It draws attention to how adaptive façade systems, particularly in hot and arid areas, can improve environmental performance and user well-being in architectural schools.

REFERENCES

REFERENCES

AHMED, D., ABDELKADER, M., & NESSIM, A. (2023). Effect of Adaptive Facades on Daylight-An Analytical Study in Hot Arid Climate. *Arts and Architecture Journal*, *4*(1), 1–26.

Ahmed, M. M., Abdel-Rahman, A. K., Bady, M., & Mahrous, E. (2016). The thermal performance of residential building integrated with adaptive kinetic shading system. *International Energy Journal*, *16*(3).

Attia, S. (2017). Evaluation of adaptive facades: The case study of Al Bahr Towers in the UAE. *QScience Connect*, *2017*(2), 6.

Bahdad, A. A. S., Fadzil, S. F. S., & Taib, N. (2020). Optimization of daylight performance based on controllable light-shelf parameters using genetic algorithms in the tropical climate of Malaysia. *Journal of Daylighting*, *7*(1), 122–136.

Bashir, F. M., Dodo, Y. A., Mohamed, M. A. said, Norwawi, N. M., Shannan, N. M., & Afghan, A. A. (2024). Effects of natural light on improving the lighting and energy efficiency of buildings: Toward low energy consumption and CO2 emission. *International Journal of Low-Carbon Technologies*, *19*, 296–305.

Cheryan, S., Ziegler, S. A., Plaut, V. C., & Meltzoff, A. N. (2014). Designing classrooms to maximize student achievement. *Policy Insights from the Behavioral and Brain Sciences*, *1*(1), 4–12.

Choi, S.-J., Lee, D.-S., & Jo, J.-H. (2017). Lighting and cooling energy assessment of multi-purpose control strategies for external movable shading devices by using shaded fraction. *Energy and Buildings*, *150*, 328–338. https://doi.org/10.1016/j.enbuild.2017.06.030

Daich, S. (2019). *Modélisation du système anidolique pour un environnement lumineux intérieur intégré*.

Daich, S., Saadi, M. Y., Zemmouri, N., Morello, E., & Piga, B. (2016). Evaluation quantitative et qualitative du système anidolique sous un climat chaud et aride. In *Ambiances, demain| Ambiances, tomorrow| Ατμόσφαιρες, Αύριο* (pp. 219–226). GRC.

Do, C. T., & Chan, Y.-C. (2021). Daylighting performance analysis of a facade combining daylight-redirecting window film and automated roller shade. *Building and Environment*, *191*, 107596.

Eltaweel, A., Mandour, M. A., Lv, Q., & Su, Y. (2020). Daylight distribution improvement using automated prismatic louvre. *Journal of Daylighting*, *7*(1), 84–92.

Elzeyadi, I. (2017). The impacts of dynamic façade shading typologies on building energy performance and occupant’s multi-comfort. *Architectural Science Review*, *60*(4), 316–324.

Evola, G., Gullo, F., & Marletta, L. (2017). The role of shading devices to improve thermal and visual comfort in existing glazed buildings. *Energy Procedia*, *134*, 346–355.

References

Fakhr, B. V., Mahdavinejad, M., Rahbar, M., & Dabaj, B. (2023). Design Optimization of the Skylight for Daylighting and Energy Performance Using NSGA-II. *Journal of Daylighting*, *10*(1), 72–86.

Faraji, A., Rezaei, F., Rahnamayiezekavat, P., Rashidi, M., & Soleimani, H. (2023). Subjective and simulation-based analysis of discomfort glare metrics in office buildings with light shelf systems. *Sustainability*, *15*(15), 11885.

Giovannini, L., Verso, V. R. L., Karamata, B., & Andersen, M. (2015). Lighting and energy performance of an adaptive shading and daylighting system for arid climates. *Energy Procedia*, *78*, 370–375.

Hou, G. (2016). *An investigation of thermal comfort and the use of indoor transitional space*.

Huang, K.-T., Liu, K. F.-R., & Liang, H.-H. (2015). Design and energy performance of a buoyancy driven exterior shading device for building application in Taiwan. *Energies*, *8*(4), 2358–2380.

Kim, H.-J., Yang, C.-S., & Moon, H. J. (2019). A study on multi-objective parametric design tool for surround-type movable shading device. *Sustainability*, *11*(24), 7096.

Lam, C. K. C., Weng, J., Liu, K., & Hang, J. (2023). The effects of shading devices on outdoor thermal and visual comfort in Southern China during summer. *Building and Environment*, *228*, 109743.

Liébard, A., & Herde, A. de. (2005). *Traité d'architecture et d'urbanisme bioclimatiques: Concevoir, édifier et aménager avec le développement durable ; [en 368 fiches didactiques]*. Observ'ER [u.a.].

Marty, C., Fontoynont, M., Christoffersen, J., Dubois, M.-C., Wienold, J., Osterhaus, W., Carco, E., & Carco, R. F. (2003). User assessment of visual comfort: Review of existing methods. *Ingélux (France) with Danish Building Research Institute (SBi, Denmark) and Fraunhofer Institute for Solar Energy Systems (ISE, Germany), DOI: 10.13140/RG. 2.1*, *4803*.

Noailly, J. (2012). Improving the energy efficiency of buildings: The impact of environmental policy on technological innovation. *Energy Economics*, *34*(3), 795–806.

Özdemir, H., & Çakmak, B. Y. (2022). Evaluation of daylight and glare quality of office spaces with flat and dynamic shading system facades in hot arid climate. *Journal of Daylighting*, *9*(2), 197–208.

Ruck, N., Aschehoug, Ø., & Aydinli, S. (2000). *Daylight buildings. A source book on daylighting systems and components*.

Sheikh, W. T., & Asghar, Q. (2019). Adaptive biomimetic facades: Enhancing energy efficiency of highly glazed buildings. *Frontiers of Architectural Research*, *8*(3), 319–331.

Von Wachenfelt, H., Vakouli, V., Diéguez, A. P., Gentile, N., Dubois, M.-C., & Jeppsson, K.-H. (2015). Lighting energy saving with light pipe in farm animal production. *Journal of Daylighting*, *2*(2), 21–31.

Yi, H., Kim, M.-J., Kim, Y., Kim, S.-S., & Lee, K.-I. (2019). Rapid simulation of optimally responsive façade during schematic design phases: Use of a new hybrid metaheuristic algorithm. *Sustainability*, *11*(9), 2681.

References

Zarewa, Y., Tukur, R., & Abdulhamid, F. (2023). Optimising indoor lighting condition for visual comfort via light pipes in design of Kada-city shopping mall. *Savannah Journal of Science and Engineering Technology*, *1*(4), 111–122.

Internet sites:

https://expomaison.wordpress.com/lieux/bauhause/

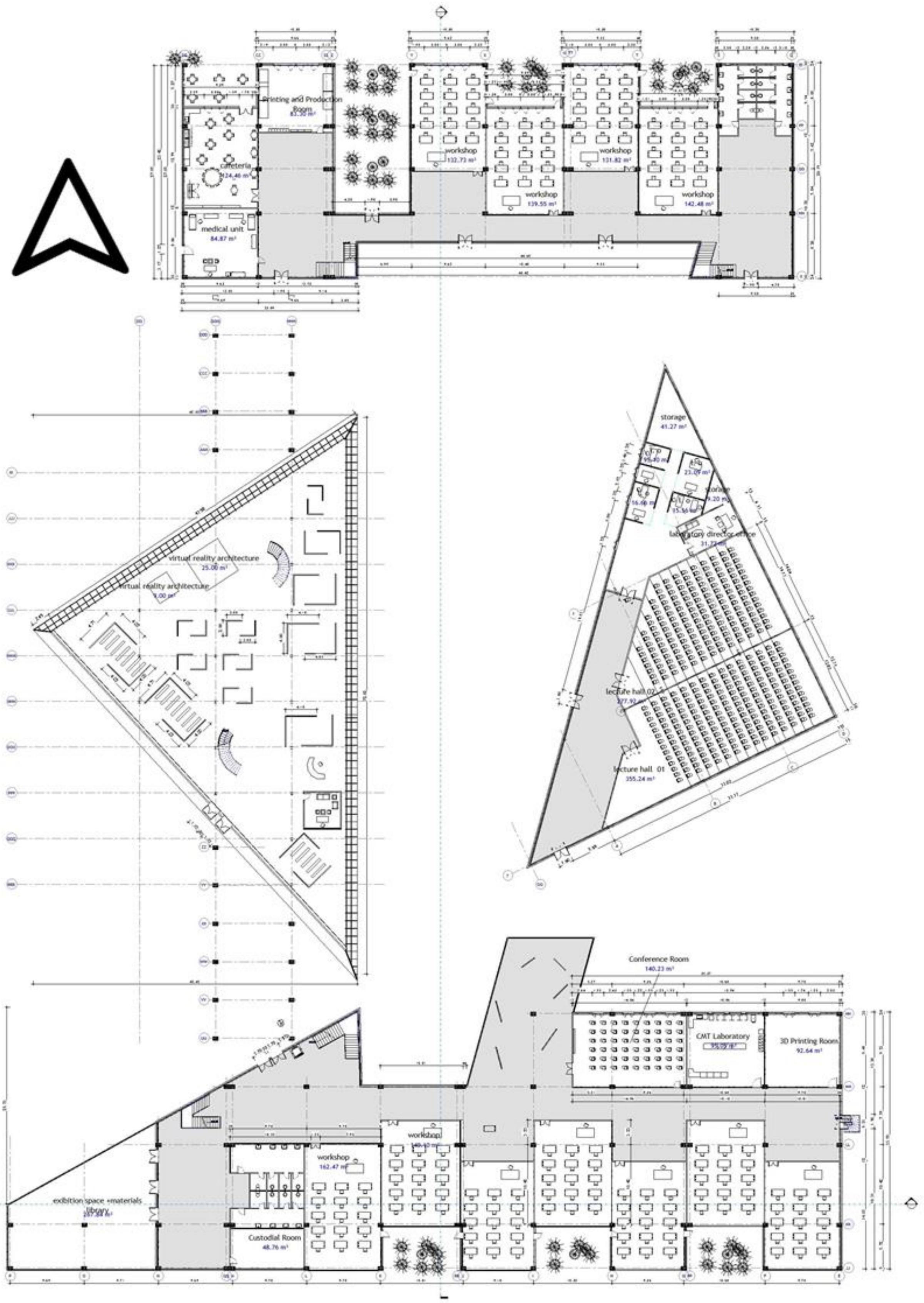
https://www.archdaily.com/129400/austin-e-knowlton-school-of-architecture-mack-scogin-merrill-elam-architects?ad_source=search&ad_medium=projects_tab

https://www.bordeaux.archi.fr/wp-content/uploads/dmdocuments/Deliberation_2022-100-2_SDIA_ENSAPBordeaux.pdf

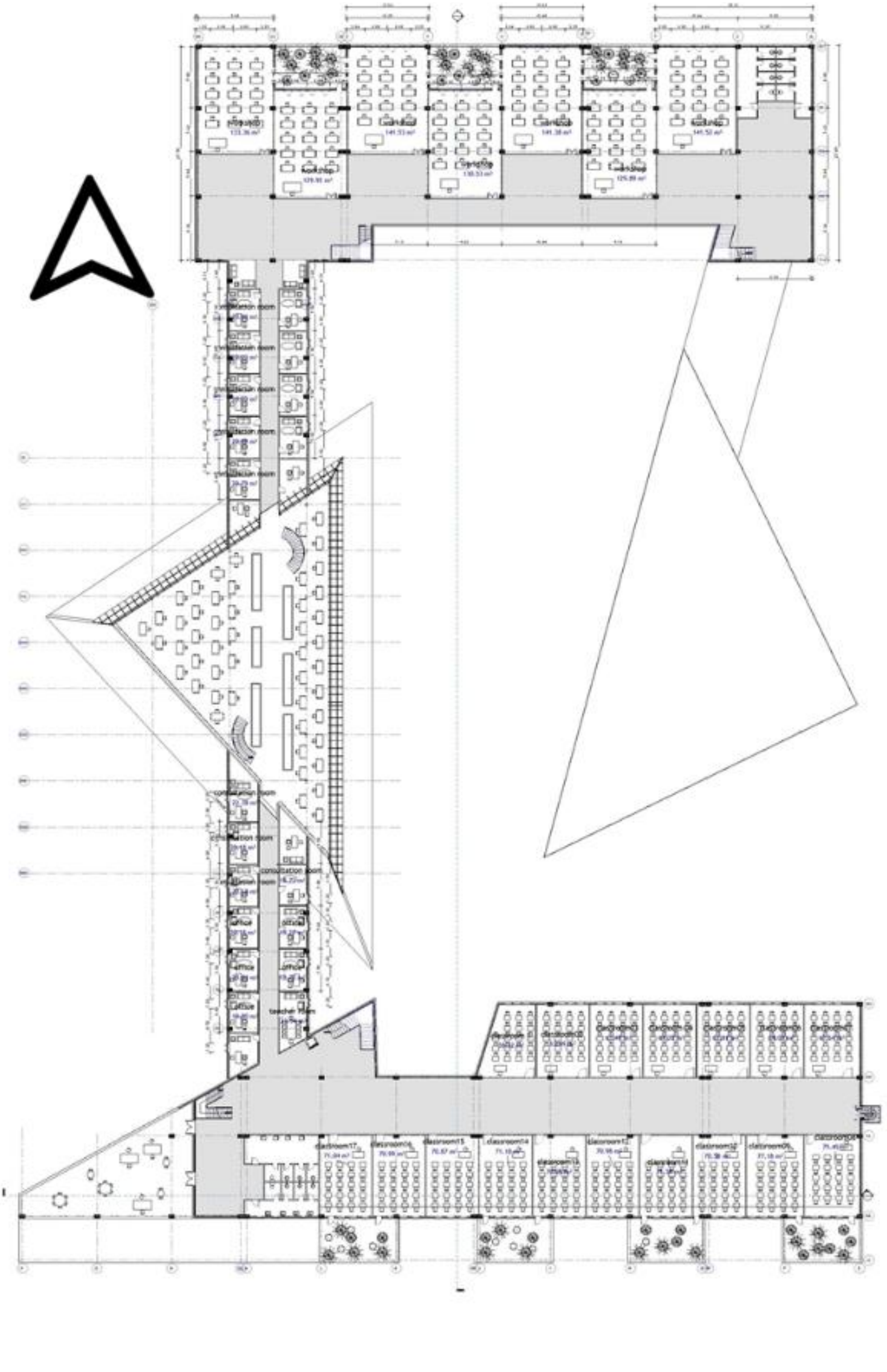
https://www.archdaily.com/906527/university-of-miami-school-of-architecture-arquitectonica

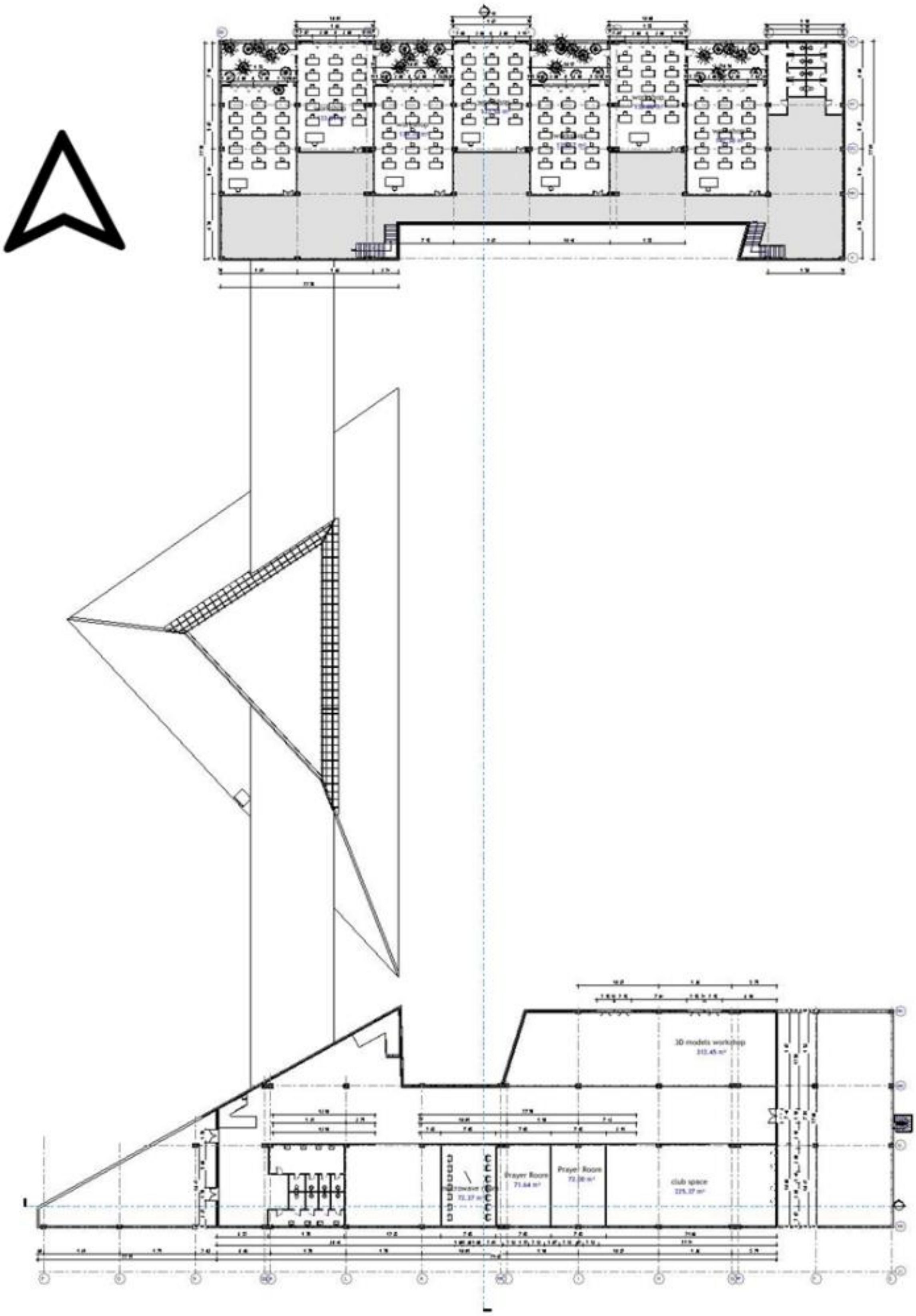
APPENDICES

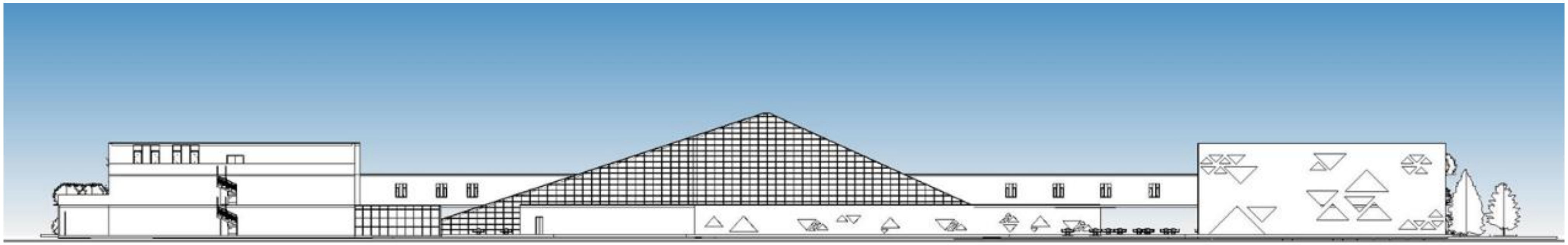
APPENDIX 01

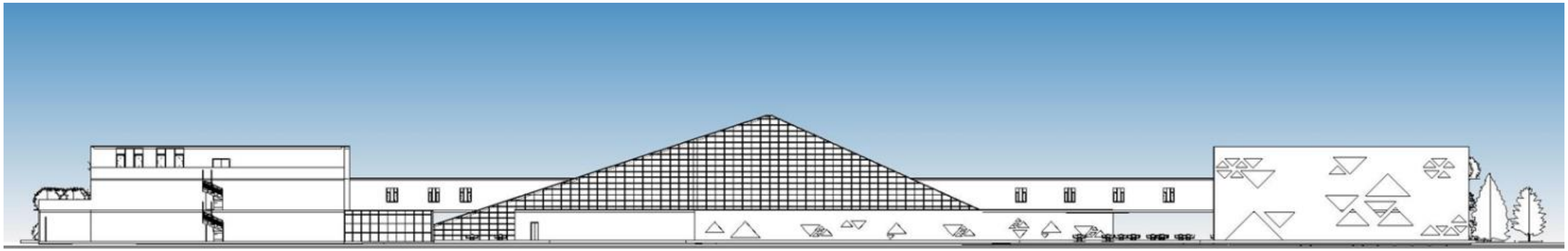


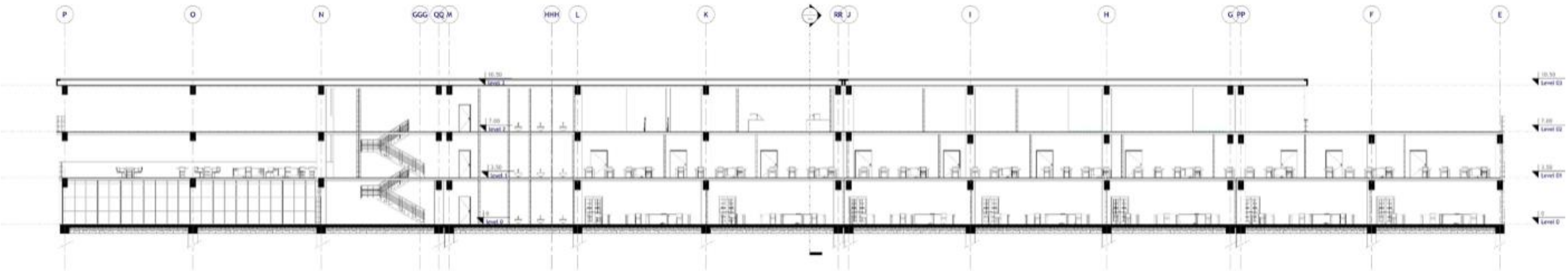
Printing and Production Room
83.50 m²
cafeteria
124.46 m²
medical unit
84.87 m²
workshop
132.72 m²
workshop
139.55 m²
workshop
131.82 m²
workshop
142.48 m²
storage
41.27 m²
storage
9.20 m²
laboratory director office
31.72 m²
lecture hall 02
277.92 m²
lecture hall 01
355.24 m²
virtual reality architecture
25.00 m²
virtual reality architecture
9.00 m²
Conference Room
140.23 m²
CMT Laboratory
3D Printing Room
92.64 m²
workshop
workshop
162.47 m²
Custodial Room
48.76 m²
exibition space +materials library

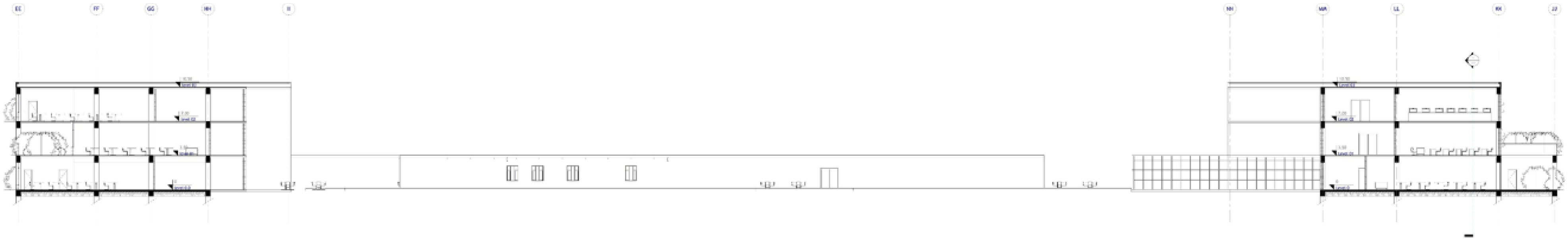

consultation room
office
teacher room
classroom17
classroom15
classroom14


3D models workshop
Prayer Room
71.64 m²
Prayer Room
club space






P
O
N
GGG
QQ
M
HHH
L
K
RR
J
I
H
G
PP
F
E

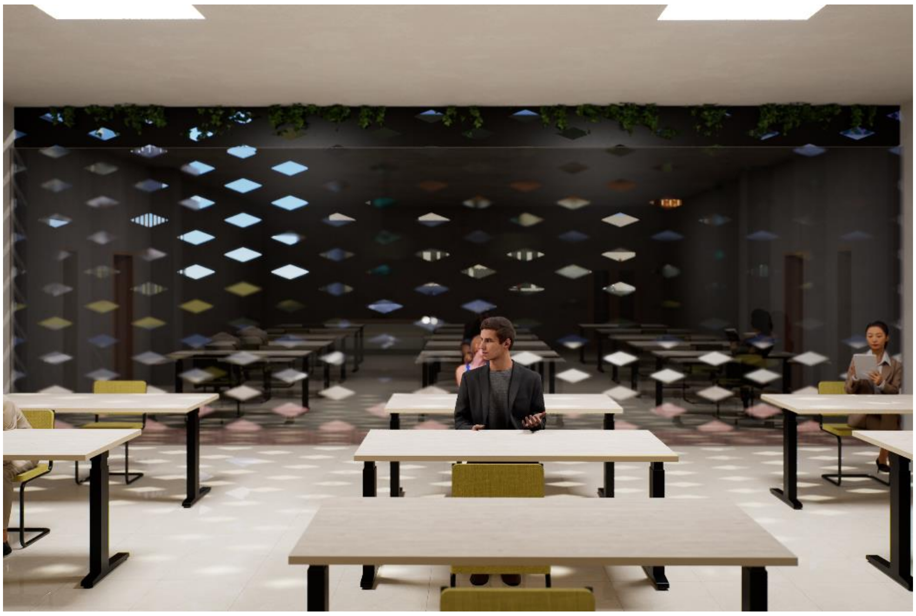


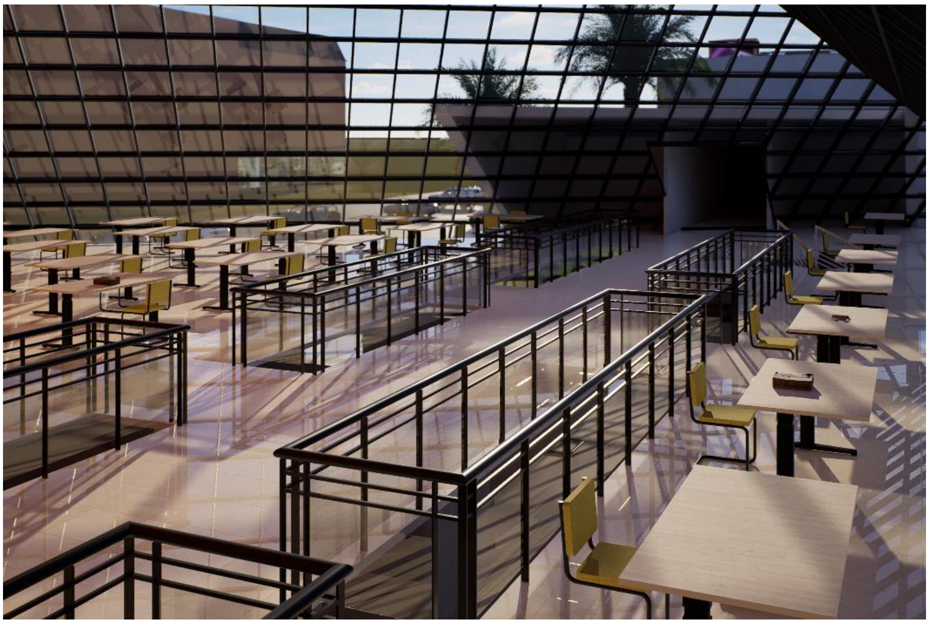
Project exterior views

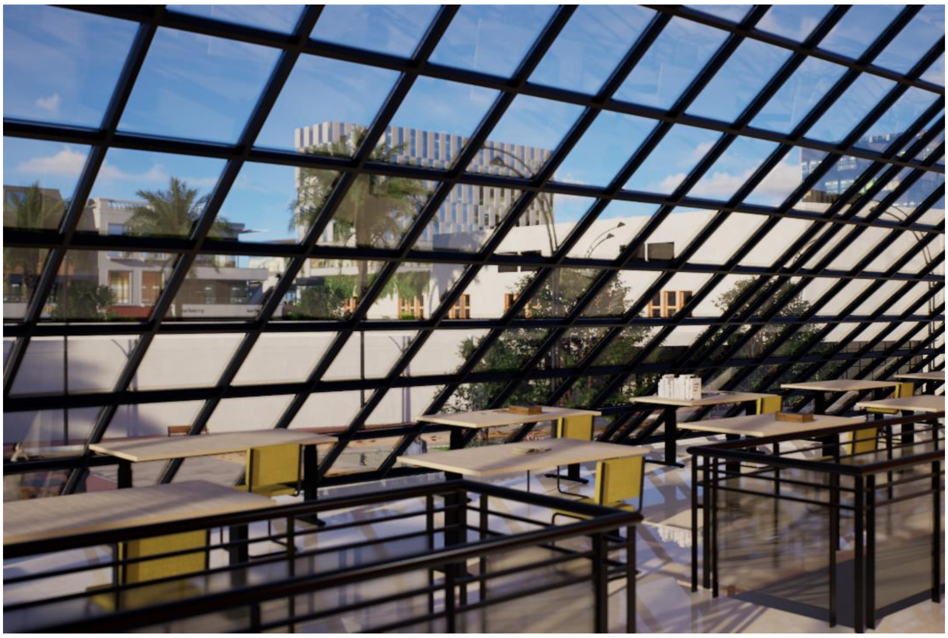

MRC 1920


HOTEL

Project interior views

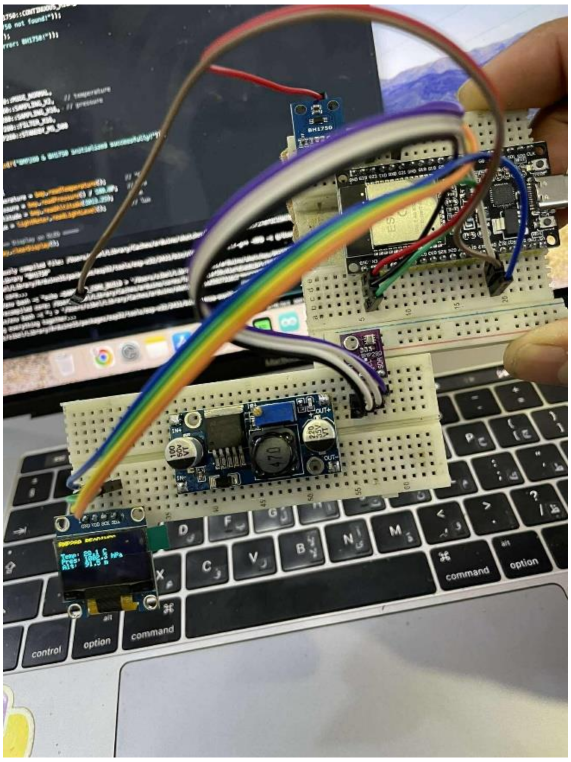


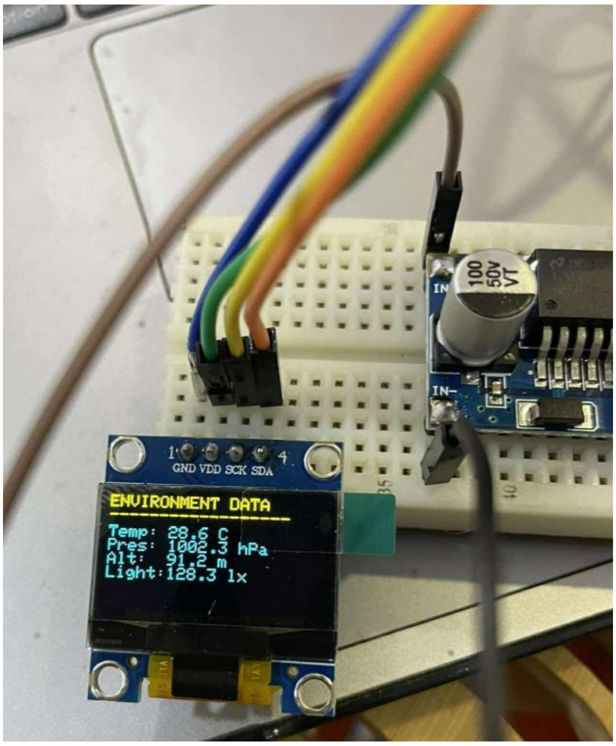




APPENDIX 02

The prototype hardware pictures:






TCM


Smart Facade MANUAL
Temp: 26.4 C
Pres: 1000 hPa
Lux: 45
S1:112 S2: 4


Smart Facade AUTO
Temp: 26.4 C
Pres: 1000 hPa
Lux: 43
S1:112 S2: 4


VIN
GND
SCL
SDA
BH1750

The analysed projects spaces surfaces:

Austin E. Knowlton school of architecture:

space	surface
ground floor	
jury space and lecture room	380 m²
classroom	100m² 63m² 150m² 115m²
gallery	130m²
first floor	
Auditorium	510 m²
faculty offices	23m²
seminar room	50m²
computer room	40m²
Administration	12 offices + open spaces 435m²
second floor Studios	
Studios	1530m² 1930m²
computer Laboratories	30 offices: 185 m²
PhD offices	10 offices: 14 m²
City and Regional planning	190m²

Bauhaus school of architecture:

space	surface
ground floor	
Laboratory	2: 70m²
classroom	178m² 135m² 172m² 190m² with lockers
display room and exhibition	280m²
display room for materials	60m²
first floor	
Library	150m²
Conference Room	60m²
Lecture room	155 m²
Studio	45 m²
second floor Studios	
classroom	95m² 120m² with lockers
Lecture room	210m²
Studio	32m²

Epau:

space	surface
Parking	95 places
Workshop	137m² 212m² 72m² 95m²
Teaching materials room of Workshop	23m²
Conference room	120 m²

classroom	
Prayer room	152 m
Cafeteria	60 m²
laboratory	74m² 74m² 124m²
classroom	82m² 65m²
medical unit	91m²
lecture hall + storage room	350 places: 450m² 100 places: 81m² 170 places: 210m²
computer room	70m² 46m²
printing and production room	82 m²

Biskra Departement:

space	surface
drawing room	98m²
classroom	60m²
internet room	79.5m² 75m²
reading room	293m²
lending room and store	110m² 82m²
librarian's office	28.5m²
computer-assisted design room	80m²
teachers' room	63m²
consultation office	11m² 14m² 17m²
projection room	75m²
practical work room	75m²
printing room	74m²
exhibition hall	195m²
model room	123m²
testing room	98m²
visual arts workshops	98m²
200-seat lecture hall	200m²
staff office	30m² 44m²

APPENDIX 03

Mahoney's table :
a – Temperature ;

	J	F	M	A	M	J	J	A	S	O	N	D
Avrg Temp Max	18	19	23	27	28	31	37	41	40	28	22	18
Avrg Temp Min	8	8	11	15	19	25	29	28	24	17	12	8
E.D.T	10	11	12	12	12	12	12	12	10	11	10	10

La+ high	TAM
41	24,5
8	33
La+ low	EAT

b - Humidity, Rain and Wind:

	J	F	M	A	M	J	J	A	S	O	N	D
Humidity Rel. Max	61	56	51	47	44	40	35	38	47	55	57	60
Humidity Rel. Min	60	51	46	42	36	31	26	31	42	50	55	59
Humidity Rel. Moy	60.5	53.5	48.5	44.5	40.0	35.5	30.5	34.5	44.5	52.5	56.0	59.5
Group (G.H)	3	3	2	2	2	2	2	2	2	3	3	3
Rain (mm)	15.9	17.5	24.7	22.6	5.7	23.6	0.0	3.7	10.4	16.3	44.8	0.3

Prevailing Wind	4.5	4.7	5.0	4	5.2	4.6	2.9	2.9	2.9	3.4	3.8	3.2
Secondary Wind												

Total annual rainfall
185,5

G.H	
< 30%	1
30–50	2
50–70	3
> 70	4

c- confort:

	J	F	M	A	M	J	J	A	S	O	N	D
G.H	3	3	2	2	2	2	1	2	2	3	3	3

-thermal stress:

Day	f	f	/	/	/	c	c	c	c	/	f	f
Night	f	f	f	f	/	c	c	c	/	/	f	f

-temperature:

Moy. Mens. Max	18	19	23	27	31	37	41	40	34	28	22	18
Confort Maxi Diurnal Mini	29 23	29 23	31 23	31 23	31 23	31 23	34 26	31 23	31 23	29 23	29 23	29 23
Moy. Mens. Min	8	8	11	15	19	25	29	28	24	17	12	8
Confort Maxi Nocturne Mini	23 17	23 17	24 17	24 17	24 17	24 17	25 17	24 17	24 17	23 17	23 17	23 17

d- indicators

	J	F	M	A	M	J	J	A	S	O	N	D

H1									X			
H2												
H3				X	X					X		
A1			X									
A2							X	X				
A3	X	X				X					X	X

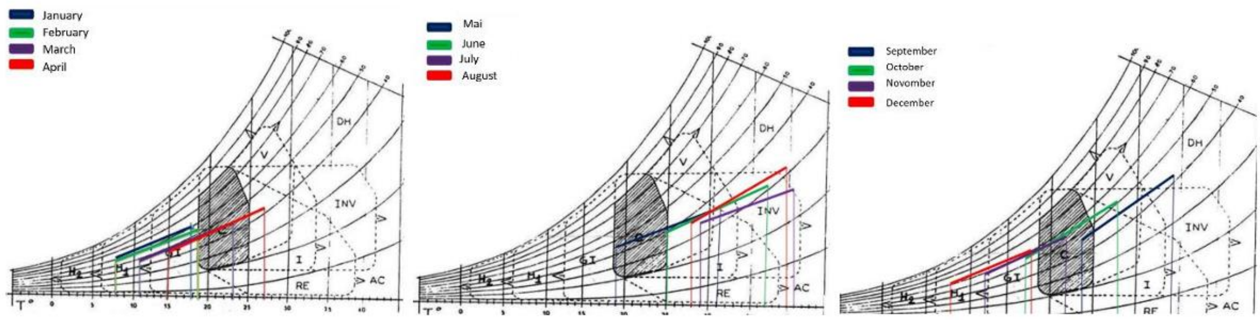
Givoni's diagram :

a- Humidity :

	J	F	M	A	M	J	J	A	S	O	N	D
Humidity Rel. Max	61	56	51	47	44	40	35	38	47	55	57	60
Humidity Rel. Min	60	51	46	42	36	31	26	31	42	50	55	59

b- Teperature ;

	J	F	M	A	M	J	J	A	S	O	N	D
Avrg Temp Max	18	19	23	27	31	37	41	40	34	28	22	18
Avrg Temp Min	8	8	11	15	19	25	29	28	24	17	12	8



Recommendations drawn from Givoni diagrams:

Month	Recommendations	Month	Recommendations	Month	Recommendations
January	H1, GI	May	V, I, INV, AC	September	V, I, INV, AC, DH
February	H1, GI	June	V, I, INV, AC	October	GI, C, V, I
March	H1, GI, C	July	V, I, INV, AC	Novermber	H1, GI
April	GI, C, V	Auguest	V, I, INV, AC, DH	December	H1, GI

H2: Active solar heating
H1: Passive solar heating
C: Comfort
V: Ventilation
I: Strong inertia
H: Heating
GI: Internal gain

AC: Cooling
DH: Dehumidification
INV: Very high inertia and night ventilation
RE: Ventilation cooling

Architectural recommendations for Algeria (N.Ould Hnia):

summer climate zones :

According to the summer climatic zones which were defined by Ould Hnia, the wilaya of Biskra is located in zone E3 (pre-Sahara tassili), this zone is characterized by a very hot and dry summer.

Recommendations	Principles for the Summer Period
1. Orientation	North-south (east and west are to be avoided).
2. Spacing between buildings	Compact layout by reducing the exposure of walls to the exterior
3. Summer ventilation or aeration	Night ventilation
4. Openings/windows	Average 25 to 40%
5. Walls and floors	Solid walls and floors. High multi-day thermal inertia (excluding overheating periods) with light colors.
6. Roof	Solid. High multi-day thermal inertia (excluding overheating periods) with light colors.
7. Thermal insulation	Insulated roof
8. Protection	Summer protection. Complete shading of openings, north-south openings
9. Outdoor spaces	Outdoor sleeping areas. Outdoor kitchen
10. Vegetation	Vegetation shades walls and windows.
11. Passive Heating	/

b-winter climate zones :

According to the winter climatic zones, which were defined by Ould Hnia, the wilaya of Biskra is located in zone H3a, this zone is characterized by an altitude between 500-1000.

Recommendations	Principles for the Summer Period
1. Orientation	Desired north-south with vertical occupation of spaces.
2. Spacing between buildings	Compact layout by reducing the exposure of walls in contact with the exterior
3. Summer ventilation or aeration	/
4. Openings/windows	For the total area of planned openings, allocate a south-facing glazing area equal to 0.15 per m² of floor space for winter sun capture.
5. Walls and floors	Solid walls and floors - daily thermal inertia > 8 hours, compromise to be made with summer.
6. Roof	Solid and insulated roof.
7. Thermal insulation	Thermal insulation of the roof.
8. Winter protection	from sandstorms by planting evergreens that grow in the south.
9. Outdoor spaces	/
10. Vegetation	Evergreen vegetation to protect against cold and especially sandstorm prevailing winds.
11. Passive Heating	Passive heating through storage, solid walls, inertia phase shift 8 to 12 hours or south-facing glazing.
12. Climatisation	/

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

جامعة محمد خيضر - بسكرة

حاضنة أعمال جامعة بسكرة

رقم 41/م الحاضنة /2025

شهـــادة توطيـــن / تحضيـــن "مشروع مبتكر ضمن قرار 1275"

انا الممضي أسفله، السيد (ة): **محمد جلاب**

مسير(ة) حاضنة الأعمال: **جامعة محمد خيضر – بسكرة.**

المقر الاجتماعي / العنوان: **المجمع الإداري المقابل لكلية العلوم الاقتصادية، الطابق الثاني، جامعة بسكرة 07000**

رقم علامة الحاضنة : **2311223051**

تاريخ تسليم العلامة : **23 نوفمبر2022**

أشهد أن الطالب / الطلبة التالية أسمائهم :

الاسم و اللقب	الطور الدراسي	التخصص	الكلية
حنين سطايفي	ماستر 2	هندسة معمارية	الهندسة المعمارية و العمران و الهندسة المدنية و الري

تحت إشراف الاستاذ/الاساتذة التالية أسمائهم :

الاسم و اللقب	الرتبة	التخصص	الكلية
دعيش صفاء	أستاذ محاضر- أ-	هندسة معمارية	الهندسة المعمارية و العمران و الهندسة المدنية و الري
سعدي محمد ياسين	أستاذ محاضر- أ-	هندسة معمارية	الهندسة المعمارية و العمران و الهندسة المدنية و الري

تم احتضانه على مستوى حاضنة أعمال جامعة محمد خيضر - بسكرة بمشروع تحت اسم :

تصميم نظام متكامل للإضاءة الطبيعية يهدف الحد من التوهج، تعزيز الراحة الحرارية، و تحسين كفاءة استهلاك الطاقة خلال السنة الجامعية 2024 / 2025.

سلمت هذه الشهادة بطلب من المعني للإدلاء بها في حدود ما يسمح به القانون .

حرر في بسكرة بتاريخ : 2025/07/08

مدير الحاضنة

مسؤول حاضنة الأعمال

د/ محمد جلاب

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي جامعة محمد خيضر – بسكرة –

جامعة محمد خيضر – بسكرة

عنوان المشروع:

تصميم نظام متكامل للإضاءة الطبيعية بهدف الحد من التوهج، تعزيز الراحة الحرارية، وتحسين كفاءة استهلاك الطاقة

صورة العلامة التجارية

TRILUX
ADAPTIVE FACADE SYSTEM

الاسم التجاري

TriLux

السنة الجامعية 2025/2024

بطاقة معلومات:

حول فريق الإشراف وفريق العمل

1-فريق الإشراف

فريق الإشراف	
الأستاذة المشرفة دعيش صفاء	كلية الهندسة المعمارية و العمران و الهندسة المدنية و الري
الأستاذ المشرف سعدي محمد ياسين	كلية الهندسة المعمارية و العمران و الهندسة المدنية و الري

2-فريق العمل

الطالبة	التخصص	الكلية
سطافي حنين	هندسة معمارية	كلية الهندسة المعمارية و العمران و الهندسة المدنية و الري

فهرس المحتويات

المحور الأول: تقديم المشروع

1. المحور الأول: تقديم المشروع

يتمثل مشروع المؤسسة الناشئة في تطوير واجهة معمارية متكيفة مع المناخ الحار والجاف، قادرة على الاستجابة لحركة الشمس بغرض الحد من التوهّج وتقليل الكسب الحراري مع الحفاظ على الإضاءة الطبيعية داخل الفضاءات.

وتعدّ الراحة البصرية والحرارية وكفاءة الطاقة من أهم المعايير التي يجب أن تتوافر في الفضاءات المعمارية، وخصوصًا في المباني التعليمية التي تتطلب بيئة بصرية وحرارية متوازنة لتعزيز عملية التعلم. إن إدراك هذه الحاجة الملحّة دفعنا إلى التفكير في ابتكار حل عملي لتحقيق هذه المتطلبات.

وتشير البيانات العالمية إلى أنّ المباني تستهلك أكثر من 40% من إجمالي الطاقة النهائية عالميًا، فيما تشكل المباني في الجزائر وحدها نحو 33% من إجمالي استهلاك الطاقة في البلاد ، فضلاً عن أنّ قطاع المباني يمثّل حوالي 46% من الاستهلاك النهائي للطاقة في الجزائر حسب بيانات التقرير الدولي لعام 2022 .

ومن هذا المنطلق، فإنّ الحل الذي نقترحه يسهم بشكل فعّال في تحسين الأداء الطاقوي للمباني، علاوة على تعزيز الراحتين البصرية والحرارية، بما يتوافق مع أهداف العمارة المستدامة. يستند الابتكار إلى ترتيب مبتكر لمواد متوفّرة محليًا، داخل تجميع طبقي يعمل بآلية بسيطة، مع إمكانية إضافة أنظمة استشعار للتحكّم اللحظي عند الحاجة، مما يوفّر حلًا عمليًا وجماليًا يعمل على تقليل استهلاك الطاقة وتحقيق الراحة، مع مراعاة سهولة التركيب والصيانة والملاءمة للسياق المحلي، وموجّهًا لمكاتب الهندسة، شركات الاستشارات البيئية، والمطورين العقاريين الباحثين عن حلول تجمع بين الكفاءة والجمال في البيئات القاسية.

1.1. فكرة المشروع: الحل المقترح

يقوم المشروع على تصميم وتطوير "نظام معماري متكامل وذكي، يعمل على التفاعل مع الظروف المناخية الخارجية لتحقيق التوازن المطلوب بين الاستفادة المثلى من الإضاءة الطبيعية وتقليل الوهج البصري، إضافةً إلى تعزيز الراحة الحرارية داخل الفضاءات المبنية، مع ضمان كفاءة عالية في استهلاك الطاقة".

يرتكز الحل على لوحات واجهة مبتكرة مكونة من طبقات مدروسة بعناية:

طبقة خارجية من الألمنيوم لمقاومة الظروف الجوية وضمان المتانة،

يليها فراغ هوائي يساهم في تحسين العزل الحراري،

ثم طبقة من الخشب الرقائقي تمنح خفة الوزن وسهولة التركيب والاستخدام.

ويكتسب هذا الاختيار صلة مباشرة بخصوصيات المناخ الحار والجاف لمدينة بسكرة، حيث الحرارة المرتفعة والسطوع الشمسي القوي، إلى جانب ملاءمة المواد المقترحة من حيث التكلفة والوفرة في السوق المحلي.

يعتمد النظام على مجموعة من الأدوات المدمجة، من بينها:

لاقِط حراري لمتابعة التغيرات المناخية بدقة،

محرك كهربائي منخفض الاستهلاك للتحكم في حركة الألواح،

خوارزميات تحكم ذكية تتعلم من أنماط الاستخدام لتوليد حلول تفاعلية،

إضافةً إلى مجسات للضوء والحرارة تضمن استجابة فورية لأي تغير في البيئة،

مع إمكانية ربط النظام ببرمجيات محاكاة وإدارة الطاقة لتحقيق أعلى أداء.

ولتعزيز الفعالية والاعتمادية، يمكن دمج النظام مع مصادر طاقة متجددة صغيرة مثل ألواح شمسية ضوئية، مما يمنحه استقلالية أكبر ويقلل من الأثر البيئي.

تم اختيار هذا الحل لكونه يجمع بين البساطة في التصميم و المرونة في الاستخدام، بحيث يمكن تركيبه وصيانته بسهولة، وفي الوقت نفسه يوفر قيمة مضافة في المشاريع المعمارية المختلفة مثل المدارس والجامعات والمكتبات والمباني الإدارية والمجمعات السكنية. كما يتميز بقدرته على الاندماج في مختلف أنماط المشاريع المعاصرة دون أن يخلّ بالجانب الجمالي للواجهات، مما يجعله خيارًا جذابًا يجمع بين الأداء الوظيفي و التكلفة الاقتصادية و البعد التسويقي القائم على الاستدامة والابتكار.

2.1. وصف النظام:

يعتمد النظام المطوَّر من طرف المؤسسة الناشئة على حل معماري وتقني ذكي يهدف إلى تحسين الأداء البيئي للواجهات في المناطق الحارة والجافة، مثل مناخ مدينة بسكرة.

يتمثل هذا النظام في واجهة تفاعلية قادرة على التكيف مع الظروف المناخية الخارجية في الزمن الحقيقي، من خلال ضبط فتحات الواجهة بطريقة آلية أو يدوية لتحقيق التوازن بين الإضاءة الطبيعية المثلى (حوالي 500 لوكس) والراحة الحرارية (24–26°C) مع الحفاظ على نسبة رطوبة تتراوح بين 40% و60%.

يُدار النظام عبر وحدة تحكم إلكترونية (Microcontroller ESP32) تجمع بيانات من مستشعرات الضوء (BH1750) والحرارة والرطوبة (BME280)، ليتم تحليلها وتوجيه محركات السيرفو (MG996R) لضبط زوايا الألواح المكونة للواجهة.

كما يتضمن النظام شاشة عرض (OLED) تُظهر القيم اللحظية، بالإضافة إلى إمكانية التشغيل الآلي أو اليدوي حسب رغبة المستخدم.

يتميز النظام بكونه بيئياً وتكنولوجياً ومعمارياً في آنٍ واحد، حيث يجمع بين الحفاظ على الجمالية المعمارية للواجهة وتقليل التوهج وتحسين الراحة الحرارية وخفض استهلاك الطاقة، مما يجعله حلاً مبتكراً ومناسباً للمدن ذات المناخ الحار والجاف.

3.1. تعريف المشروع

العنصر	الشرح
طبيعة المشروع	مشروع صناعي–تقني–معماري مبتكر يهدف إلى تطوير نظام ذكي متكامل للإضاءة الطبيعية بهدف الحد من التوهج، تعزيز الراحة الحرارية، وتحسين كفاءة استهلاك الطاقة
اسم المشروع	الاسم الأكاديمي: "النظام الذكي المتكامل للحد من التوهج، تعزيز الراحة الحرارية، وتحسين كفاءة استهلاك الطاقة ". الاسم التجاري: TriLux
مجال النشاط	يأتي المشروع ضمن المجال صناعي – المعماري – التكنولوجي
موقع المشروع	ولاية بسكرة
النطاق	محلي – وطني
الفئة المستهدفة	المؤسسات التعليمية (مدارس، جامعات، مكتبات). المؤسسات الإدارية والمكاتب. المجمعات السكنية الحديثة. مكاتب الدراسات المعمارية وشركات البناء.
عدد العمال	6 إلى 8 عمال موزعين بين فريق إداري (مدير ومساعد)، وفريق تقني (مهندس معماري/طاقات متجددة ومطور برمجيات)، إضافة إلى فريق تركيب وصيانة
تسمية النشاط	تطوير وتصنيع وتركيب أنظمة ذكية للتحكم المناخي والطاقي في المباني
مضمون النشاط	يتجسد مضمون النشاط في تصميم لوحات واجهة متكيفة مصنوعة من مواد محلية وفعّالة، مع إنتاج وتجميع النظام بكامل مكوناته من أجهزة استشعار ومحركات وبرمجيات ذكية. كما يشمل النشاط تركيب هذه الأنظمة وتكوين فرق مختصة بالصيانة والتشغيل لضمان استمرارية الأداء. إضافة إلى ذلك، يوفر المشروع خدمات استشارية متخصصة في مجالات الإضاءة والراحة الحرارية وكفاءة الطاقة، بما يعزز من القيمة المضافة للحلول المقدمة

الشكل القانوني للمؤسسة	"شركة ذات مسؤولية محدودة (SARL)" أو "مؤسسة ناشئة (Startup)" معتمدة لدى الوكالة الوطنية لدعم وتنمية المقاولاتية
تكلفه شراء الارضية	00 دينار جزائري

4.1. القيم المقترحة

1. واجهة متكيفة مع البيئة المناخية

تتمثل القيمة الأولى في تطوير واجهة معمارية ديناميكية قادرة على التكيف مع الظروف المناخية السائدة في المناطق الحارة والجافة. فالواجهة لا تُعتبر مجرد عنصر إنشائي أو جمالي، بل منظومة متحركة تعتمد على تقنيات الاستشعار والتحكم الآلي لتغيير وضعياتها بما يتلاءم مع حركة الشمس وزوايا الإشعاع. هذا التكيف المستمر يسمح بتحقيق توازن بين الاستفادة من الإضاءة الطبيعية والحد من الآثار السلبية للحرارة والوهج، ما يجعلها حلاً علمياً وتقنياً ملائماً للبيئة المحلية.

2. تحسين الراحة الحرارية والبصرية وتقليل استهلاك الطاقة

تسعى المؤسسة من خلال منتجها إلى تحقيق قيمة مضافة على صعيد جودة الفضاء الداخلي، وذلك عبر تعزيز الراحة الحرارية والبصرية للمستخدمين. فالواجهة الذكية تقلل من الحاجة إلى التبريد الاصطناعي والإضاءة الكهربائية، مما يؤدي إلى خفض الاستهلاك الطاقوي بنسبة معتبرة. هذا الأمر لا يساهم فقط في التخفيف من التكاليف التشغيلية للمباني، بل ينسجم أيضاً مع أهداف التنمية المستدامة التي تركز على رفع كفاءة استخدام الطاقة في قطاع البناء.

3. اعتماد ترتيب مبتكر للمواد والأنظمة

تقوم الفكرة الأساسية للواجهة على دمج مواد محلية وفعّالة ضمن نظام متعدد الطبقات يوازن بين العزل الحراري، خفة الوزن، والقدرة على مقاومة الظروف المناخية القاسية. إن الابتكار في هذا الجانب لا يتوقف عند اختيار المواد فحسب، بل يشمل أيضاً طريقة تركيبها وترتيبها لتحقيق أداء تكاملي. ويمثل هذا الجانب بُعداً تقنياً أساسياً يعكس قدرة المشروع على تطوير منتج يجمع بين المعايير العالمية والملاءمة البيئية المحلية.

4. بساطة الاستعمال وسهولة التشغيل

على الرغم من الطبيعة التقنية للنظام، فإن التصميم يأخذ بعين الاعتبار جانب البساطة وسهولة التعامل. فالواجهة مزودة بآليات تشغيل أوتوماتيكية تعتمد على الحساسات والمحركات الصغيرة، مما يقلل من تدخل المستخدم ويضمن له تجربة مريحة. كما تقدم المؤسسة خدمات دعم وتكوين أساسية لفائدة المستعملين وفرق

الصيانة، بهدف ضمان التشغيل السلس على المدى الطويل. هذه البساطة في الاستعمال تعد عنصراً جوهرياً لتشجيع تبني التقنية وعدم جعلها حكراً على فئة محدودة من المختصين.

5. قابلية الدمج والتوظيف في مشاريع متنوعة

تتمثل إحدى القيم المميزة للمشروع في مرونة النظام وقابليته للتكامل مع أنماط مختلفة من المشاريع المعمارية. فالواجهة المقترحة لا تقتصر على المباني الحديثة فحسب، بل يمكن تكييفها مع المباني القائمة في إطار عمليات التجديد الطاقوي أو التحديث المعماري. هذا التوظيف المتعدد يمنح المنتج بعداً استراتيجياً، كونه لا يرتبط بسوق ضيق، بل يجد مجالاً للتطبيق في المباني السكنية، التعليمية، الإدارية، والتجارية.

6. المساهمة في الاستدامة والابتكار المعماري

إضافة إلى القيم المباشرة المرتبطة بالراحة وكفاءة الطاقة، يقدم المشروع قيمة رمزية وعلمية مهمة تتمثل في دفع عجلة الابتكار في ميدان البناء بالجزائر. فهو يجمع بين المعرفة الأكاديمية، التقنيات الذكية، واستخدام المواد المحلية، ليشكل مثالاً عملياً على كيفية الانتقال نحو مبانٍ أكثر استدامة. كما أن هذا التوجه يعزز صورة المؤسسة الناشئة كمساهم فعلي في تطوير حلول بيئية ومعمارية تلبي احتياجات الحاضر وتستجيب لتحديات المستقبل.

7. الجدوى الاقتصادية من خلال الاعتماد على المواد المحلية

إحدى أبرز القيم المضافة للمشروع تكمن في اعتماده على مواد متوفرة في السوق المحلي بكميات وأسعار مناسبة، مما يضمن تخفيضاً ملموساً في تكاليف الإنتاج والتركيب. هذا الخيار لا يحقق فائدة اقتصادية للمؤسسة الناشئة فحسب، بل يساهم أيضاً في تحريك عجلة الاقتصاد الوطني عبر دعم سلاسل التوريد المحلية وتشجيع الصناعات الوطنية. كما يضمن هذا التوجه استمرارية النظام من خلال سهولة الحصول على قطع الغيار والمواد المستبدلة، مما يقلل من التبعية للأسواق الخارجية ويعزز من قدرة المشروع على الانتشار في محيطه المحلي والإقليمي.

5.1. فريق العمل

الطلبة	التخصص	الدورات التكوينية
سطافي حنين	هندسة معمارية	– شهادة في اللغة الانجليزية مستوى C1 – تربص ميداني على مستوى مديرية السكن

		- تربص ميداني على مستوى مديرية التجهيزات العمومية

6.1. أهداف المشروع :

- **الأهداف قصيرة المدى (من 12 إلى 24 شهراً):**

- إعداد النموذج الأولي وتجربته ميدانيًا: العمل على تصميم وتنفيذ نموذج أولي للواجهة المتكيفة وتجريبه في بيئات واقعية مثل قاعات التدريس أو المكاتب الإدارية، بهدف تقييم الأداء والتحقق من الفعالية التقنية والوظيفية.
- إنشاء علامة تجارية أولية: الاسم، الشعار، الهوية البصرية، حضور على وسائل التواصل الاجتماعي، موقع إلكتروني، محتوى تسويقي بسيط
- الحصول على شهادة اعتماد تقنية–معمارية: السعي لاعتماد المنتج من هيئات مختصة في مجالي التقنية والعمارة، بما يضمن مطابقته للمعايير المحلية والدولية ويمنحه ثقة أكبر لدى الشركاء والعملاء.
- بناء شبكة شراكات استراتيجية: إبرام اتفاقيات تعاون مع جامعات، مكاتب دراسات ومؤسسات عامة أو خاصة من أجل توفير فضاءات للتجريب والدعم العلمي والفني، مما يعزز المصداقية ويتيح فرصًا للتطوير المشترك.
- إرساء الإطار القانوني والمالي للمؤسسة: استكمال جميع الإجراءات القانونية الخاصة بتأسيس المؤسسة الناشئة بما يتوافق مع القوانين الجزائرية، والسعي للحصول على تمويل أولي من خلال برامج الدعم، الحاضنات التكنولوجية أو مسابقات الابتكار.
- تجهيز فريق العمل: تكوين فريق عمل متكامل يتراوح بين 6 إلى 8 أشخاص يغطون التخصصات الأساسية (تصميم معماري، إدارة، تقنيات كهربائية، برمجيات، تركيب وصيانة)، مع الحرص على تدريبهم لضمان التكامل في الأداء.
- إطلاق حملة تعريفية وتسويقية أولية: اعتماد استراتيجيات تسويق منخفضة التكلفة مثل إنشاء موقع إلكتروني، تنظيم ورشات تعريفية، والمشاركة في الفعاليات العلمية والابتكارية للتعريف بالمنتج واستقطاب العملاء المحتملين.

الأهداف بعيدة المدى (3 من إلى 5 سنوات):

بعد مرحلة التأسيس والتجريب الأولي، تتجه المؤسسة الناشئة إلى توسيع نطاق عملها وتعزيز حضورها في السوق من خلال تحقيق أهداف استراتيجية بعيدة المدى، أهمها:

- تثبيت المنتج في السوق الوطنية: الانتقال من مرحلة التجريب المحدود إلى مرحلة الإنتاج الصناعي نصف–المكثف وتوزيع الواجهات المتكيفة على نطاق أوسع، مع اعتمادها في مشاريع إسكان عمومية وخاصة، وكذا في المباني الجامعية والإدارية.
- التوسع الإقليمي والدولي: العمل على إدخال المنتج إلى أسواق مجاورة ذات ظروف مناخية مشابهة (مثل بلدان شمال إفريقيا والشرق الأوسط)، بما يمنح المؤسسة بعدًا إقليميًا ويزيد من قدرتها التنافسية.
- التطوير المستمر للمنتج: الاستثمار في البحث والتطوير (R&D) من أجل إدماج تقنيات جديدة مثل الذكاء الاصطناعي وإنترنت الأشياء (IoT) لزيادة فعالية النظام في الاستجابة للتغيرات المناخية وتحسين كفاءة الطاقة.
- تعزيز الجانب الاقتصادي المحلي: الاعتماد على المواد المتوفرة في السوق الوطنية وتشجيع الصناعة المحلية، مما يسهم في تقليل التكاليف ويوفر فرص عمل إضافية، ويعزز صورة المؤسسة كفاعل اقتصادي مستدام.
- الحصول على اعتماد دولي: السعي وراء شهادات جودة واعتماد عالمية (ISO، أو اعتماد من منظمات معمارية وتقنية دولية) مما يرفع المصداقية ويفتح الأبواب أمام شراكات كبرى.
- تعزيز وتقوية العلامة التجارية حتى تكون مرجعًا في السوق الوطني وربما الإقليمي، مع اكتساب سمعة مرتبطة بالابتكار والجودة والاستدامة مما يجعل المؤسسة مرجعًا في حلول الواجهات الذكية.

المحور الثاني: الجوانب الابتكار

2. المحور الثاني: الجوانب الابتكارية

1.2. طبيعة الابتكار:

ابتكار بيئي–تكنولوجي–معماري يجمع بين الاستدامة، توظيف التقنيات الذكية، والحلول التصميمية المعمارية المتكيفة مع المناخ

2.2. مجالات ابتكارية:

- الابتكار المادي (المواد): يقوم على استخدام مواد محلية متوفرة في السوق الجزائري (مثل الألمنيوم والخشب الرقائقي) ضمن ترتيب طبقي مبتكر (معدن – فراغ هوائي – خشب)، ما يضمن الأداء المتكامل من حيث العزل الحراري والمتانة وخفة الوزن وسهولة التركيب.
- القيمة التكاملية للنظام: يمثل الحل المقترح نظامًا واحدًا يجمع بين ثلاث وظائف أساسية: تقليل التوهج، تحسين الراحة الحرارية، وتقليل استهلاك الطاقة، مما يجعله ذا قيمة عملية واقتصادية عالية.
- الابتكار في المراقبة اللحظية (**Real–Time Monitoring**): إدماج خاصية المراقبة اللحظية للأداء، بما يتيح متابعة فورية وتقييم مستمر لمدى فعالية النظام، وضمان قدرته على التكيف مع التغيرات المناخية في الوقت الحقيقي.
- الابتكار التقني: يتمثل في اعتماد نظام تحكم ذكي مدمج ببرمجيات متطورة وأجهزة استشعار دقيقة، مما يسمح بضبط الإضاءة الطبيعية وتقليل الوهج وتحقيق التوازن الحراري بشكل لحظي، بما يعزز الأداء العام للنظام.
- الابتكار التصميمي والمعماري: يتجلى في بساطة الشكل وقدرته على الاندماج مع مختلف المشاريع المعمارية (سكنية، تعليمية، إدارية)، مع الحفاظ على جمالية الواجهة وإضفاء طابع عصري يعزز الهوية المعمارية المحلية.
- **الابتكار الاقتصادي:** يظهر من خلال خفض تكاليف الإنتاج والتركيب بفضل الاعتماد على المواد المحلية وتبسيط آليات التشغيل والصيانة، مما يجعل المنتج في متناول شريحة واسعة من العملاء، ويعزز قدرته التنافسية في السوق الوطنية.
- **الابتكار البيئي والاستدامة:** يساهم المشروع في ترشيد استهلاك الطاقة والحد من الانبعاثات الكربونية عبر تعزيز الإضاءة الطبيعية وتقليل الاعتماد على التبريد الاصطناعي، مع التركيز على التكيف مع الظروف المناخية الحارة والجافة لمدينة بسكرة.

المحور الثالث: التحليل الاستراتيجي للسوق

3. المحور الثالث: التحليل الاستراتيجي للسوق

1.3. تحليل PESTEL

السياسي	الاقتصادي	الاجتماعي	التقني	البيئي	القانوني
دعم الدولة للطاقات المتجددة وترشيد استهلاك الطاقة يخلق بيئة ملائمة لمثل هذه المشاريع، خصوصاً مع وجود برامج حكومية لمواجهة التغير المناخي.	توفر المواد الأولية في السوق المحلي (الألمنيوم، الخشب) يساهم في خفض التكاليف. لكن الأوضاع الاقتصادية المتقلبة والتضخم قد يشكلان عائقاً أمام القدرة الشرائية لبعض الشرائح.	الاجتماعي (Social): تزايد الوعي لدى الأفراد والمؤسسات بأهمية الاستدامة وتحسين الراحة الحرارية والإضاءة الطبيعية، خاصة في المدن الكبرى.	توفر تقنيات الاستشعار الذكي والبرمجيات المدمجة يعزز الابتكار، مع وجود فرص للتكامل مع أنظمة "البيئة الذكية" (Smart Environment).	المناخ الحار والجاف في مدن مثل بسكرة يفرض حلولاً مبتكرة للحد من التوهج وتحسين العزل الحراري، مما يجعل المشروع ملائماً لسياقه المحلي.	وجود معايير بناء وتشريعات بيئية جديدة يشجع على تبني الحلول المستدامة، مع ضرورة الالتزام بالمواصفات الوطنية والدولية للحصول على الاعتماد.

2.3. تحليل Porter (القوى الخمس)

- شدة المنافسة بين الشركات القائمة: المنافسة محدودة في السوق الجزائري لغياب حلول مماثلة محلية، لكن هناك احتمال دخول شركات أجنبية بحلول جاهزة.
- قوة الموردين: متوسطة؛ لأن المواد متوفرة محلياً لكن بعض الأجهزة الذكية أو المستشعرات قد تحتاج للاستيراد.
- قوة الزبائن: قوية نسبياً؛ حيث الزبون يبحث عن الجودة مع السعر المناسب، خاصة المؤسسات العمومية والجامعات التي تعتمد المناقصات.
- تهديد المنتجات البديلة: متوسط؛ إذ يمكن اللجوء إلى حلول تقليدية مثل الزجاج العاكس أو الستائر، لكنها لا توفر نفس الأداء التكاملي.

- تهديد دخول منافسين جدد: وارد لكنه يحتاج وقتاً ورأسمالاً، مما يمنح المشروع ميزة البداية (First Mover Advantage).

3.3. تحليل SWOT

نقاط القوة	نقاط الضعف
- منتج يجمع بين الاستدامة، التكنولوجيا، والتصميم المعماري. - استخدام مواد محلية يقلل التكاليف. - نظام ذكي يوفر مراقبة لحظية (Real–time monitoring).	- محدودية الخبرة المحلية في الأنظمة المدمجة الذكية. - تكلفة البحث والتطوير في المراحل الأولى.

الفرص	التهديدات
- توجه الدولة لدعم المشاريع الخضراء. - إمكانية التوسع نحو أسواق شمال إفريقيا والشرق الأوسط. - ارتفاع الطلب على الراحة الحرارية في المباني التعليمية والإدارية.	- تقلبات اقتصادية تؤثر على القدرة الشرائية. - منافسة محتملة من شركات أجنبية. - تغييرات سريعة في التقنيات قد تجعل النظام بحاجة لتحديث مستمر.

4.3. المزيج التسويقي

المنتج/ الخدمة	خصائص ومميزات منتجاتك/خدماتك	الاحتياجات التي يلبيها
المنتج عبارة عن نظام واجهات معمارية ذكية بيئية، يجمع بين التقنية والتصميم المعماري، موجّه خصيصاً للمباني الواقعة في المناخات الحارة والجافة مثل مدينة	تصميم معماري متكيف مع المناخ المحلي. تقليل التوهج (Glare) وتحسين الإضاءة الطبيعية داخل الفضاءات. تحسين الراحة الحرارية عبر مواد عازلة وحلول تصميمية متكاملة. نظام مراقبة لحظي (Real–time monitoring) للأداء البيئي والطاقوي.	- حاجة المؤسسات والمباني التعليمية والإدارية إلى حلول بيئية مستدامة. - الاستجابة لمتطلبات التشريعات الوطنية والدولية في البناء المستدام. - تحقيق الراحة البصرية والحرارية للمستخدمين، خاصة في المناخ الحار والجاف.

بسكرة. النظام يعتمد على دمج تقنيات التحكم في الإضاءة الطبيعية، الراحة الحرارية، وتقليل استهلاك الطاقة، مع المحافظة على الجانب الجمالي للواجهة.	تقليل استهلاك الطاقة بنسبة معتبرة مقارنة بالأنظمة التقليدية. إمكانية التصنيع من مواد محلية متوفرة مثل الألمنيوم والخشب، مما يخفض الكلفة ويعزز الاستدامة. واجهات ذات جمالية عالية تحافظ على الهوية المعمارية.	- تقليل تكاليف التشغيل والصيانة على المدى البعيد بفضل تقليص استهلاك الطاقة. - المساهمة في التوجه الوطني والعالمي نحو المباني الخضراء والذكية.

5.3. السعر

سيتم الاعتماد على سياسة التسعير بالتكلفة بحيث: سعر المنتج = تكلفة الوحدوية للمنتج + هامش الربح

السعر المقترح حسب نوع العميل

نوع العميل	السعر المقترح للوحدة الأساسية	الملاحظات
المؤسسات التعليمية و الجامعية	30,000 دج	سعر مدعوم لتشجيع الاستدامة في الفضاءات التعليمية، مع إمكانية تخفيض إضافي للطلبات الكبيرة بعد استقرار المشروع
مكاتب الدراسات والهندسة	31,000 دج	تحفيز التعاون والشراكات التقنية طويلة المدى، وإمكانية منح أسعار تفضيلية عند تكرار المشاريع
المطورون العقاريون	33,000 دج	تسعيرة ملائمة للمشاريع السكنية والتجارية ذات الأرباح المرتفعة، مع قابلية التفاوض في العقود الضخمة
الإدارات العمومية	32,000 دج	سعر رسمي يراعي المواصفات القياسية، وإمكانية تخفيض تدريجي في حال تطبيق واسع النطاق على عدة مبانٍ

6.3. الترويج

وسيلة الترويج	التفاصيل	التكلفة
الحملات الرقمية	إنشاء صفحات على مواقع التواصل الاجتماعي + إعلانات ممولة	حسب الإعلان
المعارض والفعاليات	المشاركة في الصالونات الوطنية مثل BATIMATEC + تنظيم ورش عمل تعريفية داخل الجامعات	حسب المعرض
إنشاء موقع خاص	فتح موقع خاص بالمؤسسة لتسهيل العملية	مجاني
التسويق المباشر	الاتصال المباشر بالمؤسسات التعليمية والإدارات + توزيع كتيبات وبروشورات تقنية	مجاني

اللوحات الإعلانية	تثبيت لوحات إعلانية في مناطق استراتيجية (بالقرب من الجامعات أو مناطق التطوير العقاري)	تكلفة الطباعة

7.3. التوزيع

الخدمة الإضافية التي تقدمها المؤسسة تتمثل في توفير خدمة التوصيل المباشر للمنتج إلى موقع المشروع، وذلك حرصًا على ضمان سلامة النظام أثناء النقل وتسليمه في الوقت المحدد.

تهدف هذه الخدمة إلى تسهيل عملية اقتناء المنتج وتطبيقه ميدانيًا، مع ضمان جودة التركيب ومتابعة عملية التسليم من قبل الفريق التقني، بما يعزز من ثقة العملاء ويعكس احترافية المؤسسة في جميع مراحل التعامل.

طريقة الدفع: طريقة الدفع تكون على شكل كاش عند الاستلام او عن طريق CCP

8.3. عرض القطاع السوقي

- السوق المستهدف (Target Market)

يشمل المؤسسات التعليمية (جامعات، مدارس، معاهد)، الإدارات العمومية، والمطورين العقاريين الذين يبحثون عن حلول مبتكرة لواجهات المباني. هذا السوق يمثل الطلب الأساسي على النظام نظرًا لارتباطه المباشر بالراحة البصرية والحرارية وكفاءة الطاقة في فضاءات ذات استعمال جماعي.

- السوق المحتمل (Potential Market)

يمتد ليشمل قطاعات أوسع مثل المكاتب الخاصة، المباني الإدارية للشركات، المراكز التجارية، وحتى المشاريع السكنية الكبرى التي تهدف للحصول على شهادات استدامة (LEED، HQE). كما يمكن أن يتوسع السوق ليشمل مدن أخرى في الجزائر ذات مناخ مشابه لبسكرة (ورقلة، غرداية، تمنراست).

- السوق المتخصص (Niche Market)

يتجلى في المشاريع النموذجية أو التجريبية (Pilot Projects) التي تبحث عن واجهات تكنولوجية ذكية أو حلول متقدمة في مجال الاستدامة المعمارية. مثل مراكز البحث، مباني الابتكار، أو المشاريع التي تموّلها منظمات بيئية. هذا السوق ضيق لكنه يوفر فرصًا قوية لإبراز الابتكار وتصديره لاحقًا.

9.3. تحليل السوق

1.9.3 تحليل الزبائن

الفئة	الاحتياجات	طريقة الاقناع
المؤسسات التعليمية و الجامعية	تقليل التوهج في القاعات، تحسين الراحة الحرارية للطلبة، تقليل استهلاك الكهرباء في التبريد والإضاءة	تقديم تجارب محاكاة بصرية وحرارية تثبت فعالية النظام + عرض كلفة تشغيل أقل على المدى البعيد
الإدارات العمومية	مبانٍ مريحة وفعّالة، استدامة وربط بالمخططات الحكومية للطاقة	إبراز أن المشروع محلي ويدعم الاقتصاد الوطني + توافقه مع أهداف التنمية المستدامة
المطورون العقاريون	حلول معمارية جمالية، مبيعات أسرع للمشاريع السكنية	تسويق النظام كميزة تنافسية تزيد قيمة المشروع العقاري وتمنحه طابعًا عصريًا مستدامًا
الشركات الخاصة	تحسين بيئة العمل للموظفين + تقليل استهلاك الطاقة	إقناعهم بالأثر الإيجابي على إنتاجية الموظفين وخفض تكاليف التشغيل

2.9.3 تحليل المنافسين

1. Hunter Douglas (هولندا)

تأسست عام 1919 بواسطة هنري سوننبرغ في ألمانيا ثم توسّعت لتصبح شركة هولندية متعددة الجنسيات.

تشتهر بتقديم أنظمة تظليل وواجهات معمارية تجمع بين الجمالية والوظيفة، مثل الستائر الذكية، الألواح المعدنية، وأنظمة التظليل التي تحكم الضوء والتدفئة الخارجية. تتميز بخبرة طويلة جدًا، جودة تصنيع عالية، وتنويع كبير في المنتجات. لكنها غالبًا باهظة الثمن ومتطلباتها التقنية قد تكون عالية بالمقارنة مع حلول محلية.

2. Okalux (ألمانيا)

شركة ألمانية مقرها في Marktheidenfeld، متخصصة منذ نحو الخمسة عقود (أكثر من 50 سنة) في تصنيع الزجاج المعزول (insulating glass) وواجهات زجاجية تحمل إدخالات داخلية (inserts) لتعديل الضوء والتوهج والتوزيع البصري للنهار.

تقدّم حلولًا حساسة لضوء النهار مع تصاميم زجاجية متطورة، مع قدرات تصنيع حديثة مثل خطوط إنتاج زجاج بحجم كبير. من مميزاتها القوة في التخصيص لمتطلبات التصميم المعماري والضوء، لكنها منتجاتها غالبًا معقدة وتتطلب تكلفة عالية، إضافةً إلى أنه ليس من السهل دائمًا استخدام مثل هذه التقنيات في مناخات حارة إذا لم تُعدّل لتناسبها.

أغلب المنافسين يعتمدون على تقنيات عالية التكلفة.

المشروع المحلي في بسكرة سيكون منافسًا من حيث التكلفة الأقل + ملاءمة المناخ المحلي + إمكانية التصنيع المحلي.

3.9.3 الموردون

الفئة	الموردون المحتملون	الموقع	الملاحظات
المستشعرات (حرارية/إضاءة)	Arduino – Raspberry Pi – شركات إلكترونيات محلية	الجزائر العاصمة، وهران / استيراد من أوروبا أو الصين	توفر بأسعار متفاوتة – يمكن البدء بمكونات مفتوحة المصدر
المواد الخشبية	ورشات النجارة المحلية – موردو الخشب الصناعي	بسكرة، باتنة	تقليل التكلفة عبر شراء كميات بالجملة
الألمنيوم	مصانع محلية (مثل ENAL) أو ورش خاصة	الجزائر العاصمة – سطيف	جودة عالية وتكلفة معقولة
الهياكل المعدنية	ورش الحدادة المحلية	بسكرة	تصنيع مخصص حسب المقاسات المطلوبة
مكونات كهربائية	متاجر الأدوات الكهربائية والإلكترونية	بسكرة، الجزائر العاصمة	تشمل الأسلاك، المحولات
البرمجيات	منصات مفتوحة المصدر + شراكات مع مطورين	عالمي (عبر الإنترنت)	لا تحتاج استثمار كبير في البداية

4.9.3 استراتيجية التسويق

- استراتيجية الانطلاق التسويقي

التركيز على السوق المحلي (ولاية بسكرة) كنقطة انطلاق، لكونها تمثل البيئة المناخية المستهدفة (حار وجاف).

استهداف الجامعات والمؤسسات التعليمية باعتبارها الفئة الأكثر تقبلًا للتجديد المعماري والطاقوي.

التسويق عبر القنوات الرقمية (موقع إلكتروني – صفحات تواصل اجتماعي – محتوى مرئي عن آلية عمل النظام).

العروض التجريبية (Pilot projects): تركيب واجهات نموذجية في مبنى جامعي أو إداري لإبراز فعالية النظام.

بناء علامة تجارية قوية ترتبط بالابتكار، الاستدامة، والتكلفة المنخفضة.

- استراتيجية التوسع التسويقي

التوسع الجغرافي: بعد نجاح التجارب في بسكرة، يتم الانتشار إلى ولايات أخرى ذات مناخ مشابه (ورقلة، غرداية، إليزي)، ثم التوجه نحو السوق الوطني.

التوسع القطاعي: استهداف قطاعات جديدة مثل العقار السكني الفاخر، المستشفيات، الإدارات الحكومية الكبرى. الشراكات الإستراتيجية: التعاون مع مكاتب الدراسات المعمارية، شركات البناء، والمقاولين لتبني النظام في مشاريعهم. حضور المعارض والملتقيات الوطنية والدولية في مجالات البناء المستدام والطاقات المتجددة لزيادة التعريف بالمنتج.

التحضير للتصدير نحو الأسواق المغاربية (تونس، المغرب، ليبيا) التي تشترك في نفس الظروف المناخية والاحتياجات الطاقوية.

المحور الرابع: خطة الإنتاج والتنظيم

4. المحور الرابع: خطة الإنتاج والتنظيم

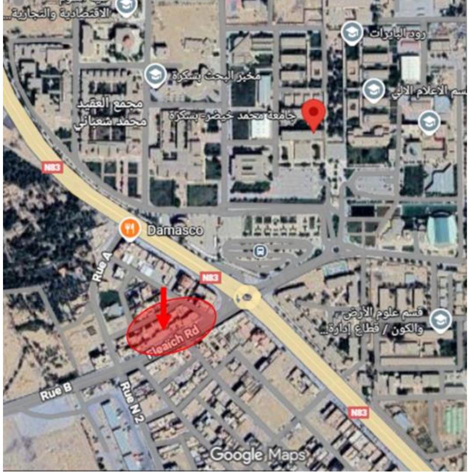
1.4. المخطط الإنتاجي

1.1.4 الموقع:

يقع المشروع في طريق الوادي – تقرت بمسافة 7 كلم عن مركز تقرت بجانب مركز الردم التقني للنفايات ما بين البلديات النزلة

2.1.4 سبب اختيار الموقع:

- كان سبب اختيارنا للمنطقة لبعدها عن المنطقة السكانية وكونها في منطقة صناعية، وكما انها أرضية تحت أمالك الدولة للاستغلال ضمن مشاريع الشركات المصغرة بمبلغ رمزي 1دج للمتر مربع.
- كما تم اختيار مقرّ المؤسسة في منطقة حضرية نظرًا لقربها من جامعة محمد خيضر، مما يسهّل عملية التواصل والتنسيق مع قسم الهندسة المعمارية وباقي الأقسام ذات الصلة.



3.1.4 الجانب المعماري للمشروع

تقدر مساحة المشروع ب 1000 م2

المكان	المساحة	الاستعمال
المستودع 1	200م^2	مكان الإنتاج والتصنيع
المستودع 2	150م^2	مكان وضع الآلات
الإدارة	150م^2	خاص بمكتب المديرة والعمال مع مرحاضين وحمامين
مخزن	150م^2	مخصص للمنتوجات الجاهزة للبيع
مخزن	150م^2	مخصص للمواد الأولية
مركز الحراسة	50م^2	مخصص لعمال الحراسة
مساحة مخصصة للسيارات	50م^2	خاصة بسيارات عمال المؤسسة
استراحة العمال	100م^2	تتكون من غرفة استراحة العمال وقت الغداء+حمامين+مصلى

2.4. احتياجات المشروع

المعدات و الالات

اسم العتاد	الكمية	السعر	السعر الإجمالي
مستشعرات ضوئية (LDR)	10	2000 دج	20000 دج
مستشعرات حرارة (DHT22)	5	3,000 دج	15.000 دج
محركات كهربائية (Servo)	5	4,500 دج	22.500 دج
لوحات تحكم (Arduino/ESP32)	3	6000 دج	18.000 دج
ألواح خشب رقائقي (m²)	20	2,500 دج	50.000 دج
ألواح ألمنيوم (m²)	20	4,000 دج	80.000 دج
الهيكل المعدني (تصنيع محلي)	1	60,000 دج	60.000 دج
منشار كهربائي لقص الخشب	1	25,000 دج	25.000 دج
آلة ثني/قص الألمنيوم	1	45,000 دج	45.000 دج
آلة لحام كهربائي	1	35.000 دج	35.000 دج
مثقاب كهربائي (Drill)	1	15.000دج	15.000 دج
أدوات يدوية (مفكات، مطارق)	1 طقم	10.000دج	10.000 دج

المجموع	395.500 دج

المعدات المكتبية

اسم العتاد	الكمية	السعر	السعر الإجمالي
مكتب عمل	2	20.000 دج	40.000 دج
كراسي مكتبية	4	8.000 دج	32.000 دج
حاسوب مكتبي أو محمول	2	75.000 دج	15.000 دج
طابعة/ماسح ضوئي	1	40.000 دج	40.000 دج
خزانة ملفات	2	15.000 دج	15.000 دج
المجموع			277.000دج

احتياجات الطاقة والكهرباء

الخدمات	احتياجات الثلاثي % الزيادة ب 1%	تكلفة سنة 1
الماء	1600m³	31200دج
الكهرباء والغاز	5 00.000 kw	13.000.000دج
انترنت وهاتف	غير محدود	38.400دج
صيانة	/	700.000دج
المجموع	14.469.600دج	

3.4. النظام الانتاجي: خطوات الإنتاج

ينقسم النظام الإنتاجي للمشروع إلى مجموعة من المراحل المتكاملة، تبدأ من تصميم النموذج وتنتهي بتركيب النظام لدى العميل، وفق الخطوات التالية:

<u>مرحلة التصميم والتخطيط:</u>

إعداد الرسومات التقنية والمعمارية الخاصة باللوحات المتكيفة.

تحديد مقاييس الأبعاد والمواد المناسبة حسب المشروع (خشب رقائقي، ألمنيوم، هيكل معدني).

برمجة النظام الذكي والتحكم في أجهزة الاستشعار والمحركات الكهربائية.

مرحلة تجهيز المواد الأولية:

اقتناء المواد من الموردين المحليين (ألواح الألمنيوم، الخشب الرقائقي، الهيكلة المعدنية).

فحص المواد للتأكد من مطابقتها لمعايير الجودة.

تخزينها في ظروف ملائمة لحمايتها من التلف.

مرحلة التصنيع والتجميع:

قص الخشب والألمنيوم حسب المقاسات المطلوبة باستخدام آلات دقيقة.

تركيب الهيكل المعدني وربطه بالطبقات الأخرى (معدن – فراغ هوائي – خشب).

تثبيت المكونات التقنية: مستشعرات، محركات كهربائية منخفضة الاستهلاك، وحدة تحكم ذكية.

اختبار أولي للتأكد من سلامة التركيب ووظائف النظام.

مرحلة التركيب والتشغيل:

نقل النظام إلى موقع المشروع (مبنى جامعي، إداري، أو سكني).

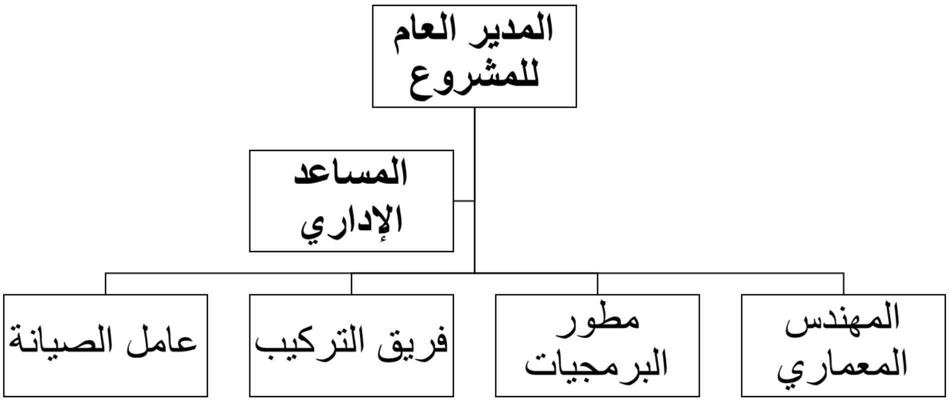
تثبيت اللوحات على الواجهة وفق التصاميم المعمارية.

ربط النظام بالطاقة الكهربائية ووحدة التحكم.

تشغيل النظام وإجراء اختبار نهائي أمام العميل للتأكد من فعاليته.

تسليم كتيب استعمال وصيانة لضمان استمرارية الأداء.

4.4. المخطط التنظيمي



5.4. احتياجات اليد العاملة

المنصب	العدد	التخصص	الوظيفة	الأجور
مهندس معماري	2	هندسة معمارية	تصميم وتطوير النماذج و إدارة	60.000 دج
مهندس كهرباء/إلكترونيك	1	كهرباء/إلكترونيك	برمجة وتركيب المستشعرات	65.000 دج
تقني ميكانيك/حدادة	1	ميكانيك / تصنيع معدني	صناعة وتجميع الهياكل	45.000 دج
نجار مختص بالخشب	1	نجارة	قص وتجهيز الألواح الخشبية	40.000 دج
مساعد فني	1	متنوع	مساعدة في التركيب والتجميع	30.000 دج
موظف إداري/سكرتير	1	تسيير/إدارة أعمال	متابعة الشؤون الإدارية	35.000 دج
المجموع				275.000 دج

6.4. التموين

ستكون سياسة الشراء كما يلي

- الآلات: تكون مرة واحدة فقط الا إذا احتجنا آلات جديدة فأيضا يكون الشراء مرة واحدة فقط والدفع يكون اما عند الاستلام او عن طريق CCP
- مواد أولية: تكون حسب الطلب و الحجم
- تجهيزات المكتبة والوازم: تكون مرة واحدة

7.4. الشركاء

الأهمية	الشريك
شريك مالي أساسي يساهم في تمويل المشروع	البنك
توفير الدعم القانوني والإداري، التوجيه، والمرافقة للحصول على الاعتماد.	حاضنة المؤسسات الناشئة
إدماج المنتج في التصاميم والمشاريع المعمارية قيد الإنجاز.	مكاتب الدراسات المعمارية
تزويد المؤسسة بالمواد الأولية (ألمنيوم، خشب، هياكل معدنية) بأسعار مناسبة.	الموردون المحليون
تموين المكونات التقنية (مستشعرات، محركات، أنظمة تحكم) ذات جودة عالية.	الموردون الدوليون
المساهمة في الاختبارات التقنية والتجارب الأولية وتقديم الخبرة العلمية.	الجامعة/المخابر البحثية
المساعدة في تركيب النظام على المشاريع الكبيرة وضمان خدمات ما بعد البيع.	شركات التركيب والصيانة
تسهيل الإجراءات ومنح شهادات اعتماد بيئية وتقنية للمنتج.	الجهات الرسمية (ADEME، ANDER أو وزارة البيئة)

المحور الخامس: الخطة المالية

5. المحور الخامس: الخطة المالية

1.5. تكاليف المشروع واستهلاك الاستثمار

1.1.5 تكاليف استثمارية

الأصول	التكلفة
العقار	300.000 دج
الآلات والمعدات	400.000 دج
الأثاث	250.000 دج
رأس المال العامل	600.000 دج
المجموع	1.550.000 دج

2.1.5 التكاليف التشغيلية (سنويا)

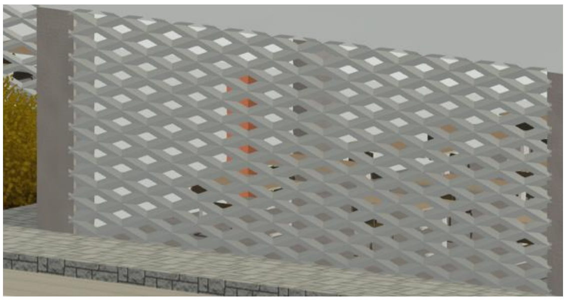
الأصول	التكلفة
الأجور	8.400.000
الهاتف والانترنت	240.000 دج
الكهرباء والماء	480.000 دج
المجموع	9.120.000دج

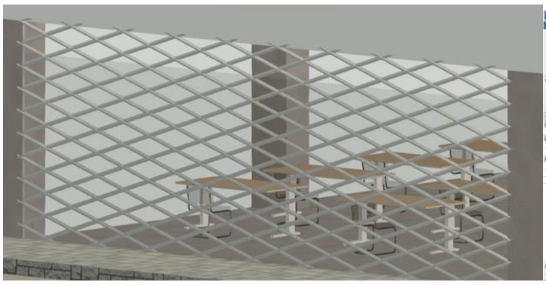
3.1.5 تقدير المبيعات

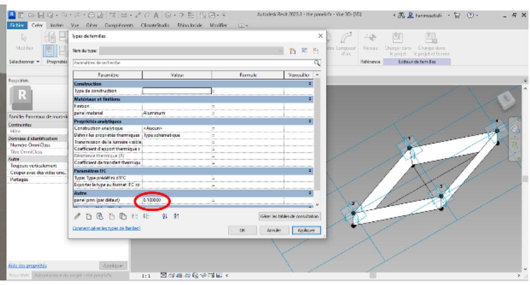
السنة / الشهر	جانفي	فيفري	مارس	أفريل	ماي	جوان	جويلية	أوت	سبتمبر	أكتوبر	نوفمبر	ديسمبر	المجموع السنوي
2026	1,275,000دج	1,360,000دج	1,445,000دج	1,530,000دج	1,615,000دج	1,700,000دج	1,785,000دج	1,870,000دج	1,955,000دج	2,040,000دج	2,125,000دج	2,210,000دج	21,910,000دج
2027	2,210,000دج	2,295,000دج	2,380,000دج	2,465,000دج	2,550,000دج	2,635,000دج	2,720,000دج	2,805,000دج	2,890,000دج	2,975,000دج	3,060,000دج	3,145,000دج	32,130,000دج
2028	3,145,000دج	3,230,000دج	3,315,000دج	3,400,000دج	3,485,000دج	3,570,000دج	3,655,000دج	3,740,000دج	3,825,000دج	3,910,000دج	3,995,000دج	4,080,000دج	43,350,000دج
2029	4,080,000دج	4,165,000دج	4,250,000دج	4,335,000دج	4,420,000دج	4,505,000دج	4,590,000دج	4,675,000دج	4,760,000دج	4,845,000دج	4,930,000دج	5,015,000دج	54,570,000دج
المجموع العام													151,960,000 دج

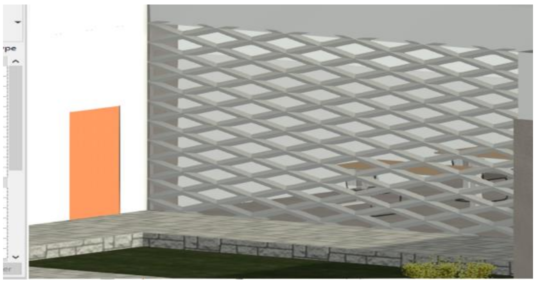
المحور السادس النموذج الاولي التجريبي:

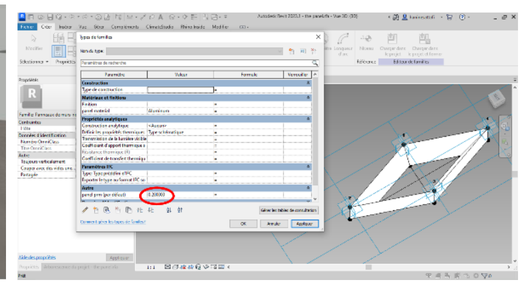
6. المحور السادس النموذج الاولي التجريبي :

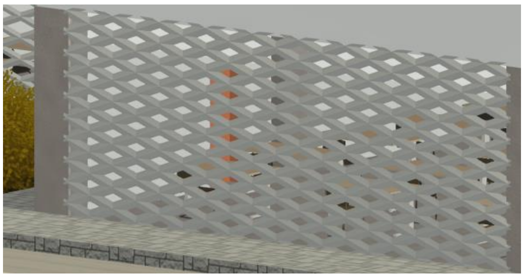


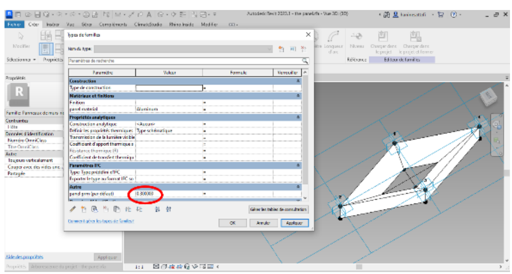


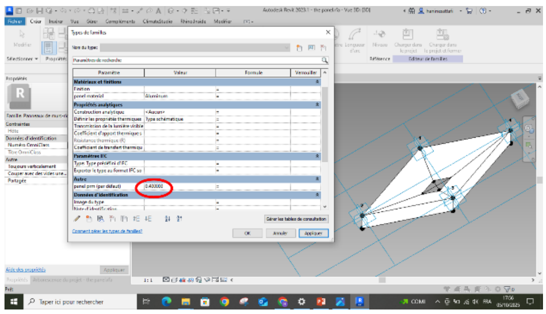




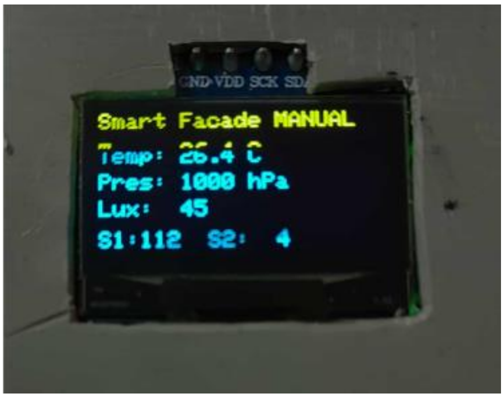









VDD SCK
Smart Facade AUTO
Temp: 26.4 C
Pres: 1000 hPa
Lux: 45
S1:112 S2: 4


VDD SCK
Smart Facade MANUAL
Temp: 26.4 C
Pres: 1000 hPa
Lux: 45
S1:112 S2: 4


VIN
GND
SCL
SDA
BMP280
BH1750

شرائح العملاء مكاتب التصميم المعماري والهندسي الباحثة عن حلول مبتكرة. شركات الاستشارات البيئية. المطورون العقاريون الساعون للحصول على شهادات استدامة. الجامعات أو مراكز البحث المهتمة بالتقنيات المناخية.	**العلاقات مع العملاء** تواصل شخصي مباشر في البداية لبناء الثقة. دعم تقني بعد البيع. فيديوهات ومواد توضيحية لتسهيل الفهم. تفاعل دوري عبر المنصات الرقمية.	**القيم المقترحة** واجهة متحركة تتجاوب مع الشمس في المناخ الحار والجاف. تحسين الراحة الحرارية والبصرية وتقليل استهلاك الطاقة. ترتيب مبتكر للمواد في طبقات تؤدي إلى أداء متكامل. تصميم بسيط لسهولة الاستعمال. قابلية الدمج في مختلف أنواع المشاريع المعمارية.	**الأنشطة الرئيسية** الأنشطة الرئيسية تصميم المنتج باستخدام برامج معمارية متخصصة. دراسة ميدانية وبيئية لموقع الاستخدام. تنفيذ نموذج أولي واختباره في ظروف حقيقية. مراقبة أداء الواجهة وتحليل النتائج. توثيق الأداء وإنشاء دلائل الاستخدام والتركيب.	**الشركات الرئيسية** الحاضنة الجامعية كمصدر للدعم والتوجيه. شركاء محتملون في تصنيع أو توفير المواد. دعم أساتذة أو خبراء تقنيين .
	القنوات المعارض والفعاليات الجامعية والمهنية. صفحات المنتج على مواقع التواصل (LinkedIn، Instagram...). تقديم مباشر للعملاء المحتملين (عروض تقديمية). خدمة ما بعد البيع (كتيبات، دعم فني، توجيه).		**الموارد الرئيسية** الموارد الرئيسية برامج التصميم (Rhino، Revit). أدوات ومعدات لاختبار النموذج الأولي. المواد المختارة لتكوين طبقات الواجهة. المعرفة الأكاديمية والإشراف العلمي. الاتصال بالحاضنة والدعم المؤسساتي.	

المصادر والإيرادات بيع منتج جاهز بأسعار متفاوتة حسب المواصفات. خدمة تركيب بمقابل إضافي. عروض ترويجية أولية بسعر منخفض. خدمات تصميم مخصصة حسب الطلب. استشارات مجانية أولية لبناء علاقة ثقة.	**هيكل التكاليف** مواد أولية لصنع النموذج التجريبي. أجهزة وأدوات اختبار ومراقبة. طباعة كتيبات وشروحات. لا توجد تكاليف تسويق أو تصميم حالياً (بفضل المهارات الذاتية). التنقل والطباعة تتم بتمويل ذاتي ولا تُحتسب ضمن تكاليف المشروع.