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Theme:

Façade of the future: development of an advanced shading device to maximize daylighting in the building

The project:

Art Museum

Examiner's committee

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Academic year: 2024 - 2025

Summary:

In hot and arid climates, balancing the benefits of natural daylight with the challenges of thermal discomfort, glare, and material degradation is a critical concern in museum architecture. This thesis explores the development of an advanced, responsive façade shading system tailored to optimize daylight performance in an art museum located in Biskra, Algeria. The research aims to enhance energy efficiency, visual comfort, and the conservation of sensitive artworks through climate-adaptive design.

The study adopts a mixed-methods approach, integrating literature review, precedent analysis, site-specific environmental assessment, and digital simulation. A comprehensive theoretical framework on kinetic architecture and shading technologies is established, emphasizing dynamic systems and smart materials. Case studies of internationally acclaimed museums and local site analysis inform the design strategy. A custom shading system is then developed and evaluated through parametric daylight and energy performance simulations using tools such as Rhinoceros, Grasshopper, and Ladybug.

Results demonstrate that the proposed kinetic façade system significantly improves daylight autonomy and glare control while reducing reliance on artificial lighting and cooling loads. The integration of smart control mechanisms and responsive materials offers a sustainable and context-sensitive solution for museums in extreme climates.

This research contributes to the evolving discourse on adaptive architecture, proposing a replicable design methodology that aligns aesthetic, environmental, and curatorial imperatives. The findings underscore the importance of dynamic façade technologies in shaping future-ready cultural institutions that are both energy-efficient and human-centered.

Keywords: Dynamic shading systems; Kinetic architecture; Daylighting optimization; Visual comfort; Energy efficiency; Museum lighting; Climate-responsive design; Hot and arid climate.

الملخص :

في المناخات الحارة والجافة، يُعد تحقيق التوازن بين فوائد الإضاءة الطبيعية والتحديات المرتبطة بعدم الراحة الحرارية، والوهج، وتدهور المواد، مسألةً بالغة الأهمية في تصميم المتاحف. تستكشف هذه الأطروحة تطوير نظام تظليل متقدم ومتجاوب لواجهة مبنى، مصمم خصيصًا لتحسين أداء الإضاءة الطبيعية في متحف فني يقع في مدينة بسكرة، الجزائر. وتهدف الدراسة إلى تعزيز كفاءة الطاقة، وتحقيق الراحة البصرية، والحفاظ على الأعمال الفنية الحساسة من خلال تصميم يتكيف مع المناخ المحلي.

تعتمد هذه الدراسة على منهج متعدد الأساليب يجمع بين مراجعة الأدبيات، وتحليل السوابق، وتقييم الخصائص البيئية للموقع، بالإضافة إلى المحاكاة الرقمية. وقد تم تطوير إطار نظري شامل حول العمارة الحركية وتقنيات التظليل، مع التركيز على الأنظمة الديناميكية والمواد الذكية. كما استُخدمت دراسات لحالات متاحف مشهورة عالميًا وتحليل ميداني للموقع المحلي لتوجيه الاستراتيجية التصميمية. بعد ذلك، تم تطوير نظام تظليل مخصص وتقييمه من خلال محاكاة معيارية لأداء الإضاءة والطاقة باستخدام أدوات مثلRhino ، وGrasshopper، و.Ladybug

تُظهر النتائج أن نظام الواجهة الحركي المقترح يُحسّن بشكل كبير من الاستقلالية في استخدام الإضاءة الطبيعية والتحكم في الوهج، مع تقليل الاعتماد على الإضاءة الاصطناعية وأحمال التبريد. إن دمج آليات تحكم ذكية ومواد متجاوبة يوفر حلاً مستدامًا وحساسًا للسياق المناخي الخاص بالمتاحف في البيئات القاسية.

تُساهم هذه الدراسة في الخطاب المتطور حول العمارة التكيفية، من خلال اقتراح منهجية تصميم قابلة للتكرار تُحقق توازنًا بين الجوانب الجمالية والبيئية والمتعلقة بالحفاظ على المقتنيات. وتؤكد النتائج على أهمية تقنيات الواجهات الديناميكية في تشكيل مؤسسات ثقافية جاهزة للمستقبل، تتسم بالكفاءة الطاقوية ومحورية الإنسان في التصميم.

الكلمات المفتاحية :أنظمة التظليل الديناميكية؛ العمارة الحركية؛ تحسين الإضاءة الطبيعية؛ الراحة البصرية؛ كفاءة الطاقة؛ إضاءة المتاحف؛ التصميم المتجاوب مع المناخ؛ المناخ الحار والجاف

Gratitude and appreciation

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A special thanks goes to my fellow classmates and colleagues those who shared with me the deadlines, the challenges, the long nights, the stress, and the laughter. Your presence made this academic journey lighter, more human, and rich with unforgettable moments.

To each person who, in one way or another, contributed to this journey your presence, support, and belief will always remain a part of what made this achievement possible. Thank you.

Saadaoui Noura

Dedication

All praise is due to Allah the One who granted me strength when I felt weak, clarity when I was lost, and light when the path seemed dim. Without His guidance and mercy, I would not have reached this point.

To Nawras...

who learned to fly alone in a sky full of obstacles...

who soared when the light dimmed,

who held fast when the waves raged,

who chose to remain a flyer, not because she wasn't afraid of falling, but because she always believed that a sky was waiting for her.

Thank you for my silence when screaming was easier, and for continuing when stopping was more merciful.

Thank you for every morning I started despite staying up late, and for every decision I made to strive instead of rest.

I could have given up, but I chose to BE.

To my family my constant support, my safe haven, and my quiet strength.

Thank you for every word of encouragement, every silent prayer, and every moment of understanding.

Your love was the shelter I leaned on, and your presence the fuel that kept me moving forward.

This accomplishment is not mine alone it carries your fingerprints in every line.

To my dearest friends" Hanine, Abir, Roumaissa, and Aridj,"

You came into my life like a quiet miracle, at a time when I had almost stopped expecting warmth.

You were the beautiful replacement for the heaviness I carried alone for so long.

In your presence, I found safety, laughter, and the kind of love that asks for nothing yet gives everything.

To all the beautiful souls "**Rima, Malak, Mariem, Ibtissam,Fatima, khoulod and Inas**"

Thank you for your presence, your encouragement, your quiet support.

Whether through a kind word, a sincere smile, or a gentle reminder that I was not alone.

Your kindness, in all its forms, made the path feel lighter, and for that, I will always be grateful.

This chapter carries traces of you all.

Saadaoui Noura

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I General Introduction:

Natural lighting is a fundamental element in modern building design due to its critical role in enhancing indoor environmental quality, promoting user well-being, and reducing energy consumption. By decreasing reliance on artificial lighting, daylighting contributes to lower operational costs and minimizes environmental impact, aligning with sustainable design objectives.

In addition to its energy-saving potential, daylighting exerts profound visual and non-visual effects on building occupants. Visually, it determines the luminous quality of indoor spaces through variable intensity, color temperature, and sky conditions. These qualities influence spatial perception and are typically assessed through parameters such as vertical luminance, illuminance distribution, and glare potential.(Costa et al. 2024) Non-visual effects, meanwhile, extend beyond sight and involve physiological responses to light, especially its impact on the circadian system. Exposure to natural daylight-particularly in the blue spectrum during morning hours-helps synchronize the body's internal clock with the 24-hour day, regulating sleep-wake cycles, hormone secretion, alertness, and overall cognitive performance. Insufficient daylight exposure has been associated with sleep disturbances, mood disorders, and diminished productivity. As such, the integration of daylight into building design is not only a matter of comfort and aesthetics but also a determinant of occupant health and performance.(S. N. Hosseini et al. 2022)

However, excessive daylight can pose challenges related to visual discomfort, such as glare and overheating, particularly in spaces requiring controlled lighting environments. These issues are intensified by the widespread use of large glass façades in contemporary architecture, especially in regions with high solar radiation, such as the city of Biskra. This underscores the need for optimizing the building envelope to balance daylight benefits with its potential drawbacks.(A. A. Y. Freewan 2014) To address this, sustainable design strategies-such as fixed and dynamic shading systems-are employed to regulate daylight penetration, improve spatial lighting quality, and reduce glare. These systems are designed with consideration for solar angles, thermal performance, and architectural aesthetics. Technological advancements have also enabled the development of adaptive façades that respond to environmental conditions in real time, enhancing energy efficiency and visual comfort.(Leu and Boonyaputthipong 2023)

In the specific context of an art museum, the façade design assumes a particularly critical role. Artworks are highly sensitive to light, especially ultraviolet radiation and excessive brightness, which can cause fading, discoloration, and long-term material degradation.(Harrison 1961) Therefore, an advanced shading system must not only optimize daylight for energy and visual performance but also protect exhibits by ensuring stable and appropriate lighting conditions. Furthermore, the quality of natural light significantly affects the experience of museum visitors and staff alike. When carefully filtered and controlled, daylight can enrich the aesthetic and emotional engagement with the artwork, support curatorial intentions, and enhance the cultural value of the space as a whole.

II Problematic:

In hot and arid climates such as Biskra, the extensive use of glass façades in modern architecture presents a significant challenge in managing daylight. While natural lighting enhances energy efficiency and improves the occupant experience, uncontrolled daylight can lead to visual discomfort, glare, and potential damage to sensitive art collections in museums. Existing static shading systems often lack adaptability, resulting in suboptimal lighting conditions. This highlights a critical need for an intelligent, responsive shading solution that maximizes the benefits of daylight, ensures visual comfort, and protects artwork quality in museum spaces.

III Research Questions:

1. How can an advanced shading system be designed to optimize daylight performance and ensure visual comfort in art museums located in hot and arid climates?
2. What role do smart shading technologies play in balancing natural light with the conservation requirements of art museum exhibits?
3. What design parameters and environmental factors must be considered when developing a responsive façade system for museums?
4. How can a dynamic shading system contribute to the energy performance of buildings in hot and arid climates?

IV Hypotheses:

To address the research objectives, the following hypotheses have been proposed:

1. An advanced shading system tailored to hot and arid climates can significantly improve daylight distribution and visual comfort in art museums, compared to conventional façade solutions.
2. Smart shading technologies, such as sensor-based and adaptive mechanisms, can effectively regulate natural light levels to meet both visual comfort needs and conservation standards required for art exhibits.
3. The effectiveness of responsive façade systems depends on carefully considering design parameters such as solar orientation, material reflectance, glazing properties, and local climatic conditions.
4. Dynamic shading systems provide superior control over glare and indoor lighting quality compared to static solutions, leading to a more stable and visually comfortable environment for museum occupants.

V Objectives of the study

The main goal of this thesis is to develop an advanced, responsive shading system that optimizes daylight performance while achieving high energy efficiency and comprehensive visual comfort in an art museum located in a hot and arid climate. **A key focus of the research is to control the amount, quality, and timing of natural light entering the building, ensuring that interior lighting conditions remain both functional and protective - particularly for sensitive artworks**. By integrating advanced technologies and sustainable design principles, this study aims to provide an adaptive and visually harmonious solution that addresses climatic and environmental challenges, while laying the groundwork for future sustainable buildings - especially those designed for sensitive and experience-driven programs such as art museums. The following points outlines the objectives in greater detail:

1. Design a responsive and visually integrated shading device that optimizes daylight utilization, minimizes visual discomfort, and protects sensitive artworks from harmful ultraviolet (UV) radiation. The system should contribute to reducing dependence on artificial lighting and lowering cooling demands, thereby enhancing the museum's energy efficiency.
2. Assess the shading system's effectiveness through advanced daylight and energy performance simulations.

VI Methodology

This study employs a combination of qualitative and quantitative methods to achieve a comprehensive understanding of the research objectives. Various techniques, including literature review, simulation modeling, and the project analysis and design, are used to investigate the impact of daylighting and dynamic shading systems on building performance in hot and arid climates. Each of these methods is explained in detail in the following sections:

1- **literature review:** will involve a comprehensive study of current research and practical applications related to shading devices, daylighting strategies, and sustainable façade technologies, with a specific focus on their implementation in art museums. This review will explore the use of advanced materials for responsive or adaptive shading systems, such as photochromic, electrochromic, and thermochromic materials, which can adjust their properties in response to environmental conditions. It will also examine both fixed and dynamic shading systems, analyzing their effectiveness in improving daylighting performance, reducing glare, and protecting sensitive artworks from harmful light exposure. Additionally, the integration of shading devices into sustainable building design will be assessed, with emphasis on how these systems contribute to energy efficiency, thermal comfort, and overall user experience in museum environments.

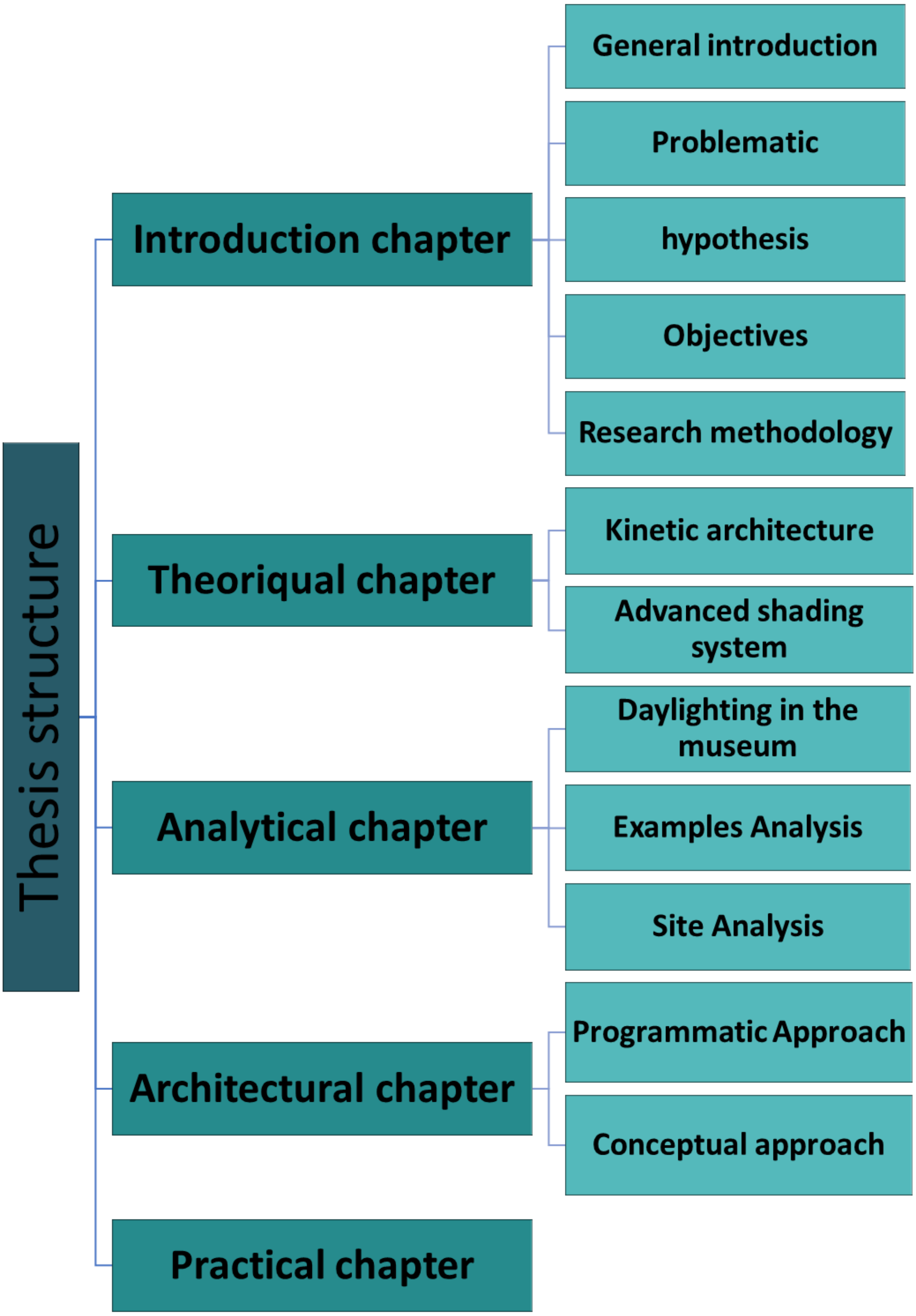
2- **The project analysis:** will begin with a series of case studies focused on art museums that successfully integrate innovative façade systems and advanced daylighting strategies. Examples will be examined to extract best practices in balancing natural lighting with the preservation of artwork and visitor comfort. Following the case studies, a detailed site assessment of the proposed project location will be conducted. This includes an analysis of climatic conditions, solar orientation, sun path movements, and seasonal variations in daylight availability, all of which are essential for optimizing the performance of a responsive shading system. Lastly, the programmatic and functional requirements of the art museum will be thoroughly studied, focusing on spatial organization, zoning of exhibition areas, circulation paths, and specific lighting needs of gallery spaces to ensure both visual comfort and conservation of art pieces.

3- **The project design:** involves the development of a comprehensive architectural proposal for the art museum, with careful attention to spatial hierarchy, visitor circulation, exhibition lighting requirements, and the overall user experience. The design will aim to create an environment that not only supports the functional and curatorial needs of the museum but also enhances its aesthetic and environmental performance. Parallel to the building design, a concept for an advanced shading device will be developed, drawing directly from the findings of the literature review and site analysis. This shading system will be designed to dynamically respond to changing light conditions throughout the day and across seasons, enhancing daylighting performance while minimizing glare and UV exposure to artworks. Importantly, the shading device will be integrated seamlessly into the architectural language of the museum, contributing to its visual identity and aligning with its structural and material expression.

4- **The experimental phase:** focuses on digitally modeling and testing the proposed shading device. A detailed 3D model will be created using BIM tools, accurately representing the device’s geometry, materials, and operability within the museum façade. Site-specific data such as orientation and climate will be integrated to ensure realistic simulation results. Various daylighting and energy simulation tools will be used to evaluate the device's impact on daylight autonomy, useful daylight illuminance, glare control, and visual comfort across key museum spaces.

VII Thesis Structure:

The different components of the thesis are presented in the following figure:



Chapter I:

Literature review on Advanced shading devices and kinetic architecture

Introduction:

In contemporary architecture, the use of transparent materials—particularly large glass façades—has grown considerably due to their aesthetic appeal and ability to create a sense of openness. However, in regions with high solar radiation, these materials often lead to excessive solar heat gain, resulting in thermal discomfort, increased cooling demands, and glare. To address these challenges, adaptive shading devices have emerged as essential solutions. These systems respond dynamically to environmental changes, enhancing indoor thermal and visual comfort while significantly reducing energy consumption.

The objective of this chapter is to establish a comprehensive theoretical framework for climate-responsive design, with a focus on advanced shading systems and kinetic architecture. It examines the functional, environmental, and architectural roles of these systems and analyzes key typologies, design parameters, and technological innovations. By doing so, the chapter provides a conceptual foundation for integrating adaptive façade solutions that improve daylighting performance, optimize energy efficiency, and respond to the unique demands of hot and arid climates.

I Kinetic Architecture

I.1 Definitions

The term "kinetic" is an adjective that refers to the motion of material bodies. The term "architecture" is a noun that refers to the art or science of building. When combined, "kinetic architecture" refers to the techniques of structure design to enable building elements to change their shape(Fouad 2012) including adaptable, foldable, deployable, empowered, evolutionary, flexible, intelligent, kinetic, mobile, performance-based, reconfigurable, responsive, rotatable, intelligent, transformable and transportable(İlerisoy and Başeğmez 2018). Without compromising the general structural stability. This ability can be applied to enhance the aesthetics of a building, interact with environmental factors to meet the needs of its occupants, and adapt to external conditions. (Elghazi, Wagdy, and Abdalwahab 2015) Chuck Hoberman describes it as "the possibility of movement" to create "transforming environments, responsive building elements, or interactive public spaces" (Sanchez-del-Valle 2005).

I.2 Kinetic architecture typologies:

Three types of kinetic architecture applications can be distinguished: kinetic facades, kinetic interiors, and kinetic structure systems.

I.2.1 Kinetic structure:

Buildings or building components with variable geometry, location, and/or mobility are known as kinetic structure systems. These structures might be able to expand, slide, fold, or change in shape and size. These motions can be produced mechanically, chemically, magnetically, or naturally. The Sliding House project by London-based dRMM is a great illustration of kinetic structure systems; it features movable walls and a roof that can be raised or lowered to reveal and conceal different areas of the house(Elmokadem et al. 2018). There are three additional categories into which Kinetic Structure Systems fall.

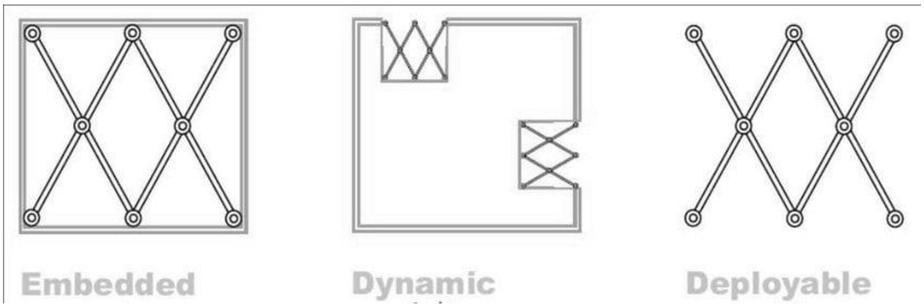


Figure 1:kinetic structure systems
source: Elmokadem et al. 2018

I.2.1.a Embedded Kinetic Structures:

These are systems that are fixed in place and part of a larger architectural whole. These kinetic structures' main job is to regulate the bigger architectural systems in reaction to shifting conditions.(Fox and Yeh 2000)

I.2.1.b Deployable Kinetic Structures:

These are easily transportable and usually exist in temporary locations. They consist of quickly deployable emergency shelters and movable theaters. Although they are a component of a larger architectural whole, dynamic kinetic structures have the ability to act independently in terms of the larger system's control. These comprise both large architectural features like windows, doors, and movable partitions as well as smaller ones. The automation and intelligence of these kinetic systems are growing.(Fox and Yeh 2000). However, different kinetic structures can be created by arranging kinetic devices in patterns in two or three diminutions. Furthermore, while there are numerous potential pattern designs, the following are the most popular ones(Elmokadem et al. 2018).

I.2.1.c Centric configuration:

This style relies on a central point to serve as the room's focal point. It features two typological patterns:The kinetic devices in this structure are generally designed to move back and forth from the center toward the periphery, with a central pivot serving as the main supporting element. A prime example of this mechanism is an umbrella-like structure. In a peripheral configuration, the supporting components are arranged along the outer edge of the form, similar to the roof design of the QiZhong Tennis Center in China.(Stevenson 2011)

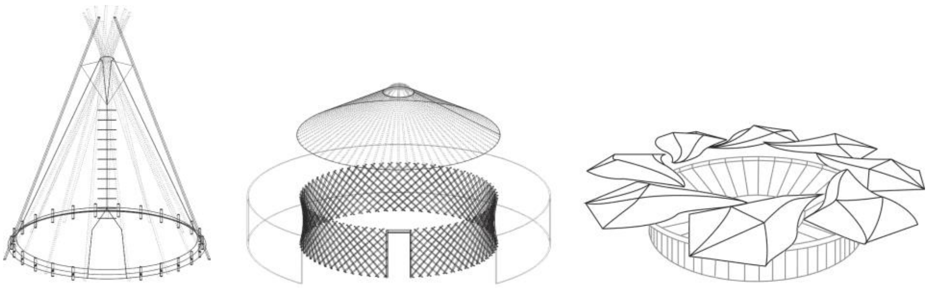


Figure 2:Kinetic architectural structures with centric configuration
(source):(Stevenson 2011)

I.2.1.d Linear configuration:

This kind relies on a straight or curved axis and is made up of a number of modules, or kinetic devices, connected by their vertices or edges to transfer movement from one to the next.(Stevenson 2011).

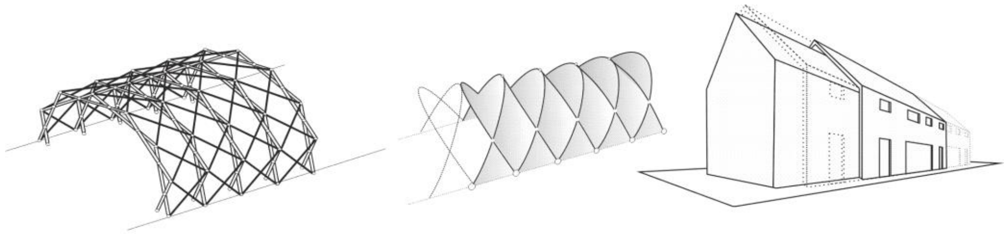


Figure 3 : Kinetic architectural structures with centric configuration source:(Stevenson 2011)

I.2.2 Interior Kinetics:

shop fronts and kinetic walls are just two examples of the various scales at which the kinetic design concept is being applied. This application's primary categories are:

Transformable Spaces: Throughout history, architects and interior designers have worked to create more dynamic and adaptable living and working environments that can accommodate the evolving needs of their occupants. The concept is used on many levels, such as in multipurpose furniture and adaptable spaces(Murray, Whibley, and Ramírez-Lovering 2008)

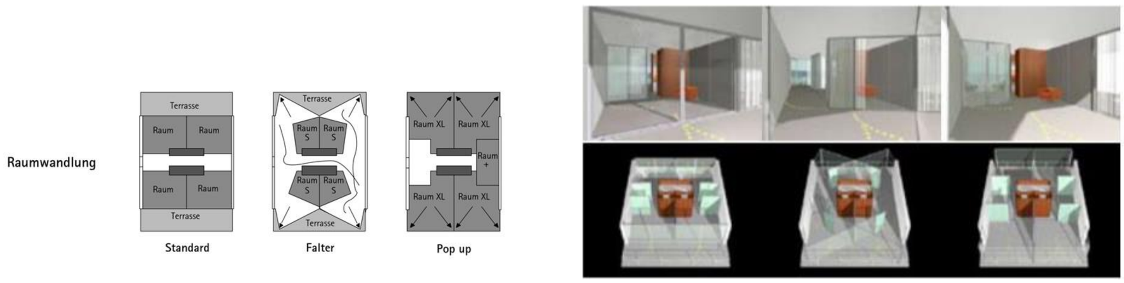


Figure 4:Different options adapting housing by kalhoefer korschildgen

Walls with Kinetics: To give the appearance that they react to our movements; kinetic walls are employed. A variety of interconnected components come together to create this impression. Three distinct strategies are used to create the response(Elmokadem et al. 2018):

1) A camera is used to centrally record the movement. then performing a central computation of a corresponding reaction using a subsequent inductive computer analysis of the captured images.

2) The movement is recorded using decentralized methods that rely on sensors, followed by a centralized computation of a corresponding reaction and a subsequent deductive analysis.

3) A completely decentralized method is used to capture the movement. Numerous tiny elements then absorb the direct, local reaction.

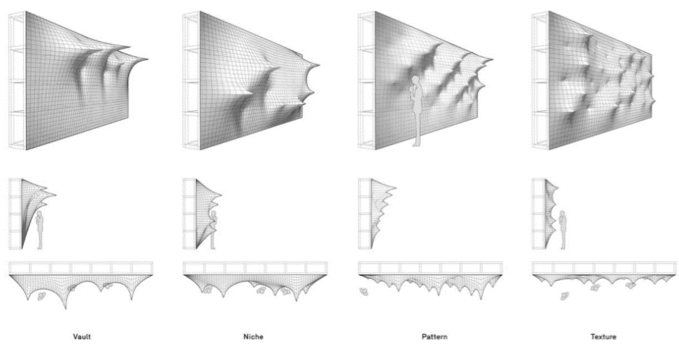


Figure 5:Kinetic Wall (source: https://www.world-architects.com/en/architecture-news/products/kinetic-wall)

I.2.3 Dynamic Facades:

Using geometric transformation to produce motion or movement in space is the idea behind kinetic facades. Without compromising the building's structural integrity, this motion or movement alters the building facades' material characteristics or physical structure. Although there are many different ways to categorize kinetic facades, the façade transformation is the most widely used. Four geometric transitions can be used to move kinetic facades in space:

1) Translation: A vector direction is used for motion.

2) Rotation: The item rotates on all axes.

3) Scaling: This refers to a change in size.

4) Motion via material deformation is contingent upon modifiable material characteristics, such as elasticity or mass. (Schumacher, Schaeffer, and Vogt 2012)

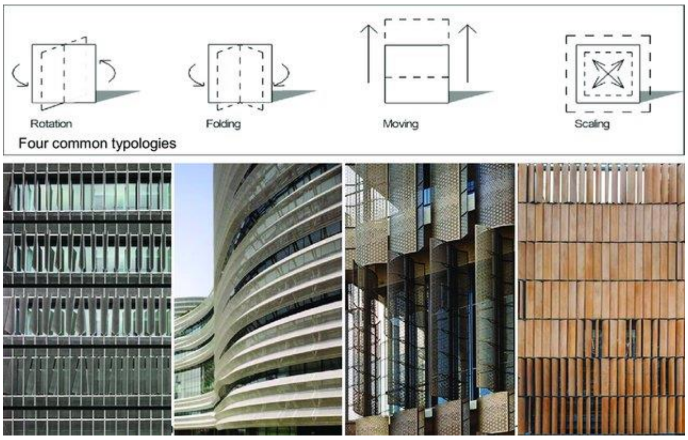


Figure 6:Typologies and examples of dynamic facades. source:(Shi, Abel, and Wang 2020)

I.3 Control systems:

Michael Fox classified control systems for kinetics into six types depending on the level of complexity:

1) Internal controls: They do not have any direct control or mechanism like mechanical hinges.

2) Direct control: They are moved directly by an energy source outside the devices.

3) Indirect control: It depends on a sensor feedback system.

4) Responsive indirect control: it depends on multiple feedback sensors

5) Ubiquitous responsive indirect control: It can be predicted using a network of controls with predictive algorithms.

6) Heuristic, responsive indirect control: It depends on algorithmically mediated networks that have a learning capacity .(Fouad 2012)

II Shading devices

II.1 Definition of shading devices:

Shading devices are architectural elements or systems designed to mitigate solar heat gain and glare by obstructing direct sunlight from entering building windows (Habitat 2018). These devices can be classified as fixed (e.g., overhangs, horizontal and vertical louvers) or mobile (e.g., Venetian blinds, roller shades), allowing varying degrees of control over solar radiation(Legg 2017). Their primary function is to reduce the amount of solar radiation penetrating living spaces during peak sunlight hours in summer while facilitating essential solar gain during winter months, thus enhancing thermal comfort and promoting energy efficiency(Hlaing and Kojima 2022).

The effectiveness of shading devices is influenced by factors such as geographic location, building orientation, window dimensions, and the specific design characteristics of the device (including shape, type, depth, and height)(Manzan 2014). Properly designed external shading can reduce solar heat gain by up to 80% compared to internal shading(Al-Yasiri and Szabó 2021), significantly impacting energy consumption and indoor climate. Additionally, shading devices contribute to the visual environment. They can serve as protective elements against atmospheric conditions, though the poor design may inadvertently increase reliance on artificial lighting and limit beneficial winter sunlight.

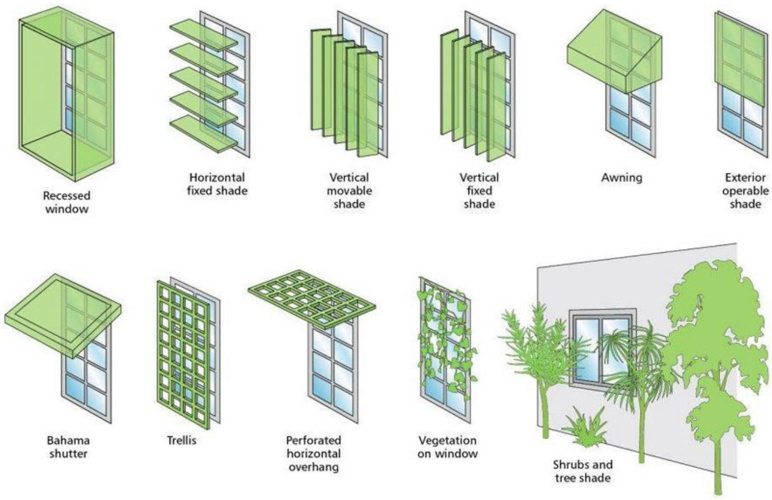


Figure 7: examples of shading devices
source :(Al-Yasiri and Szabó 2021)

II.2 Benefits and Disadvantages of Sun Shading Devices:

II.2.1 Benefits

Thermal Comfort:

- Reduces solar heat gain during summer, Promotes it during winter.
- Maintains a generally comfortable internal temperature.(A. A. Freewan 2014)

Energy Efficiency:

- Reduces HVAC (heating, ventilation, and air conditioning) loads, lowering energy costs.
- Lowers peak electricity demand, which helps to reduce utility costs.

Visual Comfort:

- Reduces glare, minimizing discomfort and eye strain.(Ye et al. 2016)
- Enhances natural daylight availability, improving indoor lighting quality.(Manzan 2014)

Aesthetic and Privacy:

- Internal shading devices (like curtains) can beautify interior spaces and create a sense of privacy.(Ye et al. 2016)

- Trees used as shading devices can enhance landscaping and provide oxygen.

II.2.2 Disadvantages:

- Difficulty in handling internal shading devices: Curtains and blinds can be inconvenient to operate and maintain.

- Glare issues with low-angle winter sunlight: Shading devices like light shelves can block beneficial winter sunlight, leading to glare.

- Architectural incompatibility: External shading may clash with the original style of highly stylized buildings (e.g., Neoclassical or glass cube).

- Obstructed views: Shading devices inevitably block some portion of the view, especially the part of the sky where the sun travels.

- Azimuth specificity: Some shading methods are highly dependent on the building's orientation. For example, fixed horizontal shading may not be effective on non-south-facing walls.

II.3 Shading device types:

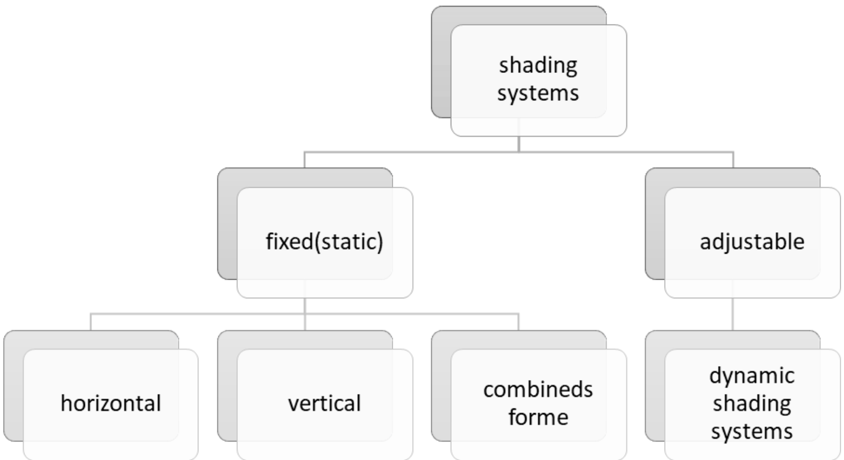


Figure 8:shading device types.
Source: Author

II.3.1 Static shading devices:

II.3.1.a definition:

Static shading devices include traditional shading methods, such as shutters, curtains, and other fixed elements, that provide consistent shading without the capacity to adjust to varying weather conditions or user preferences(Hraska 2018). These devices are integral to passive design strategies, focusing on energy efficiency and thermal comfort without relying on active mechanical systems.(Hans 2006)

II.3.1.b Typologies:

The formal typologies of static shading devices include:

- **Horizontal Projections:** designed to block direct sunlight during peak summer hours while allowing lower-angle winter sunlight to penetrate.(Dev, Saifudeen, and Sathish 2021)

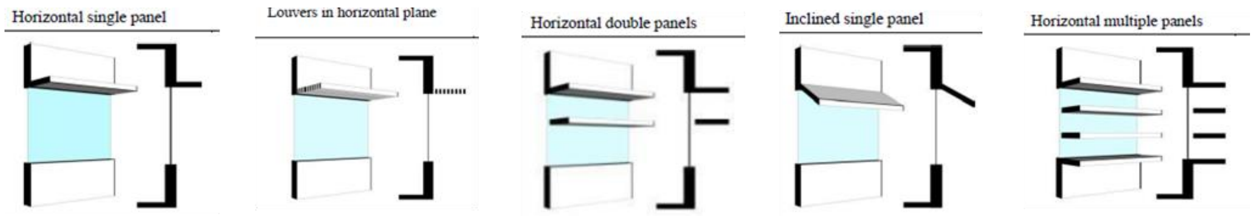


Figure 9:horizontal shading devices (a). source:(Zhang et al. 2018)

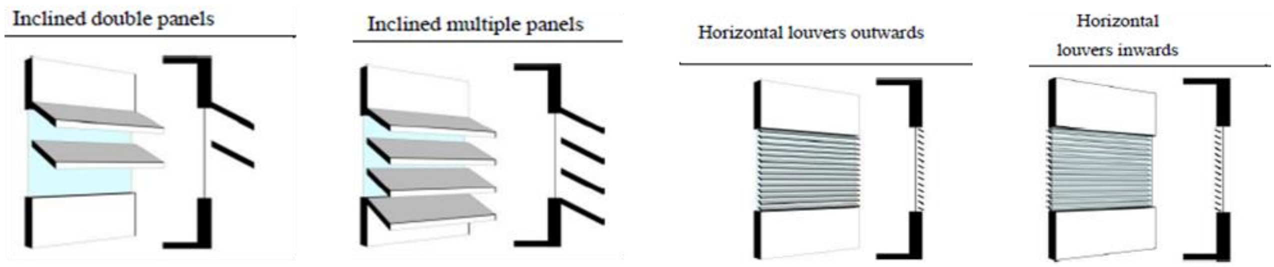


Figure 10:horizontal shading devices (b) .source:(Zhang et al. 2018)

- **Vertical Projections:** mitigate direct solar radiation from the east and west while keeping views and daylighting.(Hans 2006)

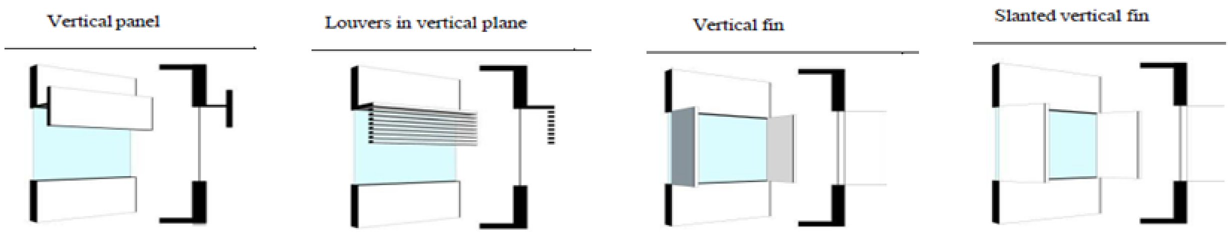


Figure 11:vertical shading devices. source:(Zhang et al. 2018)

- **Combined Forms:** Hybrid designs that contain both horizontal and vertical elements to enhance shading performance and aesthetic appeal.(Hans 2006)

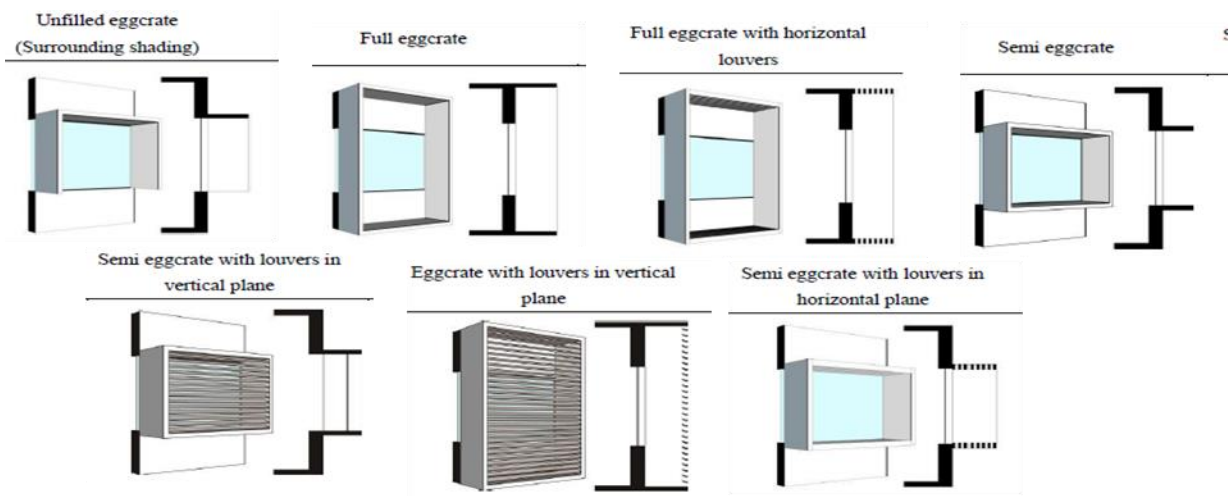


Figure 12:combined forms of shading devices.

Source:(Zhang et al. 2018)

II.3.2 Dynamic shading system:

II.3.2.a Definition:

Dynamic shading devices are advanced systems composed of movable elements that operate within an algorithmic framework to regulate the penetration of light and heat based on real-time external and internal environmental parameters, such as solar angles and solar insolation. The term "dynamic" signifies the continuous and adaptive nature of these systems, which respond to variations in environmental conditions and user needs.(Al-Masrani and Al-Obaidi 2019)

These devices typically consist of multiple layers, beginning with a transformative skin layer that interacts with the building's facade and is equipped with components such as sensors, controllers, and mechanical actuators(Minelli et al. 2023). This integration enables the automatic adjustment of shading elements, such as shades and blinds, to optimize indoor comfort while enhancing energy efficiency. By leveraging real-time data on factors like sunlight, wind, and temperature, dynamic shading systems allow for tailored responses that balance the requirements of building occupants with overall energy performance, thus improving the functionality of architectural spaces.(Kahramanoğlu and Çakıcı Alp 2023)

II.3.2.b Literature review:

The purpose of this literature review is to provide a comprehensive overview of the most relevant studies conducted between 2018 and 2024 concerning dynamic and kinetic shading systems in architectural applications. The review aims to identify the main research trends, objectives, and simulation methodologies used to enhance daylight performance, visual comfort, and energy efficiency in buildings. Table 1 summarizes the selected studies by highlighting their key characteristics, including the year of publication, study objectives, shading device type, climatic context, simulation tools, time periods analyzed, project locations, and study limitations. This synthesis not only clarifies the technological and methodological evolution in this field but also helps to position the current research within the broader context of smart and adaptive façade design.

In addition to these studies in table 01, a comparative analysis was conducted to evaluate the performance and characteristics of the different dynamic shading systems reviewed (annex 02). The comparison focused on several key aspects, including energy consumption, daylighting performance, movement mechanisms, and overall efficiency. By contrasting these approaches, the analysis highlights how variations in material selection, motion type, and control strategy influence environmental responsiveness and architectural integration. This comparative overview not only clarifies the evolution of kinetic façade design but also establishes the foundation for developing the proposed smart shading system, which will be presented in detail in the practical chapter.

Table 1:Studies on dynamic systems from 2018 to2024

Study	Year	Study objective	Shading device/system	Climate	Simulation tool	Simulation time	Project	Limits
1- Performative design environment for kinetic photovoltaic architecture(Jayathissa et al. 2018)	2018	Presents a practical performative design environment for the design and fabrication of kinetic architectural elements	Adaptive Solaire façade (kinetic PV shading system)	Temperate oceanic climate (Dubendorf, Switzerland)	Rhinoceros 3D Grasshopper Python Ladybug Karamba3d	every hour of the year	Hilo building (Dubendorf, Switzerland)	The computational time. (The full annual energetic analysis, for example, may take 6 h to solve)
2- Interactive kinetic façade: Improving visual comfort based on dynamic daylight and occupant's positions by 2D and 3D shape changes.(S. M. Hosseini, Mohammadi, and Guerra-Santin 2019)	2019	understand the hierarchical filtering steps of transferring daylight between sun and occupants, which identify three different façade functions: conservative, regulator, and interactive	kinetic interactive façade	Hot and arid (Yazd, Iran)	Rhinoceros Grasshopper Diva	9:00, 12:00, 15:00 of 21st of Mar, Jun, and Dec	Office building (Yazd, Iran)	many parameters have been applied in the simulation both 2D & 3D SCFs provide visual comfort based on interacting with an occupant in different positions, individually
3- A Unified Framework for Optimizing the Performance of a Kinetic Façade.(Im et al., n.d.)	2019	Create a thorough process for optimizing the rotation angle of kinetic façade systems (OKFS) to balance solar irradiance levels and	Oculi Kinetic Façade System	humid subtropical climate (Charlotte, NC)	Rhino Grasshopper Diva 4.0	March 21st, June 21st, September 21st December 21st.	Office space (theory)	/

		improve inside daylight availability.						
4- Developing a kinetic façade towards a solar control façade design prototype.(Nakapan and Pattanasirimongkol 2019)	2019	1. To develop a kinetic façade prototype as a proof of concept to demonstrate an aesthetic point of view, 2. To do a sun shading analysis of the façade through computer simulation	Kinetic façade with aluminum fins	tropical savanna climate	Rhino-Grasshopper Ladybug	21 December 21 March, 21 September 21 June	/	/
5- SMP Prototype Design and Fabrication for Thermo-responsive Façade Elements.(Yoon 2019)	2019	to design a prototype of Shape Memory Polymer (SMP) using 3D parametric design software and to create scaled-down models to test the feasibility of 3D printing different types of kinetic SMP cells. The research also aims to examine the shape-changing behaviors of these cells when subjected to heat.	Kinetic SMP applications in circular cell-type shading devices with five different morphologies	humid continental climate	Rhinoceros Grasshopper Honeybee and Ladybug Kangaroo	Between May 1st and September 30th	/	The use of SMP, which shows instabilities depending on the manufacturing and operating environments.

6- Integrating interactive kinetic façade design with colored glass to improve daylight performance based on occupants' position.(S. M. Hosseini et al. 2020)	2020	investigate the integration of colored glass from Orosi with an interactive kinetic façade triggered by sun timing and occupant positions	Integration of interactive kinetic façade with colored glass	Hot and arid (Yazd, Iran)	Rhino Grasshopper Diva	December 21st, March 21st and June 21st 9:00 .12:00 .15:00	Office building	/
7- Conceptual Designs of Kinetic Facade Systems.(Karaseva and Cherchaga 2021)	2021	develop a kinetic facade design that can adjust to the sun's movement, to control natural lighting, maintain comfortable indoor temperatures during hot seasons, and save energy.	Horizontal and vertical kinetic fins	humid continental climate with hot summers (Rostov-on-Don.Russia)	/	August 14: 12.2 .3pm (Horizontal fin positions) August 14: 2. 3. 4 pm (Vertical fin positions)	Office building	/
8- Biomimetic Kinetic Shading Façade Inspired by Tree Morphology for Improving Occupant's Daylight Performance.(S. M. Hosseini et al. 2021)	2021	develop a biomimetic kinetic shading façade for improving occupants' daylight performance inspired by plant movements.	Multilayered and complex kinetic facade form inspired by dense mass and curvature intersected vectors	Hot desert climate (Yazd, Iran)	Rhino 6, Grasshopper, and Diva.	December 21st, March 21st and June 21st 9:00 12:00 15:00	Office building	/
9- Indoor Daylight Performances of Optimized Transmittances with Electrochromic-Applied Kinetic	2022	propose and analyze a louver-type electrochromic façade that can create a uniform indoor illuminance.	electrochromic horizontal kinetic louvers	temperate climate (Gwangju. South Korea)	Rhino Grasshopper	March 20 9:00 a.m. and 3:00 p.m.	Office space	. Because this study was analyzed through simulation different results

Louvers.(J.-H. Kim and Han 2022)								might be obtained when applied to real buildings . this study only considered the equinoxes 9:00 a.m. and 3:00 p.m. following the method of LEED v4.1 daylight option 2
10- Investigation into the daylight performance of expanded-metal shading through parametric design and multi-objective optimization in Japan.(Khidmat et al. 2022)	2022	develop a comprehensive parametric framework for modeling expanded-metal shading and undertake MOO (multi-objective optimization) alongside daylight simulation	Expanded-metal shading	Kitakyushu, Japan	Rhino Grasshopper, Ladybug and Honeybee Octopus Microsoft Excel .JMP Python	December 21 at 12:00 p.m.	/	/
11- Using a Biomimicry Approach in the Design of a Kinetic Façade to Regulate the Amount of Daylight Entering a Working Space.(Sankaewthong et al. 2022)	2022	1. To research the suitable façade forms (form-finding) that are effective in providing an appropriate interior environment with natural light using science;	shading devices module merging physical DNA and phototropism behavior, compared with	Overcast sky (Bangkok, Thailand)	Rhino and Grasshopper Climate Studio and Wallacei	Daylight: annual period analysis, time analysis (from 8:00 a.m. to 6:00 p.m.).	/	/

		2. To study the optimal efficacy of the façade; 3. To evaluate the kinetic façade in terms of LEED version 4.1 criteria; 4. To evaluate the efficacy of a kinetic façade in a real-world situation.	vertical static louver and vertical rotating louver					
12- Louver Configuration Comparison in Three Canadian Cities Utilizing NSGA-II.(Rafati, Hazbei, and Eicker 2023)	2023	1.Assessing how small changes in a geographical location significantly affect louver design. 2. Investigating the effect of louver parameters on daylight performance and energy consumption. 3. Proposing design alternatives for three Canadian cities.	louver	three different climate zones.(7/6A/4C)	Rhinoceros Grasshopper Radiance EnergyPlus NSGA-II algorithm	/	/	/
13- Enhancing visual comfort with Miura-ori-based responsive facade model.(Kahramanoğlu and Çakıcı Alp 2023)	2023	design an origami-based responsive facade and evaluate its visual comfort	Miura-ori-based responsive facade	Mediterranean climate (Istanbul. Turkey)	Rhinoceros Grasshopper the Kangaroo the Ladybug the ClimateStudio	December 21st, March 21st and June 21st 9:00 12:00 15:00	Office space	Since the occupant locations are analyzed separately in the study, there are no facade

								configurations when the occupants are in the room at the same time.
14- Kinetic Photovoltaic Facade System Based on a Parametric Design for Application in Signal Box Buildings in Switzerland.(Choi 2023)	2023	study building facades and create an architectural design using parametric design to increase the energy independence of buildings	Kinetic photovoltaic façade	temperate oceanic climate (Basel, Switzerland)	Autodesk Revit 2020 Dynamo Insight	from January to December 2022	the Signal Box auf dem Wolf	an economic analysis of the driving principle of the solar panel facade device and the renewable energy produced through this study has not been performed
15- Optimizing the Shading Device Configuration of Kinetic Façades through Daylighting Performance Assessment.(D.-H. Kim, Luong, and Nguyen 2024)	2024	improve daylighting effectiveness in an office in Incheon, Korea, featuring a kinetic sun shading system.	Three types of Dynamic Shading Panels: vertical, horizontal, and multi-directional.	humid continental climate (Incheon, South Korea)	Rhino 7 Grasshopper Galapagos or Octopus	21st day of March, June, September, and December from 8:00 am to 6:00 pm	Commercial Reference Building	constraints pertaining to time and computational infrastructure necessitated a focused examination solely within the realm of daylighting, with assessments confined to the locale of Icheon City.

16- A Study on the Effect of Dynamic Photovoltaic Shading Devices on Energy Consumption and Daylighting of an Office Building.(Jiang et al. 2024)	2024	(1) To study the impact of three control strategies of PVSDs on building daylighting and energy consumption throughout the year. (2) To explore the energy-saving and daylighting application value of three control strategies of PVSDs in office buildings in cold areas.	three dynamic strategies of photovoltaic shading devices PVSDs (rotation, sliding up and down, and hybrid)	maritime climate cold-climate (Qingdao.China)	Grasshopper Ladybug	throughout the year	room on the sixth floor of office buildings	only studied the application of dynamic PVSDs in office buildings in cold-climate areas in China only studied the performance of south-facing PVSDs

- **Literature review discussion:**

The findings of this study underscore the growing effectiveness and necessity of dynamic shading systems, particularly in the context of hot and arid climates. Through the review of recent research between 2018 and 2024, it became evident that kinetic facades—ranging from rotating louvers and adaptive photovoltaic panels to biomimetic structures inspired by natural phenomena—consistently outperform static systems in enhancing daylight distribution, reducing glare, and minimizing energy consumption. Notably, studies conducted in desert environments such as Yazd, Iran, highlight the value of integrating occupant behavior and solar orientation into the design process, resulting in user-responsive systems that optimize comfort throughout the day. Furthermore, the adoption of smart materials, such as shape memory polymers, and bio-inspired mechanisms introduces new possibilities for passive climate adaptability. These advancements are strongly supported by parametric and environmental simulation tools like Grasshopper, Diva, and Ladybug, which enable precise, location-specific optimization. those studies reinforce a clear trend toward context-aware, interactive, and aesthetically integrated shading solutions, emphasizing their pivotal role in the future of sustainable building design for extreme climates

II.3.2.c The key requirements:

The selection of an appropriate dynamic shading system necessitates several critical requirements. First, a thorough understanding of the system's behavior across various climates is essential for establishing effective criteria for controlling solar gains. Additionally, it is important to consider climate-specific impacts on heating and cooling loads, particularly in tropical regions where the correlation between visual and thermal performance is crucial. The selection process must also account for factors such as space activity, climate characteristics, aesthetics, maintenance, safety, cost, privacy, and stakeholder needs. Finally, technical design aspects—such as geometric design, control strategy, and automation technology—should be based on well-defined criteria and guidelines to ensure optimal performance.(Al-Masrani and Al-Obaidi 2019)

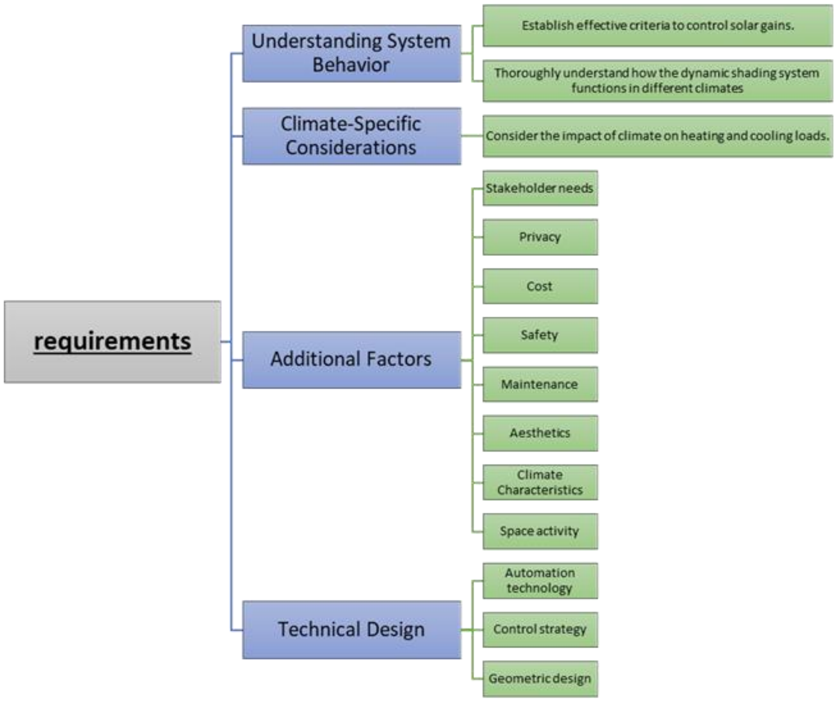


Figure 13: diagram of the key requirements to design dynamic shading devices
source: Author

II.3.2.d Design elements of dynamic shading systems:

We must understand the essential elements and layers in designing an effective dynamic shading system. The design is divided into two main sections: "physical and operational layers" (referred to as the shading skin) and "digital electronics." This section is dedicated to "Automation and Control." Together, these elements form a comprehensive framework for designing and managing the shading system.(Al-Masrani and Al-Obaidi 2019)

II.3.2.d.1 Shading skin:

The shading skin consists of two main components. The first component is the physical layer, which includes static parts (shading elements) and mechanical parts, such as gears and rails. The second component is the operational layer, which provides the necessary power utilities to operate the system.

- **Architectural components:**

The architectural design of dynamic shading systems begins with identifying the geometric shape and device movements. There are three primary forms of motion:

- Translation: Linear movement parallel to coordinate axes.
- Rotation: Changing orientation around coordinate axes.
- Scaling: Changing the size of the unit.(Moloney 2011)

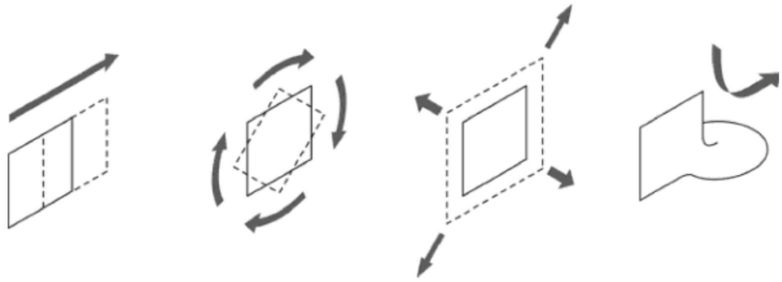


Figure 14:Basic Movement Types.
source:(Moloney 2011)

Movements can exhibit three degrees of freedom, which are determined by changes in position or orientation along one, two, or three axes.(Schumacher, Schaeffer, and Vogt 2012)

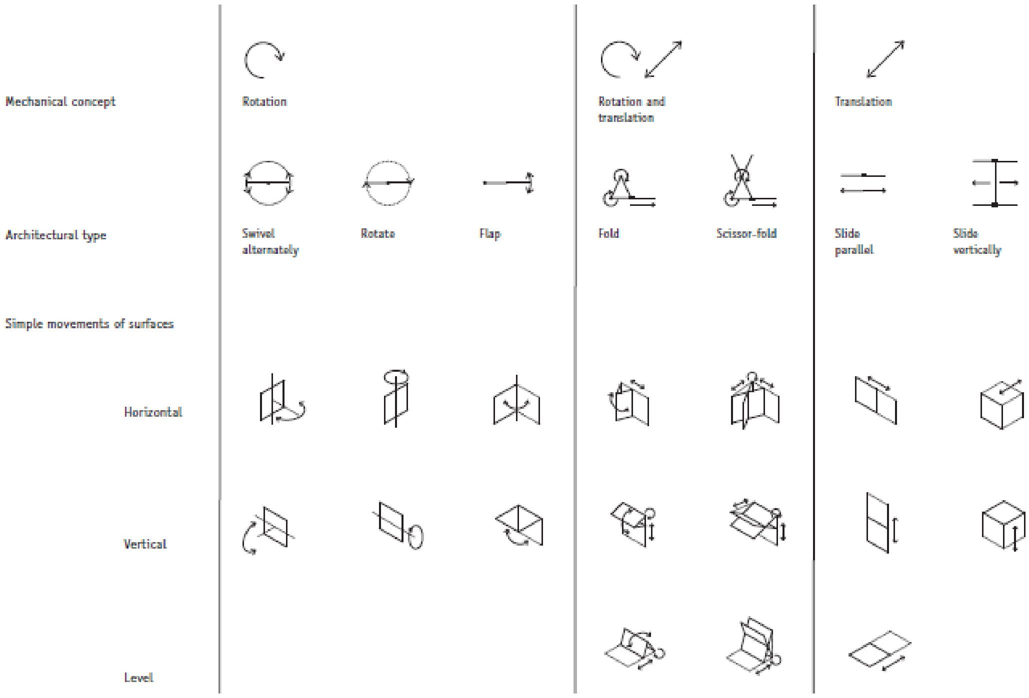


Figure 15:Movements of rigid building elements
source:(Schumacher, Schaeffer, and Vogt 2012)

- **Mechanical components:**

Mechanical studies examine the kinematic and kinetic design of dynamic shading devices at a macro level. Schaefer and Vogt mentioned that moving elements consist of rigid bodies connected by joints, and these elements create complex movements. These rigid bodies can move on two scales: kinematic and kinetic. Kinematics studies the motion of bodies over time, including parameters like duration, velocity, and acceleration. Kinetics examines the relationship between motion, forces, and torques, utilizing analytical dynamics. Mechanical devices, functioning as machines or actuators, manage movement by organizing the application of forces through components like bars, pulleys, and gears.

These components directly activate the shading process, varying by motion type, degree of freedom, and the characteristics of the shading elements.(Al-Masrani and Al-Obaidi 2019)

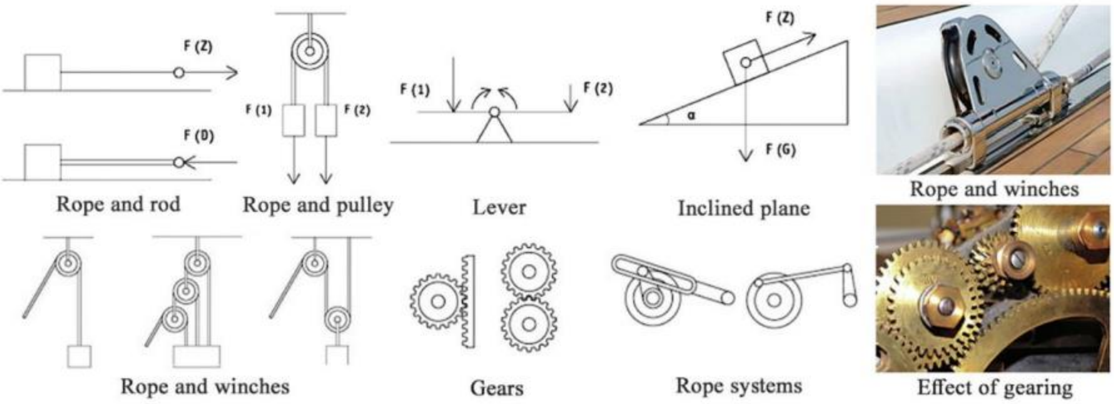


Figure 16:Some mechanical devices employed for actuating mechanism
Source :(Al-Masrani and Al-Obaidi 2019)

- **Electrical components:**

Electricity is essential for operating dynamic shading systems, often powering actuator mechanisms. Energy consumption can vary based on movement direction, object weight, bearing type, actuator choice, and placement. Alternative energy sources, like solar panels or photovoltaic cladding, have proven effective in reducing energy demands for shading system motors.(Al-Masrani and Al-Obaidi 2019)

II.3.2.d.2 Digital electronics of dynamic shading systems (automation and control strategies): Dynamic shading systems utilize rule-based automation to react to external data, employing both hardware (including sensors, controllers, and logic units) and software components. The control systems comprise inputs that collect and convert environmental data, and controllers that process this data to operate actuators. The controller acts as the interface between the inputs and the actuators, functioning through computation or software management.

- **Control strategies:**

There are two types of control systems: Open-loop controls are those that adjust the actuator output based on external input only without utilizing feedback. On the other hand, a closed-loop system compares the actual output to the desired output (reference) and uses this comparison as a feedback signal to continually reduce any discrepancies (errors). This is because the controller has two inputs (the measured signal and the reference signal) and one output (the controller signal).(Mukherjee et al. 2010)

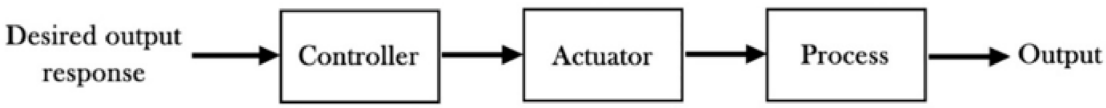


Figure 17:Open-loop control system without feedback
Source :(Mukherjee et al. 2010)

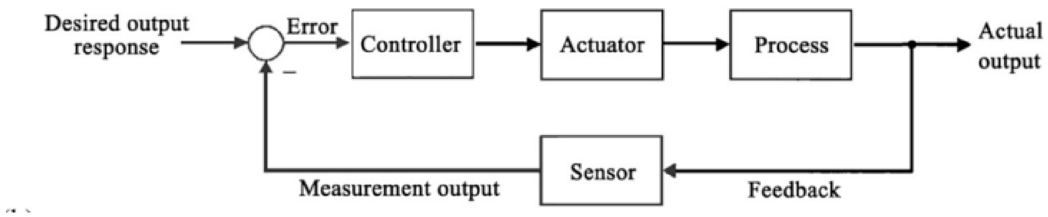


Figure 18:Closed-loop (feedback) control system.
source :(Mukherjee et al. 2010)

- **Control technological attributes (automatic control characteristics):**

Based on the control system layout, controller characteristics, and the involvement of a third party (agent), there are two classes of systems: reactive and interactive.

A dynamic shading system is typically classified as reactive or responsive when it automatically adjusts to external environmental conditions, such as the angle of sunlight, without user intervention. Reactive systems respond to specific stimuli in a predetermined way to regulate the flow of natural light and heat at building façades. These systems operate using open-loop protocols.(Al-Masrani and Al-Obaidi 2019)

On the other hand, automated shading systems are categorized as interactive when they adapt to both environmental conditions and user preferences, often employing closed-loop feedback mechanisms.(Achten, Zumancic, and Matějovská 2011)

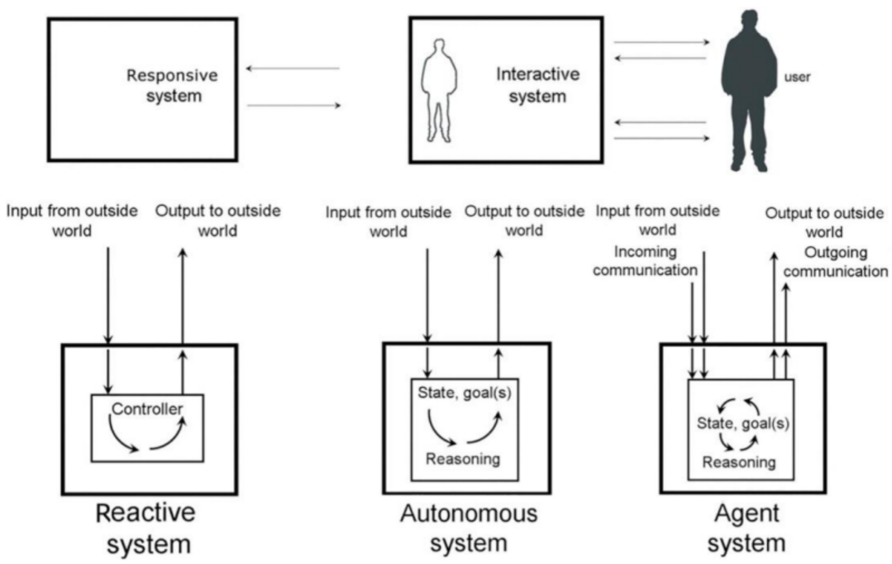


Figure 19:Responsive architectural systems based on types of technology
Source :(Al-Masrani and Al-Obaidi 2019)

- **Potential scenarios and issues to control a dynamic shading system:**

a- Single-Protocol Scheme: This scheme exclusively focuses on dynamic shading control and can function as either an open-loop or a closed-loop system.(Mukherjee et al. 2010)

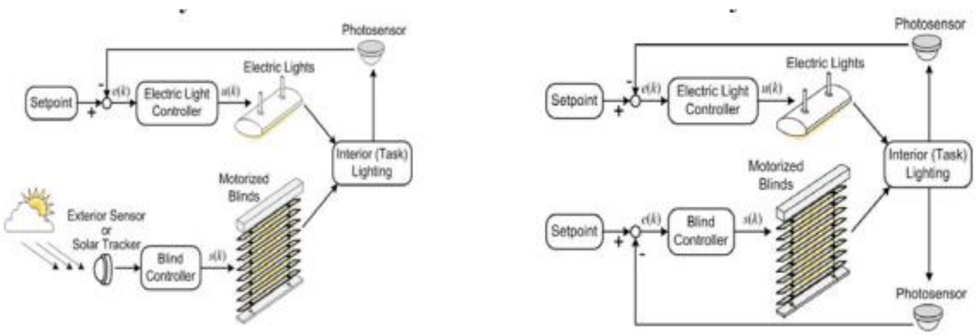


Figure 20:(left) Independent control of closed-loop lighting system and open-loop blind system. (right) Independent control of closed-loop lighting system and closed-loop blind system.
source:(Mukherjee et al. 2010)

b-Multi-Protocol Scheme: This approach connects dynamic shading control with other building systems. It can operate as an independent loop, where each system functions separately, or as an integrated loop, in which dynamic shading control is fully coordinated with other systems such as HVAC.(Mukherjee et al. 2010)

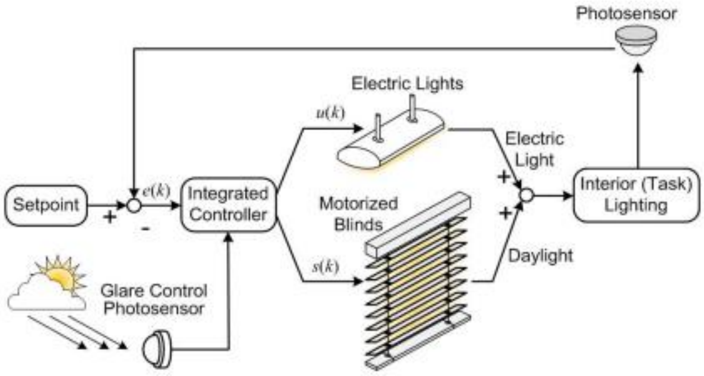


Figure 21:Integrated Lighting and Daylight Control System.
Source:(Mukherjee et al. 2010)

II.4 Dynamic shading devices and smart materials:

Dynamic shading devices are designed to adapt to changing environmental conditions, optimizing daylight control in indoor spaces. These devices typically rely on actuators and require electricity for operation. Smart materials in solar shading aim to minimize energy use, and some, like integrated photovoltaics (PVs)(Zhang et al. 2018), can even generate energy. Additionally, smart materials enable static devices, such as smart glass windows, to achieve dynamic control without moving parts.(Elkhayat 2014)

Table 2:smart materials for dynamic shading devices

type	Materials		Explanation
Type 01	Color-changing materials	photochromic materials	materials that change color when exposed to light
		Thermochromics materials	materials that change color due to temperature changes;

		electrochromic materials	materials that change color when a voltage is applied
	Shape-memory materials (SMM)	shape-memory alloys (SMA)	alloy materials able to revert, or remember, a previously memorized or present shape;
		shape-memory polymers (SMPs)	engineering polymers able to revert, or remember, a previously memorized or preset shape;
		shape-memory hybrids (SMH)	composed by the combination of the two
Type 02	Photovoltaics (PVs)		semiconducting materials that convert light into electricity

Conclusion:

In conclusion, the theoretical exploration of kinetic architecture and advanced shading devices has underscored their growing significance in contemporary sustainable design, particularly in hot and arid climates. The reviewed literature demonstrates that dynamic and responsive systems—ranging from kinetic facades and biomimetic structures to photovoltaic-integrated shading—are essential tools in regulating solar exposure, improving daylight quality, and enhancing occupant comfort. These technologies reflect a broader architectural shift toward environmentally adaptive solutions that intelligently respond to changing climatic conditions and user behavior. Moreover, the integration of smart materials, parametric design, and automation is expanding the potential of these systems, making buildings more resilient, energy-efficient, and user-centric. The insights gained from this chapter provide a conceptual foundation for the practical investigations that follow, reinforcing the need to align environmental responsiveness with technological innovation in the design of facades for extreme climate contexts.

CHAPTER II:

ANALYSIS OF MUSEUM EXAMPLES AND SITE CONTEXT

Introduction:

Lighting plays a fundamental role in shaping the spatial experience of museums, influencing both the visual perception of exhibits and the ambiance of the interior space. Whether through natural daylight or artificial illumination, lighting strategies must be carefully designed to balance aesthetics, functionality, and conservation needs.

This chapter delves into the analytical aspects of museum lighting, exploring its fundamental principles, design considerations, and case studies of renowned museums worldwide. By examining different lighting approaches, we aim to understand how light enhances architectural expression and visitor engagement in museum spaces.

I Daylighting in museums:

II.5 Generalities on lighting:

II.5.1 Definition of light:

Light is electromagnetic radiation that exhibits wave-particle duality. It is visible to the human eye within wavelengths of 380 to 780 nanometers and propagates as waves characterized by wavelength, amplitude, and frequency. Light also behaves as particles called photons, with its wave nature explaining propagation phenomena and its particle nature accounting for interactions with matter.(Zribi 2011)

II.5.1.a Naturel light:

Natural light, or daylight, is the visible portion of solar radiation with a complete and continuous spectrum, encompassing all wavelengths in the visible range. It varies in intensity, direction, and color depending on the time of day, seasons, atmospheric conditions, and interactions with particles in the atmosphere. Quantities such as illuminance and luminance measure and characterize natural light's distribution and visual impact on surfaces.(Agence régionale de l'environnement et des nouvelles énergies and Institut pour la conception environnementale du bâti 2014)

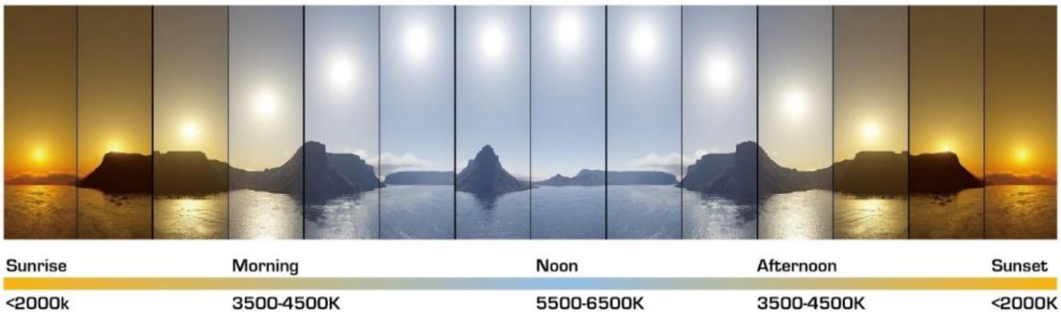


Figure 22:Natural light at different times of the day.
source : https://www.uk.lumistrips.com/lumistrips-blog/color-temperature-explained/

II.5.1.b Artificial light:

Artificial light is lighting generated by man-made sources such as lamps and spotlights, which produce light when activated. Some artificial light sources, like incandescent lamps, emit a continuous spectrum, enabling accurate color rendering of objects. Alongside natural daylight, artificial light plays a crucial role in shaping our perception of the environment and supporting daily activities. Its warm quality, reminiscent of firelight and sunlight, contributes to its familiar and comforting presence in our lives.(Odile and Sandra 2009)

Figure 23:Artificial sources of light
source : https://k8schoollessons.com/sources-of-light/

II.5.2 Fundamental Principles of Lighting:

II.5.2.a Color temperature:

Color temperature refers to the hue of light produced by a source, defined as the temperature of an ideal black-body radiator that emits light of the same color. Measured in kelvins (K), it ranges from warm tones (below 4000 K, appearing red or yellow) to cool tones (above 4000 K, appearing blue).(Thollander et al. 2020) This measurement is essential in lighting, photography, and manufacturing, as it influences a space's visual perception and ambiance. The concept is often explained using correlated color temperature (CCT), which estimates the black-body temperature of non-incandescent light sources.(Choudhury 2014)

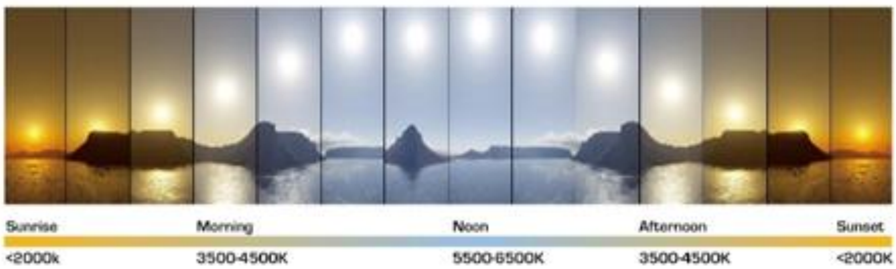


Figure 24: Color temperature
source : https://www.uk.lumistrips.com/lumistrips-blog/color-temperature-explained/

II.5.2.b Color rendering index:

In comparison to an ideal or natural light source, like daylight, the Color Rendering Index (CRI) quantifies how well a light source captures the colors of objects. Better color fidelity is indicated by a higher CRI, which ranges from 0 to 100. Perfect color rendering is represented by a CRI of 100, whereas most applications consider values below 80 to be subpar. When assessing lighting quality in settings like photography, retail, and art displays, CRI—which is dependent on the spectrum of the light source—is essential.(—CIE 17.4, International Lighting Vocabulary,(Schanda 2002)

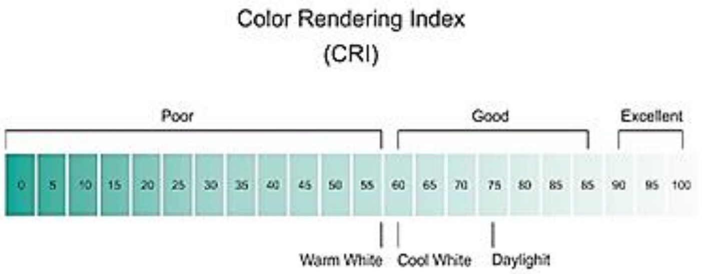


Figure 25:color rendring index .
source: https://www.dominant-semi.com/cdn/application-notes/Color_Rendering_Index-VerA.pdf

II.5.2.c Ambiance of light:

The overall impact of light on a subject in a particular setting, influenced by both artificial and natural lighting, is referred to as the lighting atmosphere. Three essential components are integrated in this concept: the architectural setting, the light, and the person observing the surroundings. Together, the architecture and light create the external lighting environment, which influences how people view and react to the area.

Numerous factors influence the atmosphere, such as:

Luminance Distribution: The way light intensity is arranged in space.

Illuminance: The total amount of light, expressed in lux, that strikes a surface.

Light Direction and Interior Illumination: How light sources are positioned and oriented.

Light Variability: Color and light intensity variations over time.

Color Rendering and Appearance of Light: The precision of color representation beneath the light source.

Glare: Uncomfortably bright lighting that obscures vision.

Flicker: Abrupt shifts in light intensity that may impact comfort and perception.(Sutter et al. 2014)

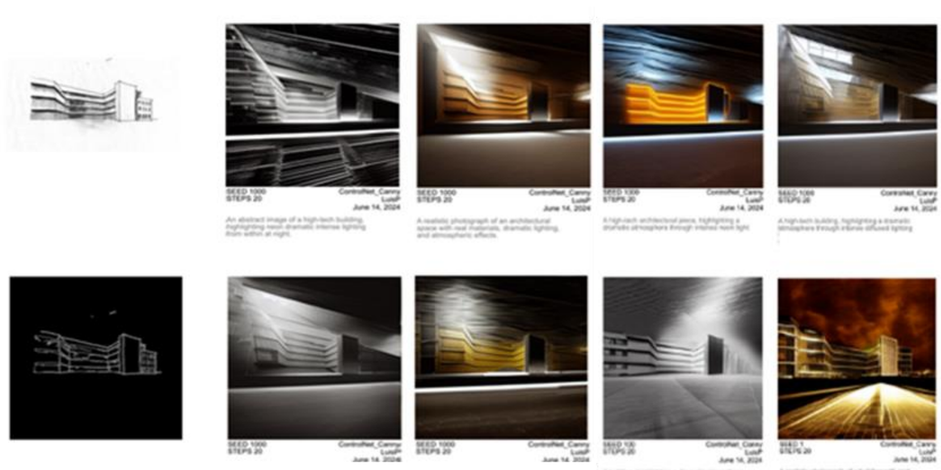


Figure 26: Ambiance of light.
source: https://blog.iaac.net/atmosphere-and-lighting/

II.5.2.d Visual Comfort:

Lighting needs to make it possible to perform a certain task without hurting the eyes. The following are the requirements for visual comfort:

• adequate lighting for fatigue-free, sharp vision,

• accurate color representation,

• a balanced distribution of light in the room, free from obnoxious shadows.

A parasitic shadow is produced by an element that is positioned between the visual spot and the light source; for right-handed people, lateral lighting from the left is preferred, and for left-handed people, lateral lighting from the right.

• the lack of glare: Too much brightness or a light contrast in glare can be very uncomfortable for the eyes.

Looking through a window allows one to avoid feeling confined and closed in.(DAICH 2011)

II.5.3 Light measurement:

II.5.3.a Daylight factor:

The Daylight Factor is a percentage that quantifies the ratio of natural light inside a room to the light available outside under standard overcast sky conditions. It is calculated as (AN INTRODUCTION TO NATURAL DAYLIGHT DESIGN IN DOMESTIC PROPERTIES 2018):

DF= (Exterior illuminance / Interior illuminance) ×100

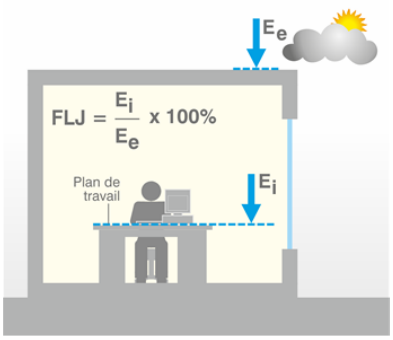


Figure 27:daylighting factor .
source: *https://energieplus-lesite.be/theories/eclairage12/physique-lumiere/facteur-de-lumiere-du-jour/*

II.5.3.b Glare Index:

Discomfort Glare Index (DGI): This index is derived from the CGI (CIE Glare Index) and aims 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. The equation is expressed as follows:(Faraji et al. 2023)

$$DGI = 10 \log\left(0{,}48 \times \sum_i \left[(L_s^{1,6} \times \Omega_s^{0,8}) / (L_b + 0{,}07 \times \omega_{wi}^{0,5} \times L_{wi}) \right] \right)$$

Degree of perceived glare	GI	DGI
Just perceptible	10 13	16 18
Just acceptable	16	20
Borderline between Comfort and Discomfort	18,5	22
Just uncomfortable	22 25	24 26
Just intolerable	28	28

Figure 28:Comparison between glare indexes (GI and DGI).
source: Faraji et al. 2023

II.6 Museums Lighting: principes and considerations

II.6.1 Daylight (natural light):

II.6.1.a sidelight:

- **The window:** The most common way to let light and air into a building is through an opening in the wall. Its location, size, shape, and the facade's orientation all affect how well a room receives lighting. "The window is a wonderful thing because it allows you to feel the light that is yours, not the sun's." (Louis Khan, Silence et lumière, Linteau, 1996)
- **The translucent wall:**The translucent wall is a vertical wall made of translucent materials (such as glass brick or acrylic) that allow light to pass through but block out sight. In some situations, these materials can also support weight.
- **The transparent wall:** The entire surface of one of a building's facades is occupied by the transparent wall, also known as the curtain wall. It is the largest lateral opening. It cannot support any weight. An independent frame supports the walls and floors. (Architecture et lumière 2011)

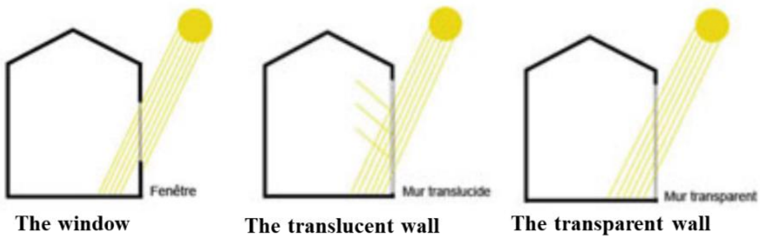
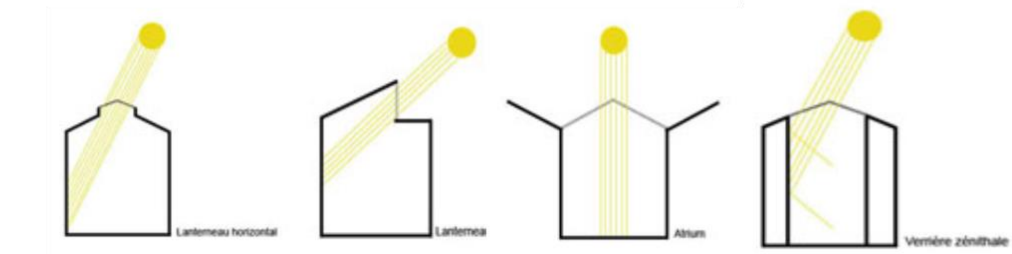


Figure 29: sidelight stratigies .
Source : Architecture et lumière 2011

II.6.1.b Toplight:

- **The horizontal skylight:** Vertical lighting can directly reach the work surface thanks to the horizontal skylight. In cloudy conditions, it offers the best natural lighting. Its drawback, though, is that it lets in more light at midday in the summer than it does in the winter. The bioclimatic principles of thermal regulation, which advocate for higher direct gains in the winter than in the summer, are at odds with this. If sunlight strikes a work surface directly, it may cause visual discomfort.
- **The vertical skylight:** The vertical skylight faces a specific direction. The light is reflected by the walls that face the aperture.
- **The atrium:** The atrium is typically the center area of a structure with a translucent ceiling or a zenithal glass roof.

- **The zenithal glass roof:** The Zenithal glass roof is a roof-level aperture that is comparatively large (surface always greater than 1 m²). Forming a light well above a stairwell is its typical location. (Architecture et lumière 2011)

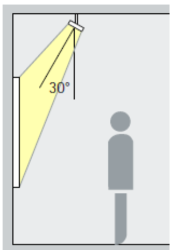
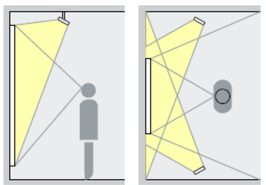
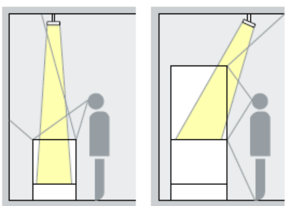
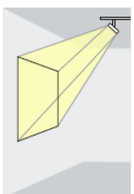


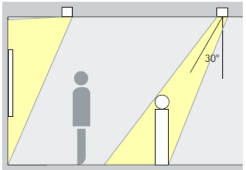
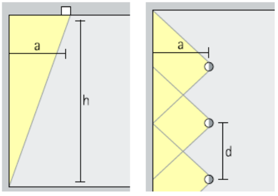
The horizontal skylight **The vertical skylight** **The atrium** **The zenithal glass roof**

Figure 30: Toplight catigories.
Source : Architecture et lumière 2011

II.6.2 Artificial light:

Table 3: Artificiel light techniques

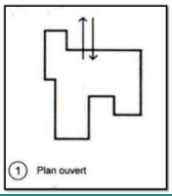
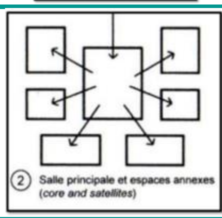
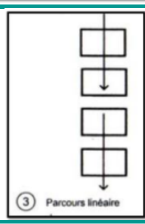
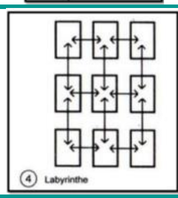
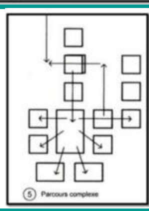
Lighting Technique	Disposition	Description
Ideal Light Positioning for Art Display		The ideal angle of incidence for lighting fixtures is 30°: when it comes to illuminating sculptures and paintings. With a wider angle, the viewer runs the risk of seeing his shadow on the painting when he is in front of it if the light source is far from the object to be illuminated. Conversely, a grazing light from a narrower angle would give the painting longer shadows.
Reducing Visitor Shadows with Lateral Lighting		Cut down on the visitor's shadow When the observer is facing the paintings, two projectors positioned on the side shine light on them without creating any shadows or dazzling reflections.
Strategic Placement of Exterior Lighting in Storefront Displays		illuminating storefront windows without being overly bright Outside projectors can also be used to illuminate storefront windows, but they must be positioned outside of the reflection surfaces from the observer's perspective.
Contouring Light Beams to Highlight Artwork		restricting the beam to the painting's contours The paintings appear to radiate light when the beam is restricted to illuminating the object on display. An intimate setting that encourages reflection can be created in a darkened room. To precisely control the light beam, just attach a cameraman to a Gobo projector.

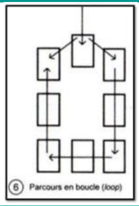
Balancing Wall and Accent Lighting to Highlight Artworks		Emphasizing the artwork and walls Uniform wall lighting, which creates a sense of clarity, and accent lighting, which models the sculptures, combine to create balanced lighting in the rooms and the exhibition.
Proper Placement of Wall-Mounted Lighting Fixtures		Place wall-mounted lighting fixtures correctly. To ensure that light is dispersed evenly throughout the wall, wall-mounted fixtures should be a third of the height of the ceiling away from the wall. The distance from the wall to the fixtures should match their spacing.

II.7 The exhibition halls:

II.7.1 path:

Table 4:Exhibition halls Path types

Path	Illustration
The open path: spacious display area, independent vision, unrestricted movement. (10th Edition) Neufert.	
The radial path: The museum's main room, which serves as orientation. (10th Edition) Neufert.	
The linear: path has a distinct entrance and exit, a defined path, a linear spatial sequence, and clear orientation. (The 10th edition of Neufert)	
The labyrinth path: Unrestricted movement, with a changeable path and direction. (Neufert, Tenth Ed.)	
The complex path: Spatial groups paired with the standard traits of 1–4; intricate collection organization. (Neufert, 10th Ed.)	

The loop path:returns to the entrance in a manner akin to the linear path. (Neufert, Tenth Ed.)	

II.7.2 architectural standards for exhibition spaces:

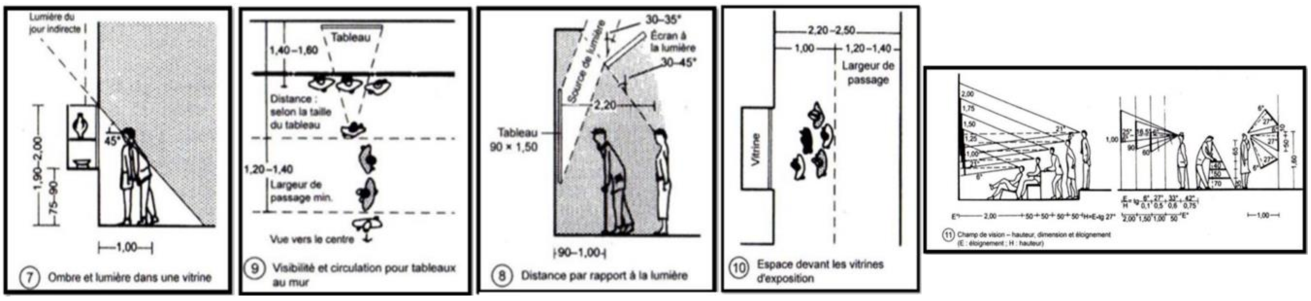


Figure 31: architectural standards for exhibition spaces. source: Neufert, 11th Ed

III Examples Analysis:

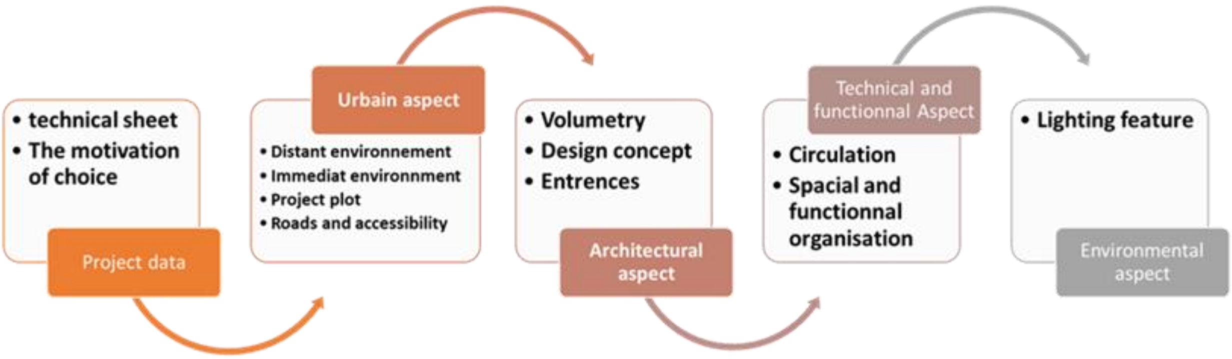
III.1 The list of examples:

Figure 32:A:The Louvre Abu Dhabi Museum, B:Eli and Edythe Broad Museum, C: Milwaukee Art Museum (MAM), D:UCCA Clay Museum

A B

Figure 33:A:Regional Museum of Biskra B :MAMA

The elements to be analyzed:

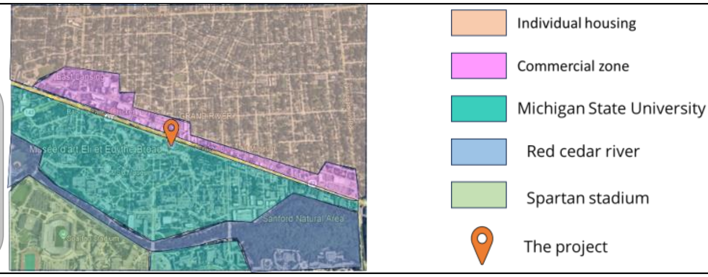


Bookish examples analysis:

Table 5:Bookish Examples Analysis

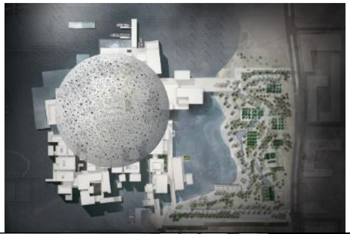
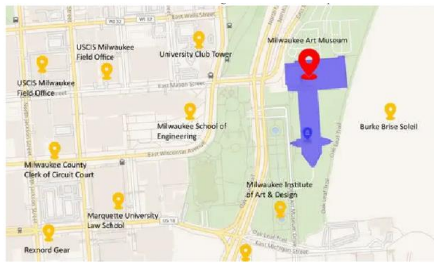
The project	Technical sheet	Motivation of choice
 **The Louvre Abu Dhabi Museum**	Project: Museums & Exhibit Sutation: Abu Dhabi, United Arab Emirates Architects: Ateliers Jean Nouvel Area: 97000 m² Year: 2006 - 2017 Status: Completed	The Louvre Abu Dhabi was chosen for its innovative architecture and sustainable design, and its massive dome is a model for advanced shading systems.
 **Eli and Edythe Broad Museum**	Project: Museum Situation: East Lansing, USA Michigan State University Architect: Zaha Hadid and Patrick Schumacher Designed in: 2007 Built in: 2012 Land Area:6038 m2 Built-up Area: 4274 m2 Status: Completed	Eli and Edythe Broad Museum was chosen due to its innovative architectural design and functionality. Its sharp geometric forms, modern materials, and seamless integration of natural light showcase a refined balance between form and function.
 **Milwaukee Art Museum (MAM)**	Project: Museum Situation: Milwaukee, Wisconsin, United States Architect: Eero Saarinen/Santiago Calatrava/David Kahler/James Shields Built in:1955 - 1957 Remodeled in:1975, 2001, 2015 Built-up Area: 13,196 m2 Status: Completed	This project was chosen for its dynamic shading device, innovative architectural design, and technology integration. Its movable "wings," connection to the environment, and emphasis on sustainability make it an ideal case study for blending aesthetics, functionality, and environmental considerations.

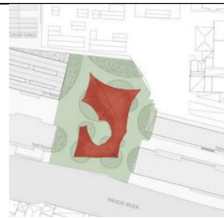
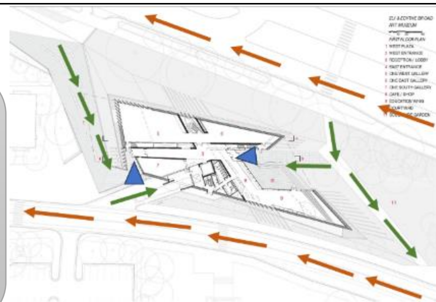
 **UCCA Clay Museum**	Project: Museums & Exhibit Sutation: Yixing, China Architects: Kengo Kuma and Associates Area: 3437 m² Year: 2024 Status: Completed	the UCCA Clay Art Center was chosen for its unique architectural form and innovative use of materials. Its distinctive, organic shape, reminiscent of a twisted ribbon, invites discussion of the design intent, construction challenges, and its contextual relationship with the surrounding environment.

The project	**Urban aspect**
	Distant environnement
The Louvre Abu Dhabi Museum	The project is situated within a multifunctional site and an expansion zone that encompasses the cultural hub 
Eli and Edythe Broad Museum	The project is located in a prime location that combines academic, residential, and commercial activity, making it ideal for developing mixed-use projects. 

Milwaukee Art Museum (MAM)	The Milwaukee Art Museum's prominent lakefront location on the shore of Lake Michigan. Its urban setting ensures easy accessibility for city residents and visitors, while its integration within a cultural complex enhances the city's vibrant arts scene. 
UCCA Clay Museum	**UNKOWN LOCATION**
The project	**Immediate environment**
The Louvre Abu Dhabi Museum	The project is situated within a cultural site that features multiple museums. It serves as both a tourist destination and a residential area. The museum is ideally located and seamlessly integrated into its surroundings 

Eli and Edythe Broad Museum	Located at the northern edge of the Michigan State University campus, the Eli and Edythe Broad Art Museum is situated in an exposed location with an active urban life, assuring visibility and encouraging community engagement 
Milwaukee Art Museum (MAM)	The Milwaukee Art Museum's site is a significant asset, contributing to its iconic status and enhancing its role as a cultural destination. Its location within the city makes it easily accessible by various modes of transportation, and the museum is part of a larger cultural complex that includes other significant buildings, contributing to a vibrant arts and culture scene.of former pottery factories. 
UCCA Clay Museu	the site of the museum was once a hub for pottery culture, surrounded by numerous factories and studios. This project aligns with the broader redevelopment plan for the area, aiming to create a vibrant center for pottery culture that includes studios and workshops while preserving the remnants of former pottery factories. 

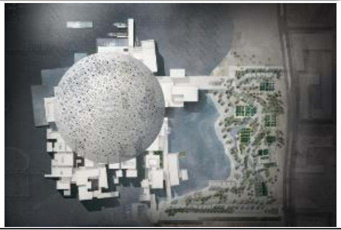
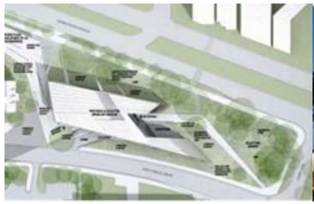
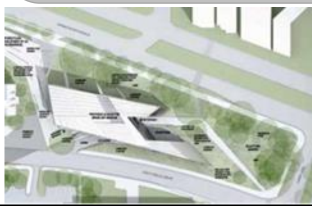
The project	The project plot
The Louvre Abu Dhabi Museum	The Louvre Abu Dhabi was designed as a "museum city" on the sea; it is a project based on water. The project occupies almost the entire island that serves the project, it is a place created on an island (100% of the plot). 
Eli and Edythe Broad Museum	The building covers 71% of the plot, with the remaining 29% dedicated to outdoor spaces, including a sculpture garden to the east, a courtyard, and a a plaza to the west . These areas enhance the functionality and aesthetic appeal of the site while fostering outdoor engagement.  **Built-up Area:** 4274 m2 **Land Area:** 6038 m2
Milwaukee Art Museum (MAM)	**Land surface :90409,73 m²** **building surfaces 31680 m²** The museum occupies 35% of the plot, with the remaining area dedicated to the Cudahy Gardens, a thoughtfully designed landscape by Dan Kiley.  

UCCA Clay Museum	The building covers 70% of the plot , with the remaining 30% allocated to outdoor spaces, including green spaces for bamboo plants as well as spaces for exterior circulation .  Land Area; Built-up Area	
The project	**Road and accessibility**	**Entrence**
The Louvre Abu Dhabi Museum	 Primary road; Scondry road; side road	 maritime access; Pedestrian entrance; mechanical access; VIP parking; visitor parking; water transport station
Eli and Edythe Broad Museum	Situated within the university, the project benefits from excellent accessibility, whether by public transportation or on foot, ensuring convenience for students, faculty, and visitors alike.  Main routs; Scondry routs	The museum has two entrances, one for the main public on the west side, entering a center hall; and another one on the east side going into the lobby.  mechanical access; Pedestrian access; entrances

<table>
<tr>
<td>Milwaukee Art Museum (MAM)</td>
<td>Its location within the city makes it easily accessible by various modes of transportation, including public transit, cars, and pedestrian walkways.

Main routs   Scondly routs</td>
<td>The Milwaukee Art Museum has three primary entrances: Main Entrance: Accessible via the Reiman Pedestrian Bridge. School Group Entrance: Located near the collection galleries and accessible for organized visits. Parking/Underground Entrance: Connected to the museum's parking facility for visitors arriving by car. Each entrance is designed for specific types of visitors or approaches.

</td>
</tr>
<tr>
<td>UCCA Clay Museum</td>
<td>
Main road (mechanical access)   Pedestrian access</td>
<td>
Museum entrance
Cofe shop entrance
Multi-functional hall entrance
Museum logistic/ cargo entrance</td>
</tr>
</table>

The project	Architectural aspect	
	Volumetry	**Design concept**
The Louvre Abu Dhabi Museum	The project, designed as a "museum city" in the sea, features a collection of 55 scattered rectangular structures. These separate blocks, including 23 galleries, are unified under a striking dome with a diameter of 180 meters.  	The architectural approach of the Louvre Abu Dhabi began with the reinterpretation of the traditional Arabic dome, blending ancient Islamic architectural elements with modern design. Inspired by the natural interplay of light through palm trees, the dome creates a dynamic "rain of light" effect, symbolizing a universal connection across cultures and ages..    
Eli and Edythe Broad Museum	There is no apparent usage of any organic geometric shapes, the structural elevation is formed out ofthe analysis obtained from the study of the topography and the paths of circulation in the surroundingshence the structure is formed out of a variety of polygonal 3D shapes.meters.  	The design concept draws inspiration from movement paths and visual connections, transforming two-dimensional pathways into three-dimensional folded planes. This integration connects the vibrant street life to the north with the historic university campus to the south, emphasizing fluidity, relationships, and perspectives while seamlessly blending the museum into its surroundings.   

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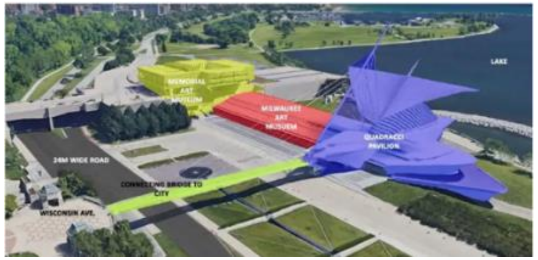
<tr>
<td>Milwaukee Art Museum (MAM)</td>
<td>The Milwaukee Art Museum's volumetry is a fascinating interplay of geometric forms. The original structure, features clean lines and low-profile rectangular volumes. Quadracci Pavilion introduces a bold contrast with its soaring white concrete wings, the Burke Brise Soleil. The overall effect is a captivating combination of grounded stability and dynamic movement.

</td>
<td>There are multiple elements in the structure inspired by its location facing the lake: mobile steel blinds inspired by the wings of a bird, a wired pedestrian bridge with a raised mast inspired by the shape of a sailboat, and a curved gallery of a single floor resembling a wave.
</td>
</tr>
<tr>
<td>UCCA Clay Museum</td>
<td>The building takes the form of a mountain, evoking Shushan Mountain and the historic dragon kiln nearby. This mountain-like shape is punctured to establish connections with the pottery factory and canal, aligning the structure with the site’s axis and the surrounding industrial complex.
 </td>
<td>The design concept of the UCCA Clay Museum draws inspiration from its cultural and natural context, integrating the historical significance of Shushan Mountain and the traditional dragon kiln. The mountain-like form symbolizes the region’s pottery heritage, while punctures in the volume establish a seamless connection to the pottery factory and canal, aligning the museum with its surroundings.
 </td>
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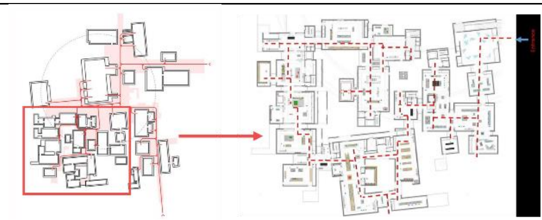
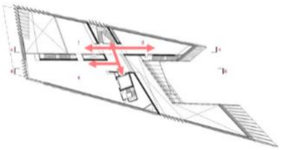
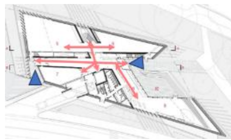
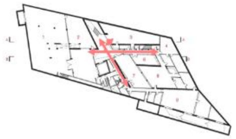
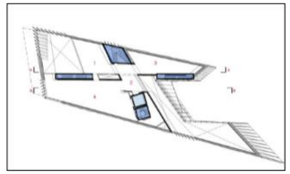
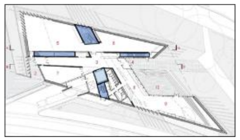
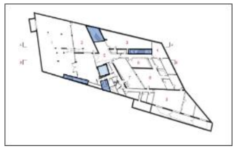
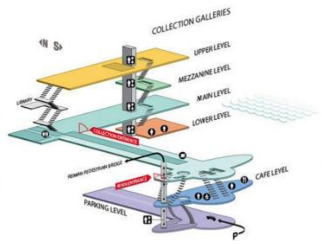
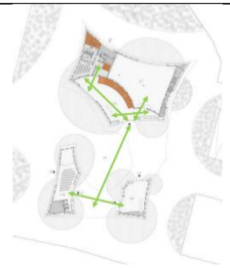
The project	Technical and functional Aspects
	Circulation
The Louvre Abu Dhabi Museum	The museum employs a labyrinthine route, allowing visitors the freedom to choose their own path through its elements. The components are thoughtfully arranged to inspire exploration and encourage moments of contemplation. 
Eli and Edythe Broad Museum	The design ensures free movement and facilitates easy vertical circulation through well-placed stairs and lifts, enhancing accessibility and user experience throughout the building.       Vertical circulation by left Vertical circulation by stairs
Milwaukee Art Museum (MAM)	The circulation of the museum is a free and open circulation system, allowing visitors to move easily between different areas.  

<table>
<tr>
<td>UCCA Clay Museum</td>
<td>The museum features a flexible and accessible layout, enabling visitors to navigate effortlessly between its various sections.
Vertical circulation (stair /left)
horizontal circulation
</td>
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<table>
<tr>
<td rowspan="2">The project</td>
<td colspan="3">Spatial and function organisation</td>
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<tr>
<td>Special organisation</td>
<td>Functional organisation</td>
<td>Comment</td>
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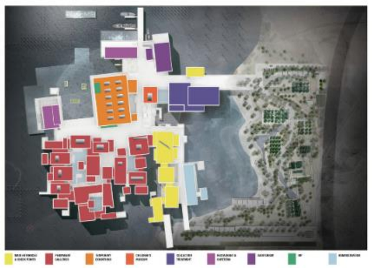
<tr>
<td>The Louvre Abu Dhabi Museum</td>
<td>

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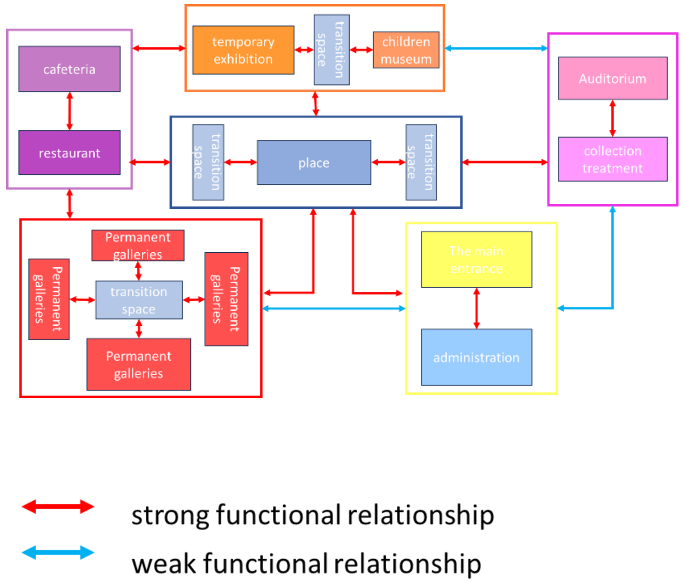
<td>
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<td>Louvre Abu Dhabi is an archipelago built at the top of the sea, which consists of one floor. People can enter the building by foot or by boat through the main entrance. The function of the building is structured as follows: main entrance, permanent gallery, temporary exhibition, children’s museum, collection treatment, restaurant & cafeteria, auditorium, VIP, and administration. The layout of the floor plan of the Louvre Abu Dhabi serves up</td>
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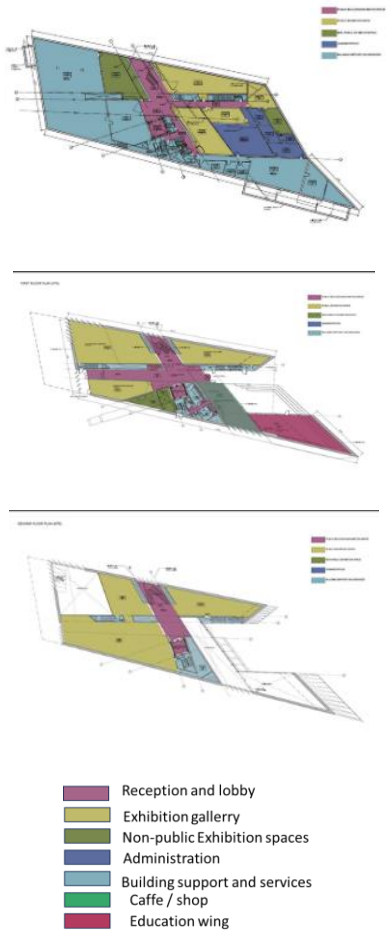
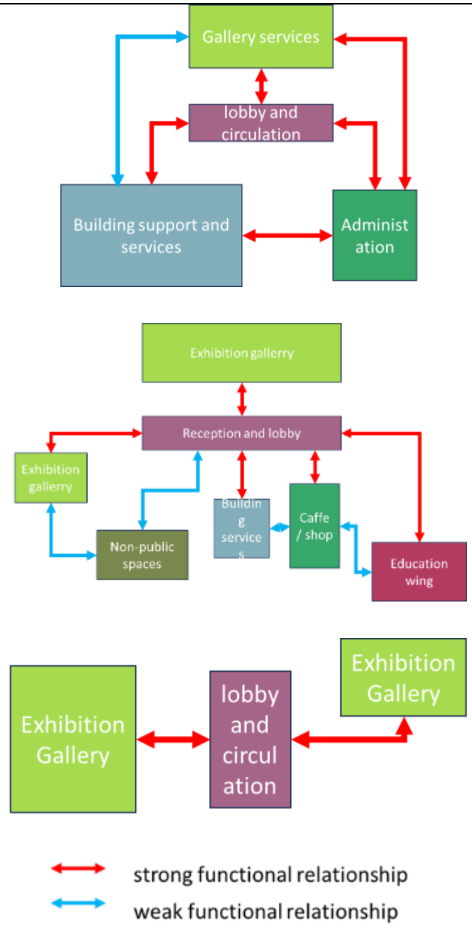
<table>
<tr><td></td><td></td><td></td><td>the main aim of the Museum space by dividing the space into open and closed spaces that contain different valuable pieces</td></tr>
<tr><td>Eli and Edythe Broad Museum</td><td>
</td><td>
</td><td>The museum includes 1600 m² of exhibition space in double-height galleries. This space is split between three stories, two floors above ground and one basement level. These areas offer space for special exhibitions, modern and contemporary art, new media, and photography, and since the galleries are double-height, they can hold large installations. The museum includes an educational facility for lectures and seminars, administration offices, a café and a shop, a pedestrian plaza, and a sculpture garden.</td></tr>
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<tr>
<td>Milwaukee Art Museum (MAM)</td>
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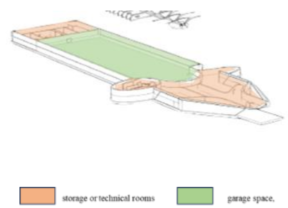
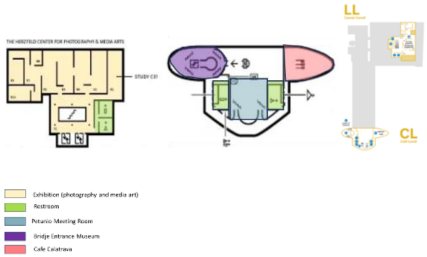
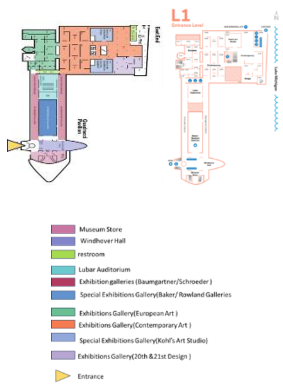
TAJ GARAGE



Lower Level and Café Level



Entrance Level



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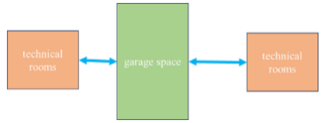
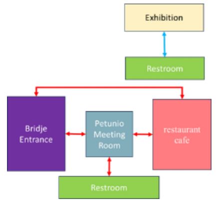
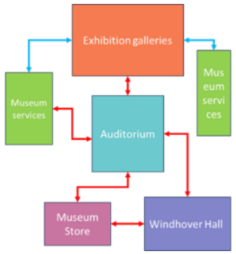


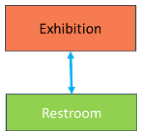
Lower Level and Café Level

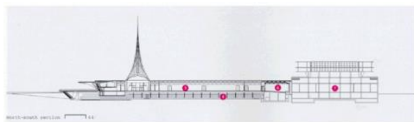


Entrance Level



Top Level





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this building is divided into 4 main part :

- The basement has parking.

- Then, on the lower floor, there are some meeting spaces and a restaurant.

- The different spaces are divided into the main floor like reception hall, exhibition hall,terrace, and lobby.

- This main floor has also a mezzanine floor which is connected to the bridge and themezzanine floor has a board room, lobby, and existing galleries.

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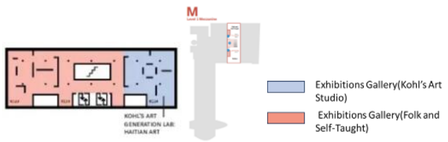
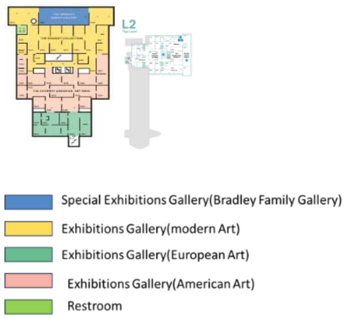
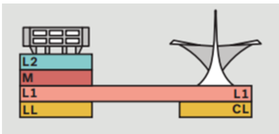
Level 1 Mezzanine



Top Level





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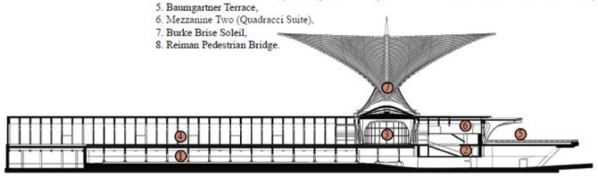
Spatial Division
The following have been identified as pertinent spatial compartments:

1. Taj Garage (Service Rooms),
2. Mezzanine One (Cafe Calatrava, Petunio Meeting Room, Service Rooms),
3. Windhover Hall,
4. Galleries (Schroeder Gallery, Baumgartner Gallery, Lubar Auditorium, Store, Baker/Rowland Gallery),
5. Baumgartner Terrace,
6. Mezzanine Two (Quadracci Suite),
7. Burke Brise Soleil,
8. Reiman Pedestrian Bridge.



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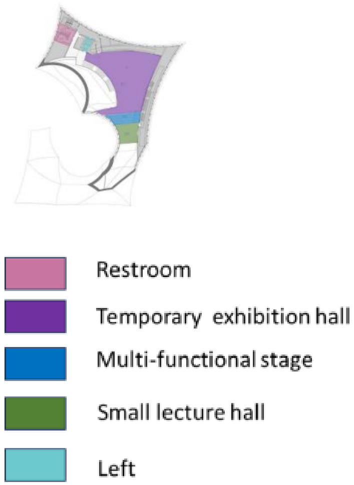
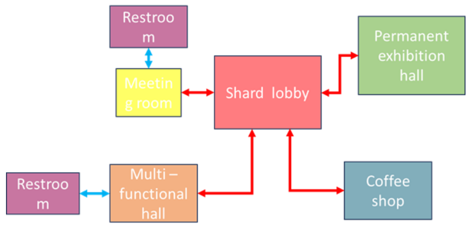
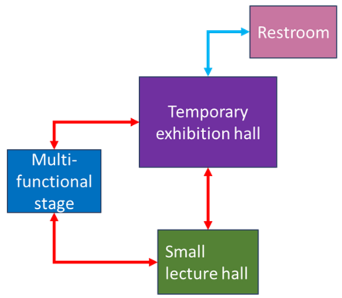
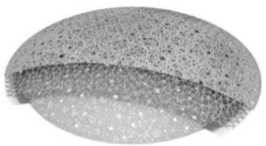
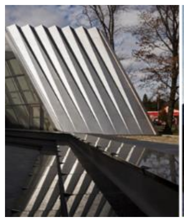
UCCA Clay Museum

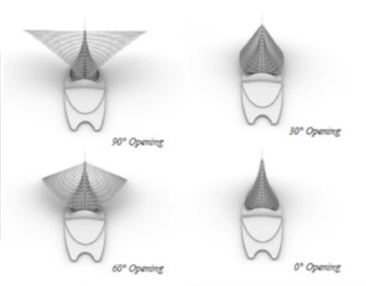






The UCCA Clay Museum features a wave-like form that connects with the ground-level plaza, leading to a lobby, exhibition hall, events space, and café through arched glazed openings. Large bamboo-lined walkways beneath the museum visually link the canal and industrial surroundings. The upper levels, including the café and exhibition area, are unified by an exposed wooden lattice roof that enhances the sense of space and openness.

The project	Environmental Aspect
	Lightning feature
The Louvre Abu Dhabi Museum	The Louvre Museum dome creates a transformative effect on both interior and exterior spaces. Inside, its intricate geometric pattern filters sunlight into a mesmerizing "rain of light," producing dynamic light and shadow plays that evoke serenity and natural beauty while providing shade and cooling. Outside, the dome's immense size and 7,850 stars form a landmark visible from Abu Dhabi and beyond, harmonizing with the natural environment by echoing the light-diffusing qualities of palm trees. At night, it becomes a luminous spectacle, enhancing its iconic presence.   
Eli and Edythe Broad Museum	The museum's lighting design creates a dynamic ambiance, balancing natural and artificial light to enhance the art experience. Treated glass with pleated stainless-steel fins allows controlled natural light while minimizing glare, while some galleries rely on artificial lighting for focused environments, such as the windowless new media gallery. Floor-to-ceiling windows in the main gallery provide vibrant natural light and views of the surroundings, and the varied light qualities across galleries offer diverse and tailored spatial experiences.   

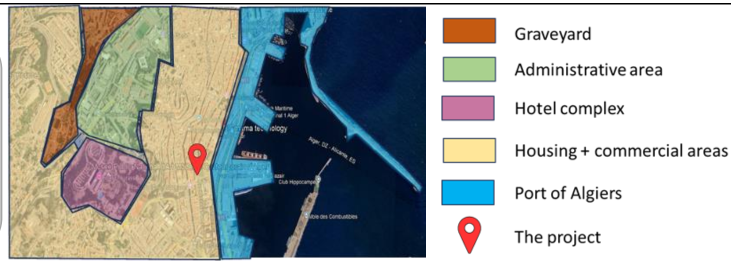
Milwaukee Art Museum (MAM)	The Burke Brise Soleil is the signature element of the Calatrava addition. Supported by the glass and steel atrium above the pavilion, the two wings are each composed of 36 steel rectangular tube fins having a constant cross-section of 360 mm, but varying in length, depth, and thickness For each wing there is a rotating spine attached to the main mast trusted into the roof allowing for a maximal opening of 90 degrees. The wings are. programmed to open each day at noon   The Burke Brise Soleil, the movable "wings" of the pavilion, play a crucial role in regulating natural light. They can be opened to allow more light to enter or closed to reduce glare and heat gain, creating a dynamic interplay of light and shadow throughout the day. The use of white concrete and other light-colored materials helps to diffuse the natural light, creating a soft and even illumination that is comfortable for viewing art.   
UCCA Clay Museum	The interplay of light and shadow forms a vital part of the experience. Skylights and strategically placed windows allow natural light to seep through, casting dynamic patterns across walls and floors. The ever-changing interplay reminds one of the organic nature of pottery making, where each piece is shaped by light, heat, and the touch of the artisan.   

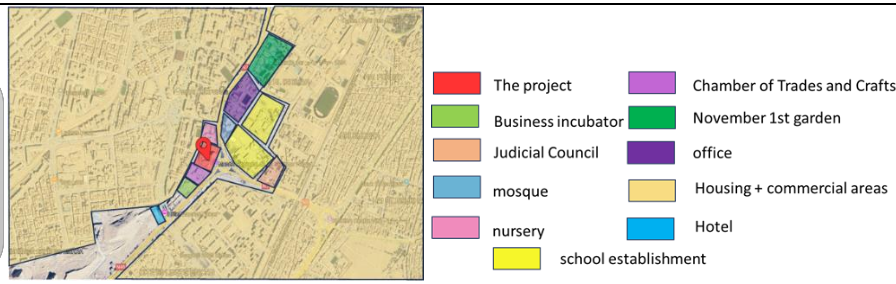
1. **Existing examples Analysis:**

Table 6:Existing Examples Analysis

The project	Technical sheet	The motivation of choice
 **The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)**	Project: Museums & Exhibit Sutation: Larbi Ben M'hidi street, Alger Architects: Henri Petit Area: 13500 m2 Year: 1914 (Galeries de France) and 2008 restoration (Museum of Modern Art of Algiers (MAMA)) Status: Completed	The National Public Museum of Modern and Contemporary Art of Algiers (MAMA) is an excellent choice due to its unique neo-Moorish design, blending European and Algerian influences, and its historical transformation from a 1909 department store to a modern art museum. Its intricate details, materiality, and spatial design reflect its colonial past and role as a contemporary cultural hub, making it a rich subject for studying architecture's interaction with heritage, identity, and functionality.
 **Regional Museum of** **Moudjahid Biskra**	Project: History Museum Sutation: Biskra, Algeria. Architects: Mirad Yasin Area: 4773 m2 Year: 2008 Status: Completed	The museum was chosen because it has a distinctive architectural style, combining modern elements with traditional Islamic features, and because it allows me to visit and experience the spaces.

<table>
<tr><td rowspan="2">The project</td><td>Urbain aspect</td></tr>
<tr><td>Distant environnement</td></tr>
<tr><td>The National Public Museum of Modern and</td><td>The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)is located in the heart of Algiers, near the Port of Algiers and close to significant landmarks like the Casbah and Place des Martyrs. The building is situated on Rue Larbi Ben M'Hidi, a bustling street that reflects the city’s vibrant cultural and historical atmosphere.


</td></tr>
<tr><td>Regional Museum of Moudjahid Biskra</td><td>This site is ideal for a museum as educational, cultural, and community-focused amenities surround it. Its location within a mixed-use urban area ensures accessibility, making the museum a central cultural hub that fosters community engagement and enhances its vibrancy.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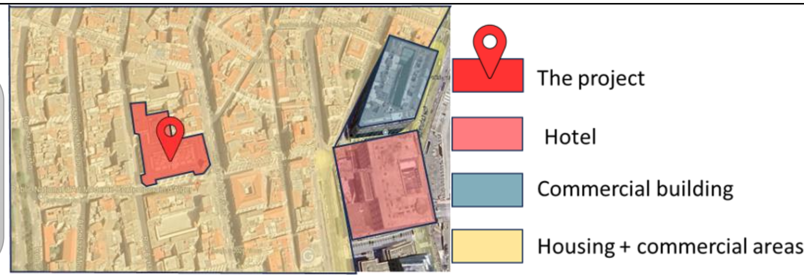
<tr><td>The project</td><td>Immediat environnment</td></tr>
<tr><td>The National Public Museum of Modern and</td><td>The project site is centrally located within a vibrant urban context, surrounded by a mix of functions that enhance its accessibility and significance. This integration of cultural, residential, and commercial zones positions the museum as a key landmark within Algiers, fostering interaction between different aspects of city life.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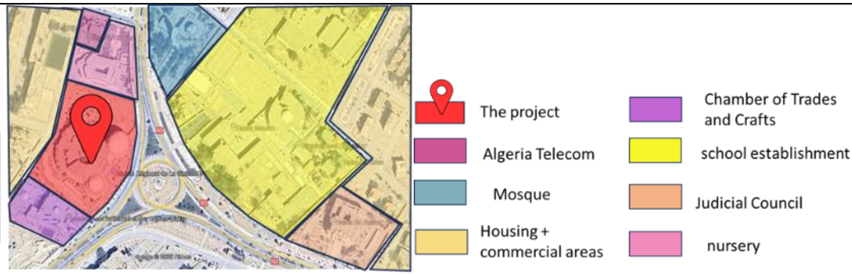
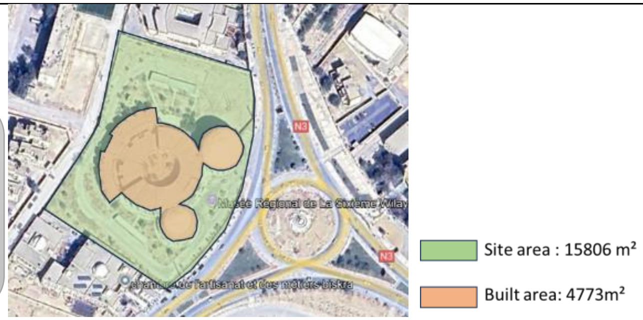
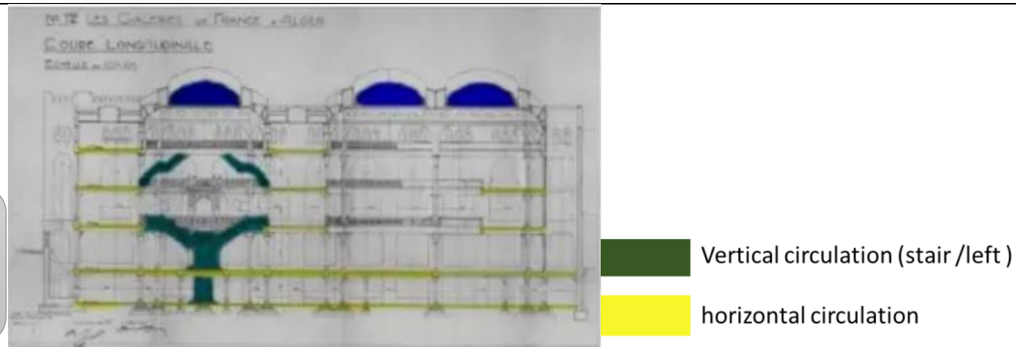
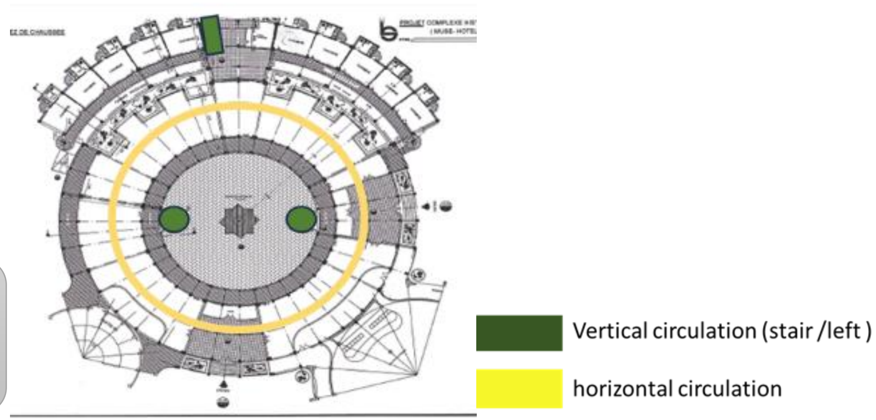
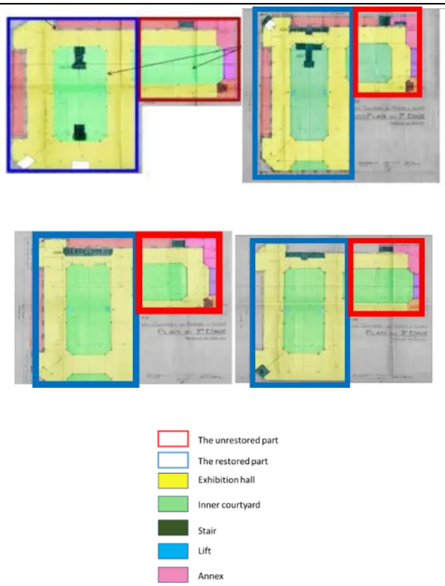
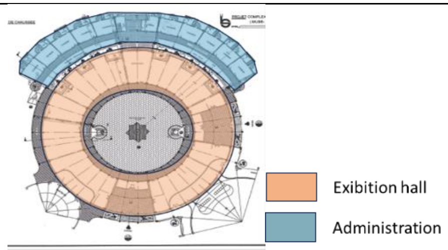
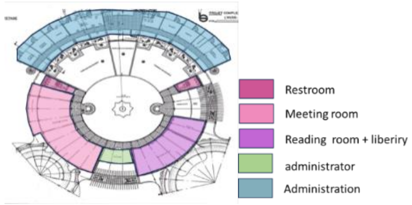
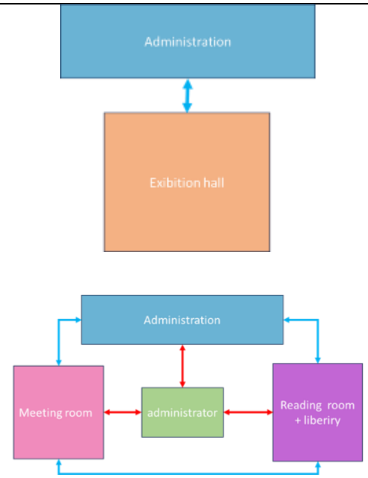
Regional Museum of Moudjahid Biskra	The project site is centrally located within a vibrant urban context, surrounded by a mix of functions that enhance its accessibility and significance.	
The project	**Project plot**	
The National Public Museum of Modern and Contemporary Art of	The project occupies 100% of the plot.	
Regional Museum of Moudjahid Biskra	The building covers 30% of the plot, with the remaining 70% allocated to outdoor spaces, including green areas, spaces for exterior circulation, and a garage	

The project	Roads and accessibility	Entrences
The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)	The MAMA is highly accessible due to its prime location on Rue Larbi Ben M'Hidi, a central and well-connected street in Algiers. It is easily reachable by public transportation, including buses and taxis, with nearby stops ensuring convenience for visitors. 	
Regional Museum of Moudjahid Biskra	The museum is located in the heart of Biskra, near the city's main square. It is easily accessible by public transportation or by car. 	

The project	**Architectural aspect**	
	Volumetry	**Design concept**
The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)	The volumetry of the MAMA is defined by its balanced, rectangular form and neo-Moorish style, featuring large symmetrical arches, intricate decorative details, and rhythmic façade elements. Its multi-story design combines solidity with openness, creating a harmonious interplay of voids and solids.  	Originally built in 1909 as a department store by the French architect Henri Petit, the building is a prime example of early 20th-century neo-Moorish architecture. Its design blends European architectural principles with local Algerian and Islamic influences,  
Regional Museum of Moudjahid Biskra	 	the museum has a complex and dynamic volumetry, defined by a central dome, a circular base, a radial layout, multiple wings, and a central courtyard. The use of multiple volumes and shapes creates a visually interesting and functional space.

The project	Technical and fonctionnel Aspect
	Circulation
The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)	We find the same route on each floor: a closed circuit around the patio. 
Regional Museum of Moudjahid Biskra	The road forms a closed loop around the inner courtyard. 

The project	Spacial and functionnal organisation		
	Special organisation	Functional organization	Comment
The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)		/	The Museum of Modern Art of Algiers (MAMA), is designed as a building of neo-Moorish architecture, the museum rises on five levels; a basement reserved for temporary exhibitions, displays and cultural events that the museum hosts each month. And four levels designed from the current floor in free plans, organized around the two central patios. The first three levels, house permanent exhibitions, and the last upper level is devoted to science in Islam. The museum is also equipped with a terrace containing the glass domes, ensuring zenithal lighting.

Regional Museum of Moudjahid Biskra	 		The Regional Museum of Mujahideen in Biskra has two main floors. The lower floor houses the exhibition hall at the center, surrounded by administration offices. The upper floor includes meeting rooms, a reading room with a library, restrooms, an administrator's office, and additional administration spaces, ensuring a functional balance between exhibition, research, and management areas.
The project	**Environmental Aspect**		
	Lighting feature		
The National Public Museum of Modern and Contemporary Art of Algiers (MAMA)	The zenithal lighting of the MAM Algiers Museum is provided by five modestly sized glass roofs (8 meters long by 6 meters wide), in the shape of domes. They are distributed over the entire surface of the roof and cover approximately 60% of its surface area. These glass roofs provide natural zenithal lighting that highlights the museum's exhibitions, from the entrance to the exit.		

Regional Museum of Moudjahid Biskra	Although there are sources of natural lighting, whether from openings overlooking the interior courtyard or open to the outside, they are all covered and depend 100% on artificial lighting.   

<u>Examples synthesis</u>

Table 7:Exemples Analyses synthèses

1. Situation	Museums are strategically located in culturally significant, urban, or historically rich areas to enhance accessibility and relevance. Their placement often aligns with tourism, academic institutions, or artistic districts, reinforcing their role as cultural and educational hubs.
2. Immediate Environment	The surroundings of a museum influence its functionality and visitor engagement. Museums are often integrated into urban, academic, or historical settings, benefiting from their proximity to cultural institutions, public spaces, and transportation networks.
3. Project Plot	The distribution of built and open spaces varies depending on design intentions. Some museums maximize plot usage with expansive structures, while others allocate portions for outdoor spaces, gardens, and circulation areas, enhancing visitor interaction with the environment.
4. Roads and Accessibility	Accessibility is a key factor in museum design, ensuring smooth connectivity via public transport, pedestrian pathways, and vehicular access. Well-planned entrances and circulation routes enhance visitor flow and create an inviting experience.
5. Volumetry	The volumetric approach is influenced by architectural intent, cultural representation, and environmental adaptation, contributing to the museum's visual identity.
6. Design Concepts	Museum designs balance cultural identity, innovation, and environmental adaptation. Architectural approaches often reinterpret traditional elements, emphasize movement and connectivity, or integrate natural and historical inspirations into modern forms.
7. Entrances	Entrances are designed to facilitate access and movement while reinforcing the architectural character. Some museums emphasize a singular grand entrance, while others incorporate multiple access points to manage visitor flow and improve functionality.
8. Circulation	Circulation strategies define how visitors navigate exhibition spaces. Some museums encourage free exploration, while others follow structured movement paths.
9. Spatial and Functional Organization	Museums balance exhibition areas with public and operational spaces. Layouts often separate permanent and temporary galleries while incorporating amenities like educational zones, cafés, and administrative areas. The organization adapts to architectural constraints and visitor needs.
10. Lighting Features	Lighting design combines natural and artificial sources to enhance visual experiences while preserving exhibits. Strategies include daylight modulation, shading systems, and controlled artificial lighting to create optimal ambiance and highlight architectural elements.

IV Site Analysis:

IV.1 The geographic location of Biskra city:

Biskra is a city in northeastern Algeria, located at the edge of the Sahara Desert with geographic coordinates of approximately 34.85°N latitude and 5.73°E longitude. Situated at an altitude of around 120 meters, it lies between the Aurès Mountains to the north and the vast Saharan plains to the south. It's about 399 km (248 miles) from Algiers, 114 km (71 miles) southwest of Batna, and 220 km (137 miles) north of Touggourt. Known as the "Gateway to the Sahara," Biskra blends Mediterranean and desert climates, making it a key transitional zone in the region.

IV.2 Site location:

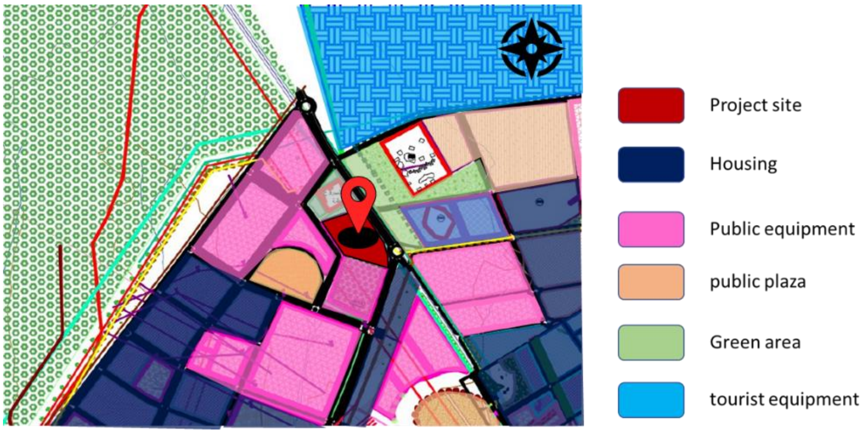
The project site is situated in the western expansion zone of Biskra, within what is considered the city's "new urban development area." It is located at the northern entrance of the city along the road to Batna, approximately 4,41 kilometers from the city center.

Its position ensures high accessibility and visibility, making it an ideal gateway for both local residents and visitors arriving from neighboring regions. The surrounding environment creates a vibrant and welcoming setting that enhances the museum's potential to serve as a cultural and social landmark.

IV.3 Motivation Behind the Choice:

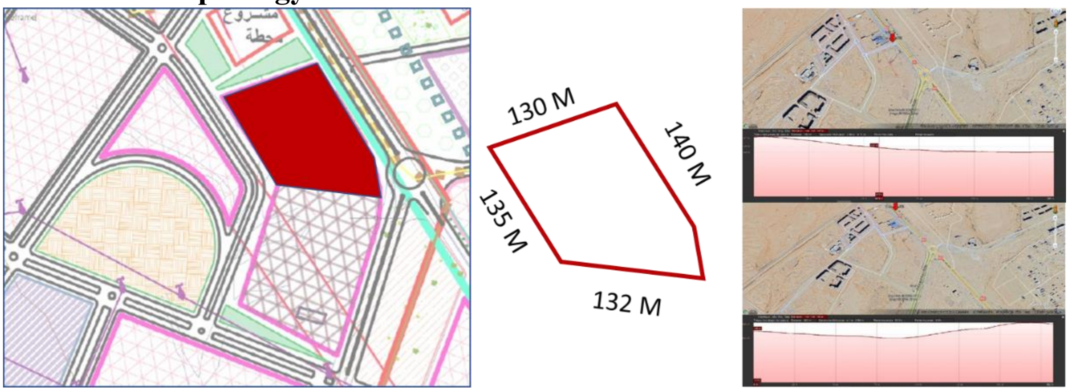
- Strategic Location: Positioned within a new urban development zone, the site offers strong potential for growth, innovation, and future opportunities.
- High Accessibility: Located at the northern gateway along the Batna road, the site ensures smooth circulation for pedestrians and vehicles, enhancing public reach and engagement.
- Active Environment: The mix of residential units and public spaces around the site fosters a dynamic urban environment conducive to cultural exchange and social interaction.
- Urban Integration: Close to housing and amenities, encouraging community interaction and visitor flow.

IV.4 Immediate environment:



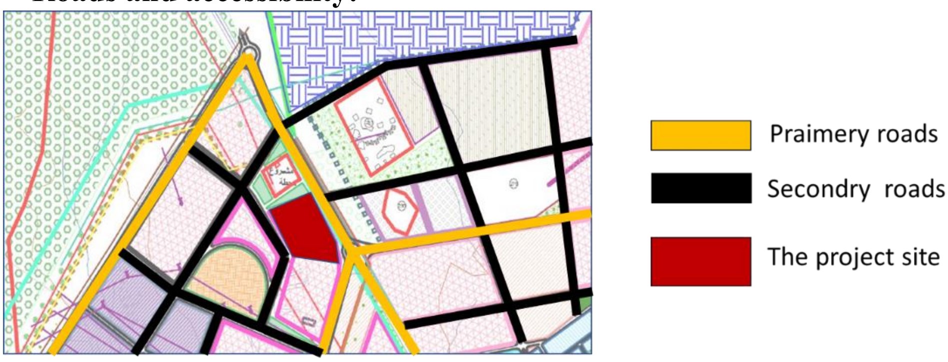
The museum is well-situated within a diverse and active urban setting, surrounded by residential neighborhoods, public infrastructure, green areas, and tourist amenities. This environment offers a balanced mix of functions, fostering both everyday accessibility for local residents and appeal to tourists.

IV.5 Site morphology:



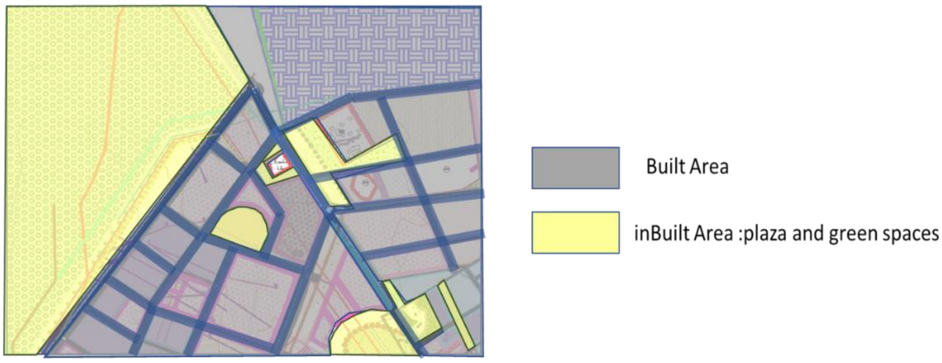
The site features a naturally flat terrain with a shape resembling an oblique trapezoid. This level topography significantly reduces the need for excavation, thereby simplifying construction and facilitating easier project implementation.

IV.6 Roads and accessibility:



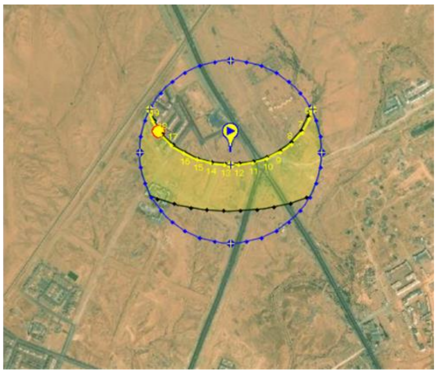
The site is well-integrated into the road network, with direct access to a major primary road that ensures high visibility and easy access for local and regional visitors. Secondary roads nearby enhance local circulation and offer alternative routes, facilitating smooth traffic flow and convenient access for visitors, service vehicles, and potential public transport.

IV.7 Built and inbuilt Area:



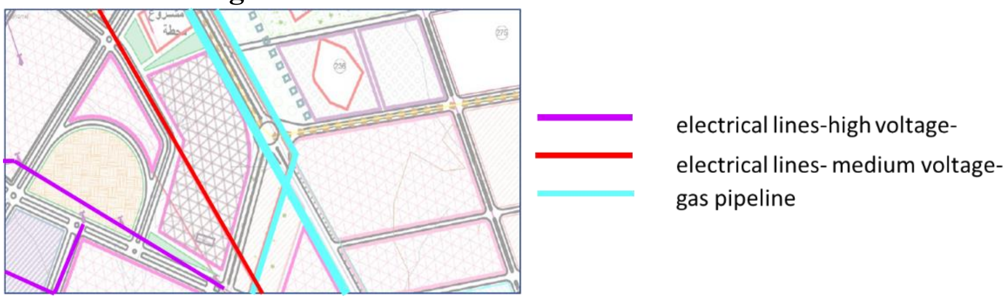
The study area shows a high building density, with 79% built and 21% inbuilt spaces, indicating a predominantly constructed environment where open spaces serve as supportive elements for public use.

IV.8 Orientation and sun path:



The site takes full advantage of winter sunlight by capturing low-angle rays from the south and west. In summer, the higher sun position ensures that the project receives light from all directions, enhancing natural illumination while allowing for effective solar control.

IV.9 Site Servicing Infrastructure:



The site benefits from essential infrastructure, as both the gas pipeline and the electrical lines—high and medium voltage—run along the peripheral area of the project site, ensuring ease of future service connections.

IV.10 site analysis synthesis:

IV.10.1 synthesis as SWOT points

Table 8:Site Analysis Synthesis as SWOT points

SWOT Category	Points
Strengths	- Strategic location in Biskra's western expansion zone within a new urban development area. - Direct access to a primary road and connection to secondary roads ensures excellent accessibility and visibility.

	- Proximity to housing, public, and tourist facilities enhances community integration. - Balanced surrounding environment with green spaces and public plazas. - Naturally flat terrain minimizes excavation and simplifies construction. - Winter sun exposure from the south and west enhances passive heating.
Weaknesses	- Summer exposure to sunlight from all directions can cause overheating if not properly shaded. - Exposure to southeastern winds in summer may lead to dust infiltration. - Lack of existing shade or natural barriers on east and west facades. - Potential heat gain due to semi-arid climate without sufficient passive cooling strategies.
Opportunities	- Potential to become a cultural anchor and catalyst for urban revitalization. - Integration of sustainable design strategies to enhance comfort and energy efficiency. - Outdoor spaces (plazas/green areas) can host public events, exhibitions, or educational activities. - Landscape design can enhance comfort and control dust and wind. - Public transport connectivity can further increase accessibility.
Threats	- Harsh summer climate may increase energy demand if passive strategies are not well implemented. - Windborne dust from southeastern winds may affect air quality and maintenance.

IV.10.2 Synthesis as schema:

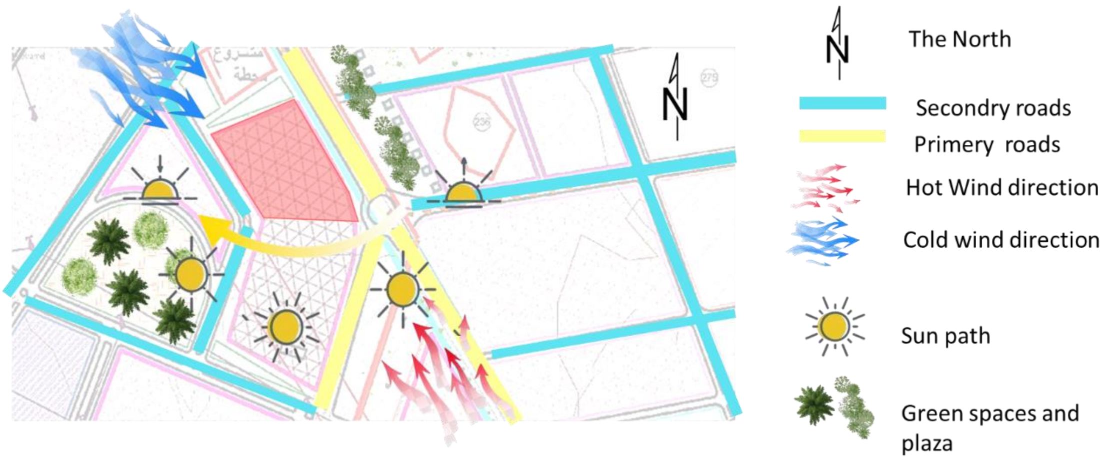


Figure 34:site analysis synthesis

Conclusion:

This chapter has explored the essential role of lighting-both natural and artificial-as a central component in museum architecture. Rather than serving merely as a functional necessity, lighting emerges as a medium through which spatial quality, visitor experience, and curatorial narrative are carefully crafted. Beginning with the fundamental principles of light. the chapter established the technical and perceptual basis for understanding how light influences architecture and museum experiences alike.

Museum architecture relies on the close integration of spatial design and functional planning. Circulation paths shape how visitors move and interact with exhibits, while zoning ensures a balance between exhibition areas and support functions like education, administration, and rest. Effective layouts prioritize flexibility, accessibility, and adaptability to diverse display needs. Spatial design is also closely linked to lighting strategies, where natural and artificial light are managed through architectural features to enhance both conservation and visitor experience. Together, these elements create a coherent, engaging, and purposeful museum environment.

In conclusion, museum lighting and spatial organization are co-dependent dimensions of design, each shaping and enhancing the effectiveness of the other. The successful integration of light into the architectural and functional framework contributes significantly to the visitor's sensory and intellectual engagement with the museum space. These findings reinforce the idea that designing a museum requires a holistic vision one that aligns lighting, spatial rhythm, and functional clarity with the cultural and emotional values that the institution seeks to embody.

Chapter III:

Architectural project

Introduction:

Drawing upon insights from the preceding theoretical and analytical chapters, the design employs a research-driven foundation—translating conceptual frameworks and contextual analyses into spatial and formal strategies. This grounding ensures that programmatic requirements and environmental imperatives are not only identified but systematically aligned with architectural form and experience.

This chapter explores two interrelated dimensions of the project: the proposed spatial program, which delineates the functional layout and area distribution, and the design development, which reveals how architectural form emerges in response to conceptual frameworks, contextual analyses, and environmental imperatives. Drawing on deconstructivism paradigms. The design synthesizes programmatic clarity, climatic responsiveness, and urban integration to support utility, environmental adaptation, and formal expression within an arid, hot climate.

I Programmatic Approach:

The surface program presented in this section is the result of a synthesis between two primary sources: the detailed analysis of several museum case studies, and the official spatial standards provided by the Ministry of Culture. By examining the functional distribution, spatial hierarchies, and surface allocations observed in real-world projects, and aligning them with regulatory requirements, this program aims to define clear and realistic surface areas for each function of the museum. The goal is to ensure both architectural coherence and operational efficiency, while also responding to the specific cultural and environmental context of the project.

Table 9: proposed program

Space	Surface(m²)
Exhibition	
Temporary exhibition	**520**
Special exhibition	**350**
Permanent exhibition	**3600**
▪ **Painting gallery**	**1000**
▪ **Sculpture gallery**	**1000**
▪ **New media art gallery**	**500**
▪ **Photography gallery**	**500**
▪ **Conceptual art gallery**	**600**
Education	
Library	
General reading room	**150**
Research reading room	**50**
Bookand periodical storage room	**70**
Archives and rare material room	**50**
Research work station /desks	**30**
Digital research area	**25**
Librarian/research staff office	**20**
Seminar room	**40**
Media booth room	**15**
Interactive media lab	**50**
Virtual reality experience room	**50**

Workshop /art studio	
Painting workshop	**150**
▪ The main space	100
▪ Materials storage	15
▪ Draying Area	10
▪ Wach room	10
▪ Technician office	15
Sculptor /clay workshop	**170**
Main space	120
Kiln room (fire)	10
Tool storage	15
Materials storage	15
Lockers room	10
Spatial needs sessions	**170**
▪ The main space	100
▪ Storage for sensory tools	20
▪ Wach room	20
▪ Waiting +reception zone	10
Community-based projects space	**180**
▪ The main space	150
▪ Storage room	10
▪ Mini office (coordinator)	10
▪ Kitchenette	10
Auditorium	
Main auditorium	300
Stage Area	40
Control room /AV booth	15
Back stage /wings	20
Storage room	20
Technical room	15
Children's zone	
Play area	150
Creative workshops	60
Storytelling room	25
Interactive exhibition room	150
Child WC (B/G)	10
Storage room	25
Children's rest room (naps room)	25
Changing room (babies)	20
Check-in zone (reception)	20
Parents waiting area (H/F)	20
Staff room (H/F)	20
Screening room	
Main space	250
Projection booth	15
Technical room	10
Equipment storage	10
Waiting area	25
Visitors services	
Main entrance lobby	450

Reception	**30**
Lokers (H/F)	**40**
Restrooms (H/F)	**50**
Museum shop	**160**
Prayer room (H/F)	**25**
Coffee and restaurant	
Customers hall	**130**
Bathrooms	**30**
Main dining area	**140**
Kitchen	**60**
Cold storage room	**10**
Dish washing area	**10**
Staff changing area	**10**
Dry storage	**10**
Wast disposal area	**5**
Administration section	
General management	
Museum's director's office	**25**
Secretariat	**15**
General administration office	**20**
Meeting room	**40**
Finance and legal	
Finance office	**20**
Grant office (sponsorship)	**15**
Legal affairs office	**15**
Curatorial	
Chief curator's office	**20**
Exhibition coordinator's	**15**
Human resource	
HR office	**15**
Public relations, communication and marketing	
Marketing office	**15**
Media relations office	**15**
Website and digital content office	**15**
Entertainment	
Staff break room	**30**
Lockers	**20**
Sanitary	**25**
Technical zone	
For art works	
Conservation lab	**80**
Art storage room	**150**
Secure art storage room	**80**
Building equipment	
IT digital infrastructure	**15**
Security management	**25**
Mechanical/Electrical room	**60**
Building maintenance	**25**
Cleaning depot	**10**
Changing room for T.Z staff	**15**

Total space	**9 535**
Circulation	
20 – 25 % of total built area	
Total space	**11 918,75**
Outdoor spaces	
Outdoor exhibition	
Entry spaces	
Parking	
▪ **Visitor parking**	
▪ **Staff parking**	
▪ **Bus parking (school visit)**	
▪ **Bike parking**	

II Conceptual Approach:

II.1 Idea:

The initial design concept is deeply rooted in the deconstructivism movement, which is characterized by fragmentation, non-linear geometries, and a deliberate subversion of traditional harmony and stability. Beginning with this theoretical foundation, the process articulated basic visual axes -viewing corridors aligned with adjacent roads- that define the optimal vantage points from which the museum will be perceived. These axes inform both the orientation and sculptural articulation of the form, ensuring that the architecture is seen in motion: as observers traverse the site, the museum dynamically reveals shifting profiles and forms. This strategic alignment fosters continuous perceptual engagement, embedding the museum within its urban context through a choreography of movement and sightlines.

II.2 The objectives and the intentions:

In response to an arid, hot climate, this project sets out to achieve the following interconnected objectives:

Table 10: The objectives and the intentions of the project

Objective	Intention
Integrate the project into its urban context	Align building massing and orientation with adjacent roads to enhance visual and contextual harmony, promoting seamless integration within the existing urban fabric
Embody Deconstructivism fragmentation	Incorporate fragmented, non-linear geometries to challenge traditional architectural norms and reinforce a dynamic aesthetic
Express "architecture seen in motion"	Design forms that reveal new spatial experiences through user movement, emphasizing the dynamic perception of architecture within its environment.
Ensure flexible interior circulation	Develop smooth junctions and adaptable pathways to facilitate intuitive spatial navigation and support varied visitor flows.
Incorporate traditional courtyard typology	Utilize a central courtyard not only as a cultural reference, but also as a strategy to mediate indoor and outdoor conditions
Maximize natural lighting and ventilation	Implement courtyard-based daylighting strategies and cross-ventilation techniques to enhance indoor comfort and minimize reliance on mechanical systems

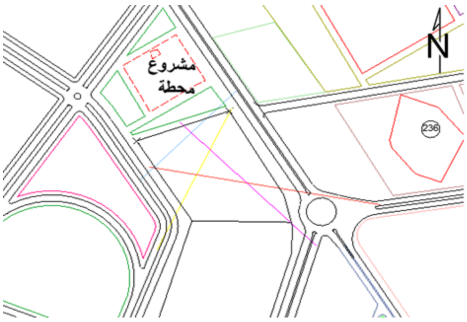
Promote environmental sustainability	Use passive design strategies—including orientation, shading devices, and courtyard microclimates—to reduce energy consumption and create a resilient, eco-friendly building

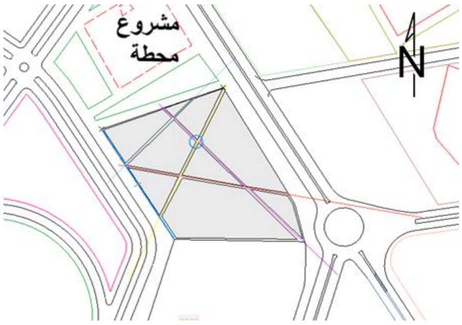
II.3 Morphological Progression:

This development sequence illustrates the architectural evolution of the museum, demonstrating how conceptual orientation and formal operations converge to shape a dynamic spatial experience. Each step integrates deconstructivism principles within the arid and hot context, while maintaining urban, functional, and experiential responsiveness.

step 1:

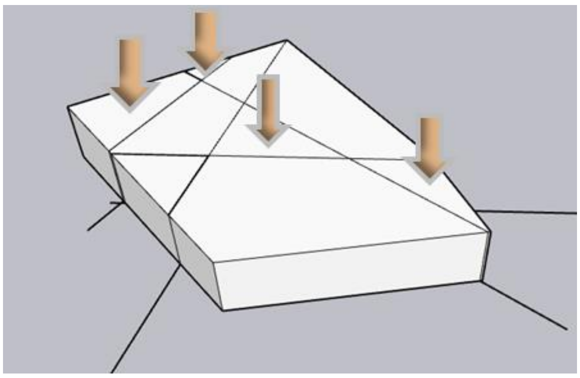
Context-driven orientation: The design begins by identifying prime viewing angles from adjacent roads and defining visual axes, which inform the fundamental organization of the building's form and orientation. This axis-based approach ensures that the evolving structure is perceptually integrated into its urban surroundings and dynamically experienced by moving observers.

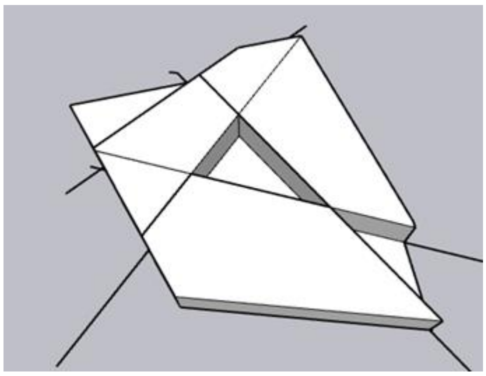




Step 2:

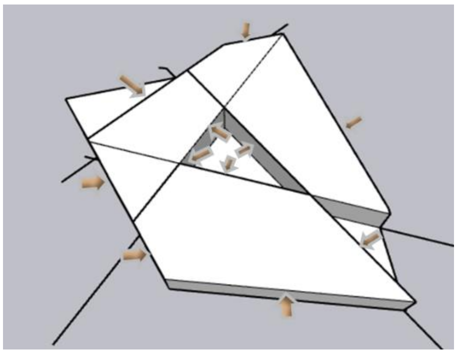
Carving the Mass (Le Vide sur le Plain): The primary architectural operation consists of subtracting volumes from the solid mass to manifest essential voids—namely, the main entrance, vehicular parking, and a central courtyard. This activation of voids not only organizes functional elements but also introduces a deconstructive interplay between mass and space, reinforcing the spatial hierarchy and daylight access.

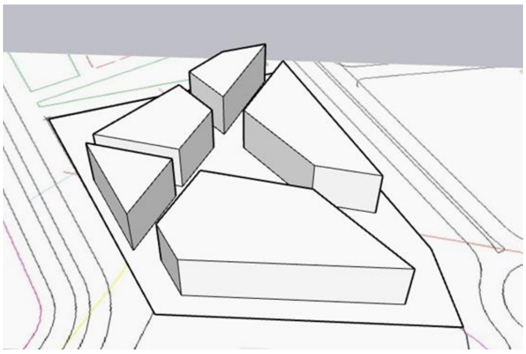




Step 3:

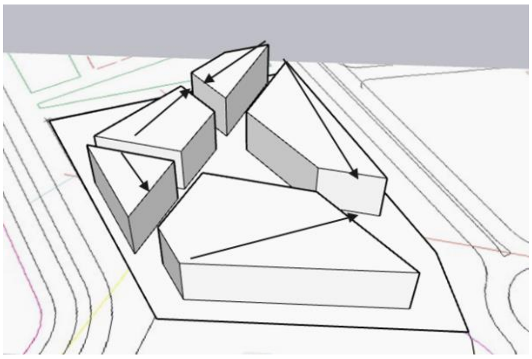
Volumetric Resizing and External Integration: Subsequent adjustments reshape the architectural volumes to accommodate exterior circulation networks and landscaped areas while aligning with established visual axes. This strategic resizing ensures visual permeability and contextual integration, allowing pedestrians and vehicles to engage with the building through defined visual corridors.

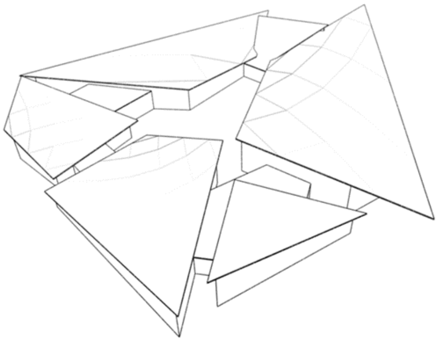




Step 4:

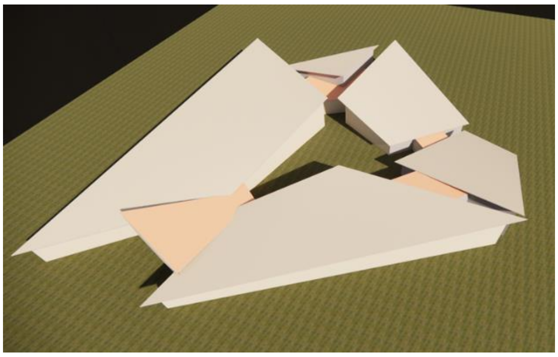
Roof Inclinations as Formal Dynamism: The introduction of inclined roof planes serves both aesthetic and environmental functions. Expressing "architecture seen in motion," tilted roofs dynamically articulate the museum's silhouette, refresh spatial perception, and aid passive climate control—facilitating daylight modulation, heat dissipation, and rainwater management.

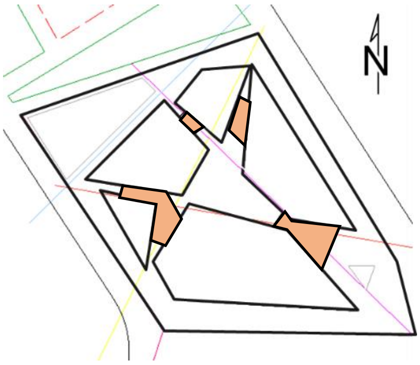




Step 5:

Linking Fragmented Volumes: Finally, the fragmented volumes are interconnected via smooth architectural junctions to generate coherent internal flow. These transitional spaces reconcile the external complexity with internal legibility, promoting circulation flexibility and enhancing visitor orientation within a rich spatial narrative.





Step 7:

Atrium Integration for Daylighting & Energy Efficiency: An atrium is introduced at the core of the essential mass to facilitate daylight penetration, passive ventilation, and a central spatial focus. Well-designed atria significantly reduce artificial lighting and cooling loads in warm climates, improving energy performance and occupant comfort

III Project presentation:

Figure 35: Master plan scale :1/200

Figure 36: ground floor Plan scale :1/100

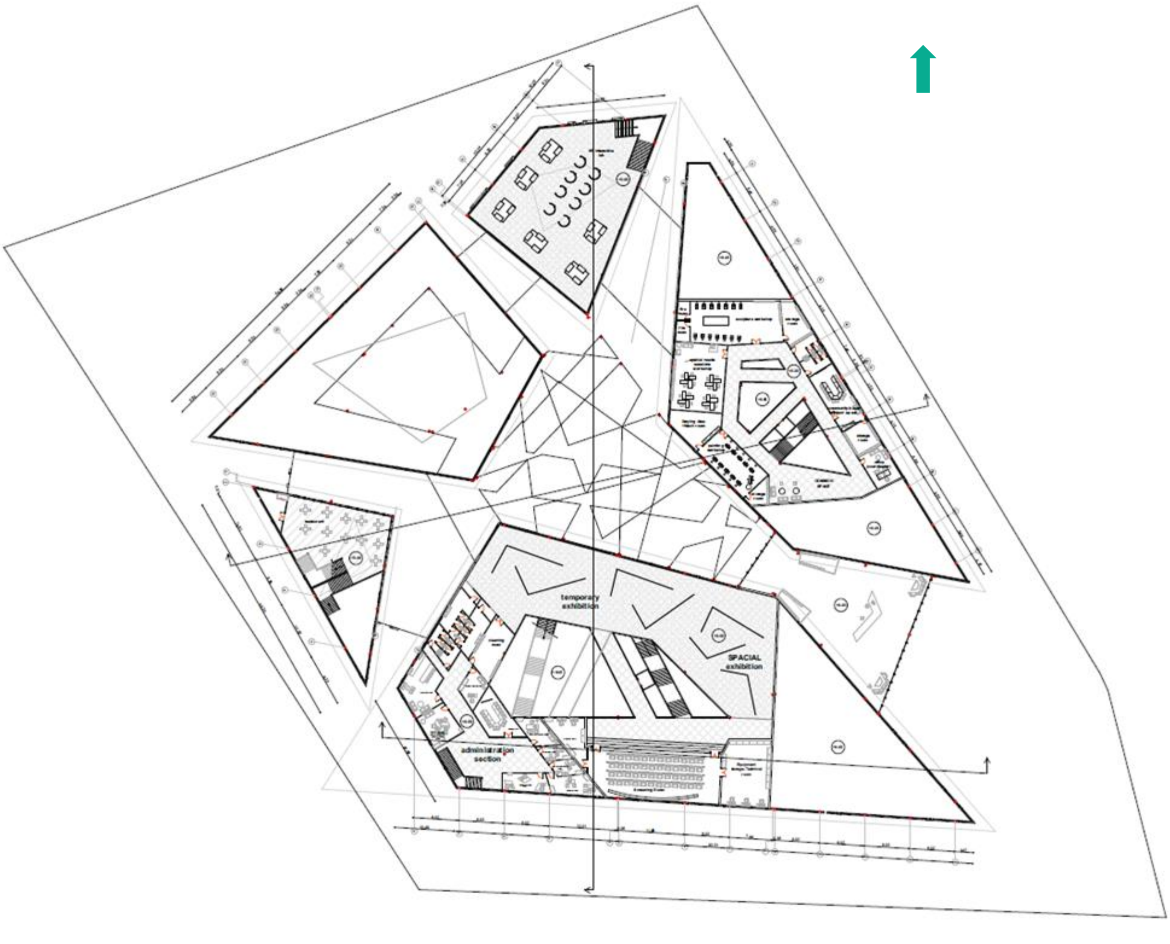


Figure 37: First floor Plan scale :1/100

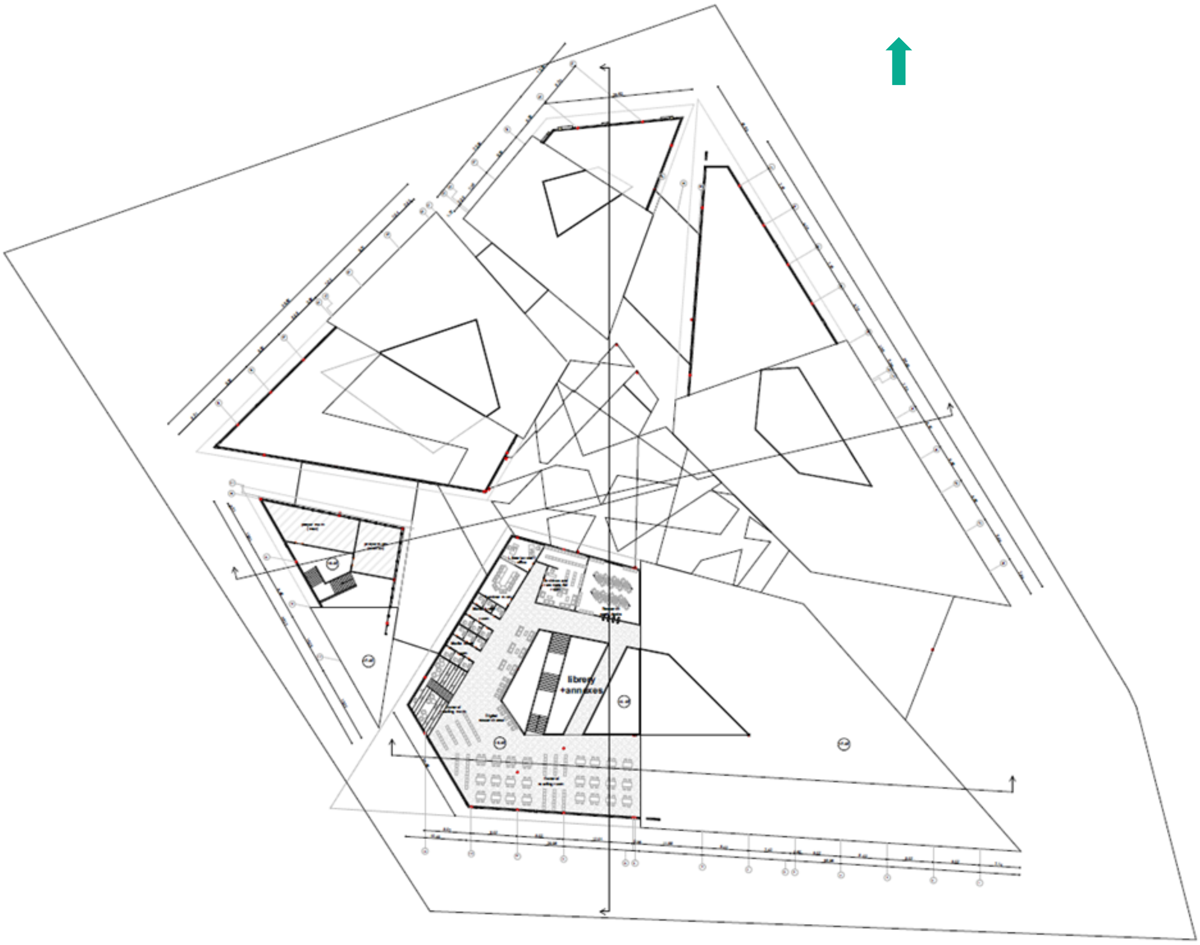


Figure 38: Second floor Plan scale :1/100

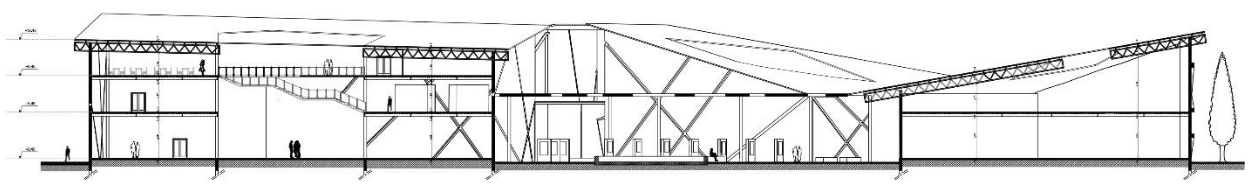


Figure 39: Section A-A scale : 1/100

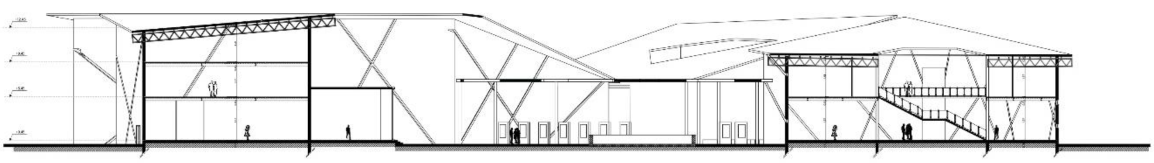


Figure 40: Section B-B scale : 1/100

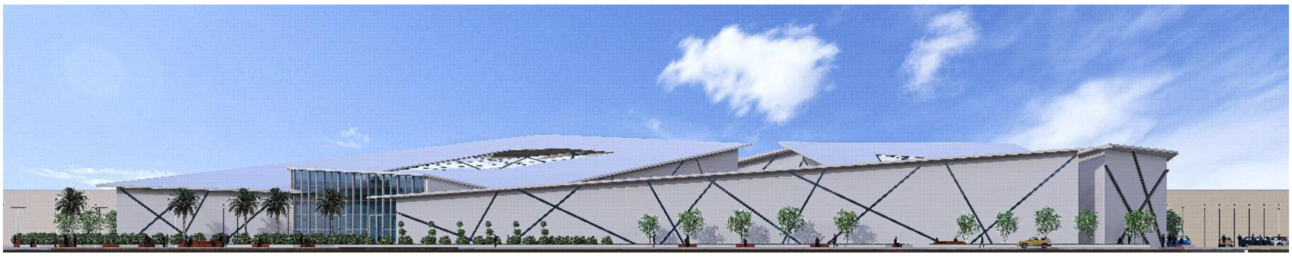


Figure 41: principale Façade scale :1/100

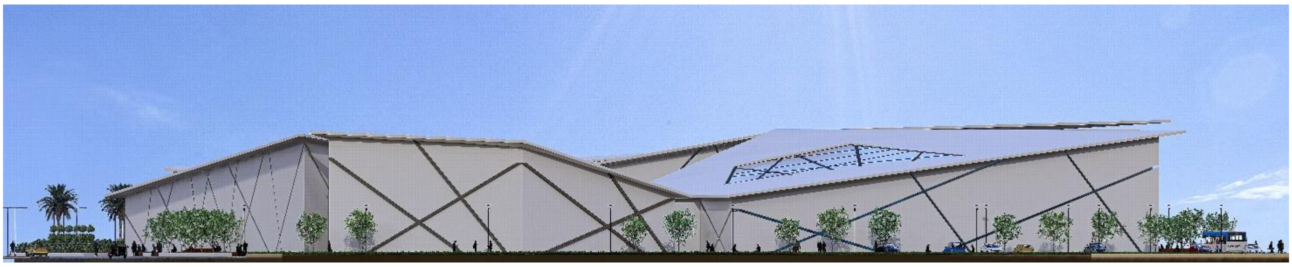


Figure 42: the North Facade scale : 1/100

Figure 43: the Ouest Facade scale : 1/100

Figure 44: The South Facade scale 1/100

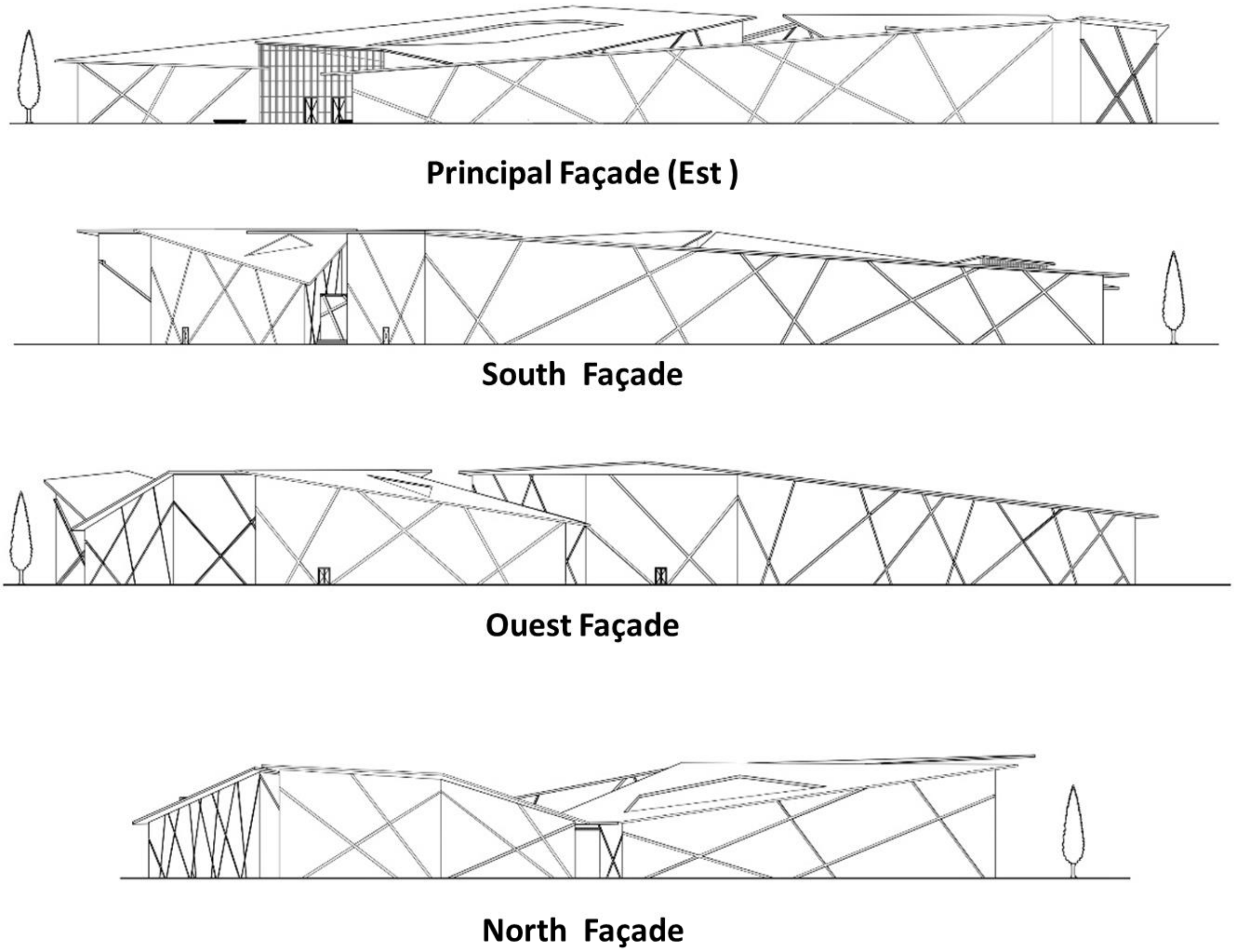


Figure 45: The Facades as technical drawing

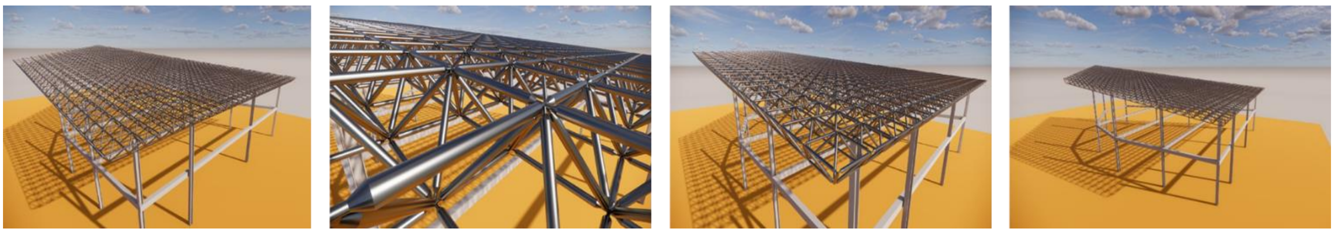


Figure 46:3D model of the structure

Figure 47: Exterior View of the project

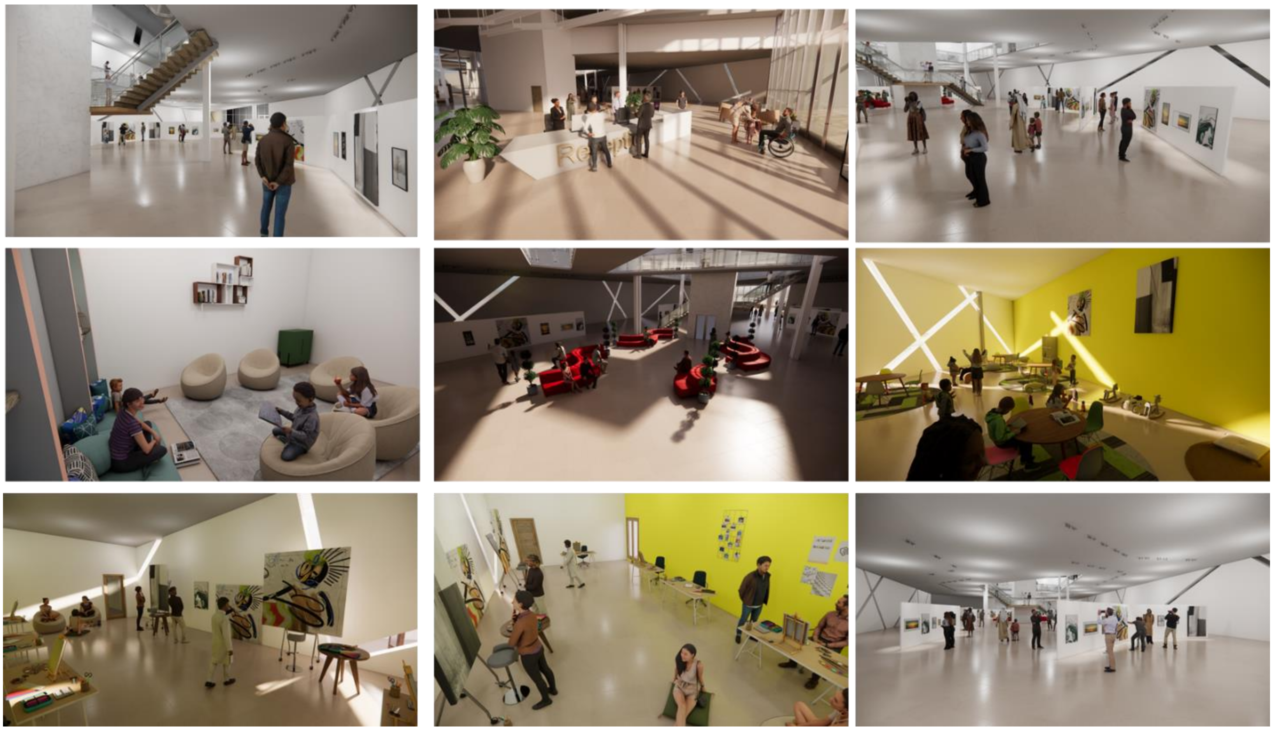


Figure 48: Interior View of the project

Chapter IV:

Practical application of the advanced shading device

Introduction:

This chapter presents the practical development of the Mira-Aura smart shading system, designed as an adaptive architectural solution for optimizing daylight and thermal comfort in hot and arid climates. It begins by outlining the main objectives of the system. The chapter then provides a detailed overview of the system, explaining its logic and how it functions in real-time by reacting to environmental conditions. Each element of the system is examined in detail, including the main components and their respective functions, which together enable the shading device to operate autonomously. Furthermore, the materials selected for fabrication are justified based on their mechanical performance, thermal behavior, and durability in extreme climates. Finally, the chapter explores the motor and actuation system, including torque calculations and mechanical integration strategies that allow the kinetic units to move smoothly and efficiently.

I Context and Motivation:

In regions with hot and arid climates—such as Biskra, Algeria—buildings are constantly challenged by intense solar radiation, high temperatures, and glaring daylight. These environmental conditions often result in uncomfortable indoor environments and excessive energy consumption due to the overuse of artificial lighting and mechanical cooling systems. As contemporary architecture moves toward sustainable and climate-adaptive solutions, there is a growing need for responsive systems that can intelligently manage light, heat, and comfort. The development of the smart shading device emerges from this context, offering a kinetic, sensor-driven facade system that responds in real time to environmental conditions.

II The objectives:

Key Objectives of the system in Hot and Arid Climates:

- Reduce solar heat gain to improve indoor thermal comfort and lower cooling demand.
- Enhance daylighting by allowing natural light without causing glare.
- Adapt dynamically to sunlight conditions throughout the day.
- Reduce energy consumption by minimizing the need for artificial lighting and air conditioning.
- Support sustainable and climate-responsive design tailored for extreme sun and heat.

III System overview:

The **kinatic** façade is a responsive shading system composed of **origami-inspired units** that open and fold depending on the intensity of solar radiation or the interior daylighting needs. The goal of the system is to provide **intelligent environmental response**, where the units move automatically according to exterior lighting conditions.

III.1 Basic Unit Specifications

- Each **main unit** is composed of **4 sub-units**.
- **Dimensions of each sub-unit**: 60 cm × 60 cm
- **Total area of the main unit**: 1.44 m²
- **Material**: Lightweight aluminum, coated with a **ceramic paint** for thermal insulation and weather resistance.

- **Approximate weight per main unit**: 5–6 kg

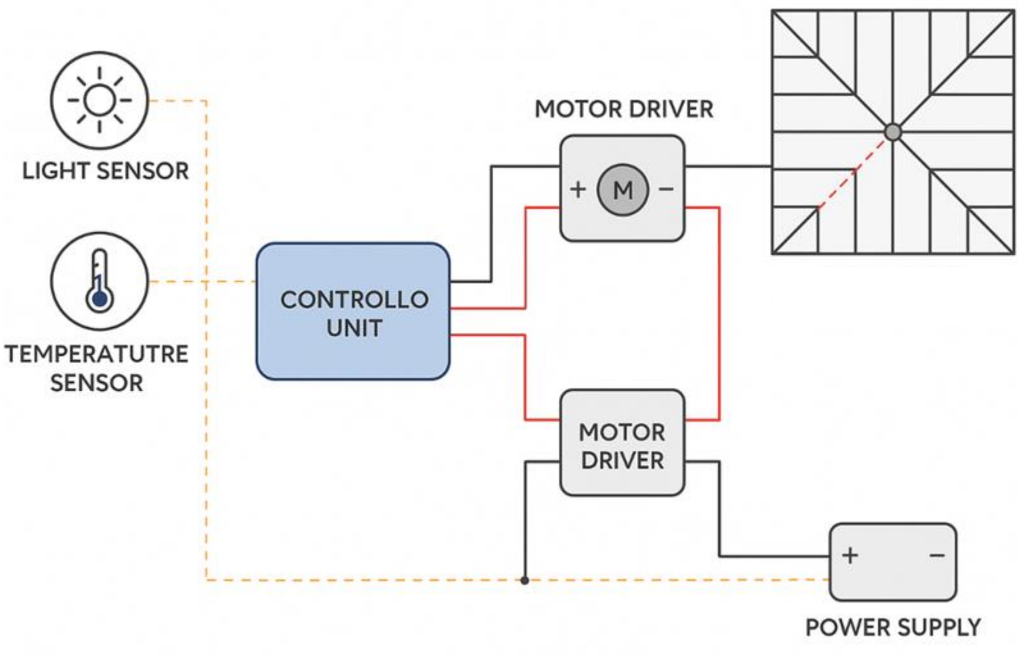
III.2 Movement Modes:

- **Fully folded**: When solar radiation is low.
- **Partially opened**: When sunlight is moderate or indirect.
- **Fully opened**: When direct solar radiation exceeds a certain threshold.

This movement requires a **precise motor** capable of adjusting the origami units based on light and heat sensors.

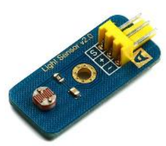
IV How the system work

1. **Light Sensor**
   The light sensor detects the intensity of sunlight on the façade. It sends real-time data to the control unit, allowing the system to respond dynamically by adjusting the shading level based on natural lighting conditions.
2. **Temperature Sensor**
   This sensor monitors ambient or surface temperature to help optimize thermal comfort. The data it collects supports decisions on whether to open or close the shading units to reduce overheating or allow passive heat gain.
3. **Control Unit**
   The control unit such as an Arduino act as the brain of the system. It receives inputs from the sensors, processes them using programmed logic, and sends the appropriate signals to the motor driver to control the movement of the shading device.
4. **Motor Driver**
   The motor driver serves as a power amplifier between the control unit and the motor. It translates low-voltage signals from the controller into higher-power outputs that are capable of running the motor in both directions.
5. **Motor**
   The motor is responsible for the physical movement of the shading device. It operates based on commands from the motor driver and moves the units to either open, close, or partially adjust their position.
6. **Power Supply**
   The power supply provides the necessary energy to run the entire system. It powers both the motor and control electronics and can be connected to a DC source, battery, or even a solar energy system.
7. **Shading Device**
   This is the kinetic element of the façade. Driven by the motor, it opens, folds, or partially adjusts based on sensor inputs and control logic, allowing the system to adapt to daylight and thermal needs throughout the day.



V System components and their function:

Table 11: System components and their function

Component		**Function**
Light Sensor		Measures sunlight intensity to trigger shading adjustments.
Temperature Sensor		Monitors ambient or surface temperature to support thermal response.
Control Unit(Arduino)		Processes sensor data and controls the motor accordingly.
Motor Driver		Acts as an interface between the control unit and the motor; amplifies signals.
DC Motor		Drives the mechanical movement to fold or unfold the shading units.
Power Supply		Provides electricity to the motor, sensors, and control unit.

VI Fabricated materials:

To fabricate this smart shading system, I chose aluminum coated with ceramic materials due to their complementary properties. This combination offers the structural lightness and flexibility needed for kinetic movement, along with the durability, thermal protection, and low maintenance required for long-term performance in a hot and arid climate. Together, these materials ensure that the system is both functional and resilient under extreme environmental conditions.

Justification:

- **Aluminum**: Aluminum is a lightweight, corrosion-resistant, and easily formable material—ideal for foldable kinetic shading units. Its good thermal conductivity helps dissipate heat, making it suitable for hot environments. However, to reduce overheating under direct sun, it is combined with an insulating surface treatment.
- **Ceramic Coating on Aluminum**: The ceramic coating acts as a thermal barrier, reducing heat transfer and preventing the aluminum from overheating. It also enhances resistance to corrosion, wear, and UV exposure, extending the unit's lifespan. This coating adds surface hardness and durability, especially important in dusty, high-stress environments like arid regions. Moreover, it requires minimal maintenance and offers long-term performance (10–20 years), supporting the sustainability of the system.

VII Motors and driven system:

VII.1 Torque Calculation for the Motor:

To calculate the torque required to operate one main unit:

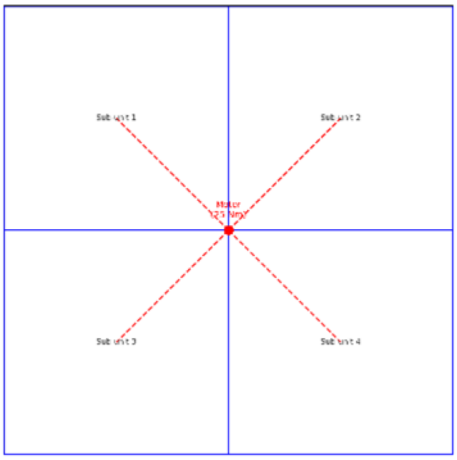
- **Force due to weight** = 6 kg × 9.81 = 58.86 N
- **Distance from pivot point** ≈ 0.3 m
- **Required torque** = 58.86 × 0.3 = **17.65 Nm**
- Adding a **safety margin (40%)**, the final required torque ≈ **25 Nm**

VII.2 Motor Specifications:

Table 12: Motor Specifications

Specification	Value
Motor type	DC Gear Motor or High-Torque Servo Motor
Required torque	25–30 Newton meters
Voltage	24V or 48V (compatible with solar power systems)
Speed	6–10 RPM (rotations per minute)
Power	Between 100 to 150 watts
Control system	Arduino or PLC unit
sensors	Light sensor, temperature sensor,
Mounting position	Inside the frame or directly behind the unit

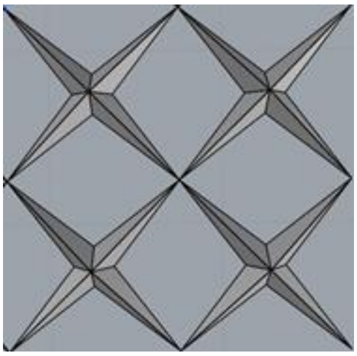
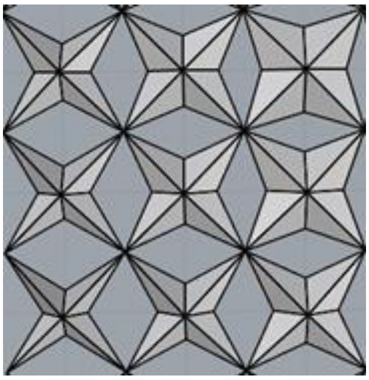
- The **4 sub-units** of each main unit can be driven by **a single motor**, connected using a unified mechanical linkage.



VIII System Operations Modes:

The advanced shading device operates through three main configurations - fully open, intermediate, and fully closed -which dynamically adjust according to solar radiation, daylight levels, and glare probability. Each state represents a specific level of openness or angular position of the shading elements, defined by measurable physical parameters.

Table 13: System Operations Modes

Mode	Description	Measurement criteria	Illustration
Fully Open Mode (100% openness)	In this position, the shading panels are completely retracted or tilted to their maximum open angle, allowing the highest possible penetration of daylight into the interior space. This mode is typically activated under low solar radiation or overcast sky conditions, when additional daylight is required to maintain visual comfort and reduce dependence on artificial lighting.	Horizontal illuminance < 250 lux Daylight glare probability (DGP) < 0.30. Vertical irradiance < 150 W/m² (no direct sunlight incidence).	
Intermediate Mode (Partial openness: 25–75%)	The system operates in an intermediate or adaptive position when daylight levels are sufficient, but there is a potential risk of glare or overheating.In this configuration, the shading elements adjust their angle or openness to balance daylight autonomy and visual comfort, while maintaining outward visibility and aesthetic coherence of the façade.This mode represents the most frequently active state during the day, as it enables the system to optimize	250 ≤ Horizontal illuminance ≤ 500 lux. DGP between 0.30–0.38. Vertical irradiance between 150–300 W/m².	

	natural lighting while controlling glare dynamically.		
Fully Closed Mode (0% openness)	In this position, the shading components completely block direct solar radiation. This mode is activated when excessive glare, overheating, or direct sunlight on sensitive artworks is detected — especially in exhibition zones.By minimizing transmittance, this configuration ensures the protection of interior spaces and maintains a uniform light distribution suitable for museum environments.	DGP ≥ 0.38 or direct sunlight detected on display surfaces. Vertical irradiance > 300 W/m². Internal illuminance > 600 lux (risk of visual discomfort).	

IX Performance Evaluation through Simulation:

In order to evaluate the environmental and visual performance of the proposed dynamic shading system, a series of digital simulations were conducted focusing on daylighting quality, glare control, and solar radiation. **The purpose of this simulation process was to analyze how the system influences the distribution, intensity, and usability of natural light within the exhibition spaces of the art museum located in Biskra**, characterized by a hot and arid climate with high solar exposure. These simulations provided a quantitative and visual understanding of how the proposed façade design performs under real climatic conditions.

IX.1 Simulation Software and Workflow:

The simulation process was carried out using **Rhinoceros 3D** (Rhino 8) and **Grasshopper**, in combination with the **Ladybug Tools** suite, specifically the **Ladybug** and **Honeybee** plugins.

The three-dimensional model was first developed in **Rhino**, including the architectural form, openings. After completing the 3D base geometry, the dynamic shading system was created and integrated parametrically using **Grasshopper**, which allowed for flexible control of the system's geometry, movement logic, and positioning on the façade.

Through Grasshopper's visual programming environment, the model was connected to the **Ladybug Tools** components to enable simulation inputs and data visualization.

- **Ladybug** was used to process the climatic data (EPW file of Biskra, Algeria) and to generate essential information such as solar paths, radiation analysis, and sky conditions.
- **Honeybee** served as the main engine for daylight and glare simulations, linking the parametric model to the **Radiance** back-end engines.
- **The Radiance engine**, developed by Greg Ward, is a validated, physically based lighting simulation software widely recognized for its accuracy in predicting illuminance, luminance, and visual comfort parameters in architectural spaces.

This integrated workflow made it possible to conduct parametric, climate-responsive, and performance-driven simulations, providing a comprehensive evaluation of the façade's behavior in terms of daylight distribution, glare control, and solar exposure.

IX.2 Simulation Setup and Methodology:

Several simulation types were conducted to comprehensively assess the system's performance. The main parameters and metrics include:

Useful Daylight Illuminance (UDI): evaluates the percentage of annual occupied hours during which indoor illuminance levels fall within the optimal range of 100-2000 lux.

- Objective: Assess visual comfort and daylight usability.
- Units: % of occupied hours.

Daylight Autonomy (DA): measures the percentage of occupied hours during which a given point achieves the target illuminance level (typically ≥ 300 lux) using only natural light.

- Objective: Determine the extent of daylight availability and potential reduction in artificial lighting demand.
- Units: % of occupied hours.

Glare Autonomy (GA): indicates the percentage of hours free from glare, based on the Daylight Glare Probability (DGP) threshold (DGP < 0.35).

- Objective: Evaluate visual comfort and glare prevention.
- Units: % of occupied hours.

Annual Irradiance: represents the cumulative solar energy received on a given surface throughout the year, measured in kWh/m².

- Objective: Assess solar exposure, overheating risk, and shading effectiveness.
- Units: kWh/m² per year.

For all simulations:

- Weather file: EPW of Biskra, Algeria.
- Run period: Full annual cycle (January 1st – December 31st).
- Sky model: CIE standard sky conditions.
- Grid size: 0.5 m spacing.
- Time step: Hourly.
- Occupancy period: Typical museum hours (08:00–18:00).

Two main configurations were simulated and compared:

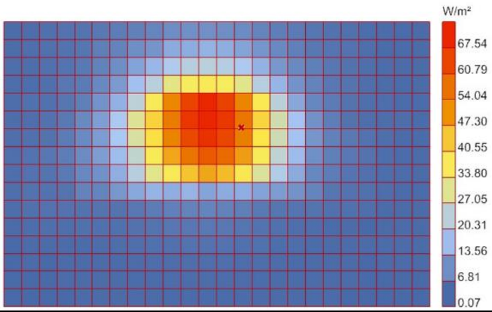
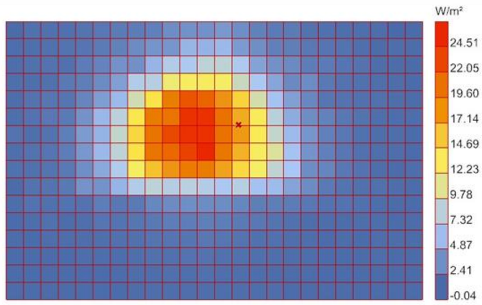
Scenario 1: System deactivated (baseline façade).

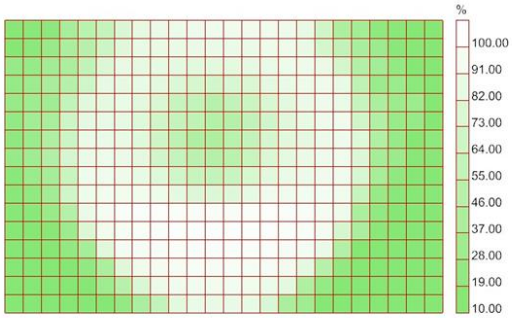
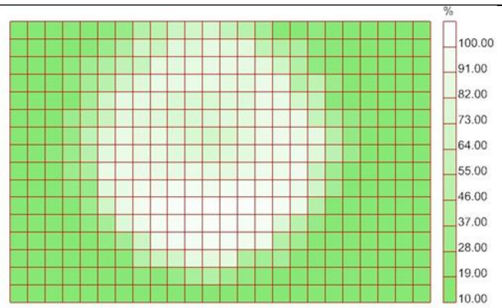
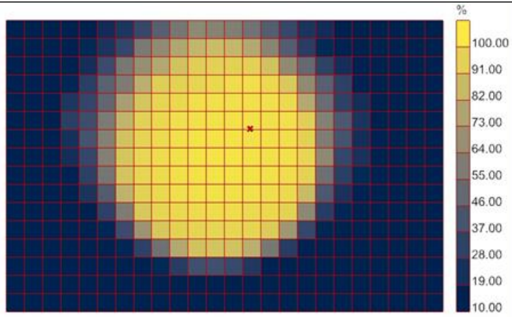
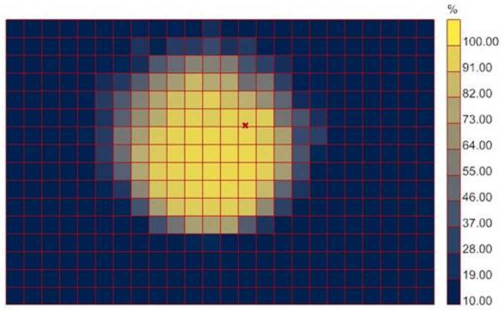
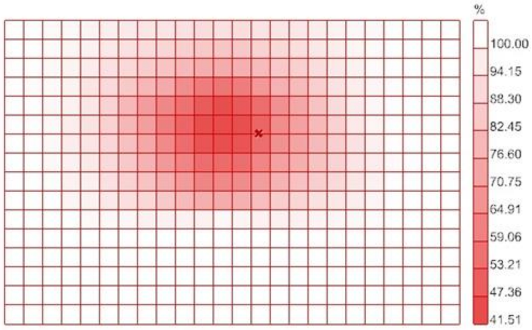
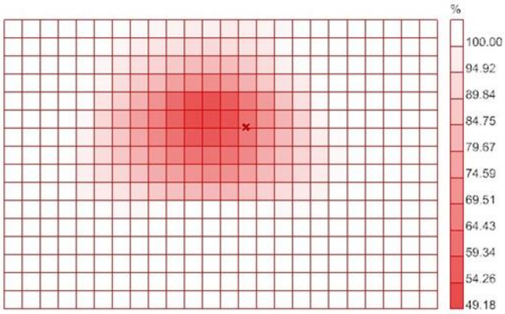
Scenario 2: System activated (dynamic shading panels in operation).

IX.3 Simulation Results and Discussion:

IX.3.1 Simulation results:

Table 14:Simulation results

	without the shading system	with the shading system
Annual Irradiance		

Useful Daylight Illuminance (UDI)		
Daylight Autonomy (DA)		
Glare Autonomy (GA)		

IX.3.2 Discussion of Results:

1. Irradiance Distribution

In the case without the shading system, the results indicated a high average irradiance on the façade and interior sensor grids, reflecting strong exposure to direct solar radiation. This excessive solar gain can lead to visual discomfort and increased cooling loads, particularly in a hot climate such as Biskra.

Conversely, with the shading system activated, a noticeable reduction in irradiance was observed. The adaptive panels effectively filtered and redirected incoming sunlight, preventing overexposure while still allowing diffuse daylight to penetrate the space. This reduction demonstrates the system's capability to regulate solar energy input, enhancing both thermal and visual comfort.

2. Useful Daylight Illuminance (UDI)

The UDI analysis further confirmed the improvement in daylight quality after implementing the shading device.

When the system was deactivated, the results showed a high concentration of UDI values near the façade (ranging around 55–91%), with a decline toward the rear zones due to uneven daylight distribution. In contrast, with the shading system active, the UDI values became more balanced across the interior. The majority of the space achieved illuminance levels within the 100–2000 lux range, which is optimal for exhibition spaces, ensuring adequate visibility while avoiding damage to sensitive artworks from excessive light exposure.

3. Daylight Autonomy (DA)

The DA results also reflected a positive trend with the system's operation. Without shading, high DA values near openings indicated excessive daylight penetration, while deeper areas received insufficient illumination. When the system was active, DA values remained high but more uniformly distributed, meaning that a greater portion of the occupied area maintained sufficient daylight for a longer period throughout the year. This indicates enhanced daylight availability and a potential reduction in artificial lighting dependency.

4. Glare Autonomy (GA)

Regarding glare performance, the GA results (percentage of hours free from glare) significantly improved when the shading system was activated. In the unshaded case, several zones near the opening experienced discomfort due to high luminance contrast and direct sun penetration. With the system engaged, the Glare Autonomy increased, showing that the adaptive façade successfully mitigated excessive brightness and improved visual comfort for users.

Overall Evaluation

Collectively, these results validate the effectiveness of the proposed dynamic shading system in enhancing the daylighting performance. The system maintains high daylight autonomy while minimizing glare and solar irradiance, achieving a balanced interior light environment suitable for visitors. The comparative analysis clearly demonstrates that the integration of such a responsive façade contributes to energy efficiency, visual comfort, and sustainable design objectives in hot, arid climates such as that of Biskra.

General conclusion

General conclusion:

This thesis explored the intersection of architectural design, environmental adaptability, and technological innovation through the development of a dynamic smart shading system for an art museum in Biskra's hot and arid climate. It aimed to demonstrate how architecture can move beyond static form to become an active mediator between light, climate, and human experience. The study addressed the dual challenge of ensuring optimal daylighting quality (essential for art exhibition environments) while maintaining visual comfort and energy efficiency in a region characterized by intense solar radiation.

The research was structured across four main chapters, each contributing to the overall objective of creating a responsive architectural façade capable of adapting to environmental variations in real time.

The first chapter, the Theoretical Framework, laid the foundation for understanding kinetic architecture and advanced shading devices. It explored their evolution, typologies, control systems, and integration with smart materials and parametric design. Through an in-depth literature review, this chapter emphasized that dynamic façades (when equipped with feedback-based control mechanisms) play a decisive role in improving building performance. It concluded that the future of sustainable design lies in responsive and interactive architecture that not only reacts to but anticipates environmental changes, thereby ensuring user comfort and energy optimization.

The second chapter, the Analytical Study, focused on the role of daylighting in museums and examined the intricate balance between light, space, and conservation. Through analysis of international case studies - such as the Louvre Abu Dhabi, Milwaukee Art Museum, and MAMA Algiers -the chapter identified successful design strategies that harmonize natural and artificial lighting to enhance both spatial quality and exhibit preservation. The site analysis of Biskra further defined the local climatic, geographic, and environmental constraints that guided the design. The chapter concluded that museum architecture must integrate environmental logic with cultural and spatial identity, ensuring that light acts as a medium for both experience and preservation.

The third chapter, the Architectural Development, translated the theoretical and analytical findings into a coherent architectural proposal. Grounded in deconstructivism principles, the design synthesized form, function, and environmental responsiveness to produce a museum that is both expressive and performative. The spatial program was developed through a synthesis of functional requirements, regulatory standards, and climatic imperatives, while the conceptual approach emphasized the dynamic interaction between form and environment. This chapter concluded that the architectural envelope must not be a passive boundary but an intelligent interface-one that shapes the building's identity while responding to its environmental context.

The fourth and final chapter, the Practical and Experimental Phase, presented the design, configuration, and simulation testing of the proposed dynamic shading system. Developed using Rhino and Grasshopper, and evaluated through Ladybug and Honeybee simulations, the system demonstrated a marked improvement in daylight autonomy, useful daylight illuminance, and glare control. The simulation results validated the research hypothesis, proving that a well-designed adaptive façade can significantly enhance visual comfort, reduce solar heat gain, and optimize daylight distribution, thus minimizing dependence on artificial lighting and cooling loads. The chapter concluded that integrating smart materials and responsive mechanisms offers a sustainable and context-sensitive solution for museum design in hot climates.

In summary, this thesis reaffirmed that the integration of kinetic architecture and advanced shading technologies is not merely a technical exercise but a profound shift in architectural thinking. It promotes a design paradigm where buildings evolve with their environment balancing aesthetics, performance, and user well-being. The proposed system not only enriches the architectural character of the museum but also demonstrates how responsive façades can reconcile artistic expression with environmental stewardship.

Future research could expand this work through real-scale prototyping, sensor-based optimization, or integration with renewable energy systems to further enhance the autonomy and intelligence of adaptive façades. Ultimately, the findings of this thesis contribute to the broader discourse on climate-responsive architecture, offering a replicable model for designing sustainable cultural spaces in hot and arid regions like Biskra.

Bibliography

Bibiliography

Achten, Henri, T Zumancic, and Dana Matějovská. 2011. "Degrees of Interaction." In , 565–72.

Al-Masrani, Salwa M, and Karam M Al-Obaidi. 2019. "Dynamic Shading Systems: A Review of Design Parameters, Platforms and Evaluation Strategies." *Automation in Construction* 102:195–216.

Al-Yasiri, Qudama, and Márta Szabó. 2021. "A Short Review on Passive Strategies Applied to Minimise the Building Cooling Loads in Hot Locations." *Analecta Technica Szegedinensia* 15 (2): 20–30. https://doi.org/10.14232/analecta.2021.2.20-30.

Choi, Ho Soon. 2023. "Kinetic Photovoltaic Facade System Based on a Parametric Design for Application in Signal Box Buildings in Switzerland." *Applied Sciences* 13 (7): 4633. https://doi.org/10.3390/app13074633.

Choudhury, Asim Kumar Roy. 2014. "Characteristics of Light Sources." In *Principles of Colour and Appearance Measurement*, 1–52. Elsevier. https://doi.org/10.1533/9780857099242.1.

Costa, João Francisco Walter, Faculty of Architecture and Urbanism, University of Brasilia, Darcy Ribeiro Campus, Ala Norte, Brasilia, DF, Brazil, Cláudia Naves David Amorim, Faculty of Architecture and Urbanism, University of Brasilia, Darcy Ribeiro Campus, Ala Norte, Brasilia, DF, Brazil, Joara Cronemberger Ribeiro Silva, and Faculty of Architecture and Urbanism, University of Brasilia, Darcy Ribeiro Campus, Ala Norte, Brasilia, DF, Brazil. 2024. "Electrochromic Glazing and Evaluation of Visual and Non-Visual Effects of Daylight: Simulation Studies for Brasilia – Brazil." *Journal of Daylighting* 11 (1): 1–22. https://doi.org/10.15627/jd.2024.1.

DAICH, SAFA. 2011. "Simulation et Optimisation Du Système Light Shelf Sous Des Conditions Climatiques Spécifiques, Cas de La Ville de Biskra."

Dev, Govind, Aysha Saifudeen, and Aparna Sathish. 2021. "Facade Control Systems for Optimal Daylighting: A Case of Kerala." In , 850:012014. IOP Publishing.

Elghazi, Yomna, Ayman Wagdy, and Sahar Abdalwahab. 2015. "Simulation Driven Design for Kinetic System; Optimize Kaleidocycle Façade Configuration for Daylighting Adequacy in Hot Arid Climates." In , 182–89. IBPSA-International Building Performance Simulation Association.

Elkhayat, Youssef Osama. 2014. "Interactive Movement in Kinetic Architecture." *JES. Journal of Engineering Sciences* 42 (3): 816–45.

Elmokadem, Ashraf, Magda Ekram, Ahmed Waseef, and Basma Nashaat. 2018. "Kinetic Architecture: Concepts, History and Applications." *International Journal of Science and Research (IJSR)* 7 (4): 750–58. https://doi.org/10.21275/ART20181560.

Fouad, SMAE. 2012. "Design Methodology: Kinetic Architecture." *Architectural Engineering, Alexandria University*.

Fox, Michael A, and Bryant P Yeh. 2000. "Intelligent Kinetic Systems in Architecture." In , 91–103. Springer.

Freewan, Ahmed A.Y. 2014. "Impact of External Shading Devices on Thermal and Daylighting Performance of Offices in Hot Climate Regions." *Solar Energy* 102 (April):14–30. https://doi.org/10.1016/j.solener.2014.01.009.

Freewan, Ahmed AY. 2014. "Impact of External Shading Devices on Thermal and Daylighting Performance of Offices in Hot Climate Regions." *Solar Energy* 102:14–30.

Hans, O. 2006. "Static Shading Devices in Office Architecture." *Theory, Shape and Potentialm (MSc Thesis), Bergische Universität Wuppertal*.

Harrison, Laurence S. 1961. "EVALUATION OF SPECTRAL RADIATION HAZARDS IN WINDOW-LIGHTED GALLERIES." *Studies in Conservation* 6 (sup1): 1–6. https://doi.org/10.1179/sic.1961.s004.

Hlaing, Thet Su, and Shoichi Kojima. 2022. "Comparative Study on Performance of Wind-Catcher Shading Device and Other Types of Shading Device on Residential Houses in Tropics." *International Journal of Sustainable Development & Planning* 17 (6).

Hosseini, Seyed Morteza, Masi Mohammadi, and Olivia Guerra-Santin. 2019. "Interactive Kinetic Façade: Improving Visual Comfort Based on Dynamic Daylight and Occupant's Positions by 2D and 3D Shape Changes." *Building and Environment* 165 (November):106396. https://doi.org/10.1016/j.buildenv.2019.106396.

Hosseini, Seyed Morteza, Masi Mohammadi, Torsten Schröder, and Olivia Guerra-Santin. 2020. "Integrating Interactive Kinetic Façade Design with Colored Glass to Improve Daylight Performance Based on Occupants' Position." *Journal of Building Engineering* 31 (September):101404. https://doi.org/10.1016/j.jobe.2020.101404.

Hosseini, Seyed Morteza, Smart Architectural Technologies, Department of the Built Environment, Eindhoven University of Technology, Netherlands, Fodil Fadli, Department of Architecture and Urban Planning, College of Engineering, Qatar University, Doha 2713, Qatar, Masi Mohammadi, and Smart Architectural Technologies, Department of the Built Environment, Eindhoven University of Technology, Netherlands. 2021. "Biomimetic Kinetic Shading Facade Inspired by Tree Morphology for Improving Occupant's Daylight Performance." *Journal of Daylighting* 8 (1): 65–85. https://doi.org/10.15627/jd.2021.5.

Hosseini, Seyedeh Nazli, Department of Interior Architecture, Faculty of Architecture & Urbanism, Tehran University of Art, Tehran, Iran, Iman SheikhAnsari, and Faculty of Architecture and Urbanism, Art University of Isfahan, Isfahan, Iran. 2022. "A Daylight Assessment on Visual and Nonvisual Effects of Light Shelves: A Human-Centered Simulation-Based Approach." *Journal of Daylighting* 9 (1): 28–47. https://doi.org/10.15627/jd.2022.3.

Hraska, Jozef. 2018. "Adaptive Solar Shading of Buildings." *International Review of Applied Sciences and Engineering* 9 (2): 107–13.

Im, Ok-Kyun, Kyoung-Hee Kim, Armin Amirazar, and Churlzu Lim. n.d. "A Unified Framework for Optimizing the Performance of a Kinetic Façade."

Jayathissa, P., S. Caranovic, J. Hofer, Z. Nagy, and A. Schlueter. 2018. "Performative Design Environment for Kinetic Photovoltaic Architecture." *Automation in Construction* 93 (September):339–47. https://doi.org/10.1016/j.autcon.2018.05.013.

Jiang, Yan, Zongxin Qi, Shenglin Ran, and Qingsong Ma. 2024. "A Study on the Effect of Dynamic Photovoltaic Shading Devices on Energy Consumption and Daylighting of an Office Building." *Buildings* 14 (3): 596. https://doi.org/10.3390/buildings14030596.

Kahramanoğlu, Betül, and Neşe Çakıcı Alp. 2023. "Enhancing Visual Comfort with Miura-Ori-Based Responsive Facade Model." *Journal of Building Engineering* 69 (June):106241. https://doi.org/10.1016/j.jobe.2023.106241.

Karaseva, L V, and O A Cherchaga. 2021. "Conceptual Designs of Kinetic Facade Systems." *IOP Conference Series: Materials Science and Engineering* 1079 (4): 042053. https://doi.org/10.1088/1757-899X/1079/4/042053.

Khidmat, Rendy Perdana, Hiroatsu Fukuda, Kustiani, Beta Paramita, Ma Qingsong, and Agus Hariyadi. 2022. "Investigation into the Daylight Performance of Expanded-Metal Shading through Parametric Design and Multi-Objective Optimisation in Japan." *Journal of Building Engineering* 51 (July):104241. https://doi.org/10.1016/j.jobe.2022.104241.

Kim, Dong-Hyun, Hieu Trung Luong, and Trang Thao Nguyen. 2024. "Optimizing the Shading Device Configuration of Kinetic Façades through Daylighting Performance Assessment." *Buildings* 14 (4): 1038. https://doi.org/10.3390/buildings14041038.

Kim, Jae-Hyang, and Seung-Hoon Han. 2022. "Indoor Daylight Performances of Optimized Transmittances with Electrochromic-Applied Kinetic Louvers." *Buildings* 12 (3): 263. https://doi.org/10.3390/buildings12030263.

Legg, Roger. 2017. "Room Heat Gains, Air Diffusion, and Air Flow Rates." In *Air Conditioning System Design*, 81–102. Elsevier. https://doi.org/10.1016/B978-0-08-101123-2.00005-4.

Leu, Leanghong, and Chumnan Boonyaputthipong. 2023. "A Study of Shading Devices in Modern Architecture for the Hot Humid Climate of Phnom Penh, Cambodia." *Nakhara: Journal of Environmental Design and Planning* 22 (1): 301–301.

Manzan, Marco. 2014. “Genetic Optimization of External Fixed Shading Devices.” *Energy and Buildings* 72:431–40.
Minelli, Federico, Diana D’Agostino, Maria Migliozzi, Francesco Minichiello, and Pierpaolo D’Agostino. 2023. “PhloVer: A Modular and Integrated Tracking Photovoltaic Shading Device for Sustainable Large Urban Spaces—Preliminary Study and Prototyping.” *Energies* 16 (15): 5786.
Moloney, Jules. 2011. *Designing Kinetics for Architectural Facades: State Change*. Routledge.
Mukherjee, Satyen, Dagnachew Birru, Dave Cavalcanti, Eric Shen, Maulin Patel, Yao-Jung Wen, and Sushanta Das. 2010. “Closed Loop Integrated Lighting and Daylighting Control for Low Energy Buildings.” *Proceedings of the 2010 ACEEE*, 252–69.
Murray, Shane, Simon Whibley, and Diego Ramírez-Lovering. 2008. *reHousing: 24 Housing Projects*. RMIT publishing.
Nakapan, Walaiporn, and A Pattanasirimongkol. 2019. “Developing a Kinetic Façade towards a Solar Control Façade Design Prototype.” In .
Rafati, Nariman, Morteza Hazbei, and Ursula Eicker. 2023. “Louver Configuration Comparison in Three Canadian Cities Utilizing NSGA-II.” *Building and Environment* 229 (February):109939. https://doi.org/10.1016/j.buildenv.2022.109939.
Sanchez-del-Valle, Carmina. 2005. “Adaptive Kinetic Architecture: A Portal to Digital Prototyping.” In , 128–40.
Sankaewthong, Sukhum, Teerayut Horanont, Kazunori Miyata, Jessada Karnjana, Chawee Busayarat, and Haoran Xie. 2022. “Using a Biomimicry Approach in the Design of a Kinetic Façade to Regulate the Amount of Daylight Entering a Working Space.” *Buildings* 12 (12): 2089. https://doi.org/10.3390/buildings12122089.
Schanda, János. 2002. “The Concept of Colour Rendering Revisited.” In , 1:37–41. Society of Imaging Science and Technology.
Schumacher, Michael, Oliver Schaeffer, and Michael-Marcus Vogt. 2012. *Move: Architecture in Motion-Dynamic Components and Elements*. Walter de Gruyter.
Shi, Xuepeng, Tablada Abel, and Lijun Wang. 2020. “Influence of Two Motion Types on Solar Transmittance and Daylight Performance of Dynamic Façades.” *Solar Energy* 201:561–80.
Stevenson, Carolina M. 2011. “Morphological Principles: Current Kinetic Architectural Structures.” *F Stacey, M Stacey Adaptive Architecture. Building Centre Trust and the University of Nottingham, London*.
Sutter, Yannick, Hélène Michelson, Ivan Fouquet, Jean-François Autissier, Ljubica Mudri, Jean-Dominique Lénard, and Ulrich Sanson. 2014. “Guide Bio-Tech: L’éclairage Naturel.”
Ye, Yunyang, Peng Xu, Jiachen Mao, and Ying Ji. 2016. “Experimental Study on the Effectiveness of Internal Shading Devices.” *Energy and Buildings* 111:154–63.
Yoon, Jungwon. 2019. “SMP Prototype Design and Fabrication for Thermo-Responsive Façade Elements.” *Journal of Facade Design and Engineering*, January, 41-62 Pages. https://doi.org/10.7480/JFDE.2019.1.2662.
Zhang, Xiang, Siu-Kit Lau, Stephen Siu Yu Lau, and Yong Zhao. 2018. “Photovoltaic Integrated Shading Devices (PVSDs): A Review.” *Solar Energy* 170:947–68.
Zribi, Salma Chaabouni. 2011. “Voir, Savoir, Concevoir: Une Méthode d’assistance à La Conception d’ambiances Lumineuses Par l’utilisation d’images Références.”

Internet site:

https://rooflightassociation.org/wp-content/uploads/2023/07/TECHNICAL_DOC_NTD12.pdf

https://www.caue34.fr/wp-content/uploads/2019/02/Architecture_lumiere.pdf

https://lacambreai2015.wordpress.com/wp-content/uploads/2016/03/erco-light-for-museums-fr.pdf

Kengo Kuma and Associates completes craft-inspired UCCA Clay Museum in China | News | Archinect

https://www.archdaily.com/1022949/ucca-clay-museum-kengo-kuma-and-associates?ad_source=search&ad_medium=projects_tab

https://parametric-architecture.com/ucca-clay-museum-kengo-kuma/?srsltid=AfmBOopAVnre0Qfy3mS2mSZQMfd6YqcF6E_1ysnxsmDGsDtR4kiKBOgX

https://mam.org/pdfs/maps/mam-visitor-map.pdf

https://archive.jsonline.com/entertainment/arts/milwaukee-art-museum-releases-design-for-new-building-254225031.html

https://www.re-thinkingthefuture.com/case-studies/a3010-milwaukee-art-museum-by-santiago-calatrava-a-spectacular-kinetic-structure/#google_vignette

The Dynamism of Zaha's Eli and Edythe Broad Museum | ArchDaily

Eli and Edythe Broad Art Museum Building - e-architect

✅ Eli and Edythe Broad Art Museum - Data, Photos & Plans - WikiArquitectura

✅ Louvre Abu Dhabi - Ficha, Fotos y Planos – WikiArquitectura

Louvre Abou Dabi — Ateliers Jean Nouvel

The Louvre Abu Dhabi Museum / Ateliers Jean Nouvel | ArchDaily

Cultural artifice: the Louvre Abu Dhabi, United Arab Emirates, by Ateliers Jean Nouvel - The Architectural Review

Enfiladed Grids: The Museum as City — op.AL / op Architecture Landscape

Louvre Abu Dhabi / Ateliers Jean Nouvel | ArchDaily

https://www.puyraimond.net/mercure/projets/2007_Mercure_MAMA.html

https://fr.scribd.com/presentation/464125482/le-mama-2

https://journals.openedition.org/gradhiva/6494?lang=en

Appendices

Annex 1: programmatic approach

1- Examples surface programs:

The Louvre Abu Dhabi Museum

Main entrance	890.45
information	586.24 m²
Ticketing	483.16 m²
Administration	1092.72 m²
Museum shop	1398.79 m²
Grand vestibule	708.54 m²
Permanent gallery	11346.75 m²
Restroom	215.71 m²
Temporary exhibition	3629.11 m²
Amphitheatre	539.34 m²
cafe	1574.52 m²
Children museum	482.54 m²
Auditorium	3559.06 m²
Restaurant	1278.66m²

Eli and Edythe Broad Museum

Reception and loby	406.27 m²
One est gallery	1073.43 m²
Café /shop	139.14 m²
Edication wing	210.81
Courtyard	117.39 m²
Bathroom	55.87 m²
Mechanical room	516.47 m²
Art handling	142.52 m²
Study collection	160.62 m²
Collection study center	50.55 m²
Benefactors' gallery	48.11 m²
New media gallery	126.52 m²
Administration wing	273.23 m²
Electrical room	397.62 m²

Milwaukee Art Museum (MAM)

Photography and media arts	1348.99 m²
Restroom	223.81 m²
technical part	236.60 m²
Museum café	253.18 m²
lobby	608.80 m²
Lockers	50.46 m²
Museum store	402.86 m²
Windhover hall	435.85 m²
entrance hall	309.96 m²
Exhibition hall	2477.87 m²
Auditorium	666.06 m²
Restroom	284.75 m²
European exhibition	1311.22 m²
Contemporary exhibition	4553.43 m²
Technical spaces	580.66 m²
Mezzanine	1258.28 m²
Technical spaces	156.96 m²
Exhibition	5923.39
Technical spaces	136.98 m²
restroom	87.84 m²

UCCA Clay Museum

Shared lobby	208.96 m²
Permanent exhibition hall	344.50 m²
Meeting room	35.83 m²
Coffee shop	110.04 m²
Multi-functional hall	136.81 m²
Toilets	87.24 m²
Temporary exhibition	373.72 m²
Multifunctional stage	139.89 m²
Small lecture hall	59.26 m²

Official program:

D E S I G N AT I O N	SURFACE m2
A- ACCUEIL, ANIMATION, INITIATION	**1080**
-Hall dégagement	515
-Accueil général du public	110
-Accueil groupe et scolaire	82
-Réception des officiels	60

-Café/salon de thé	110
-Librairie d'art	90
-Infirmerie	13
-Vestiaire et consigne	15
-Téléphone public	15
-Bloc sanitaire principal	70
B° ACTIVITES DE BASE	**3210**
-Présentation collection temporaire	780
-Présentation collection permanente	1260
-Auditorium	675
-Médiathèque publique	210
-Atelier d'initiation et d'animation	285
C° ADMINISTRATION & CONSERVATION	**290**
-Accès de service	14
-Direction/gestion/administration	216
-Conservation	45
-Logistique/maintenance	15
D° LOGISTIQUE	**920**
-Logistique muséographie	80
-Aire de chargement	40
-Réception des oeuvres	40
-Archivage & consultations spécifiques	40
-Réserves	80
-Stockage	80
-Logistique bâtiment	20
-Accès de service	12
-Locaux personnels	100
-Maintenance bâtiment	58
-Stockage concessionnaire	30
-Locaux techniques	120

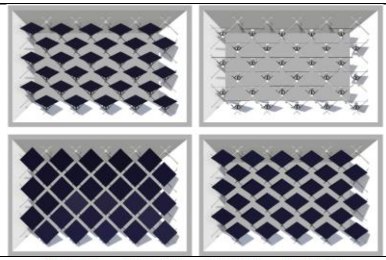
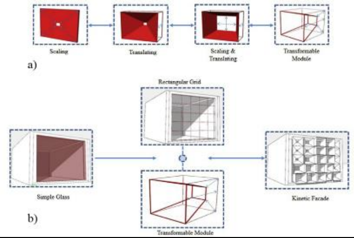
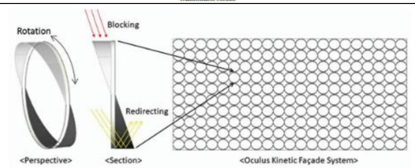
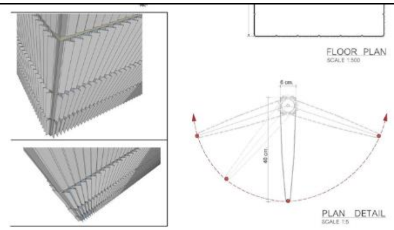
-Locaux entretien -Poste de sécurité	100 120
TOTAL SURFACE UTILE	**5.500 m2**

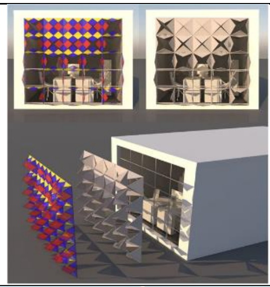
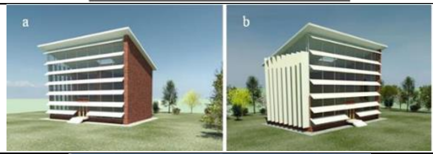
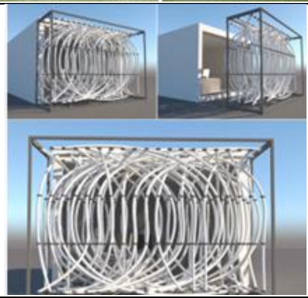
2- Organizational Standards for Museum Spaces in Algeria

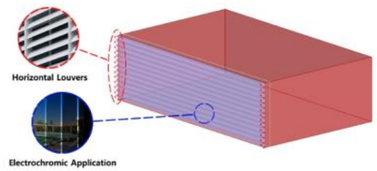
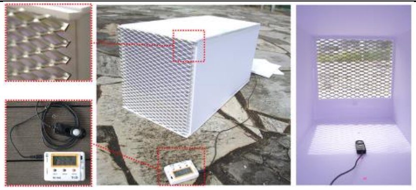
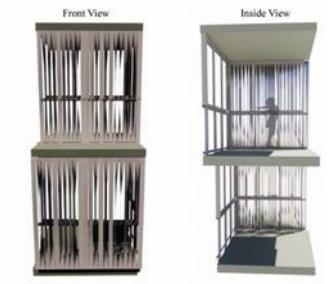
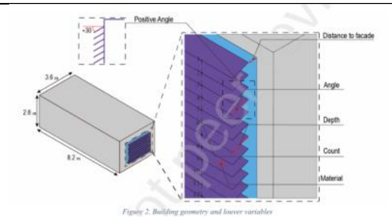
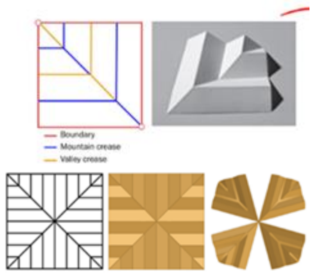
Space / Zone	Requirements / Standards
Public Reception Area	- Ground floor, only public entry point- Accessible to all (including disabled visitors)- Clear signage and routes- Independent operation from the rest of the museum
Entrance & Exterior Access	- Public transport access & parking signage- Protected queueing areas- Seating and shade near entrance
Wayfinding & Signage	- Continuous, homogeneous signage- Easy orientation and emergency exit info throughout the museum
Rest Areas	- Multiple, comfortable rest points- May include info kiosks or café integration
Sanitary Facilities	- Toilets near reception & throughout- Must include accessible toilets for disabled and elderly
Infirmary	- For visitors taken ill; should be near main entrance and accessible
Cloakroom / Lockers	- Easily accessible- Explosion-proof locker zones- Anticipate peak periods (entry/exit)
Ticketing	- Manual and/or automated systems- Design for queue flow
Info Devices	- Digital & physical maps, collection guides- Optional audiovisual room- Reception desk staffed with hostesses
Bookstore / Gift Shop	- Close to reception- Independent stock area- Adapted to museum themes
Cafeteria / Restaurant	- Located before or after control points- Careful ventilation, smell evacuation, and access planning
Adult Groups Reception	- Separate queueing & seating areas- Dedicated passageways and rest points- Special room for guides
School Groups Reception	- Separate entrance if possible- Own cloakroom, toilets, and lunch room- Preparation and activity rooms
Accessibility (Disabilities)	- Reserved parking and ramps (max slope 5%)- Accessible doors, elevators, rest areas- Adapted signage (visual/audio)
Permanent Exhibition Spaces	- Controlled lighting (50–200 lux depending on object sensitivity)- Humidity: 55 ± 5% RH; Temp: 18 ± 2 °C- No re-entrant corners; avoid dead ends- Flexible space layout
Temporary Exhibition Area	- Separate and accessible from reception- Modular, with proper lighting and climate control- Includes prep/storage rooms
Security & Fire Safety	- Fire-rated materials- Automatic detection/extinguishing systems- Compartmentalized areas- Secure exits and anti-theft barriers- Alarm systems and surveillance
Library / Documentation Center	- Nearby reading/media rooms- Includes storage and multimedia zones- Informative about museum and beyond
Auditorium / Multipurpose Hall	- Ideally at ground level or basement- Controlled access and sound/acoustic treatment- Includes control room and technical backstage
Conservation & Restoration Labs	- Near storage/reserves- Isolated for fire, humidity, chemical safety- Natural light avoided- Spaces for diagnostics, testing, and treatment

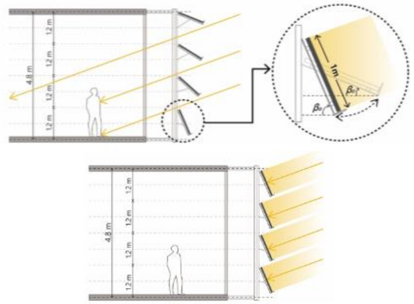
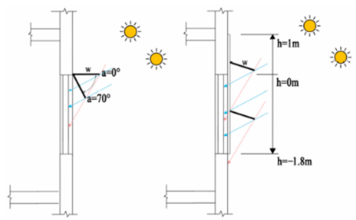
Storage / Reserves	- Controlled climate & restricted access- Underground preferred- Reinforced walls and handling space- Includes quarantine room for incoming works
Photography Studio	- Near conservation labs- Used for documentation, education, and promotion
Administration Offices	- Separate from public areas- Independent entrance with strict control- Must include all management departments
Staff Facilities	- Changing rooms, break rooms, rest areas, showers, sanitary facilities
Technical & Maintenance Areas	- Include heating/cooling, power, waste management, extinguishing systems- Strict isolation and noise control
Vehicle Zones & Delivery Docks	- Separate loading zones for works and supplies- Connected directly to storage or technical areas
Director's Residence (Optional)	- Optional functional apartment for director and head of security

Annex 2: compression of the systems

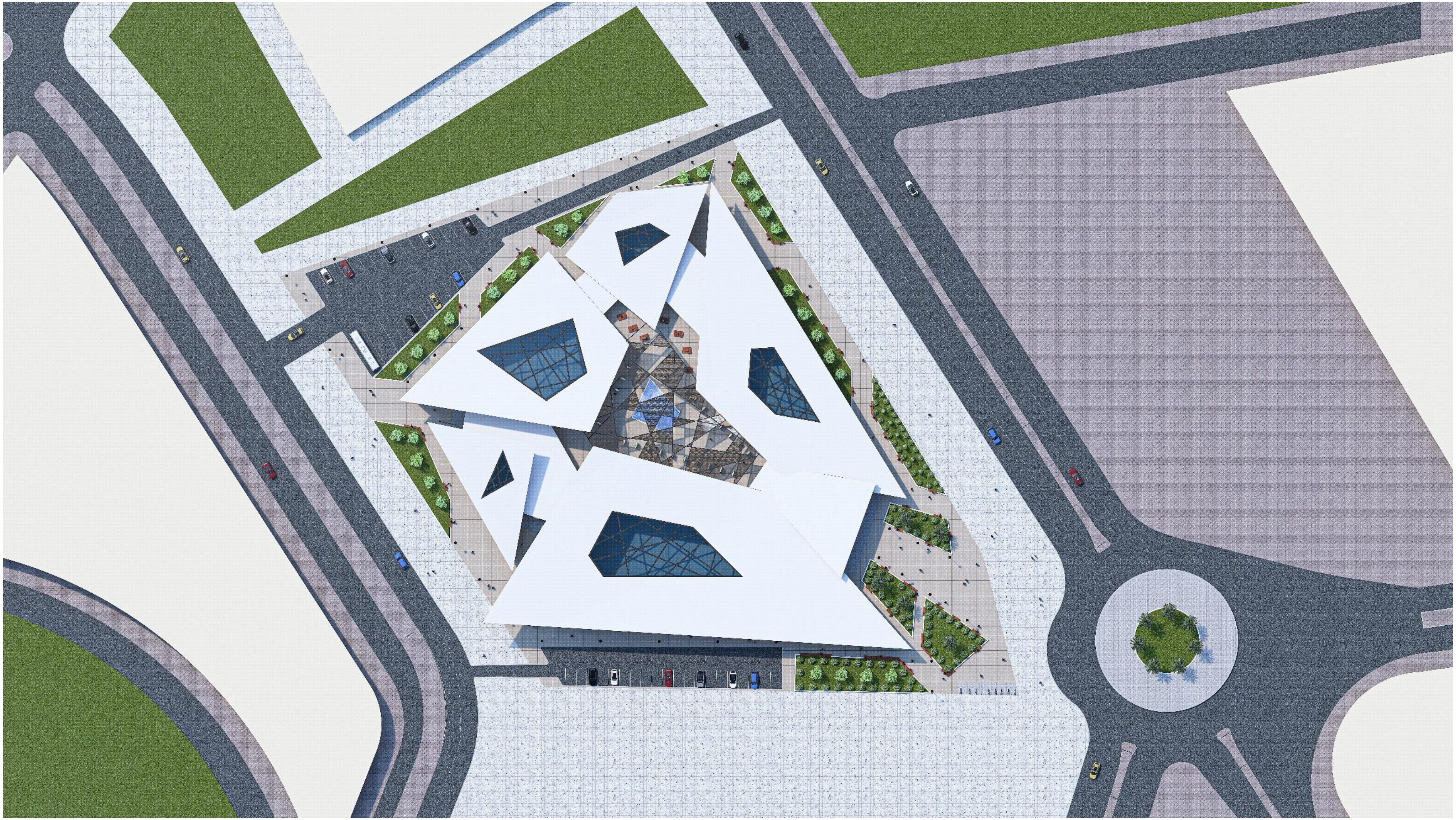
	System / Study	Illustration	Consumption	Energy Efficiency (Stats)	Daylighting Performance (Stats)	Movement Type
1	Jayathissa et al. (2018) – Adaptive Solaire PV façade		Energy-generating	Reduced energy demand by 35% for cooling	Maintained indoor illuminance around 300–500 lux	Rotating PV panels
2	Hosseini et al. (2019) – Interactive façade		Low	Reduced lighting energy use by 25–30%	Improved daylight autonomy (DA) by 28%	2D & 3D responsive shape
3	Im et al. (2019) – Oculi kinetic façade		Moderate	Solar irradiance optimized to stay below 400 W/m²	Daylight factor increased by 15–20%	Rotating circular modules
4	Nakapan & Siripattanamongkol (2019) – Aluminum fins		Low	Not quantified numerically	Daylight reduction near façade: 30–45% during peak sun hours	Rotating fins

5	Yoon (2019) – SMP responsive façade		Passive (thermo-responsive)	Potential cooling load reduction: 10–15%	Variable performance, illuminance fluctuated between 200–700 lux depending on morphology	Heat-induced cell deformation
6	Hosseini et al. (2020) – Colored glass façade		Low	Reduced glare risk by up to 40%	Colored glass improved daylight uniformity; sDA increased by ~20%	Movement based on time + occupant
7	Karaseva & Cherchaga (2021) – Fin systems		Low	Estimated energy savings of 10–18%	Daylight reduction during summer up to 50%	Horizontal and vertical fins
8	Hosseini et al. (2021) – Biomimetic tree form		Low	Reduced solar exposure by 45% during hot periods	Enhanced daylight uniformity and DA by 30%	Plant-inspired adaptive panels

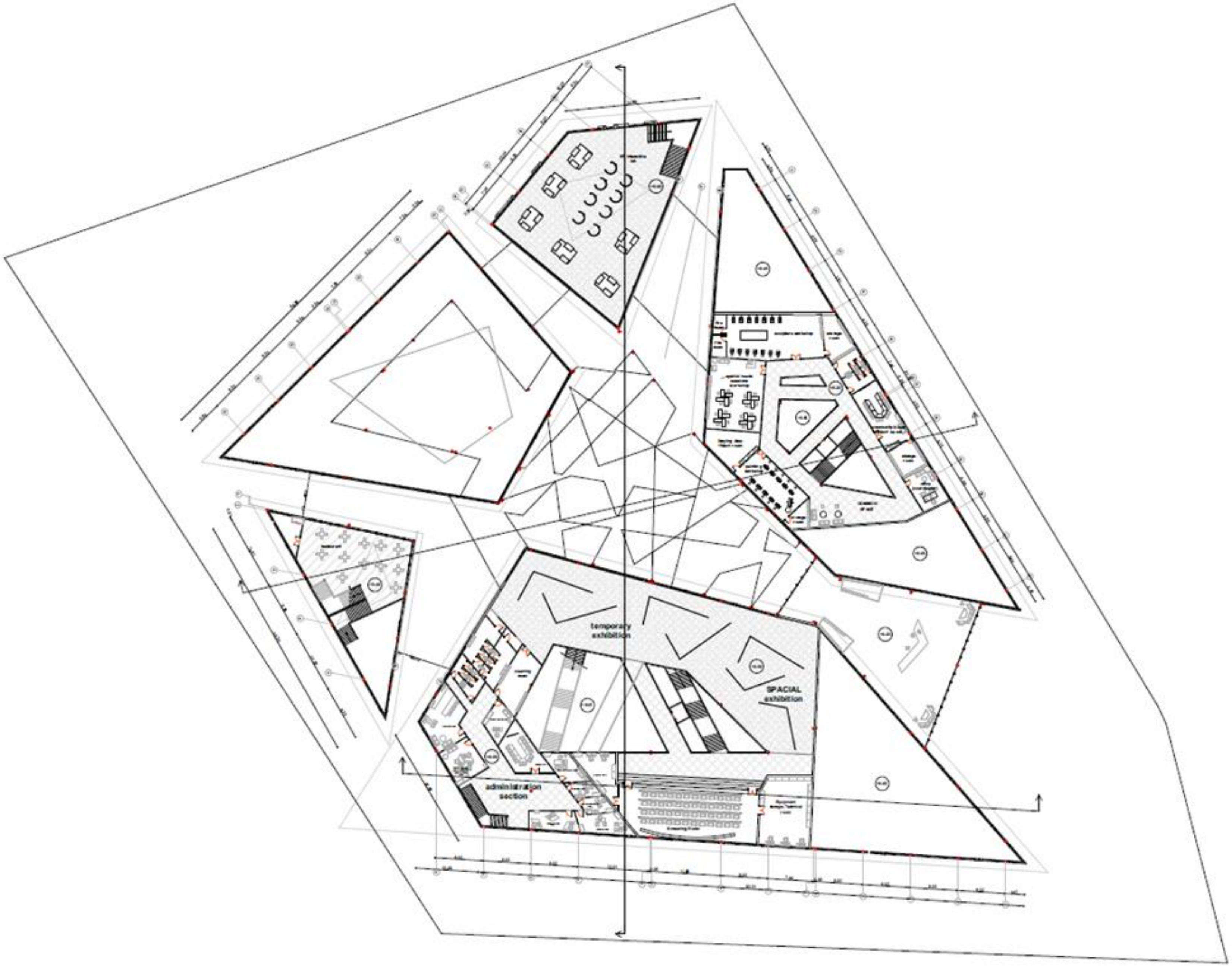
9	Kim & Han (2022) – Electrochromic louvers		Very low (optical control)	Reduced lighting power density (LPD) by 12–15%	Maintained uniform 300–400 lux indoor lighting	Electrochromic tinting
10	Khidmat et al. (2022) – Expanded metal shading		Passive	Reduced solar radiation by up to 60%	Achieved acceptable glare control and sDA > 55%	Static mesh pattern
11	Sankaewthong et al. (2022) – DNA biomimicry		Low	Daylight autonomy (DA) up to 68%, compared to 51% for static	Balanced lighting levels between 250–500 lux	Bio-inspired movement based on stimuli
12	Rafati et al. (2023) – NSGA-II louvers		Low	Energy demand reduced by 15–22% based on city	sDA increased by ~10–15% with optimized angles	Adjustable static (optimized orientation)
13	Kahramanoğlu & Alp (2023) – Miura-ori façade		Low	Improved daylight availability by 32%	Reduced UDI overexposure by 40%	Origami-based folding panels

14	Choi (2023) – Kinetic PV façade		Energy-generating	Energy production: 15.2 MWh/year; improved self-sufficiency	Indoor daylight levels remained within LEED comfort range	Foldable PV panels (angle shifts)
15	Kim et al. (2024) – Dynamic shading panels	/	Low	Increased useful daylight illuminance (UDI) by 20–25%	Annual daylight simulations showed sDA up to 80%	Vertical, horizontal, and multidirectional motion
16	Jiang et al. (2024) – PVSDs (rotation/sliding/hybrid)		Moderate	Hybrid system reduced HVAC & lighting energy by 28.7% yearly	Average UDI: Rotation (67%), Sliding (71%), Hybrid (75%)	Three modes: rotational, sliding, and hybrid

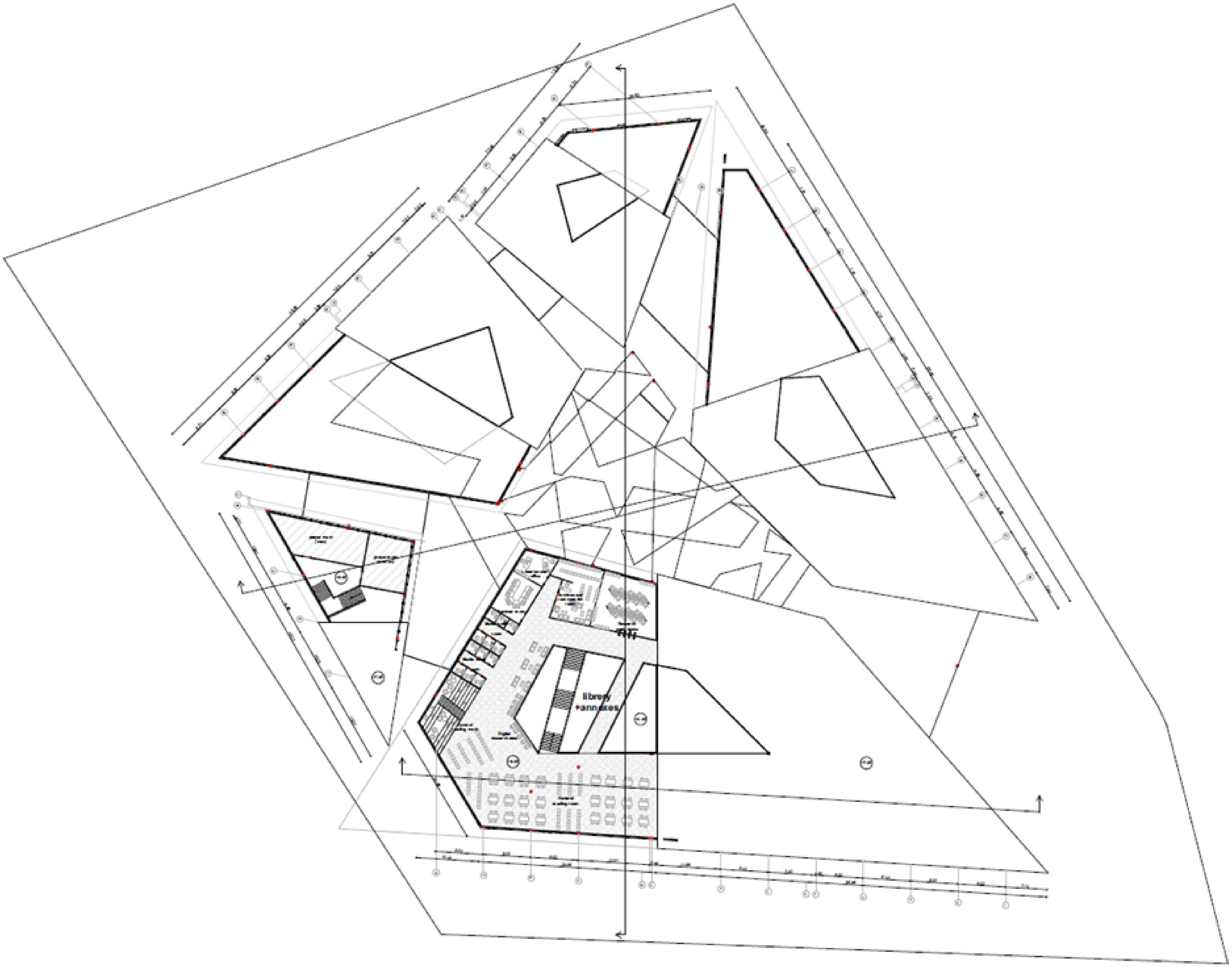
Annex 03: Architectural documents




exterior exhibition
painting exhibition
kitchen
scuptural exhibition
reception
technical zone
conceptual art exhibition

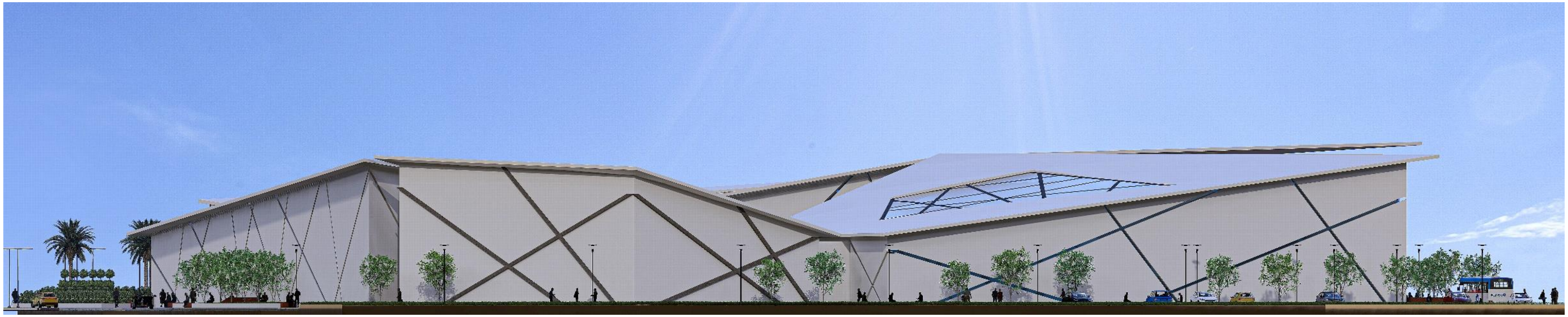


temporary exhibition
SPACIAL exhibition
administration section

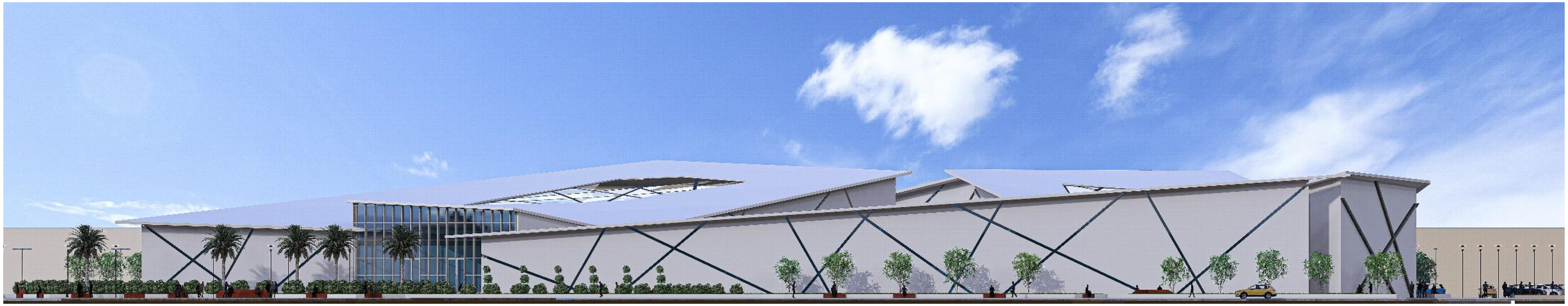

library
+annexes

South façade

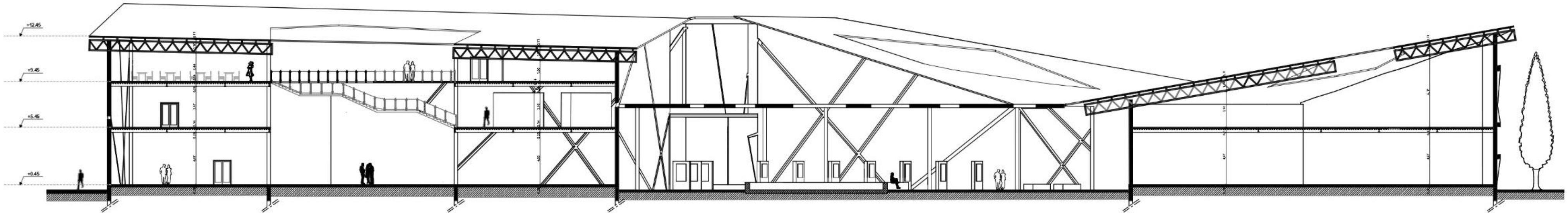
Ouest facade



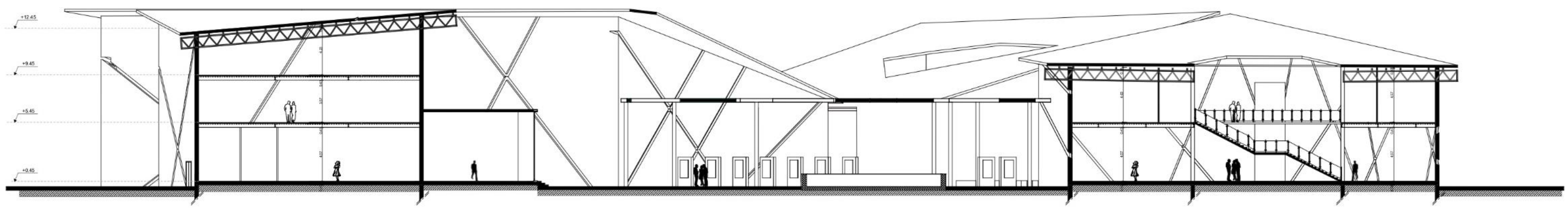
North façade



Principal façade (Est)

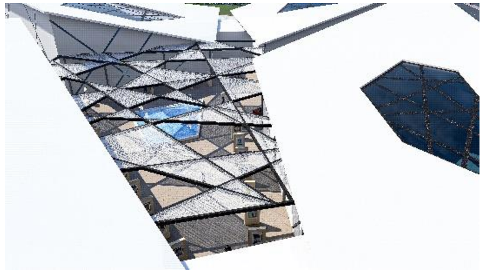


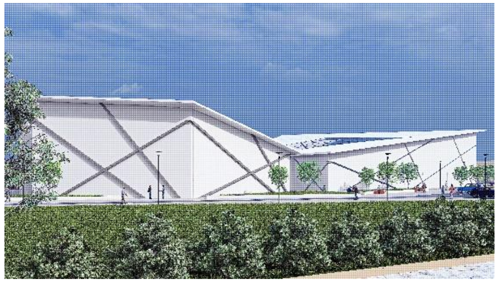
Section A-A



Section B -B













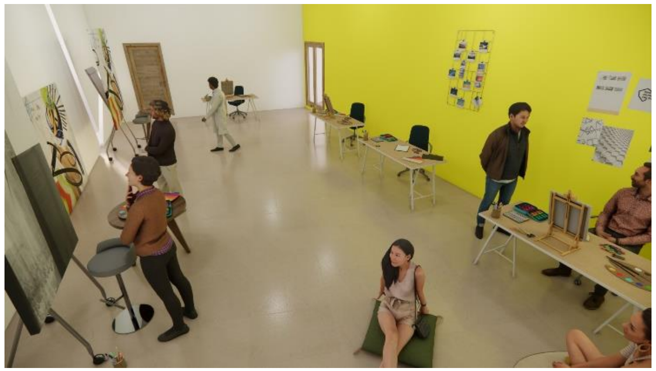















الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

جامعة محمد خيضر - بسكرة

حاضنة أعمال جامعة بسكرة

رقم 43/ الحاضنة /2025

شهــادة توطيــن / تحضيــن "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
سعداوي نورة	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
عمراوي خولة	أستاذ محاضر - ب-	هندسة معمارية	الهندسة المعمارية و العمران و الهندسة المدنية و الري

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

واجهة المستقبل : تطوير جهاز تظليل متقدم لتنظيم أداء الإضاءة في المباني .

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 المؤسسات الناشئة

د/ محمد جلاب

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

جامعة محمد خيضر - بسكرة -

عنوان المشروع :

واجهة المستقبل: تطوير جهاز تظليل متقدم لتعظيم أداء الإضاءة الطبيعية في المباني

الاسم التجاري :

InShado

صورة العلامة التجارية :

بطاقة تعريفية حول فريق الاشراف وفريق العمل:

1- فريق الاشراف :

الاسم و اللقب	الرتبة	التخصص	الكلية
دعيش صفاء	استاذ محاضر"أ"	هندسة معمارية	كلية الهندسة المعمارية والهندسة المدنية والري
عمراوي خولة	استاذ محاضر"ب"	هندسة معمارية	كلية الهندسة المعمارية والهندسة المدنية والري

2- فريق العمل :

الاسم و اللقب	الطور الدراسي	التخصص	الكلية
سعداوي نورة	ماستر 2	هندسة معمارية	كلية الهندسة المعمارية والهندسة المدنية والري

فهرس المحتويات

المحور الاول : تقديم المشروع

المحور الثاني: الجوانب الابتكارية

المحور الثالث: التحليل الاستراتيجي للسوق

المحور الرابع : خطة الإنتاج والتنظيم

المحور الخامس :الخطة المالية

المحور السادس: النموذج الولي التجريبي

المحور الأول

تقديم المشروع

المحور الاول : تقديم المشروع

1. مقدمة عامة :

تواجه المدن الواقعة في المناطق ذات المناخ الحار والجاف تحديات بيئية ومناخية معقدة، تتعلق أساسًا بشدة الإشعاع الشمسي، ارتفاع درجات الحرارة، وانخفاض الرطوبة النسبية. وتزداد هذه التحديات حدة مع التغيرات المناخية العالمية، التي أدّت إلى موجات حرّ أطول وأكثر قسوة في المناطق الصحراوية وشبه الصحراوية مثل الجنوب الجزائري. في هذه البيئات، تصبح الواجهات المعمارية عرضة مباشرةً للإشعاع الشمسي المكثف، مما يؤدي إلى اكتساب حراري مفرط داخل المبنى، وارتفاع استهلاك الطاقة المرتبط بأنظمة التبريد، خاصة خلال فصول الصيف التي قد تمتد لعدة أشهر.

يتطلب تحقيق الراحة الحرارية والبصرية داخل الفضاءات المعمارية في مثل هذه المناطق استراتيجيات تصميمية دقيقة تأخذ بعين الاعتبار سلوك الشمس طوال اليوم، اتجاه الرياح، نوعية الضوء، واحتياجات المستخدم. وعلى الرغم من وجود أنظمة تظليل تقليدية كالستائر الثابتة أو الزجاج المعالج، فإن هذه الحلول غالبًا ما تكون محدودة الاستجابة وغير فعالة في تلبية الحاجات الديناميكية للفضاء، كما أنها قد تُقلص من جودة الإضاءة الطبيعية، وتؤدي إلى الاعتماد المفرط على الإضاءة الاصطناعية، وهو ما يتنافى مع مبادئ العمارة المستدامة.

الواجهات المعمارية في السياقات المناخية الجافة لا يجب أن تكون مجرد عناصر حاجزة بين الداخل والخارج، بل يجب أن تتحول إلى أنظمة ذكية قادرة على التفاعل في الزمن الحقيقي مع المتغيرات المناخية. التظليل، في هذا السياق، لا يجب أن يكون حلاً جامدًا، بل استراتيجية متكيفة تراعي شدة الإضاءة، الزاوية الشمسية، واحتياجات الاستعمال الداخلي. وهنا يبرز سؤال محوري في هذا البحث التطبيقي: كيف يمكن تطوير نظام تظليل ذكي، متجاوب ومتكيف، يساهم في تحسين أداء الواجهة المعمارية في المناخات الحارة والجافة دون الإخلال بجودة الإضاءة الطبيعية أو الجمالية المعمارية؟

ينطلق هذا المشروع من هذه الإشكالية ليقترح حلاً تقنيًا ومعماريًا مبتكرًا يتمثل في **نظام تظليل ديناميكي** يعتمد على **تقنيات الاستشعار والتحكم الآلي**، في إطار تصميم تفاعلي مستوحى من طيّات الأوريغامي، قادر على التفاعل مع الإشعاع الشمسي لحظة بلحظة. ويهدف هذا النظام إلى تقليل الحمل الحراري على المبنى، تحسين الإضاءة الطبيعية، وتقديم واجهة ديناميكية متكاملة تمثل جيلًا جديدًا من أنظمة التظليل الموجهة للبيئات القاسية.

2. فكرة المشروع او الحل المقترح :

استنادًا إلى التحديات البيئية التي تواجه المباني في المناطق ذات المناخ الحار والجاف، يقترح مشروع Inshado حلاً تكنولوجيًا ومعماريًا مبتكرًا يتمثل في نظام تظليل ديناميكي ذكي وتفاعلي،

يدمج بين التصميم الحركي (Kinetic Design) وتكنولوجيا الاستشعار والتحكم الآلي. الهدف من هذا النظام هو تمكين الواجهة من الاستجابة في الزمن الحقيقي للمتغيرات المناخية الخارجية (الضوء، الحرارة) لضمان التوازن بين التظليل الفعّال والإضاءة الطبيعية الجيدة، مع تقليل الاعتماد على الأنظمة الميكانيكية الثقيلة أو التشغيل اليدوي.

يقوم هذا النظام على مبدأ التفاعل اللحظي مع الظروف البيئية من خلال تكنولوجيا الاستشعار والتحكم الأوتوماتيكي، مما يسمح بتعديل وضعية وحدات التظليل . وقد تم تصميمه بهيئة وحدات

هندسية قابلة للفتح والطي ، ما يمنحه جمالية عالية ومرونة وظيفية.يتكون النظام من العناصر التالية:

- الوحدة المتحركة (وحدة التظليل): مكوّنة من أربع وحدات ثانوية بأبعاد 60×60 سم، مصنوعة من الألمنيوم ومغطاة بطبقة خزفية، قابلة للحركة وفق آلية طيّ هندسي.
- المحرك (DC Motor): محرك تيار مستمر صغير الحجم يُستخدم لفتح أو طيّ الوحدات تلقائيًا.
- المتحكم الإلكتروني (Microcontroller): يتلقى بيانات من المستشعرات ويصدر أوامر للمحرك.
- مستشعر الضوء (Light Sensor): يقيس شدة الإضاءة الطبيعية الساقطة على الواجهة.
- مستشعر الحرارة (Temperature Sensor): يراقب درجة الحرارة الخارجية أو حرارة سطح الواجهة.
- وحدة التغذية (Power Supply): تزوّد النظام بالطاقة اللازمة، ويمكن أن تكون كهربائية أو عبر ألواح شمسية.
- الهيكل الداعم: يتضمن الإطار الحامل ووسائل التثبيت والوصلات الكهربائية، مصمم بشكل ينسجم مع جمالية الواجهة ويضمن ثبات العناصر الميكانيكية.

طريقة عمل النظام باختصار:

- يقوم المستشعر الضوئي بقياس شدة الإضاءة الطبيعية.
- إذا تجاوزت الإضاءة حدًا معينًا ، يُرسل المستشعر إشارة إلى المتحكم الإلكتروني.
- يقوم المتحكم بتحليل الإشارة بالتوازي مع بيانات الحرارة، ثم يُرسل أمرًا إلى المحرك لفتح أو طيّ وحدة التظليل.
- يتم تكرار هذه الدورة طوال اليوم تلقائيًا، حسب تغير ظروف الإضاءة ودرجة الحرارة.
- يمكن برمجة النظام للعمل آليًا أو يدويًا حسب الرغبة، كما يمكن دمجه في أنظمة إدارة المباني الذكية.

المجالات الممكنة لتطبيق النظام:

نظام Inshado قابل للتطبيق في عدة أنواع من المشاريع المعمارية، منها:

- المتاحف والمعارض الفنية (تحكم دقيق في الضوء الداخلي).
- المباني الإدارية في الصحراء أو الجنوب الجزائري.
- المؤسسات التعليمية أو المكتبات الجامعية.

○ الواجهات الزجاجية للفنادق والمباني التجارية.

3. *تعريف المشروع:*

العنصر	الوصف
طبيعة المشروع	مشروع تقني–معماري مبتكر يجمع بين التكنولوجيا الذكية والتصميم المعماري المستدام.
اسم المشروع	Inshado – نظام تظليل ذكي متجاوب للواجهات المعمارية.
مجال النشاط	صناعي (البناء المستدام – الأنظمة الذكية للمباني – تصميم الواجهات المتجاوبة.)
موقع المشروع	ولاية بسكرة، الجزائر (قابل للتوسعة نحو مناطق صحراوية وشبه صحراوية أخرى).
النطاق	وطني . اقليمي
الفئة المستهدفة	المعماريون، شركات البناء المستدام، المؤسسات التعليمية والثقافية.
عدد العمال	12 عامل
تسمية النشاط	تطوير وتصنيع أنظمة تظليل ذكية مدمجة في واجهات المباني. متابعة تقنية ودعم أثناء وبعد البيع
مضمون النشاط	تصميم وحدات تظليل ذكية قابلة للحركة تعمل بحساسات ومحركات كهربائية، قابلة للتركيب على واجهات المباني.
الشكل القانوني	شركة ذات مسؤولية محدودة (S.A.R.L) – بنشاط إنتاج وخدمات تقنية متقدمة
تكلفة شراء الارضية	00 دينار جزائري

4. *القيم المقترحة:*

يقدم نظام مجموعة من القيم المقترحة التي تمثل مزيجًا بين الوظائف التقنية العالية والحلول البيئية الجمالية، بما يتماشى مع التحديات المناخية للمناطق الحارة والجافة:

- التجاوب الذكي مع المناخ الخارجي :يتميز النظام بقدرته على التفاعل التلقائي مع شدة الإضاءة ودرجة الحرارة من خلال مستشعرات ذكية، مما يسمح بتعديل وضعيات وحدات التظليل دون الحاجة لتدخل يدوي، ويوفر راحة حرارية وبصرية مثالية للمستخدمين.

- تحسين جودة الإضاءة الطبيعية :عبر آلية التحكم في التظليل، يسمح النظام بمرور كمية ضوء طبيعية متوازنة تقلل من الوهج وتحافظ على الإنارة الداخلية دون اللجوء المفرط إلى الإضاءة الاصطناعية.

- خفض استهلاك الطاقة :يساهم النظام في تقليل الحاجة للتبريد الصناعي خلال فصول الصيف الطويلة، مما يخفض استهلاك الكهرباء ويحسّن كفاءة الطاقة في المبنى.

- تصميم ديناميكي مستوحى من الأوريغامي :يعتمد النظام على وحدات قابلة للطي والفتح، ما يمنحه طابعًا معماريًا متطورًا يجمع بين الوظيفة والتعبير الجمالي، ويجعل الواجهة حية ومتغيرة حسب المناخ.

- قابلية التخصيص والتركيب على مختلف أنواع الواجهات: صُمم النظام ليكون مرنًا وقابلًا للتعديل حسب أبعاد الواجهة وطبيعة المشروع، مما يسمح بتطبيقه في مشاريع متنوعة كالمتاحف، الجامعات، الفنادق، أو المقرات الإدارية.

- مواد خفيفة وعالية المقاومة :تصنَع الوحدات من الألمنيوم المطلي بطبقة خزفية، ما يمنحها مقاومة كبيرة ضد الحرارة والتآكل، وعمرًا تشغيليًا طويلًا في البيئات الصحراوية القاسية.

- سهولة الصيانة والتحديث: بفضل بساطة المكونات الإلكترونية والميكانيكية، يمكن فحص النظام دوريًا أو تحديث برمجته بسهولة، دون الحاجة لتفكيك شامل أو تكلفة صيانة مرتفعة.

- إمكانية التكامل مع أنظمة المباني الذكية :بفضل بنيته البرمجية القابلة للتطوير، يمكن ربط النظام مستقبلاً بتقنيات إدارة المباني (BMS) أو التحكم عبر الإنترنت، مما يفتح آفاقًا للتوسع الذكي.

5. *فريق العمل :*

الطلبة	التخصص	الدورات التكوينية
نورة سعداوي	هندسة معمارية	– شهادة B2 في اللغة الإنجليزية – شهادة A2 في اللغة الإيطالية – تربص ميداني على مستوى مكتب الدراسات. – تربص ميداني على مستوى مديرية الترقية والتسيير العقاري بسكرة.

6. *اهداف المشروع:*

6.1. أولًا: الأهداف قصيرة المدى (خلال 12 إلى 24 شهرًا):

- إنهاء تطوير نموذج عملي متكامل وقابل للتكرار:تصميم وتجميع وحدة تظليل قابلة للتركيب على الواجهات، تحتوي على جميع العناصر (المستشعرات، المحرك، وحدة التحكم، وحدات الأوريغامي المصنوعة من الألمنيوم)، وتجريبها في ظروف مناخية واقعية مثل مناخ بسكرة.

- تطوير وثائق فنية كاملة للنظام:إعداد دليل تقني مفصل يشرح كيفية تصنيع، برمجة، وتركيب النظام، موجه للمهندسين المعماريين ومكاتب الدراسات، ليسهل دمجه في المشاريع دون الحاجة إلى تدخل مباشر من الفريق المطوّر.

- تجهيز عرض رقمي تسويقي محترف:إنشاء موقع إلكتروني بسيط وعملي، فيديو توضيحي يشرح مبدأ عمل النظام، ونماذج تفاعلية ثلاثية الأبعاد لعرض طريقة عمل وحدات التظليل، ما يساعد في شرح الفكرة للعملاء المحتملين بسرعة.

- اختبار النظام في مشروع حقيقي كموقع تجريبي (Pilot Site):التعاقد مع جهة واحدة على الأقل لتركيب النظام فعليًا، ومراقبة أدائه طوال فصول مختلفة بهدف تحسينه وتوثيق نتائجه.

- تشكيل فريق مصغّر متكامل:تعيين على الأقل: مهندس إلكتروني، أو تقني تصميم، شخص إداري/مالي، ومساعد تقني للتركيب الميداني.

6.2. ثانيًا: الأهداف بعيدة المدى (من 3 إلى 5 سنوات):

- إنتاج سلسلة مصغّرة من النظام حسب الطلب:بدء تصنيع النظام بمواصفات قابلة للتعديل حسب كل مشروع (حجم الوحدات، نوع التثبيت، عدد المحركات، ...)، مع تحديد الموردين المحليين للمواد الخام.

- تطوير نسخ مختلفة من النظام:

نسخة خفيفة مخصصة للبيوت الصغيرة أو الكرفانات.

نسخة صناعية قوية للمباني الكبيرة (فنادق، متاحف، مراكز تعليمية...).

نسخة هجينة تحتوي على تحكم يدوي وذكي معًا.

- ربط النظام بتطبيق رقمي بسيط:تطوير واجهة رقمية (تطبيق جوال أو لوحة تحكم على الحاسوب) تسمح بتعديل إعدادات النظام، إطفائه أو إعادة ضبطه حسب تفضيلات المستخدم.

- تكوين شبكة تركيب معتمدة:تدريب فرق محلية على تركيب النظام بطريقة معيارية (modulaire) دون الحاجة للفريق المؤسس، ما يفتح المجال لتوسيع المشروع جغرافيًا.

- إطلاق وحدة تصنيع وتجميع مصغرة:إنشاء ورشة إنتاج مجهزة داخل منطقة صناعية صغيرة لتصنيع الأجزاء وتركيبها داخليًا، مما يقلل التكاليف ويرفع جودة المنتج النهائي.

الجوانب الابتكارية

المحور الثاني: الجوانب الابتكارية

1. طبيعة الابتكار: ابتكارات تقنية و تكنولوجية

2. مجالات ابتكارية:

- تطوير واجهات متحركة تفاعلية تضيف بُعدًا ديناميكيًا للمبنى وتعيد تعريف العلاقة بين الشكل والوظيفة.

- تقليل استهلاك الطاقة الموجهة للتبريد والإنارة، مما يدعم العمارة المستدامة في المناطق الحارة.

- استخدام مستشعرات ومحركات مدمجة ونظام تحكم دقيق لتوليد حركة فعالة ومتكيفة مع المناخ.

- منتج يمكن تصنيعه وتركيبه محليًا، ما يجعله خيارًا اقتصاديًا ومتاحًا لمشاريع البناء المتوسط.

- واجهة متغيرة بصريًا تمنح المباني طابعًا مميزًا يعزز هوية المشروع، خاصة في المتاحف والمراكز الثقافية.

- يعتمد النظام على وحدة تحكم ذكية قابلة للبرمجة، تسمح له ليس فقط بالتفاعل مع الظروف الآنية ، بل أيضًا بالتعلّم من أنماط الاستخدام السابقة (ساعات الذروة، تغيّرات المواسم...) والتكيّف معها.

- تم تصميم وحدات التظليل بشكل معياري (Modulaire)، مما يتيح ربط أكثر من وحدة معًا لتشكيل أنظمة كبيرة دون إعادة تصميم كامل. هذه القابلية للتوسعة تمنح مرونة كبيرة في الاستخدام على الواجهات الكبيرة أو المعقّدة هندسيًا.

- على عكس الأنظمة الذكية التي تحتاج إلى إعدادات معقدة، يعتمد Inshado على تكنولوجيا بسيطة وموثوقة (مثل Arduino أو ESP32) يمكن تشغيلها بسهولة، مما يجعله في متناول اليد من حيث التصنيع والصيانة.

- يستخدم النظام محركات صغيرة عالية الكفاءة من نوع Servo أو Stepper، ما يتيح تشغيلًا صامتًا لا يؤثر على راحة مستخدمي الفضاء الداخلي، بخلاف بعض الأنظمة التي تصدر ضجيجًا عند الحركة.

- الشكل المستوحى من طيّات الأوريغامي يتيح دمج النظام مع واجهات حديثة أو تقليدية دون أن يبدو غريبًا عن السياق، وهو مناسب خصوصًا للمتاحف والمعالم الثقافية التي تتطلب حسًا بصريًا راقيًا.

- تم تصميم الوحدات بحيث يمكن تركيبها أو استبدال أجزائها بسهولة من قبل فريق تقني صغير، دون الحاجة إلى رافعات أو تجهيزات صناعية كبيرة.

التحليل الاستراتيجي للسوق

المحور الثالث: التحليل الاستراتيجي للسوق

1. *تحليل* PESTEL *(البيئة الخارجية):*

PESTEL

تحليل البيئة الكلية الخارجية

S – Social

تزايد الوعي البيئي والرغبة في الحلول المستدامة خصوصًا لدى المعماريين والطلبة والشركات الحديثة

E – Economic

ارتفاع تكاليف الاستيراد يعزز من فرص المنتجات المصنّعة محليًا، خاصة تلك التي تخفض استهلاك الطاقة، لكن القدرة الشرائية المحدودة في بعض المناطق قد تحدّ من التوسع

P – Political

استقرار نسبي في المناخ السياسي مع دعم حكومي للمؤسسات الناشئة والمشاريـع التكنولوجية صندوق دعم الابتكار، الوكالة الوطنية لدعم المقاولات.

L – Legal

وجود أطر قانونية تسمح بتسجيل شركة S.A.R.L ناشئة ، لكن ضعف تنظيم حماية الملكية الفكرية يشكل تحديًا لبراءات الاختراع

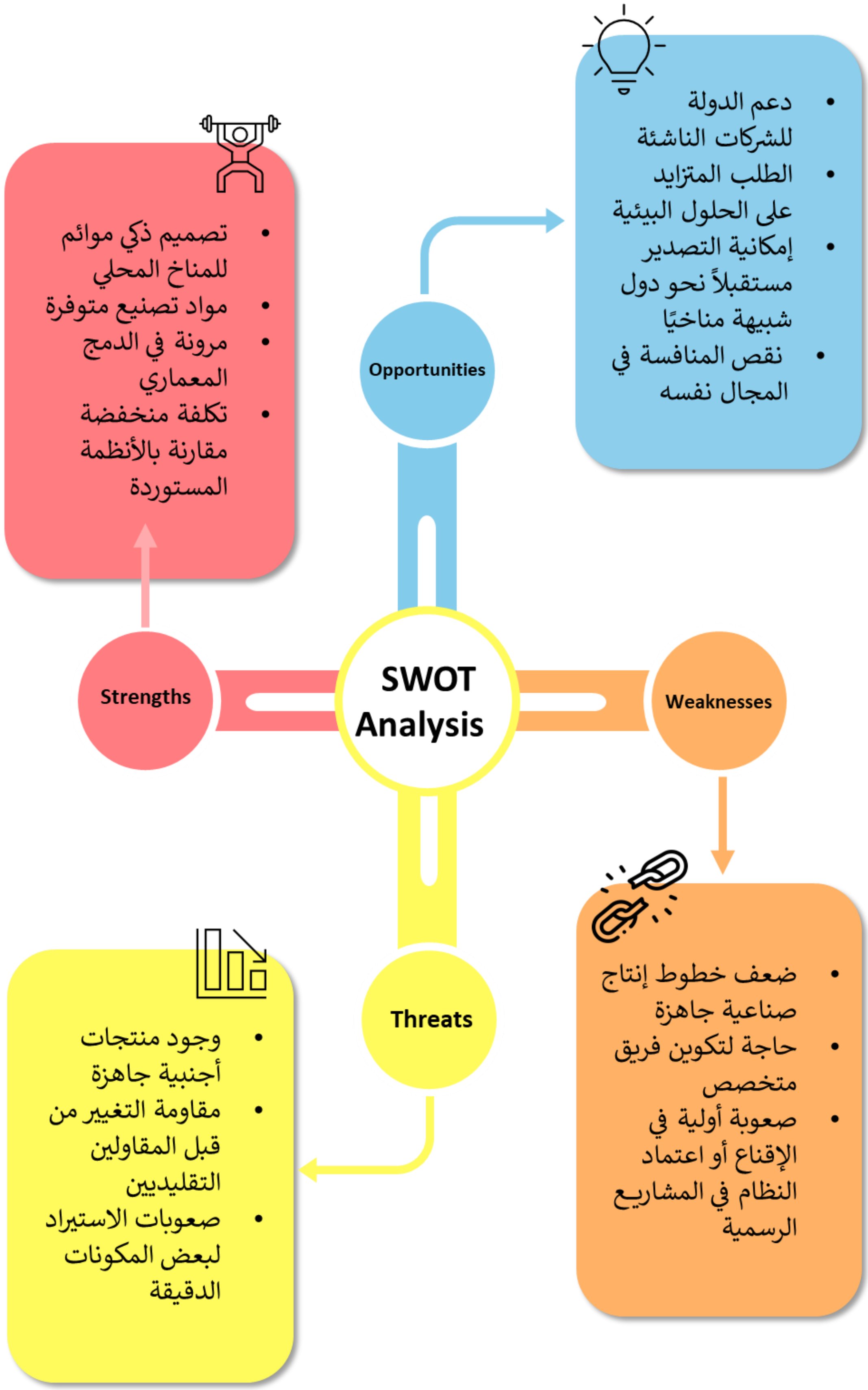
E – Environmental

المناخ الحار والجاف في ولايات الجنوب والوسط يجعل النظام مفيدًا جدًا لتوفير الطاقة وتحقيق الراحة البيئية، خاصة في المتاحف، الجامعات، والفنادق

T – Technological

وافر مكونات إلكترونية محليًا محدود، لكن هناك إمكانية للاستيراد عبر الإنترنت. وجود مهارات شبابية في البرمجة والتصميم ميزة كبيرة

2. تحليل SWOT:



SWOT Analysis
Strengths
• تصميم ذكي موائم للمناخ المحلي
• مواد تصنيع متوفرة
• مرونة في الدمج المعماري
• تكلفة منخفضة مقارنة بالأنظمة المستوردة
Opportunities
• دعم الدولة للشركات الناشئة
• الطلب المتزايد على الحلول البيئية
• إمكانية التصدير مستقبلاً نحو دول شبيهة مناخيًا
• نقص المنافسة في المجال نفسه
Weaknesses
• ضعف خطوط إنتاج صناعية جاهزة
• حاجة لتكوين فريق متخصص
• صعوبة أولية في الإقناع أو اعتماد النظام في المشاريع الرسمية
Threats
• وجود منتجات أجنبية جاهزة
• مقاومة التغيير من قبل المقاولين التقليديين
• صعوبات الاستيراد لبعض المكونات الدقيقة

3. تحليل بورتر Porter:

4. المزيج التسويقي

اسم المنتج	InShado
طبيعة المنتج	نظام معماري ديناميكي للتحكم في الإضاءة والحرارة، مكوّن من وحدات تظليل قابلة للحركة على واجهات المباني.
الخصائص التقنية	- وحدات مطوية بطريقة أوريغامي هندسية - محركات ذكية (Servo أو Stepper) - حساسات ضوئية وحرارية - نظام تحكم إلكتروني قابل للبرمجة

	- قابلية التخصيص حسب الواجهة والمناخ - مواد مقاومة (ألمنيوم + طلاء سيراميكي) - صيانة منخفضة - تشغيل صامت
مميزات تنافسية	- تصميم فني متغير بصريًا - استجابة ذاتية حسب المناخ - خفيف الوزن وسهل التركيب - يدعم الطابع الجمالي للواجهة - موائم للبيئة – يخفض استهلاك الطاقة - قابل للتصنيع محليًا بتكلفة متوسطة
الاحتياجات التي يلبيها	- تقليل الحرارة داخل المبنى - تحسين توزيع الإضاءة الطبيعية - توفير طاقة التكييف والإنارة - خلق واجهة معمارية مميزة - تعزيز الراحة الحرارية والبصرية - دعم المعايير البيئية في البناء (Green Building)

5. السعر:

تم اعتماد منهجية تسعير تعتمد على تحليل دقيق لتكاليف الإنتاج والتجميع والبرمجة، بالإضافة إلى مراعاة خصوصيات السوق المحلي وتوقعات الفئات المستهدفة من العملاء.

5.1. تسعير المنتج - نموذج تقديري مبدئي:

العنصر	السعر التقديري بالدينار (دج)	الوصف
وحدة التظليل (60×60 سم)	12,000 – 18,000	ألمنيوم + طلاء سيراميكي مقاوم للحرارة
نظام الحركة (محرك كهربائي صغير)	12,000 – 8,000	موتور منخفض الجهد مع ذراع تحريك
لوحة التحكم الذكية	15,000 – 25,000	تتضمن حساس ضوء وحرارة + متحكم
التجميع والتركيب	6,000 – 10,000	تركيب ميكانيكي وكهربائي على الواجهة
البرمجة والإعداد	10,000 – 20,000	برمجة حسب الموقع/الموسم أو بواجهة مستخدم

هامش الربح	20% – 35%	يضاف بعد احتساب التكاليف المباشرة

الناتج النهائي: يتراوح سعر الوحدة المكتملة بين 55,000 إلى 85,000 دج (حوالي 370 إلى 560 يورو).

5.2. السعر المقترح حسب نوع العميل:

نوع العميل	السعر/الوحدة (دج)	ملاحظات
مشاريع معمارية فردية	75,000 – 85,000	يشمل التركيب والبرمجة والتوصيل الكامل
شركات بناء وتطوير عقاري	65,000 – 72,000	تخفيض للكمية + تدريب مجانًا لفريق التركيب لديهم
مكاتب دراسات هندسية	60,000 – 68,000	شراكة طويلة المدى + باقات تحكم ذكي
مشاريع عمومية	55,000 – 62,000	دعم حكومي محتمل + توثيق الأداء في الدراسات

5.3. بطاقة ذكية مقترحة:

اسم العرض: Inshado Smart Kit

- يحتوي على: 4 وحدات ظل ذكية (60×60 سم)- محركات مدمجة - لوحة تحكم رقمية - تركيب + إعداد + ضمان سنة.
- السعر الكلي: 280,000 دج قابل للتوسيع حسب عدد الوحدات

سعر الإطلاق التجاري (Launch Price)**:**

- المدة: أول 6 أشهر بعد الإعلان الرسمي
- السعر الخاص: 58,000 دج للوحدة (بدل 72,000 دج) - يشمل: وحدة + محرك + تركيب + إعداد أساسي

لأول 10 عملاء:

- لوحة تحكم مجانية
- صيانة مجانية لمدة 6 أشهر
- توثيق مشاريعهم كنماذج أولية في الموقع الرسمي

عروض خاصة مميزة (Marketing Offers)**:**

باقة المشاريع البيئية :خصم 15% لمشاريع تحترم معايير العمارة الخضراء (LEED, BREEAM...)

شراكة مع المدارس المعمارية :تخفيض 30% لورشات بحث أو مختبرات طلابية ضمن مشاريع تخرج

الفنادق والمنتجعات :تهيئة تصميم مخصص **+** تحكم مركزي **+** خدمات ما بعد البيع الممتدة

باقة مكاتب الدراسات: باقة تضم تدريب **+** دعم تقني **+** كتالوجات **+** تسهيلات في التركيب للمشاريع الجديدة

1. الترويج *:*

1.1. مراحل الخطة الترويجية**:**

1.1.أ المرحلة الأولى: إطلاق أولي

- تطوير موقع إلكتروني احترافي
- إنتاج فيديو تقديمي قصير
- إنشاء حسابات على شبكات التواصل

1.1.ب المرحلة الثانية: التفاعل الميداني

- المشاركة في معارض البناء والتقنية
- ورشات عمل بالتعاون مع كليات العمارة
- إطلاق حملة بريد إلكتروني لمكاتب الدراسات
- تركيب نموذج تجريبي في مؤسسة معمارية

1.1.ج المرحلة الثالثة: تعزيز الثقة والتوسع

- حملات إعلانية رقمية موجهة
- نشر شهادات وتجارب ناجحة
- شراكات مع مكاتب دراسات

1.2. أدوات الترويج المقترحة:

- **فيديوهات توضيحية** : قصيرة وجذابة، تبين طريقة عمل النظام.
- **كتيب رقمي (PDF)** : يوضح مزايا النظام بلغة معمارية مدعمة بالصور.
- **موقع إلكتروني** : يشمل معرض صور، فيديوهات، ومقالات تقنية.
- **محتوى هندسي تقني** : ملفات CAD/3D، تصورات تفاعلية.

- **المعارض المعمارية** : عرض حي للنظام أمام الزبائن المحتملين.
- **شراكات أكاديمية** : احتضان فكري وتجريبي من كليات العمارة.

2. *التوزيع :*

الرقم	طريقة التوزيع	مثال	المميزات
01	التوزيع المباشر (Direct Distribution)	- الموقع الإلكتروني الرسمي - وسائل التواصل - بيع مباشر للمقاولين	- تحكم كامل بالعلاقة - هامش ربح أعلى - مرونة في التفاوض
02	عبر مكاتب الدراسات وشركات البناء (B2B)	- اتفاقيات مع مكاتب هندسية - دمج في دفاتر شروط المشاريع	- بيع بالجملة - سرعة الانتشار - دعم غير مباشر عبر الشركاء
03	متاجر متخصصة ومعارض (Shops & Showrooms)	- نقاط بيع الأجهزة الذكية - دمج مع حلول معمارية (نوافذ ذكية)	- سهولة الوصول للعملاء - دعم عرض حي - فرص ترويج مشترك
04	الوكلاء التجاريون (Commercial Agents)	- مندوبون في ولايات متعددة - موزعون معتمدون	- تغطية واسعة - علاقات محلية - توفير تكاليف التوسع
05	المنصات الرقمية (Online Platforms)	-Ouedkniss -Ubuy - موقع رسمي خاص	- وصول من أي مكان - تكامل مع الحملات الرقمية

3. *عرض القطاع السوقي:*

3.1. أولًا: السوق المستهدف (Target Market)

يمثل هذا الفئة الأساسية من العملاء الذين صُمم نظام Inshado ليخدمهم مباشرة، والذين لديهم حاجات واضحة تتماشى مع خصائص المنتج.

الفئات ضمن السوق المستهدف:

- مكاتب الدراسات المعمارية والهندسية :تستفيد من دمج النظام في تصاميم مشاريع جديدة كعنصر تصميم مبتكر وتكنولوجي.

- شركات البناء والتطوير العقاري :يمكنهم دمج النظام في مشاريع سكنية أو تجارية عالية المستوى (فيلات، فنادق، مراكز ثقافية).
- المؤسسات الثقافية والعمومية :مثل المتاحف، المعارض، المدارس النموذجية، التي تهتم بالتصميم المعماري الحديث والتفاعل مع المناخ.
- المهندسون المعماريون المستقلون :الذين يبتكرون واجهات حيوية أو مشاريع تخرج/بحث قابلة للتطبيق.

3.2. ثانيًا: السوق المحتمل (Potential Market)

هو الجمهور الذي لا يمثل حاليًا الزبون المباشر، لكن يمكن تحويله إلى عميل في المستقبل، مع الوقت أو عبر التوعية والتسويق المستمر.

الفئات ضمن السوق المحتمل:

- أصحاب المنازل الخاصة المهتمون بالاستدامة :خاصة من الفئة المتوسطة العليا، الذين يريدون الراحة الحرارية والتميّز في التصميم.
- قطاع السياحة والفنادق الصغيرة والمتوسطة :منتجعات، بيوت ضيافة، مشاريع سياحية في الجنوب أو المناطق المشمسة.
- المهندسون المدنيون والمصممون الداخليون :مهنيون قد يدمجون النظام مستقبلاً كجزء من مشاريعهم.
- البلديات والمشاريع الحضرية :مثل تهيئة الساحات العامة أو المرافق التعليمية في مناطق مشمسة.
- منظمات بيئية أو جمعيات تهتم بالبناء المستدام :يمكن أن تدعم أو تموّل اعتماد هذه التقنيات.

3.3. ثالثًا: السوق المتخصص (Niche Market)

هو قطاع ضيق ومحدد جدًا في السوق، لديه احتياجات تقنية أو مناخية أو تصميمية خاصة، ويصعب تلبية تلك الحاجات إلا من خلال منتج دقيق مثل Inshado.

4. الفئات ضمن السوق المتخصص:

- مشاريع معمارية في المناخات الحارة والجافة:مناطق مثل بسكرة، ورقلة، تمنراست، تحتاج إلى حل يجمع بين التظليل والتهوية الذكية.
- متاحف ومعارض فنية تعتمد على الإضاءة الطبيعية :حيث التحكم بالضوء والوهج ضروري لحماية المعروضات وتحسين تجربة الزائر.
- مشاريع معمارية ذكية تستخدم الواجهات الديناميكية: مثل مدارس معمارية حديثة، مختبرات، مبانٍ ذكية نموذجية.
- مراكز البحث والابتكار في البناء المستدام :تستعمل هذا النوع من الأنظمة للتجربة أو كجزء من منشآت بحثية.
- مصممو الفضاءات المعمارية التفاعلية :في مشاريع فنية أو ثقافية ذات بُعد تكنولوجي.

5. تحليل الزبائن:

الفئة المستهدفة	الحاجات الأساسية	العوائق المحتملة	الدوافع الأساسية للشراء
1- مكاتب الدراسات المعمارية والهندسية	- دمج نظام حديث ضمن التصاميم. - تحقيق التوازن بين الجمالية والوظيفة. - تقديم حلول مستدامة للواجهات.	- عدم معرفة تقنية كافية بالنظام. - تحفظ الزبائن التقليديين من الأفكار الجديدة. - صعوبة تجربة النظام في المشاريع الأولية.	- إبراز تميز المكتب بالمشاريع الذكية. - تحسين الأداء البيئي للمباني. - إرضاء الزبائن المهتمين بالاستدامة.
2- شركات البناء والتطوير العقاري	- تلبية متطلبات التظليل والراحة الحرارية. - تقديم مشاريع ذات قيمة مضافة. - تحسين سمعة المشروع في السوق.	- تكاليف إضافية في التوريد والتركيب. - القلق من وقت التسليم والتجهيز. - عدم وجود مرجع عملي سابق.	- زيادة جاذبية المشروع للعملاء النهائيين. - تبرير أسعار بيع أو إيجار أعلى. - مواكبة معايير البناء الحديثة.
3- أصحاب المشاريع الخاصة (فيلات، فنادق، مراكز ثقافية)	- حماية الفضاء الداخلي من أشعة الشمس المباشرة. - خلق تجربة مميزة للزائر أو المستخدم. - تقليل استهلاك الطاقة.	- الميزانية المحدودة أحيانًا. - تخوف من صيانة النظام الذكي. - عدم توفر مرجع محلي لتركيبه.	- التصميم الفريد والجذاب. - تحسين التصنيف البيئي للمبنى. - إبراز طابع الحداثة والتطور.
4- المؤسسات العامة والثقافية (متاحف، معارض، جامعات)	- التحكم الدقيق في الإضاءة الطبيعية لحماية المعروضات أو تحسين بيئة التعلم. - نظام موثوق على المدى الطويل. - تقليل التكاليف التشغيلية.	- طول الإجراءات الإدارية في التوريد. - الحاجة إلى اعتماد رسمي. - تحفظ من استخدام أنظمة غير مألوفة.	- خدمة الجمهور بكفاءة وراحة أكبر. - إبراز المؤسسة كواجهة للابتكار. - التماشي مع سياسات الطاقة الوطنية.
5- المهندسون والمصممون المستقلون	- تبني تقنيات معمارية معاصرة. - تقديم حلول ذكية ومتميزة للزبائن. - الحصول على ميزة تنافسية في السوق.	- قلة الموارد لتركيب النظام. - الحاجة إلى دعم تقني مباشر. - عدم توفر عينات أو توثيق كافٍ.	- تعزيز الملف المهني بالمشاريع الذكية. - إمكانية تطوير حلول مخصصة مع النظام. - جذب زبائن يبحثون عن حلول غير تقليدية.

6. *تحليل المنافسين:*

اسم الجهة أو النوع	بلد/نوع الأصل	نوع المنتجات أو الخدمة	السوق المستهدف	نقاط القوة الرئيسية	نقاط الضعف
Hunter Douglas	هولندا (عالمي)	أنظمة تظليل ذكية – ستائر متجاوبة – واجهات متحركة	مباني كبرى، جامعات، متاحف	- جودة عالية جدًا - أنظمة تحكم دقيقة - تجربة واسعة دوليًا	- كلفة مرتفعة جدًا - غير متوفرة بسهولة في الجزائر - لا تتماشى دائمًا مع المناخ المحلي
Warema	ألمانيا (عالمي)	ستائر خارجية، تحكم شمسي أتوماتيكي	فنادق، مشاريع راقية في أوروبا	- دقة ألمانية - تحكم فعال - تصميم متنوع	- لا توجد خدمة محلية مباشرة - الاعتماد على الاستيراد - عدم ملاءمة كل النماذج للبيئات الحارة
Schüco	ألمانيا (عالمي)	نوافذ – واجهات ذكية – دمج طاقة شمسية	مشاريع كبرى ذكية	- حلول مستدامة ومتكاملة - دعم للطاقة الشمسية - جودة ممتازة	- أسعار مرتفعة - تعقيد في التركيب - غياب دعم تقني مباشر في الجزائر
مقاولين محليين (نجّار ألومنيوم)	الجزائر (محلي تقليدي)	مظلات يدوية، شفرات ألومنيوم، ستائر بسيطة	مشاريع صغيرة ومتوسطة	-سعر منخفض - توفر محلي كبير - تركيب سهل	- بدون ذكاء صناعي - تصميم محدود وغير ديناميكي - ضعف في الجمالية والأداء البيئي
موردين خاصين للستائر الذكية (مستوردة)	الجزائر (محلي مستورد)	ستائر كهربائية، حساسات ضوء بسيطة	فلل فاخرة – مكاتب إدارية	- تقنية بسيطة وسهلة التركيب - توفر نسبي لبعض الموديلات - تفاعل أساسي مع الضوء	- لا تصلح للواجهات الخارجية - تفتقر للتكامل مع التصميم المعماري - صعوبة الصيانة والدعم الفني

7. الموردون:

المادة / المكوّن	نوع المادة	المورّد / المصدر	محلي/دولي	ملاحظات تقنية
الألومنيوم الخام	صفائح أو بروفيلات 6061 أو 6082	– Falaise Alu (Metalco) DZ – Profal / El Wafa / HPS DZ	محلي	متوفر بأشكال مختلفة، مناسب للقص والطي، خفيف الوزن ومقاوم للتآكل
الطلاء السيراميكي	دهان مقاوم حراري وعازل	– Ubuy DZ DZ (Cerakote Nasiol) – Proservice FR	مستورد	يوفر عزل حراري، مقاومة للتآكل، ولمعان ثابت. يدوم حتى 10 سنوات أو أكثر
حساس ضوء TSL2561	حساس استشعار الإضاءة الرقمية I2C	– PowerTech DZ DZ – Ouedkniss DZ	محلي	يُستخدم لقياس شدة الإضاءة وتغذية وحدة التحكم لاتخاذ قرارات الفتح أو الإغلاق
حساس حرارة LM35	حساس قياس درجة الحرارة	– Ouedkniss DZ – Websoog DZ	محلي	دقيق وسهل البرمجة، يُستخدم لمراقبة درجة حرارة الغلاف الخارجي للنظام
لوحة Arduino أو ESP32	لوحة تحكم ميكروكنترولر	– Ouedkniss DZ – Ubuy DZ	محلي + مستورد	ESP32 تقدم أداء أعلى ودعم للاتصال اللاسلكي / WiFi Bluetooth
محرك سيرفو أو Stepper	محركات كهربائية صغيرة	– Ouidekniss DZ (كميات محدودة)	مستورد	يُستخدم للتحكم في حركة الوحدات، يُفضل أن يكون بزاوية تحكم دقيقة وعزم كافٍ

		– AliExpress / Amazon CNDE		
مفصلات وقطع تثبيت	ستانلس ستيل أو ألمنيوم	–محلات مواد بناء – Ferre–Tech DZ	محلي	مقاومة للتآكل، خفيفة الوزن، ضرورية للربط بين الأجزاء المتحركة
معدات تصنيع (ماكينات)	ليزر CNC + طي معدني	– Atomstack / Aoxuan (Ubuy ،Alibaba ، AliExpress) CN	مستورد	يُنصح بشرائها للاستقلالية في الإنتاج على المدى المتوسط والطويل

8. *استراتيجية التسويق :*

8.1. استراتيجية الانطلاق التسويقي (Marketing de Lancement)

تهدف إلى تقديم النظام الذكي Inshado لأول مرة للسوق المحلي، وخلق وعي أوّلي قوي بالعلامة التجارية، وبناء الثقة مع العملاء والمهنيين المعماريين.

الوسائل المعتمدة:

1- موقع إلكتروني احترافي يعرض:

- فيديو تعريفي للمنتج وطريقة عمله.
- محاكاة ثلاثية الأبعاد (D3) لوحدات Inshado.
- صفحات للمهندسين المعماريين ومالكي المشاريع للتواصل المباشر.

2- محتوى على وسائل التواصل الاجتماعي:

- إنستغرام: صور التطبيقات المعمارية – فيديوهات قبل/بعد.

- LinkedIn: منشورات تقنية موجهة للمهنيين وشركات البناء.
- فيسبوك: حملات توعوية للسوق المحلي (خصوصًا في الجنوب الجزائري)

3- علاقات عامة موجهة:

- إرسال ملفات عرض للمكاتب الاستشارية ومهندسي الطاقة الشمسية.
- تنظيم لقاءات مصغّرة (Open Days) داخل ورشة عرض حقيقية أو بالشراكة مع فضاءات معمارية.

4- تركيب النظام في مشاريع نموذجية:

- 2–3 مشاريع صغيرة في قطاعات السياحة/العرض/المتاحف.

5- تسعير استراتيجي تمهيدي (Launch Price):

- خصم خاص لأول 3 مشاريع تركيب.
- استشارة مجانية ودراسة أولية للإدماج المعماري

8.2. استراتيجية التوسع التسويقي (Marketing d’Expansion)

بعد نجاح المرحلة الأولى، تهدف هذه المرحلة إلى **توسيع قاعدة العملاء جغرافيًا وقطاعيًا**، وزيادة الحصة السوقية داخل وخارج الجزائر.

الوسائل المعتمدة:

1- المشاركة في معارض قطاعية دولية:

- مثل BATIMATEC (الجزائر)، Archibat (تونس).
- عرض نماذج حية وتوزيع كتيبات تعريفية للمنتج.

2- بناء شبكة موزعين معتمدين:

- استهداف مورّدين ومركبين محليين في مناطق مختلفة.
- تدريبهم على خصائص النظام وتقنيات تركيبه.

3- دعم هندسي ومعماري تقني:

- توفير كتيبات BIM/CAD لـ Inshado.
- تقديم خدمات تكييف التصميمات حسب مشاريع كل عميل.

4- إطلاق نسخة مخصصة حسب القطاعات:

- نسخة خفيفة للبيوت الصغيرة أو السياحية.
- نظام مركزي موجه للفنادق أو مباني المؤسسات.

5- إستراتيجية تسعير ديناميكية:

- خصومات للطلبات الجماعية أو المستمرة.
- تسعير مرن حسب المساحة ونوع الاستخدام.

6- عروض ما بعد البيع وخدمة الزبائن:

- صيانة مجانية أول سنة.
- ضمان استرجاع في حال الأداء غير المُرضي.

المحور الرابع

خطة الانتاج والتنظيم

المحور الرابع : خطة الإنتاج والتنظيم

1. *مخطط الإنتاجي:*

1.1. الموقع :

تم اختيار المنطقة الصناعية في مدينة بسكرة نظرًا لموقعها الاستراتيجي، وتوفر البنية التحتية الملائمة لاحتضان المشاريع التقنية والإنتاجية الناشئة، إضافةً إلى قربها من شبكات النقل الرئيسية مما يسهل عمليات التوريد والتوزيع. كما توفر مساحات قابلة للتوسع المستقبلي. فضلاً عن ذلك، فإن وجود تجمع صناعي متنوع داخل المنطقة يتيح فرصًا للتعاون والشراكة مع مؤسسات أخرى في مجالات التصنيع والتطوير، مما يخلق بيئة محفزة للابتكار والنمو.

1.2. الجانب المعماري للمشروع :

الفضاء	المساحة المقترحة (م²)	الوظيفة/الملاحظات
ورشة التصنيع الرئيسية	250	تحتوي على مناطق القطع، الطي، التركيب النهائي، مفصولة بجدران خفيفة داخلية.
منطقة آلات القطع (Laser/CNC)	50	مزودة بتهوية خاصة وأرضية صناعية مقاومة للحرارة والشرر.
منطقة الطي والتجميع	80	لتجميع وحدات Inshado ميكانيكيًا مع خط إنتاج أفقي.
غرفة الطلاء والمعالجة	40	غرفة معزولة حراريًا ورطبًا، مزودة بتهوية خاصة لطلاء السيراميك أو المواد العازلة.
مختبر اختبار النماذج	30	اختبارات الإضاءة، مقاومة الحرارة، المرونة الميكانيكية، إلخ.

فضاء صيانة وتشغيل الآلات	20	لصيانة الأجهزة داخليًا وضمان الأداء المستمر.
مخزن المواد الخام	60	لتخزين الألومنيوم، الإلكترونيات، المحركات، الطلاءات.
مخزن المنتجات النهائية	50	لتخزين وحدات Inshado الجاهزة قبل الشحن أو التركيب.
مكاتب الإدارة والهندسة	100	مكاتب للمدير، المهندسين، المسوّقين، لاجتماعات تقنية.
قاعة استراحة + مطبخ صغير	20	مساحة مريحة للموظفين.
مرافق صحية	20	مغسلة + مراحيض موزعة حسب الأنظمة.
ساحة تحميل وتفريغ خارجية	100	منطقة مغطاة جزئيًا للشاحنات الصغيرة والرافعات.
فضاء توسع مستقبلي مفتوح	150	لإضافة خط إنتاج جديد، أو قاعة عرض للنظام، أو مكتب تقني موسّع.
ممرات داخلية / مسارات حركة	≈ 100	تنقل مرن بين الفضاءات حسب تسلسل التصنيع والخدمات.

2. *احتياجات المشروع:*

2.1. الألات والمعدات:

اسم العتاد	الكمية	السعر/الوحدة (بالدج)	السعر الإجمالي (بالدج)
آلة قطع ليزر CNC صغيرة	1	870,000	870,000
آلة طي كهربائية(Pliage)	1	797,500	797,500
فرن حراري صغير للطلاء	1	435,000	435,000
ضاغط هواء صناعي	1	116,000	116,000
نظام تهوية صناعي + فلتر غبار	1	217,500	217,500
حزمة حساسات ضوء (LDR / TSL2561 أو ما يعادلها)	10	1,450	14,500
حزمة محركات سيرفو – Servo motors 20kg/cm)	10	3,625	36,250

وحدات تحكم (Arduino / ESP32 / STM32)	5	4,350	21,750
وحدات استقبال شمسية (Sun Position Tracker modules)	3	6,525	19,575
شاشة تحكم لمراقبة النظام	1	29,000	29,000
أدوات يدوية (مفكات، كماشات...)	2	21,750	43,500
أدوات فحص ضوئي وحراري (Luxmeter, IR thermometer)	2	14,500	29,000
المجموع الجزئي	≈ 2,629,575 دينار جزائري		

2.2. المعدات المكتبية:

اسم العتاد	الكمية	السعر التقديري (دج)	السعر الإجمالي (دج)
حاسوب مكتبي	6	100,000	600,000
مكاتب	12	10,000	120,000
كراسي مكتبية مريحة	14	7,000	98,000
خزائن حفظ وثائق	1	17,000	17,000
مودام إنترنت	2	4,000	8,000
طابعة ملونة متعددة الوظائف	1	35,000	35,000
طاولة اجتماعات	1	30,000	30,000
جهاز عرض (Projecteur / Écran)	1	45,000	45,000
لوازم مكتبية متنوعة	–	10,000	10,000
الإجمالي التقريبي		≈ 988,000 دينار جزائري	

2.3. الاحتياجات التشغيلية الشهرية للمشروع:

البند	التكرار	التكلفة التقديرية بالدينار الجزائري (دج)
الماء	شهري	2,500
الكهرباء	شهري	15,000
الإنترنت عالي التدفق	شهري	6,000
الهاتف الثابت / المحمول	شهري	3,000
صيانة دورية للمعدات	شهري	7,000
تحديث البرمجيات / الاشتراكات	شهري	5,000
الإجمالي الشهري التقريبي:	≈ 38,500 دج / شهر	
الإجمالي السنوي التقريبي:	38,500 × 12 = 462,000 دج / السنة	

3. *النظام الإنتاجي للمشروع : خطوات الإنتاج :*

1. **مرحلة التصميم والتخطيط** : الهدف: تحويل احتياجات الزبون إلى نموذج واقعي وقابل للتنفيذ.

- تحليل متطلبات المشروع بناءً على الموقع والمناخ واتجاه الواجهة.
- تصميم النموذج الرقمي باستخدام برامج مثل Rhino أو Revit، مع محاكاة حركته وأدائه.
- إعداد ملفات القطع والتصنيع CNC أو ليزر للقطع المعدنية، وتجهيز ملفات البرمجة للمتحكمات الذكية.

2. **مرحلة التصنيع** : الهدف: تجهيز وتجميع كل المكونات الفيزيائية والرقمية.

- الميكانيكية: قص وتشكيل الهياكل من الألمنيوم أو الخشب حسب التصميم.
- الإلكترونية: تركيب الحساسات (Sensor de lumière, température...)، المحركات (Servo/Stepper)، ووحدات التحكم (Arduino, ESP32...).
- التجميع الأولي: تركيب الأجزاء في الورشة للتأكد من مطابقة المكونات.

3. **مرحلة التركيب والبرمجة :**الهدف: خلق نظام متكامل ومهيأ للاستخدام الذكي.

- دمج المكونات الميكانيكية والإلكترونية معًا.
- برمجة النظام للتحكم في الفتح/الغلق حسب شدة الضوء، الحرارة، أو الزمن.

- اختبار الحركات، سرعة الاستجابة، واستهلاك الطاقة للتأكد من كفاءة الأداء.

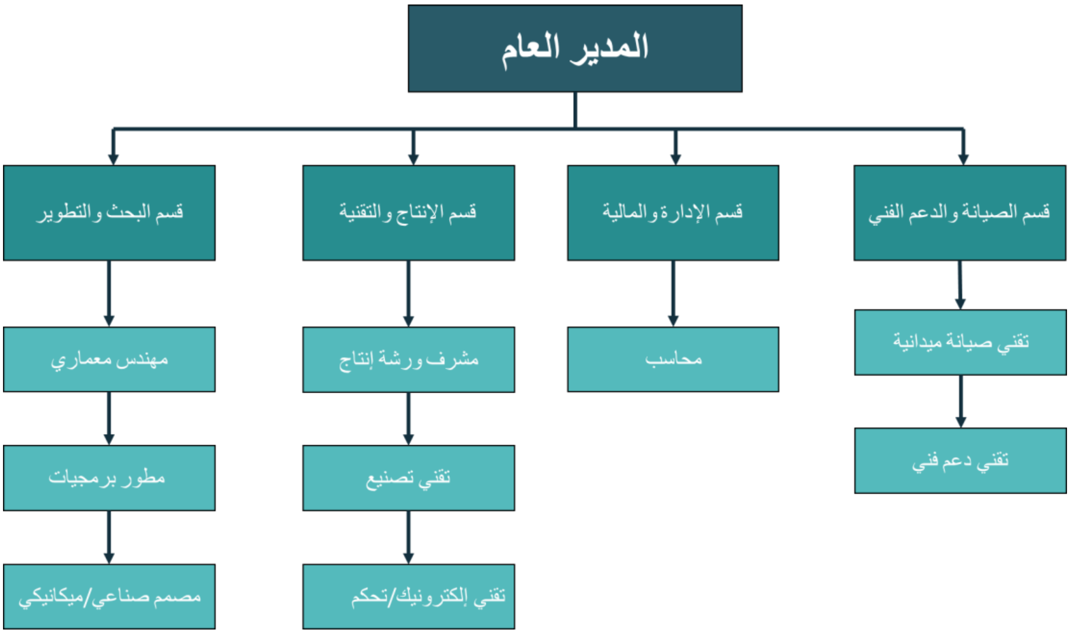
4. **مرحلة النقل والتركيب الموقعي** : الهدف: نقل المنتج إلى الموقع وتركيبه باحترافية.

- تغليف المكونات بشكل آمن لضمان عدم تلفها أثناء النقل.
- شحن النظام إلى موقع المشروع (من الورشة إلى واجهة المبنى).
- تركيب النظام على الواجهة بدقة، وربطه بباقي أنظمة المبنى (كهرباء، إنترنت...).

5. **مرحلة التكوين والتسليم** : الهدف: تسليم منتج جاهز، موثوق، وسهل الاستخدام.

- تكوين الزبون حول طريقة الاستخدام، التشغيل والصيانة.
- تسليم الوثائق: دليل الاستخدام، كتيب الصيانة، شهادة الضمان.
- تأكيد رضا الزبون، وإمضاء وثيقة التسليم الرسمية.

4. *مخطط التنظيمي:*



5. *احتياجات اليد العاملة والأجور:*

القسم	الوظيفة	عدد الموظفين	الاجور
التصميم والتطوير	مهندس معماري	1	70,000
	مصمم صناعي/ميكانيكي	1	70,000
	مطور برمجيات IoT /	1	80,000
الإنتاج والتقنية	مشرف ورشة إنتاج	1	70,000

	تقني إلكترونيك/تحكم	1	60,000
	تقني تصنيع / CNC ليزر)	2	60,000
	عامل تجميع وتركيب	2	50,000
الإدارة والمالية	محاسب	1	50,000
الصيانة والدعم الفني	تقني صيانة ميدانية	1	50,000
	تقني دعم فني	1	50,000
التكلفة الشهرية الإجمالية		720,0000	

ملاحظة :

- هذه الأجور تقديرية ومرنة حسب الخبرة وطبيعة العقد.
- يمكن في البداية تقليص الفريق مع دمج بعض الأدوار، خاصة بين التصميم والتصنيع أو بين الصيانة والدعم الفني.
- في أول سنة الأجور قابلة للمراجعة حسب أداء المشروع.

6. التموين :

- الآلات والمعدات التقنية:تتم عملية الشراء مرة واحدة فقط عند الانطلاق، ما لم تظهر حاجة لاقتناء آلات جديدة في المستقبل.
- المواد الأولية: يتم شراؤها حسب الطلب ووفقًا لنوعية المنتَج ومخطط الإنتاج لكل دورة تصنيع.
- تجهيزات المكتب واللوازم الإدارية: تُشترى مرة واحدة فقط عند الإطلاق لتجهيز المقر الإداري والوظيفي.

7. الشركاء:

فئة الشريك	أمثلة / شركاء محددون	نوع الشراكة
1- الشركاء الصناعيون / الموردون التقنيون	- مورّدي الألمنيوم المحليين مثل Alprofil DZ, Batimetal - مزوّدي المحركات والحساسات مثل : Festo, Schneider Electric, RS Components	تزويد بالمواد الأولية، قطع إلكترونية، دعم فني
2- الشركاء الأكاديميون والتقنيون	- جامعة محمد خيضر بسكرة (قسم الهندسة المعمارية و الهندسة الكهربائية)	دعم في البحث والتطوير(R&D) ، النمذجة، الاختبارات

	- مخابر الابتكار و "FabLabs"الجامعية - مراكز البحث مثل CDER الطاقة المتجددة	
3- الشركاء المؤسساتيون والداعمون	- وزارة اقتصاد المعرفة والمؤسسات الناشئة - الوكالة الوطنية لدعم المقاولاتية (ANSEJ سابقًا - مسرعات الأعمال مثل Algeria : Venture, IncubMe	تمويل أولي، احتضان، مرافقة قانونية وإدارية
4- الشركاء التجاريون والسوقيون	- شركات معمارية ومكاتب دراسات مثل : Biome Design, Eco Arch DZ - مؤسسات بناء وتطوير عقاري - مشاريع حكومية أو قطاع خاص تهتم بالبناء الذكي والمستدام	عقود بيع مباشرة، مشاريع مشتركة، إدماج النظام في مبانٍ ذكية
5- البنوك والمؤسسات المالية	- البنك الوطني الجزائري (BNA) - بنك التنمية المحلية (BDL) - الصندوق الوطني لدعم المؤسسات الناشئة	شراكة تمويلية وخدماتية واستشارية تشمل تمويل المشاريع، إدارة العمليات المالية، وتقديم المرافقة المالية والتوجيه

المحور الخامس

الخطة المالية

المحور الخامس :الخطة المالية

8. *تكاليف المشروع واستهلاك الستثمار:*

8.1. التكاليف الاستثمارية:

الآلات والمعدات	DZD 5,000,000
المعدات التقنية (حساسات، محركات، تحكم)	DZD 1,200,000
معدات مكتبية	DZD 400,000
البناء والتجهيزات	DZD 2,000,000
أثاث ومرافق	DZD 500,000
مصاريف التأسيس والترخيص	DZD 300,000
مجموع التكاليف الاستثمارية	DZD 9,400,000
المجموع	DZD 18,800,000

8.2. التكاليف التشغيلية:

الرواتب السنوية	DZD 9,600,000
الكهرباء والماء والإنترنت	DZD 960,000
الصيانة	DZD 480,000
المواد الأولي	DZD 3,000,000
نقل وتوزيع	DZD 720,000
مصاريف أخرى	DZD 600,000
مجموع التكاليف التشغيلية السنوية	DZD 15,360,000
المجموع	DZD 30,720,000

8.3. تقدير المبيعات :

	السنة 1	السنة 2	السنة 3	السنة 4	السنة 5
جانفي	3200000	4920000	6720000	10320000	18000000
فيفري	3200000	4920000	6720000	10320000	18000000
مارس	3200000	4920000	6720000	10320000	18000000
أفريل	3600000	5330000	7140000	10750000	18450000
ماي	3600000	5330000	7140000	10750000	18450000
جوان	3600000	5330000	7140000	10750000	18450000
جويلية	3200000	4920000	6720000	10750000	18450000
أوت	3200000	4920000	6720000	10750000	18450000
سبتمبر	3200000	4920000	6720000	10750000	18450000
أكتوبر	3200000	4920000	7140000	10750000	18450000
نوفمبر	3600000	5330000	7140000	11180000	18900000
ديسمبر	3600000	5740000	7980000	11610000	22950000
المجموع	4,060,000دج	8,120,000دج	14,200,000دج	18,400,000دج	22,600,000دج
المجموع المبيعات	67,400,000				

المحور السادس

النموذج الاولي التجريبي

المحور السادس: النموذج الولي التجريبي

تمّ إعداد النموذج الأوّلي التجريبي في هذه الدراسة على شكل نموذج رقمي ديناميكي باستخدام برنامجي Rhinoceros 3D وGrasshopper، بهدف تمثيل السلوك الحركي لنظام التظليل المتقدم المقترح ضمن الواجهة.

يُعتبر هذا النموذج خطوة أساسية لفهم آلية عمل النظام وطرق تفاعله مع تغيّر زوايا سقوط الأشعة الشمسية، إضافة إلى اختبار منطق الفتح والإغلاق وتوزيع الوحدات المتحركة على الواجهة.

خطوات إعداد النموذج:

تصميم الشكل الهندسي للنظام:

تمّ في برنامج Rhinoceros إنشاء الشكل العام للواجهة المعمارية التي تحتوي على النظام التظليلي، مع تحديد الأبعاد الحقيقية، وعدد الوحدات التظليلية، وطريقة تثبيتها على الإطار البنائي.

الربط البارامتري في Grasshopper:

بعد استيراد النموذج الهندسي إلى Grasshopper، تمّ إعداد شبكة من المكوّنات (Components) للتحكم بزوايا الفتح والإغلاق وفق معادلات قابلة للتعديل.

تمّ استخدام مكوّنات Sliders للتحكم بنسبة الانفتاح والإغلاق يدويًا أو بشكل تدريجي، مما سمح بتجريب ثلاث وضعيات رئيسية للنظام:

الوضع المفتوح بالكامل: تُفتح الوحدات التظليلية بزوايا كبيرة للسماح بمرور أقصى قدر من الإضاءة الطبيعية.

الوضع الوسيط: تُضبط زوايا الفتح في درجة متوسطة تسمح بمرور الضوء المنتشر فقط دون الإبهار.

الوضع المغلق بالكامل: تُغلق الوحدات كليًا لحجب أشعة الشمس المباشرة والحدّ من الحرارة المكتسبة.

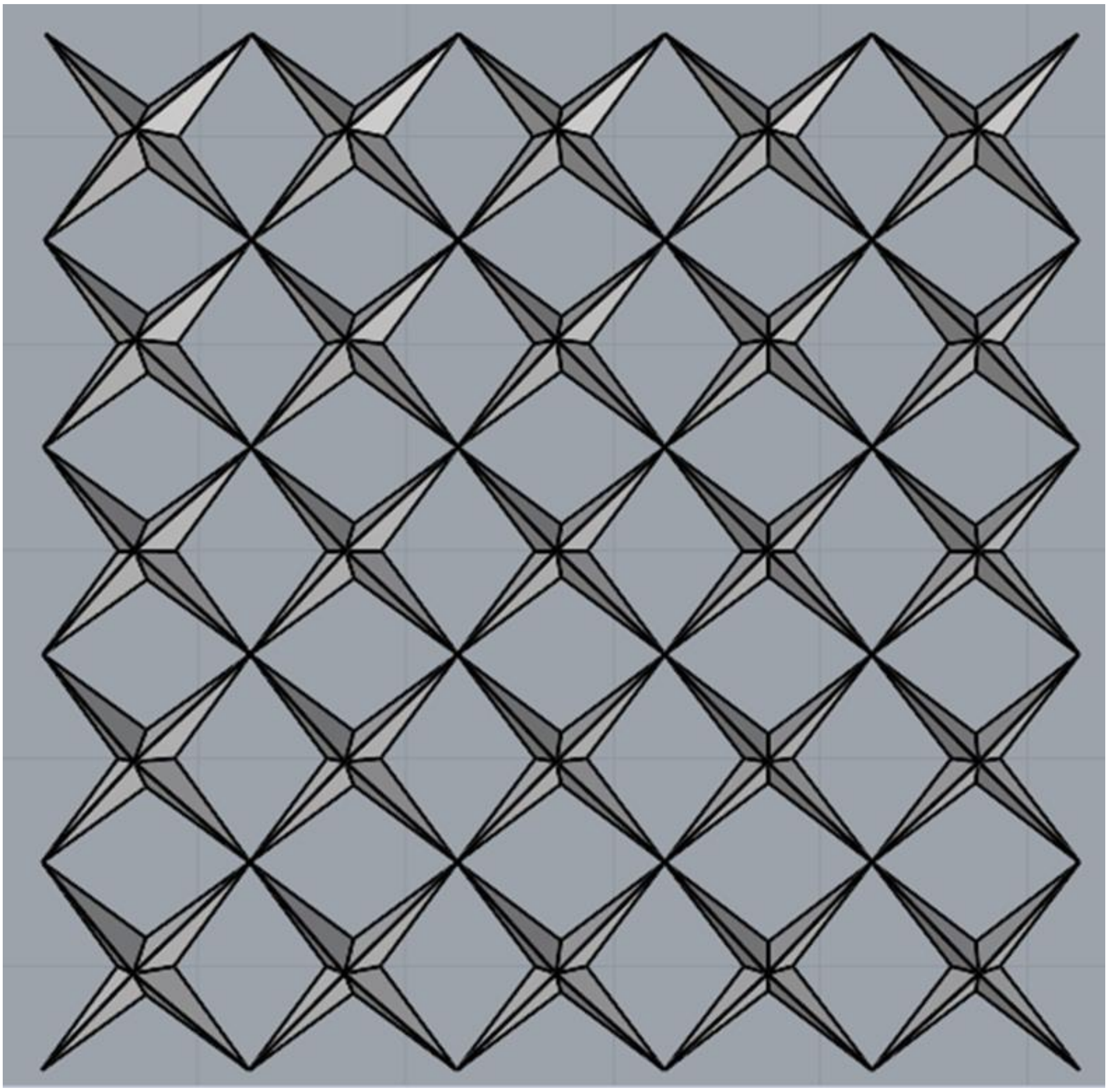
إعداد نظام الحركة الديناميكية:

تمت برمجة علاقة تفاعلية بين زاوية فتح الألواح ومعطيات الإشعاع أو زاوية الشمس عبر مكوّنات رياضية داخل Grasshopper، ما يسمح للنظام بالانتقال التدريجي بين أوضاعه الثلاثة.

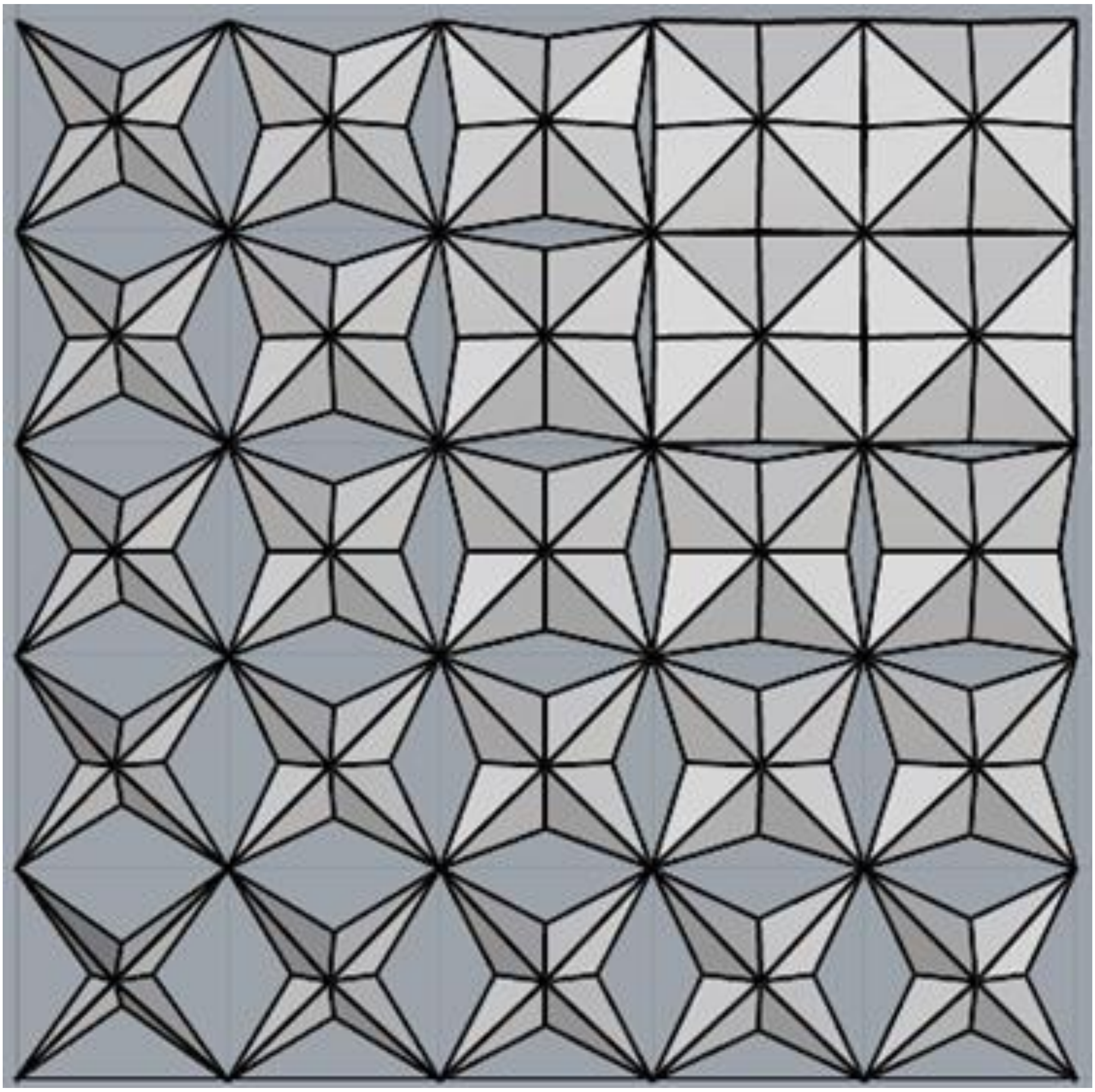
هذا الترابط يُظهر كيف يمكن للنظام أن يستجيب تلقائيًا للتغيرات اليومية أو الموسمية دون تدخل مباشر.

ضبط الإخراج البصري للنموذج:

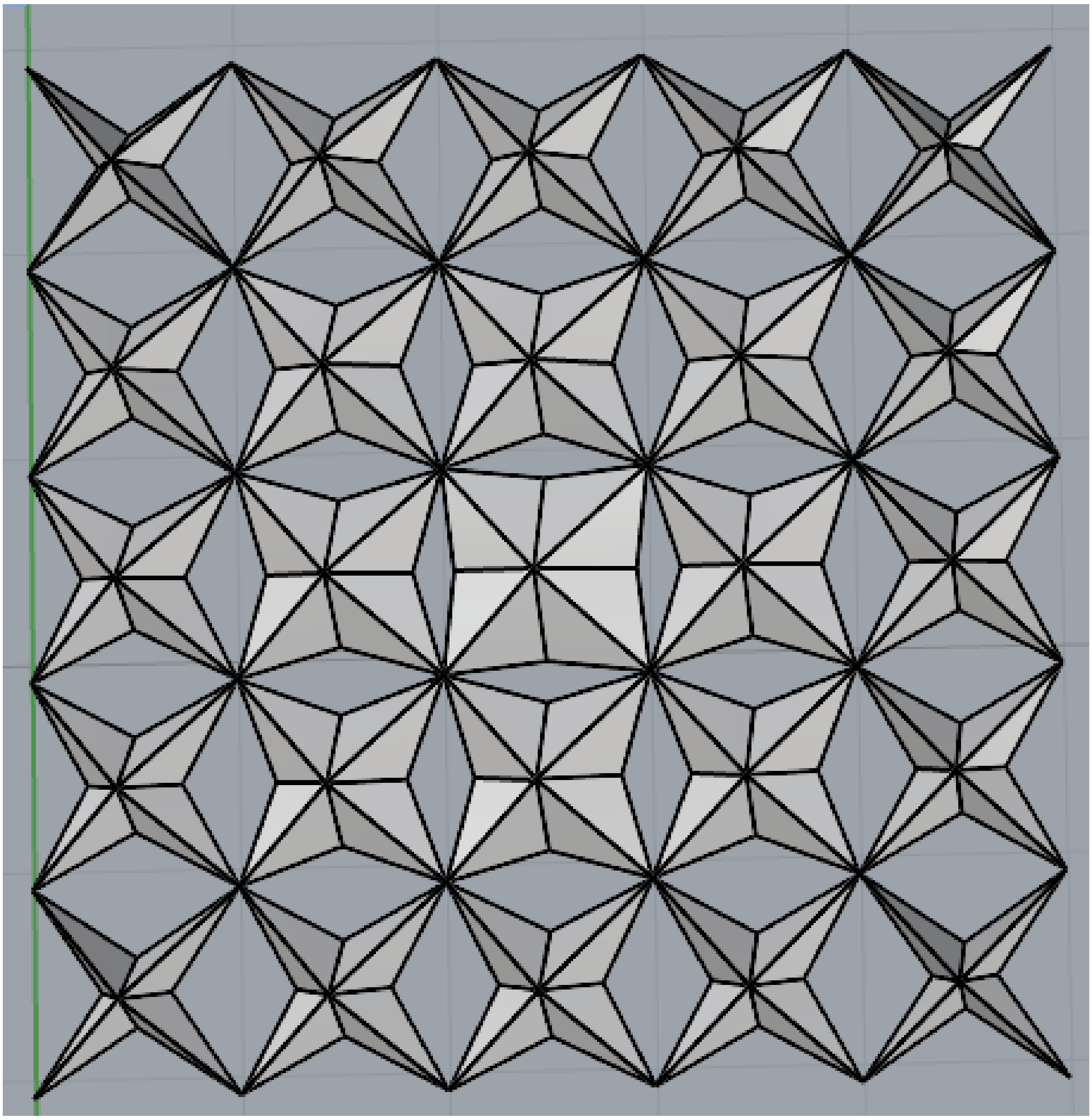
تمّ إعداد المشاهد النهائية داخل Rhinoceros لتوضيح حركة النظام في كل وضع من أوضاع التشغيل، وذلك باستخدام إطارات متتابعة (Frames) أو صور توضيحية تُظهر المراحل المختلفة للانفتاح والإغلاق.



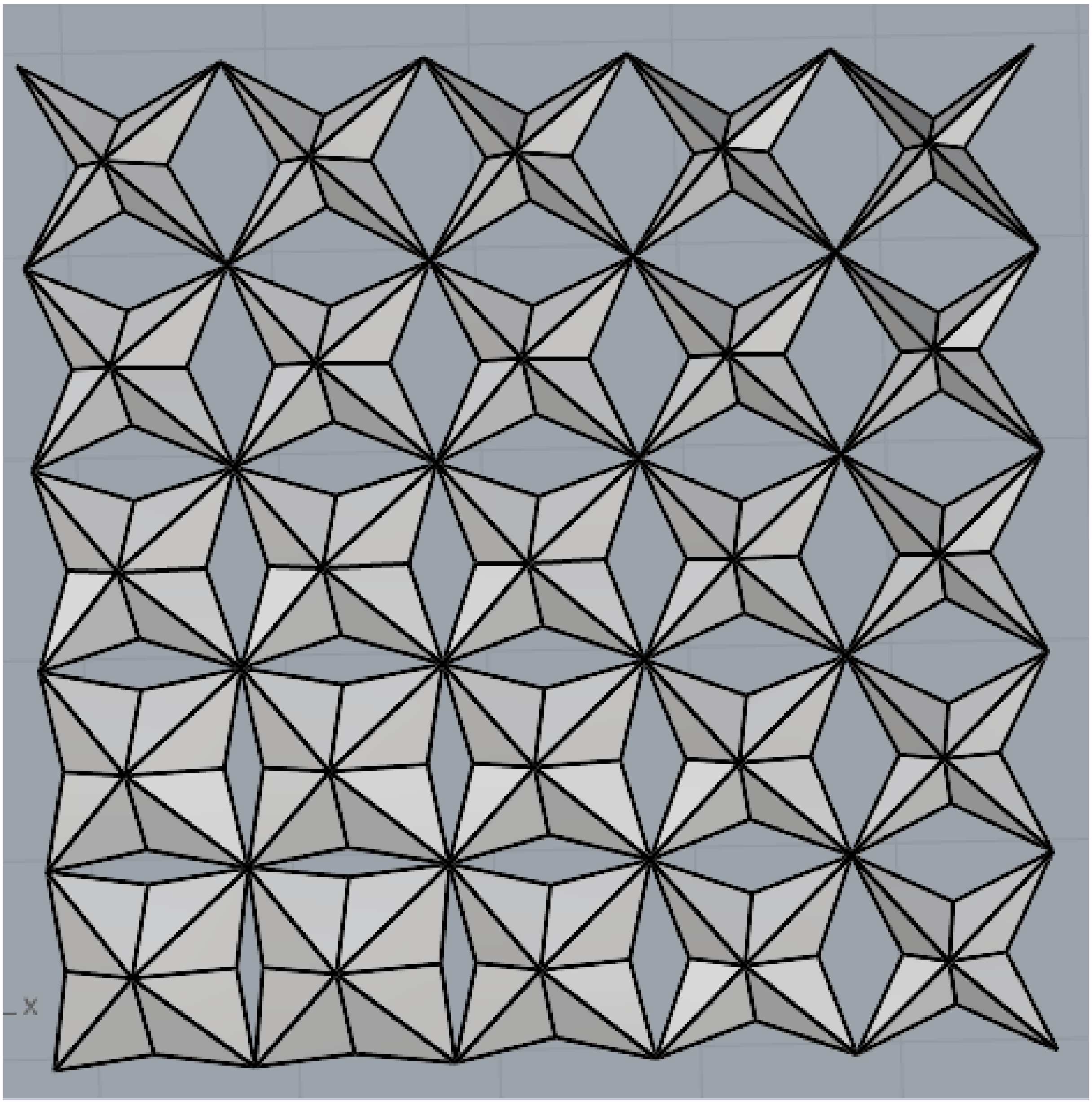
نظام الواجهة في وضع الفتح الكامل: تفاعل الوحدات الهندسية مع غياب السقوط المباشر لأشعة الشمس



تعكس هذه الحالة مرحلة وسطى بين الفتح الكامل والانغلاق التام، حيث تتكيّف الوحدات مع اختلاف زوايا سقوط الضوء لتوفير توازن بين التظليل والإضاءة الطبيعية.



في هذا الوضع، تبدأ الوحدات في الإغلاق بشكل تدريجي حسب شدة الإشعاع الشمسي، مما يقلل من نفاذ الضوء المباشر ويحافظ على راحة الإضاءة داخل المبنى.



الوحدات المغلقة عن المناطق المعرّضة للسقوط المباشر لأشعة الشمس، في حين تفتح الوحدات الأخرى للسماح بمرور الضوء الطبيعي بشكل متوازن

شريحة العملاء (Customer Segments) :

- شركات البناء العقاري والمباني الذكية
- المهندسون والمكاتب المعمارية في الجنوب الجزائري
- القطاع السياحي (الفنادق والمنتجعات)
- المتاحف والمراكز الثقافية
- المدارس والجامعات في المناطق الحارة

علاقات العملاء (Customer Relationships):

- تواصل مباشر ومخصص.
- متابعة تقنية ودعم أثناء وبعد البيع.
- شراكات طويلة المدى مع مكاتب أو جهات.
- كتيّب شرح يرافق المنتج.

قنوات التوزيع (Channels):

- وسائل التواصل الاجتماعي (Instagram، LinkedIn).
- موقع إلكتروني.
- شراكات مع مكاتب معمارية.
- منصات معارض ومجلات متخصصة.
- بيع مباشر أو عن طريق وسطاء.

القيمة المقترحة (Value Proposition) :

- تحسين جودة الإضاءة الطبيعية داخل المباني دون التسبب في التوهج أو ارتفاع الحرارة.
- تقليل استهلاك الطاقة الكهربائية عبر خفض الاعتماد على الإضاءة الصناعية وأنظمة التبريد.
- حل مخصص للمناخات الحارة والجافة، خاصة في مناطق مثل بسكرة وورقلة.
- أداء وظيفي عالي يسمح بالتحكم في كمية الضوء والحرارة بشكل فعّال.
- تقليل المخاطر البصرية والحرارية داخل الفضاءات المعمارية الحساسة .
- نظام مرن وسهل الاستخدام.
- قيمة بيئية مستدامة تساهم في تحقيق أهداف البناء الأخضر.

الأنشطة الرئيسية (Key Activities):

- تحليل المشروع والمناخ (تصميم).
- إعداد التصميم والمحاكاة.
- إنتاج النظام (تصنيع الأجزاء وتجميعها).
- الترويج والتواصل مع العملاء.
- تسليم النظام أو تركيبه.
- متابعة العميل والدعم التقني.

الموارد الرئيسية (Key Resources):

- مصممة معمارية.
- تقني تصنيع أو حرفي لتركيب النظام.
- برامج تصميم ومحاكاة .
- ملفات تصميم قابلة للتنفيذ.
- حاسوب احترافي.
- مواد أولية (ألمنيوم، زجاج).
- ورشة تصنيع .
- رأس مال بسيط لتغطية الترويج والمواد الأولية.

الشركاء الرئيسيون (Key Partners):

- ورشة تصنيع متخصصة (ألمنيوم، زجاج).
- شركة توصيل أو فني تركيب خارجي.
- مكتب معماري شريك في التوزيع أو الدمج ضمن المشاريع.
- مستشار تقني أو أكاديمي (عند الحاجة).
- منصة معمارية رقمية أو معرض متخصص.

مصادر الإيرادات (Revenue Streams):

- بيع مباشر للتصميم المخصص.
- خدمة استشارية مدفوعة.
- رسوم التركيب أو التنسيق مع جهة منفّذة (مستقبلاً).
- بيع النموذج كمنتج رقمي على منصات تصميم (مثل Gumroad أو Behance Pro).
- دورات أو ورشات تدريبية حول تصميم الواجهات الذكية.

هيكل التكاليف (Cost Structure):

- تكلفة الحاسوب والمعدات المرتبطة بالعمل.
- تكلفة التسويق الرقمي.
- شراء المواد الأولية .
- أجر الفريق الفني.
- نقل النظام إلى موقع العميل.
- فاتورة الكهرباء والإنترنت الخاصة بالعمل.
- تكلفة الصيانة الدورية للبرامج أو المعدات.