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

MASTER'S DISSERTATION

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Field: **Architecture**
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Presented and defended by:
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Theme: The role of sun shades in creating shadow for buildings in arid zones

The project: Cultural Center in Biskra

Examiner's committee

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

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This research is dedicated to all who had faith in my capabilities.

Bougherara Mohamed Mortadha

Dedication:

In the name of Allah, the Almighty, I dedicate this work with deep reverence and gratitude:

To my beloved uncle, Bougherara Namir, whose moral guidance and generous financial support provided the foundation that enabled me to complete this academic journey.

To my parents, who have been my pillars of strength throughout my entire life, offering unwavering support and unconditional love at every step of my path.

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Abstract:

This research presents a study on the design of a smart and dynamic sunshade with the aim of improving thermal comfort and well-being during the summer, The system is designed to effectively eliminate solar spots during the peak summer months particularly in July and August by adjusting to block excessive solar radiation. On the other hand, it allows maximum incident radiation during the winter months. The sunshade system will be capable of dynamically responding to environmental conditions and minimizing solar heat gains while optimizing indoor light levels. The system has integrated smart buildings. Technologies, such as AI, can make real-time adjustments to reduce energy consumption while maintaining occupant comfort. This research transitions from a theoretical study of climate and shading strategies to an applied study that will explain how shading can greatly improve thermal comfort in an arid area.

Keywords: Solar protection, smart sunshade, shading, shading device, thermal comfort.

ملخص:

تقدم هذه الدراسة بحثًا حول تصميم كاسرات شمسية ذكية وديناميكية بهدف تحسين الراحة الحرارية والرفاهية خلال فصل الصيف. تم تصميم النظام لإنشاء أقصى قدر من الظل والقضاء بفعالية على البقع الشمسية خلال أشهر الصيف، لا سيما في يوليو وأغسطس. من ناحية أخرى، يسمح هذا النظام بمرور أقصى قدر من الإشعاع الشمسي خلال أشهر الشتاء. ستكون كاسرات الشمس قادرة على الاستجابة الديناميكية للظروف البيئية، مما يساهم في تقليل مكاسب الحرارة الشمسية مع تحسين مستويات الإضاءة الطبيعية في الداخل. ويدمج النظام تقنيات المباني الذكية، مثل الذكاء الاصطناعي، التي تمكّنه من إجراء تعديلات لحظية في الوقت الفعلي بهدف تقليل استهلاك الطاقة مع الحفاظ على راحة المستخدمين. تنتقل هذه الدراسة من إطار نظري لاستراتيجيات المناخ والتظليل إلى دراسة تطبيقية توضّح كيف يمكن لكاسرات الشمس أن تُحسّن بشكل كبير من الراحة الحرارية في المناطق الجافة.

الكلمات المفتاحية: الحماية الشمسية، كاسرات شمسية ذكية، التظليل، انظمة التظليل، الراحة الحرارية.

Table of content:

List of figures:

List of tables:

List of equations:

List of Abbreviations:

• **AI**: Artificial Intelligence

• **ASHRAE**: American Society of Heating, Refrigerating and Air-Conditioning Engineers

• **Clo**: Clothing Insulation Unit

• **EPW**: EnergyPlus Weather (file format used for climate data)

• **HVAC**: Heating, Ventilation, and Air Conditioning

• **ISO**: International Organization for Standardization

• **I_cl**: Garment thermal insulation (used in clothing comfort modeling)

• **MRT**: Mean Radiant Temperature

• **PMV**: Predicted Mean Vote

• **PPD**: Predicted Percentage of Dissatisfied

• **To**: Operative Temperature

• **Ta**: Air Temperature

• **Tr**: Mean Radiant Temperature

• **Vr**: Relative Air Velocity

• **W/m²**: Watts per square meter (unit of thermal flux)

• **Ladybug**: Environmental analysis plug-in for Grasshopper and Rhino

• **Honeybee**: Environmental simulation plug-in for Grasshopper, connected to EnergyPlus and Radiance

• **Rhino**: Rhinoceros 3D, a 3D modeling software

• **Grasshopper**: A visual programming environment used within Rhino for parametric modeling

INTORDUCTORY CHAPTER

INTORDUCTORY CHAPTER:

General Introduction:

With rising energy demand and an increasingly extreme climate, countries like Algeria are facing significant challenges both environmentally and economically. In this perspective, the field of architecture is crucial, not only to reduce energy consumption but primarily to improve thermal comfort and the well-being of residents. Proposing comfortable and climate-appropriate indoor spaces, especially in hot areas like Biskra, has become a priority to meet the needs of occupants while reducing the use of energy-intensive air conditioning systems.

Incorporating sustainable practices in architecture is crucial for improving thermal comfort and mitigating the effects of climate change. The use of kinetic sunshades, combined with artificial intelligence (AI), offers a promising solution. AI can be used to optimize the performance of passive systems, such as sunshades, by dynamically adjusting them based on real-time environmental conditions. This approach improves the thermal comfort of the occupants while contributing to better energy management, particularly in hot and arid regions like Biskra, where cooling needs are high.

The cultural sector also holds significant importance in people's lives, and in the city of Biskra, a rich cultural heritage defines its identity. The planned cultural center in Biskra offers a unique opportunity to integrate bioclimatic technologies while supporting cultural activities. By employing a kinetic sunshade system powered by AI, the center can align with sustainability goals and serve as a model for future architectural projects. This approach not only improves thermal comfort but also demonstrates how architecture can contribute to both cultural promotion and environmental responsibility, offering a vision of sustainable design in Algeria and beyond.

Problematic:

Climate change-induced rising global temperatures have had significant impacts on thermal comfort and raised energy use, particularly in hot, arid areas like Biskra, Algeria. The need for cooling systems rises massively in these areas, raising expenses and energy consumption. Even though Algeria already has energy problems, it is crucial to come up with workable solutions that lower expenses, use less energy, and above all improve building occupants' comfort, safety and well-being.

Controlling incident solar radiation with creative solutions, like dynamic sunshades that adjust to environmental conditions, is a practical and accessible way to deal with these issues. We can increase indoor thermal comfort all year long by minimizing sunspots in the summer and letting in beneficial light in the winter.

Mastering sun exposure by using ingenious solutions such as dynamic sunshades adapted to environmental conditions is a practical and affordable approach to addressing these challenges. This improves thermal comfort indoors throughout the year by reducing excessive solar gains during the summer and allowing beneficial light to enter during the winter.

• How can dynamic shading systems integrating artificial intelligence contribute to improving thermal comfort and occupant well-being, while reducing energy consumption in hot and arid climates?

Hypothesis:

We assume an intelligent sunshade system designed to fulfill multiple functions, making it a versatile solution for buildings located in hot and arid regions. This system could significantly improve indoor thermal comfort, reduce energy consumption, and contribute to the well-being of occupants while enhancing architectural aesthetics.

Objectives:

• To lower internal building temperatures, lessen the impact of direct solar radiation on the facades. and maintaining a comfortable interior temperature by producing as much shade as possible during hot seasons, thereby lowering the need for climate control.

• Promoting passive solar energy in the winter by allowing controlled solar radiation penetration to maintain a good level of thermal comfort without overusing heating while also enhancing the building's overall energy efficiency.

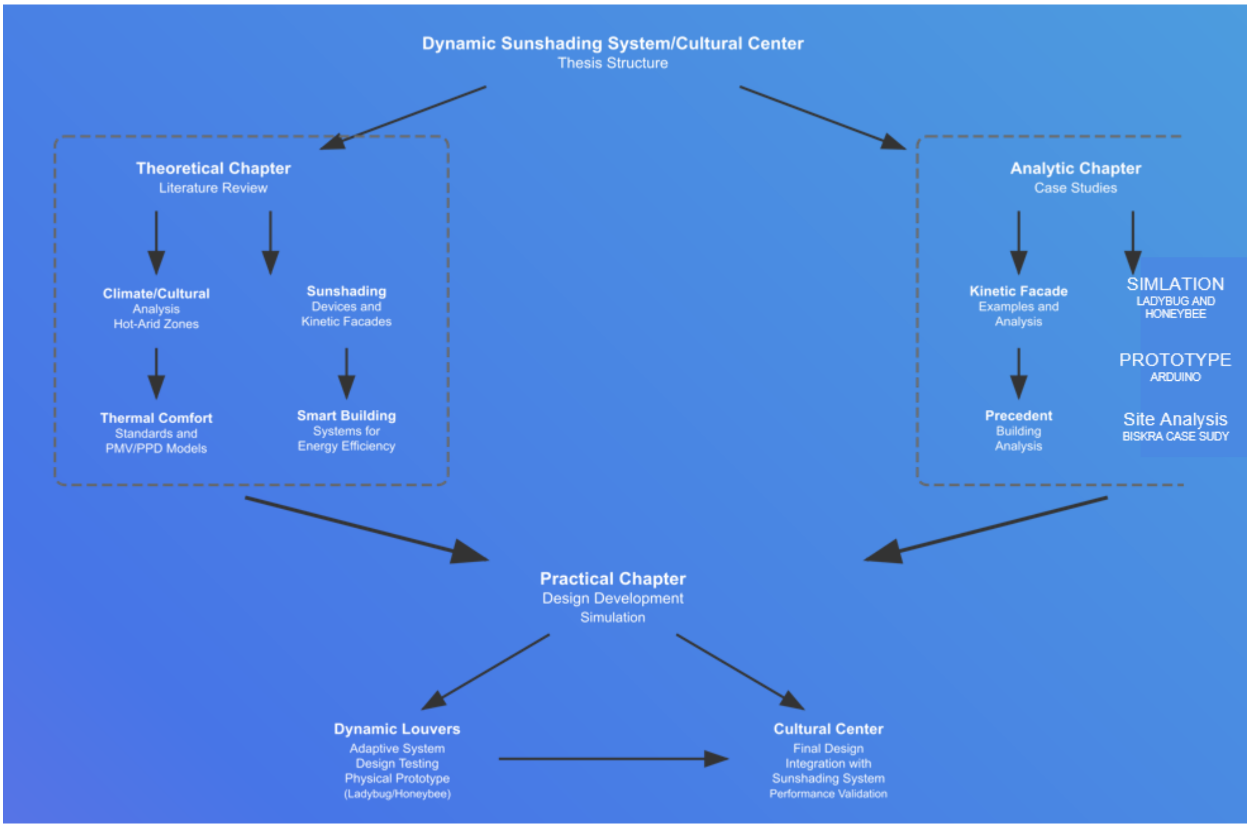
Methodology:

Our methodological approach is based on a deep understanding of all aspects related to the fundamental theoretical concepts of shading, thermal comfort, solar control, and sunshades.

the design of a dynamic intelligent model capable of optimizing thermal comfort (shading/sunlight) throughout the year for maximum effectiveness.

This model will be tested through numerical simulation using Grasshopper, Ladybug, and Honeybee, allowing for a detailed evaluation of its performance in terms of thermal comfort improvement.

Thesis structure



CHAPTER I:

Concepts of thermal comfort in arid zones

I. CHAPTER: Concepts of thermal comfort

Introduction:

This chapter gives the fundamental definition of thermal comfort and its vital role in building design, particularly for hot climates like Biskra. It explains how indoor thermal comfort is influenced by different factors, both user-related, like activity level and clothing, and environment-related, such as humidity and air temperature. By studying thermal comfort models such as PMV/PPD and adaptive models, this chapter lays the foundation for finding the parameters to which dynamic sunshades should respond.

1.1 thermal comfort:

The thermal comfort is that mental state that conveys satisfaction with the thermal surrounding. ASHRAE defines it: "*Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment*". (ASHRAE, 2020, p. 3). According to ISO 7730, individuals assess and interpret their thermal condition based on their personal preferences. They make judgments that can be predictive and preferential. Thus, thermal comfort is not limited to physical parameters alone, but also involves subjective data. ((ISO), 2005). While both Nicol and Humphreys argue that it depends not only on the physical environment but also on the expectations of the building's occupants, how they adapt their behaviors, and the opportunities available to control their environment. (NICOL, HUMPHREYS, & RAOF, 2012).

1.2 Standards for evaluating thermal comfort:

In his book, P.O. Fanger argues that thermal comfort is assessed according to six factors. The first two relate to the occupants, while the other four relate to indoor thermal conditions. To achieve thermal comfort, these factors must be in balance simultaneously, due to the complexity of their interaction in an indoor environment. (FANGER, 1970, p. 15).

These factors are:

1. Activity level (heat production in the body)
2. Thermal resistance of clothing (Clo-value)
3. Air temperature
4. Mean radiant temperature
5. Relative air velocity
6. Humidity

Together with these other components, Figure illustrates the heat exchanges that occur between the human body and its surroundings. These exchanges consist of 24% evaporation and perspiration, 35% convection, 35% radiation, 6% food consumption, and 1% conduction. Convection and evaporation with the ambient air cause the human body to lose over half of its heat. Heat exchanges that take place through radiation with walls must also be taken into account.

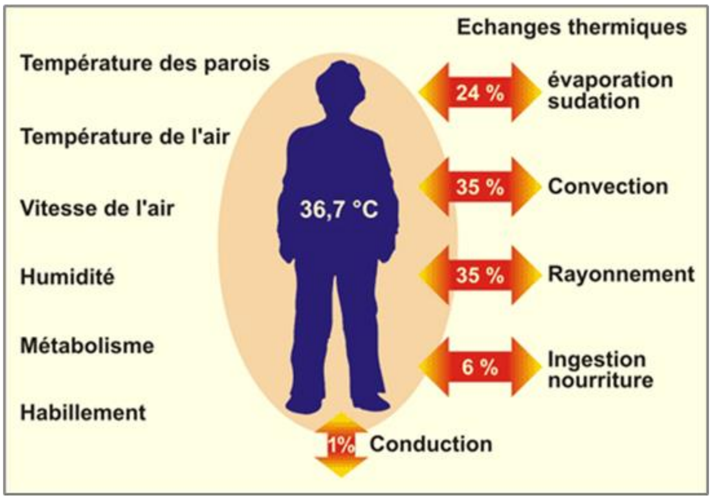


Figure I-1: Thermal exchanges of the human body with the environment taken from the Guide Bâtiment Durable website (2013)

1.2.1 User-dependent Factors:

1.2.1.1 level of activity:

The term "level of activity" is used to describe the kind and amount of physical activity a human being undertakes, the impact of which is immediate on his metabolic rate, or the quantity of energy he spends per unit of time. The energy produced because of a person remaining idle (approximately 58 W/m2) is quantified by 1.0 met, the international unit of measure for activity level in thermal comfort analysis.

The body creates greater heat at increased rates of activity, affecting thermal comfort and subjective feeling. (ASHRAE, 2020, p. 6)

Activity	Metabolic Rate met	W/m²	Btu/h·ft²
Resting			
Sleeping	0.7	40	13
Reclining	0.8	45	15
Seated, quiet	1.0	60	18
Standing, relaxed	1.2	70	22
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	2.0	115	37
1.2 m/s, 4.3 km/h, 2.7 mph	2.6	150	48
1.8 m/s, 6.8 km/h, 4.2 mph	3.8	220	70

Table I-1: Metabolic Rates for Typical Tasks

1.2.1.2 Clothing insulation:

Clothing insulation is a measurement of the clothing's thermal resistance to heat transfer between the body and the external environment. It is expressed in units of "Clo", with 1 Clo representing the level of thermal insulation of an average ensemble of clothing worn in an office environment at 21°C and with low air speed. (FANGER, 1970, p. 32).A study by Kwon and Choi (2013) explored the relationship between clothing insulation (I_cl), air temperature, clothing microclimate temperature, and total clothing mass. The results indicate that total clothing mass and the number of upper layers play very important roles in thermal insulation, while clothing microclimate temperature plays a lesser role. (KWON & CHOI, 2013)

The following table represents the garment insulation:

Garment Description	(I_cl)
Shoes	0.02
Short-sleeve knit sport shirt	0.17
T-shirt	0.08
Sweatpants	0.28

Table I-2: Garment Insulation (I_cl) *(ASHRAE, 2020, p. 9)*

1.2.2 Environmental-dependent Factors:

a. Air temperature (Ta):

Air temperature (usually denoted by Ta) represents the virial temperature of the surrounding air without direct influence from solar radiation or heat released by nearby surfaces. (ASHRAE, 2020), air temperature determines heat exchange between the body and the surrounding environment by convection to a considerable degree. The bigger the difference in air and skin temperatures, the larger the heat exchange. (FANGER, 1970, p. 12)

$$q\ conv = h\ c \cdot A \cdot (T\ skin - T\ air) \qquad (1$$

- $q\ conv$: thermal convection flux (W)
- hc: coefficient de convection (W/m²·K)
- A: exposed body surface (m²)
- $Tskin$: skin temperature (°C)
- $Tair$: ambient air temperature (°C)

This equation highlights that air temperature directly influences convection heat loss. (GIVONI, 1998)

b. Mean Radiant Temperature (MRT):

defined as *"the uniform temperature of an imaginary black enclosure in which a person would exchange the same amount of radiant heat as in the actual non-uniform environment"* (ASHRAE, 2020, p. 9) It reflects the combined effect of the thermal radiation from all surrounding surfaces (walls, ceilings, floors, etc.) and is influenced by their temperatures and geometric configuration relative to the person. (CARLUCCI & PAGLIANO, 2012) Human thermal comfort is greatly influenced by MRT, particularly in areas with cold walls or strong solar gains, and in certain circumstances, it can have a greater effect on comfort perception than air temperature. (FIALA, LOMAS, & STOHRER, 2001)

$$Tr = -\left(\frac{\sum(Ts \cdot As)}{\sum As}\right) \qquad (2$$

- ***Tr:*** mean radiant temperature (°C)
- ***Ts:*** temperature of each surface (°C)
- ***As***: apparent surface area of each surface with respect to the individual (m²)

c. Operative temperature (To):

Operative temperature is an overall indicator that quantifies thermal comfort. (ASHRAE, 2020) It is a mean of the air temperature and mean radiant temperature, thus expressing the combined effect of convection and radiation on the human body. Through the integration of these two crucial factors, operative temperature offers a handy and useful approximation of how a space inside feels to occupants. (NICOL, HUMPHREYS, & RAOF, 2012, p. 23)

It is widely used in thermal comfort studies and building design studies to estimate overall thermal sensation, especially under stationary conditions or low air velocities. ((ISO), 2005)

$$To = A\,Ta + (1 - A)Tr \qquad (3$$

- **A** = 0.5 if the relative air velocity (vr) is less than 0.2 m/s
- **Ta** = Average air temperature (°C)
- **Tr** = Mean radiant temperature (°C), defined by equation (1.2)

d. Air velocity:

Air velocity, air velocity variations, air temperature, and individual characteristics like total thermal sensibility all affect how humans perceive air movement. (TOFTUM, 2004) The speed and direction of air flow in relation to a certain spot is referred to as wind velocity and it plays a critical role in thermal comfort by influencing convective heat exchange between the human body and the environment. (CONG, et al., 2021) Higher wind velocities will further cool by raising evaporation of perspiration, making individuals feel cooler in warm environments. But excessive wind velocities will result in draught distress, especially in cold environments, inducing localized chilling. (TOFTUM, 2004)

e. Humidity:

Humidity refers to the quantity of water in the air in the state of water vapor. Humidity is a metric of water vapor content within the atmosphere. Water vapor, the gaseous state of water, is usually not perceptible by human senses. Humidity refers to the likelihood of precipitation, dew, or fog. (BUENO & AUGUSTO, 2021) Humidity is a measure that depends on temperature and pressure of the system involved. The same amount of water vapor produces higher relative humidity in cold air than in warm air. Another similar measure is the dew point. The amount of water vapor which must exist in order to produce saturation increases as temperature increases. When the temperature of a given volume of air is reduced it will eventually saturate without adding or subtracting water mass. The quantity of water vapor contained in a parcel of air can be very unreliable. For example, a saturated parcel of air has 28 g of water per cubic meter of air when it's 30 °C (86 °F) but just 8 g of water per cubic meter of air when it's 8 °C (46 °F). (ONABANJO & OLANIPEKUN, 2023, p. 10)

1.3 Thermal Comfort Models:

a. PMV/PPD Model (Fanger):

The Predicted Mean Vote (PMV) model, developed by Fanger (1970), is not just a simple thermal index; it tries to predict the mean vote of a group of subjects' thermal sensation on the ASHRAE 7-point scale from six environmental and personal variables: air temperature, mean radiant temperature, air velocity, relative humidity, clothing insulation, and metabolic rate (FANGER, 1970, p. 21) (NICOL, HUMPHREYS, & RAOF, 2012, p. 46).The basic premise of the PMV model is that thermal sensation derives from physiological discomfort, i.e., the difference between the heat produced internally and lost to the outside environment, while the subject maintains skin temperature and sweat rate comfort levels (FANGER, 1970). The criterion only applies within uniform clothing insulation levels (NICOL, HUMPHREYS, & RAOF, 2012).Empirical testing of the PMV model was conducted using experiments in a climate chamber at the Kansas State University and the Danish Technical University, both with female and male subjects. The experiments measured the heat load and permitted it to be correlated with comfort votes, thereby making it possible for PMV to estimate comfort responses in numerous various situations (HUMPHREYS & NICOL, 2002).

The Predicted Percentage of Dissatisfied (PPD) is obtained from the PMV value as an approximation of the percentage of people who would be most probably thermally uncomfortable. Dissatisfaction is defined as voting out of the middle neutral zone (±1) of the ASHRAE scale ((ISO), 2005) .

However, experimental outdoor work suggests that the PPD is not an effective measure of real thermal dissatisfaction, especially in circumstances with varied clothing and activity levels, rendering it dubious in its overall applicability (HUMPHREYS & NICOL, 2002).

Additionally, the residents use a thermal feeling scale with nine points that is defined as follows: 0 neutral, +1 somewhat warm, +2 warm, +3 hot, -3 cold, -2 cool, -1 slightly cool, and +3 hot. The acceptable range is a PMV deviation of ± 0.5 and a PPD of 10%, which indicates a thermal discomfort for the entire body. However, there is a 20% PPD with a ± 0.5 PMV difference when a 10% local in consolation percentage is added and felt on a portion of the body. The comfort zone shown in Figure 1.4 is equivalent to a PMV of ± 0.5. (ASHRAE, 2020, p. 48)

+ 3	**Hot**

+ 2	**Warm**
+ 1	**Slightly Warm**
0	**Neutral**
- 1	**Slightly Cool**
- 2	**Cool**
- 3	**Cold**

Table I-3: Seven-point thermal sensation scale *((ISO), 2005, p. 2)*

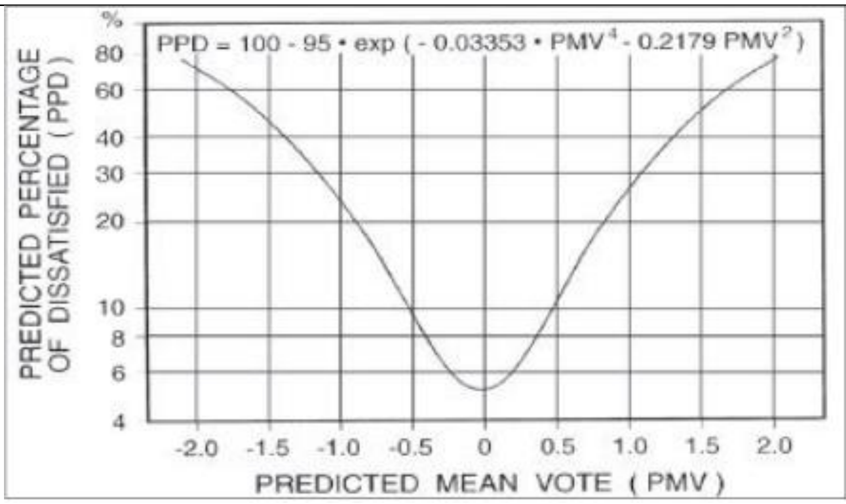


Figure I-2:PPD as a function of PMV *(ASHRAE, 2020, p. 23)*

b. Adaptive thermal comfort:

This model was introduced in ASHRAE 55 for the first time in 2004. It emphasizes the point that people interact dynamically with their environments through clothing adjustments, window operation, use of shading, or changes in activity in response to indoor and outdoor conditions that fluctuate. Compared to static thermal comfort models, the adaptive model embraces variation in acceptable indoor temperatures by climate, culture, season, and personal control over the environment. In a building cooled solely by natural ventilation, the indoor temperature depends more on the outdoor weather conditions. (NICOL, HUMPHREYS, & RAOF, 2012)

Conclusion:

The chapter concluded that thermal comfort is multifactorial and dynamic, especially critical in arid climates with intense temperature fluctuations and solar radiation. Integrating thermal comfort models enables architects to quantify user satisfaction and develop climate-responsive strategies like intelligent sunshades. We will apply one of these models to optimize our sunshade design for thermal performance and user comfort.

CHAPTER II:

Shading and solar control using shading devices

II. CHAPTER II: Shading and solar control using shading devices

Introduction:

This chapter explores solar control as a fundamental strategy for enhancing thermal comfort in arid climates. It examines the evolution of sunshades from traditional Islamic architecture to modern parametric systems, classifies shading devices (vertical, horizontal, and egg-crate), and introduces adaptive shading concepts through notable examples like Al Bahar Towers and the Arab World Institute.

2.1 Importance of solar control in arid zones

Thus, in desert regions, where solar radiation conditions are severe, solar radiation control is an essential requirement for a building to be energy-efficient and thermally comfortable. Deserts exhibit high daily range of temperature and sunshine nearly throughout the year and low relative humidity. (GIVONI, 1998, p. 34) The goal of solar control is to maximize natural lighting while minimizing unwanted thermal charges during hot weather. She may lessen reliance on mechanical climate control, which is crucial in an environment-friendly and energy-efficient setting. (OLGYAY, 1963, p. 74).Solar control systems include the orientation of the building, the size of the openings, the use of sun protections (canopies, sunshades, awnings), and the use of materials with high thermal inertia. They are complementary and work to reduce overheating, improve comfort, and assist with effective natural ventilation. (NICOL, HUMPHREYS, & RAOF, 2012, p. 124) Generally, solar control as architectural form in a dry and hot environment is not only an architectural form but also the essence of bioclimatic design itself. (FATHY, 1986, p. 58) It takes the forefront in adapting the built environment to the context, and also in honoring the available natural resources. His design vocabulary was influenced by historical craft techniques, public health considerations, and climate variables. Prof. Fathy had sophisticated passive environmental control techniques that addressed economic, cultural, and physical issues in accordance with hot, dry region norms. (FATHY, 1986)

2.2 Evolution and Historical Background of Sunshades:

2.2.1 Traditional Systems in Arid Architecture:

In deserts, civilizations have developed, over the centuries, climate-appropriate architecture, including clever devices for obtaining maximum shade and protection from intense solar radiation. The mashrabiya is among the most paradigmatic devices: designed in exquisite carved wood, it filters the light, generates moving shadows, insures privacy, and enhances natural ventilation, but represents a strong cultural and artisanal identity unique to Islamic cultures (FATHY, 1986, p. 12) (EDWARDS, 2006, p. 48). Combined with widespread screen subtraction, typically fabricated with terracotta or wood, this arrangement allowed for light and interior spaces cooling

adjustment without any application of mechanics (OLIVER, 1997).

Figure II-1: Mushrabiya *(FATHY, 1986, p. 7)*

Shaded and well-insulated corridors were also present in traditional buildings as well as used not only for circulation but also facilitation of air movement, hence contributing to cross-ventilation (OLIVER, 1997) . Distinctive architectural features such as arches, vaults, and domes were classically used not only for their aesthetic and structural value, but also because of their ability to block direct sunlight while enabling heat to be radiated out via the convection mechanism. The malqaf or wind catcher was used to trap prevailing breezes and throw them into the interior of the dwelling, actively enhancing passive cooling. (FATHY, 1986, p. 15)

Consequently, vernacular construction in hot climates such as the Maghreb, the Middle East, and the Arabian regions demonstrates an intuitive understanding of climate change articulated in morphology and materiality of architecture. These functional, sustainable, and culturally embedded passive strategies are still relevant to contemporary bioclimatic building in hot and arid climates (EDWARDS, 2006).

Figure II-2: unité d'habitation Marseille indoor street *(CURTIS, 2015, p. 173)*

2.2.2 Sunshades systems in modernism:

The solar protection issue also had a more rationalized aspect with the advent of modernism. Le Corbusier proposed the brise-soleil as a new architectural solution for solar gain in the tropics, particularly in India and North Africa. Prefabricated concrete pieces allowed modulated light and heating return from glazed surfaces, with raw concrete aesthetic caught (CURTIS, 2015, pp. 161-203). In emblematic structures such as the "Palais de l'Assemblée" in Chandigarh or the "Unite habitation" in Marseille, he applied solar regulation principles on a large scale, translating climatic demands into a modernist syntax (JENCKS, 2000). Le Corbusier's theoretical tool, Modulor, also influenced the location and size of brise-soleils in order to optimize the relationship between architectural form and thermal convenience (CORBUSIER, 1948).

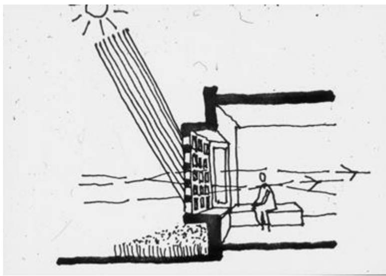


Figure II-3: Diagram of a brise soleil at Aburi Girls' School, Ghana, from Tropical Architecture in the Humid Zone, 1956, publisher B.T Batsford, Courtesy of RIBA

British architects Jane Drew and Maxwell Fry were the pioneers of Tropical Modernism, translating the modernist principles to the climatic conditions of West Africa. In structures like the Wesley Girls' School in Ghana, they utilized brise-soleil to facilitate cross-ventilation and protect interiors from direct sun light, utilizing materials and constructions suitable for the environment (AKADI, 2024).

French architect Guy Lagneau was responsible for rendering modernist architecture sensitive to tropical climates. In the Hôtel de France in Conakry, Guinea (1953–1954), he used

Figure II-4: Residential building, Conakry, 1953
(Atelier LWD Lagneau, Weill, Dimitrijevic, architect).
Adjustable façade panels designed by Jean Prouvé.

passive cooling design features such as brise-soleil, adjustable aluminum shutters, and elevated buildings to allow air circulation and reduce heat gain. The building, designed in collaboration with Michel Weill and Jean Dimitrijevic, was one of the instances of a new trend towards climate-sensitive modernism in West Africa.

Brazilian architect Oscar Niemeyer incorporated aspects of brise-soleil in a broad scale into his modernist buildings to respond adequately to the tropical climate. His buildings prefer to use sweeping curves and sculptural concrete geometry that also act as functional solar sun-shading devices.

One such example is the Niemeyer Building at Belo Horizonte, which employs horizontal concrete brise-soleil that reduce direct solar gain but heighten the building's iconic curved facade, balancing climatic accommodation and aesthetic expression (MORENO, 2017) (FRAMPTON, 1992).

Niemeyer's application of brise-soleil demonstrates how architectural language of modernism had been possible to be applied to regional climatic conditions, integrating art with environmental design solutions suitable to sunny and hot climates (HOLSTON, 1989).

2.2.3 Contemporary and Parametric Sunshades Systems:

In the context of the post-1970s environmental crisis and energy-awareness paradigm, solar protection methods made more **responsive and energy-saving systems**. Consequently, climate information and sustainability principles resulted in responsive architectural envelopes. Architect João Filgueiras Lima (Lelé) in Brazil was an early adopter in the use of **prefabricated sun shading devices** in public buildings adapted to tropical climates, combining **industrialized construction** with **climatic responsiveness** (VALE, 1992).

In the last decades, development in parametric design software and intelligent technologies enabled the possibility to design dynamic kinetic façades that respond to environmental conditions. These systems are often fitted with **real-time sensors, motors, and programmable materials** that change the configuration of the shading devices in terms of solar angles, interior light levels, and occupant preferences. For instance, **the Al Bahar Towers** in **Abu Dhabi** employ a mashrabiya-inspired **kinetic facade** made up of motorized modules that open and close depending on solar radiation, greatly **minimizing heat gain** and glare and drawing from traditional vocabulary of design (KOLAREVIC, 2003). According to (MICHELLE & DANIEL, 2005)in Smart Materials and New Technologies, such adaptive systems are an intersection of architectural performance and environmental smartness.

Rivka Oxman in her journal similarly emphasizes how performance-driven parametric design can be used to generate **optimized shading geometries** based on concept of **climate**

Figure II-5: Al Bahar Towers Responsive Façade

simulation, ushering in a new design era that is adaptive as well as sustainable (OXMAN, 2015).

2.3 Types of Sun shading devices:

Sun shading devices are architectural devices designed to control the entry of solar radiation into buildings, in order to improve thermal and visual comfort. Several types of sunshades are identified in the architectural literature, particularly in reference works such as "Design with Climate" by (OLGYAY, 1963) and the "Manual of Tropical Housing and Building" by (KOENIGSBERGER, 1974).

sunshades can be classified according to their orientation (horizontal or vertical), their operation (fixed or movable), and their position relative to glazing (external or internal).

Victor Olgyay emphasizes passive solar control as a key element in bioclimatic design. He classifies sun breakers mainly based on **building orientation** and the **sun's angle of incidence**:

2.3.1 Vertical Sunshades:

Vertical sun shades are fixed at right angles to the horizontal plane of the façade. They are very effective on east- and west-facing façades, where low-angle sunlight in the morning and afternoon early and late, respectively, strikes the building full on.

In hot, dry climates—such as those in countries like Algeria—solar radiation on these orientations makes a significant contribution to overheating, especially during summer. Since the sun's path at these latitudes directs strong, low-angle sun onto the east and west façades, stationary vertical louvers achieve maximum shading effectiveness in blocking direct sunlight without reducing daylight and ventilation. Their effectiveness will vary microscopically with the season, but overall, they are one of the most effective passive shading techniques for reducing thermal gains on low-sun-angle façades of arid, high-insolation climates. (OLGYAY, 1963, pp. 93-105)

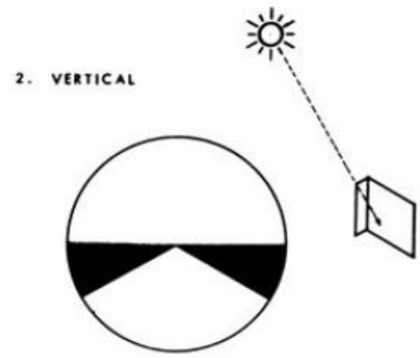


Figure II-6:Vertical solar protector with protective shade *(OLGYAY, 1963, p. 48)*

Their performance is quantified by the horizontal shadow angle (δ). Thin blades closely spaced can cast the same shadow angle as more spaciously set and thicker blades. Using the shadow angle protractor, a 'shading mask' for any particular device can be established. In a vertical device, it is the standard sector form, illustrated in Figure. If this is accurately scaled with the protractor, on trace paper, it can be traced over onto the appropriate solar chart, and the 'shading times' for the particular device (dates and hours) read directly. This is a highly expedient short-cut, avoiding having to calculate solar position angles. (KOENIGSBERGER,

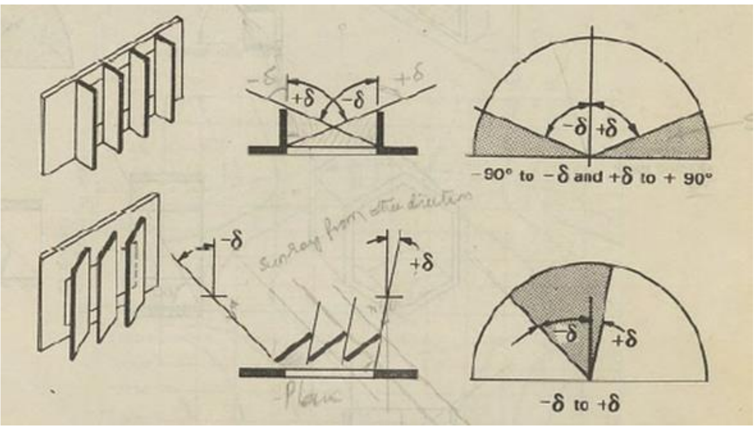


Figure II-7: Vertical shading devices *(KOENIGSBERGER, 1974, p. 113)*

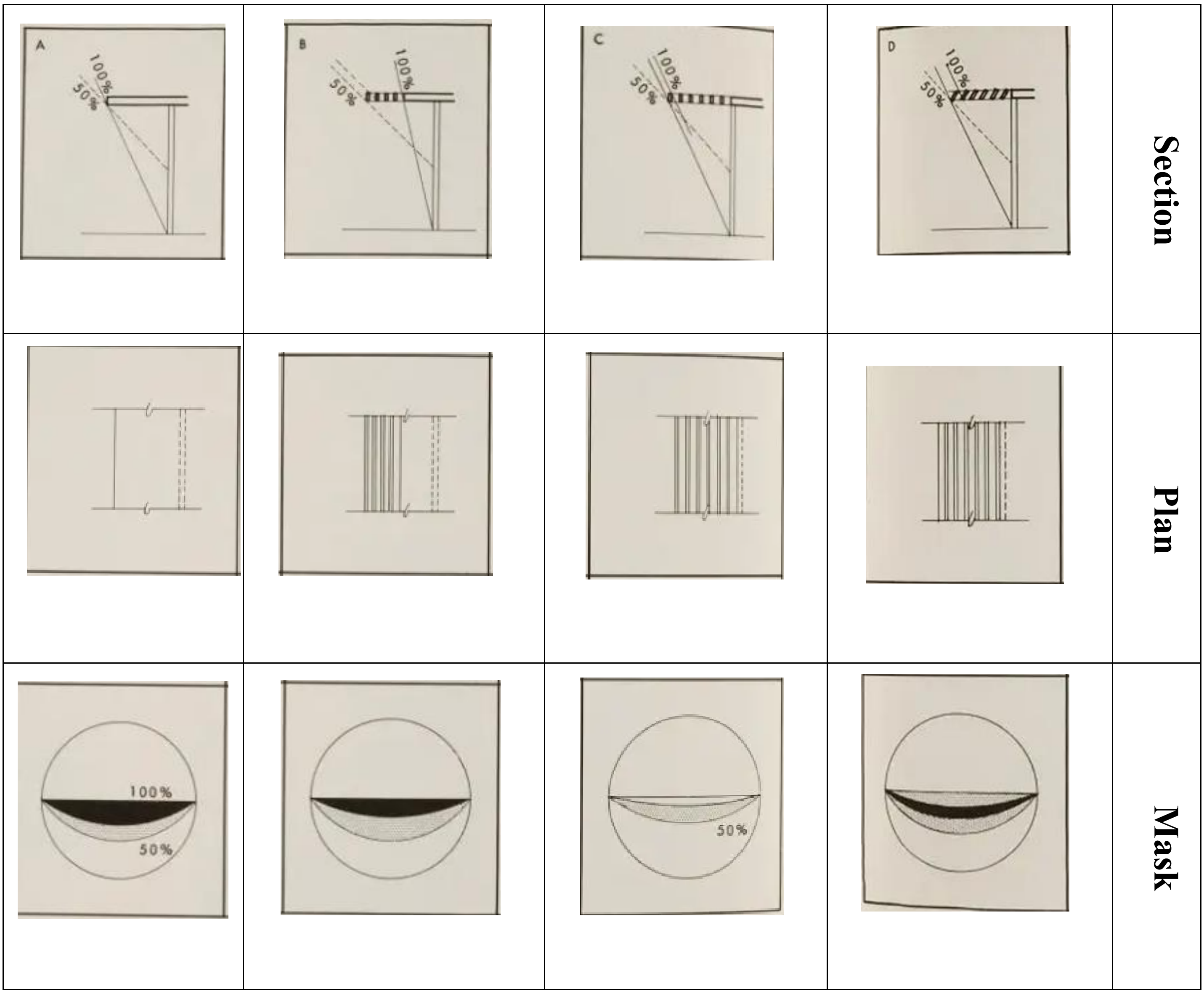
1974, p. 113).

2.3.2 Horizontal Sunshades:

In order to shelter indoor spaces from direct solar radiation when the sun is high in the sky, especially around midday, a horizontal sunshade is a stationary or movable horizontal shading device that is typically placed above windows or glazed openings (OLGYAY, 1963, p. 124) (SZOKOLAY, 2008, pp. 156-157).

One of the main reasons of interior warming, particularly during the summer, in hot and arid regions like Algeria is solar heat gain (KOENIGSBERGER, 1974, pp. 98-100)

The hottest times of the day, from late morning to mid-afternoon, are when the sun reaches its maximum angles on south-facing façades in the Northern Hemisphere (YANNAS, 1994, p. 88).



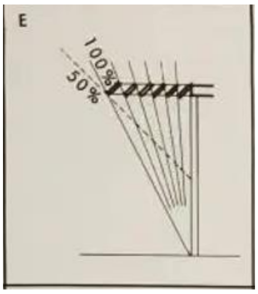
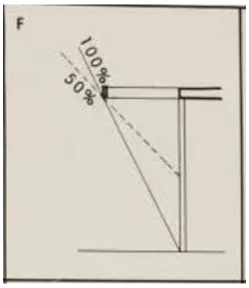
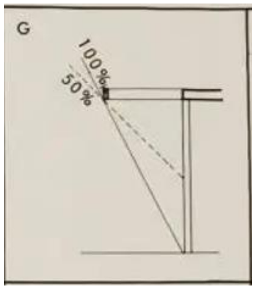
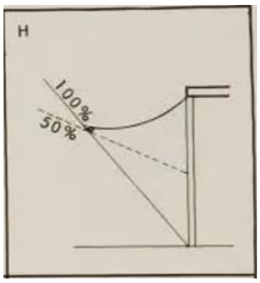
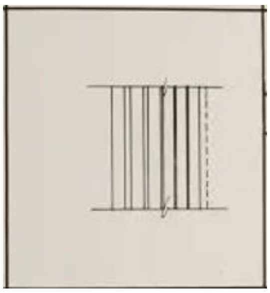
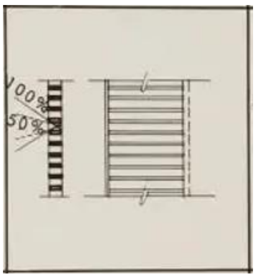
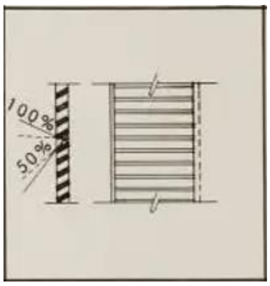
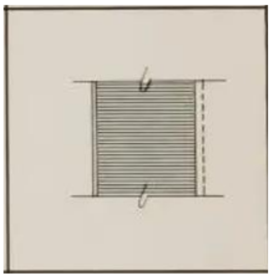
Solid horizontal overhang with 100% and 50% segmental mask.	Overhang partially solid, partially louvered	Louvers parallel to wall, which do not secure 100% shade. Therefore, the mask shows only 50% shading.	Tilted louvers parallel to wall fit in some sun rays at high altitudes, as shown in mask	

Table II-1: Horizontal types of sunshades *(OLGAY & OLGAY, 1957, pp. 88-89)*

In these situations, horizontal sunshades are most effective because they decrease the amount of heat that enters the structure by intercepting sun rays at high angles (KOENIGSBERGER, 1974, p. 99).

Additionally, they allow the winter sun penetrate the building at low angles, resulting in interior comfort and passive solar heating.

In addition to improving visual comfort and reducing the need for cooling energy, these sunshades also lessen glare and solar radiation. (SZOKOLAY, 2008, p. 157)

				**Section**
				**Plan**

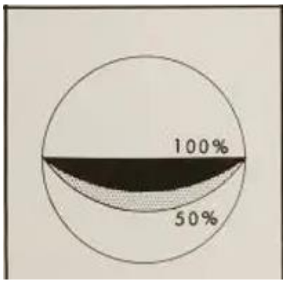
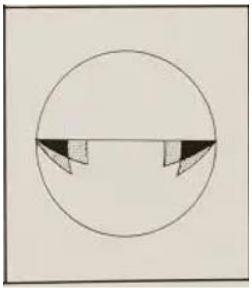
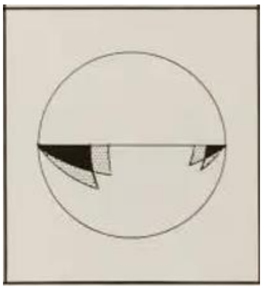
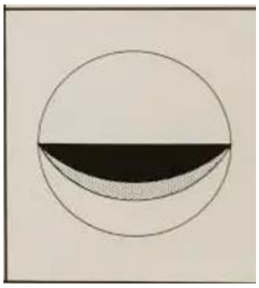
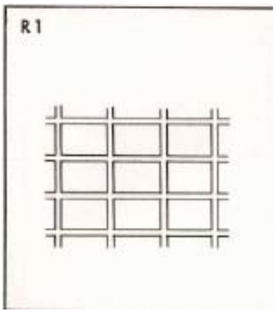
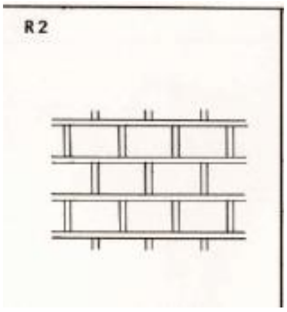
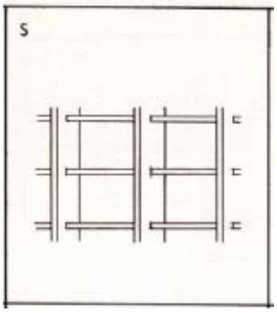
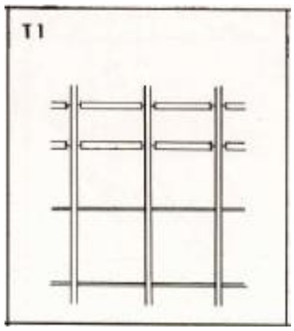
				**Mask**
Tilted louvers parallel to the wall, but unequally spaced will secure 100% shading at high sun altitudes	Overhangs with louvers perpendicular to wall will cut out sun rays from the side.	Tilted louvers perpendicular to wall will have the same characteristics as type F, but the mask will be asymmetrical	Canvas canopy will have some characteristics as a solid overhang.	

Table II-2: Horizontal types of sunshades *(OLGAY & OLGAY, 1957, pp. 88-89)*

2.3.3 Egg-crate shading devices:

Egg-crate shading devices are combinations of horizontal and vertical elements. Many types of grille-blocks and decorative screens may fall into this category. These can be effective for any orientation depending on detail dimensions.

				**Section**

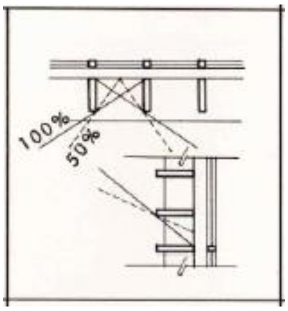
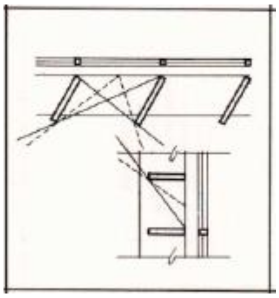
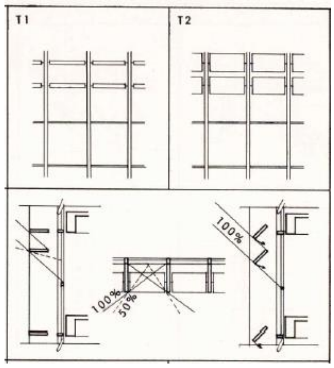
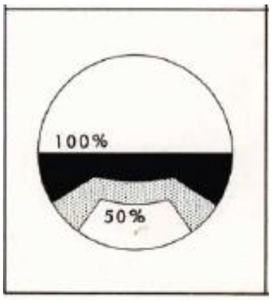
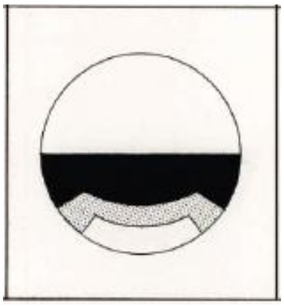
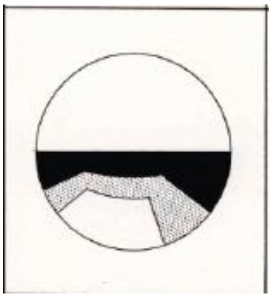
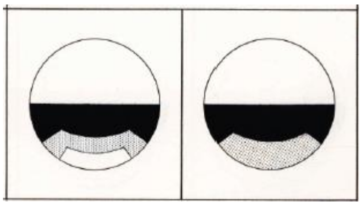
				**Plan**
				**Mask**
Tilted louvers parallel to the wall, but unequally spaced will secure 100% shading at high sun altitudes	Overhangs with louvers perpendicular to wall will cut out sun rays from the side.	Tilted louvers perpendicular to wall will have the same characteristics as type F, but the mask will be asymmetrical	Canvas canopy will have some characteristics as a solid overhang.	

Table II-3:Egg-crate types of sunshades *(OLGAY & OLGAY, 1957, pp. 88-89)*

2.4 The modes of movement of mobile sun shading devices:

According to (SCHUMACHER, SCHAEFFER, & VOGT, 2012), there are various typologies of movement for these devices:

a) The sliding movement:

These devices typically move along an axis parallel to the façade, allowing the openings to be uncovered. Their primary function is to regulate solar radiation by controlling its entry through obstruction.

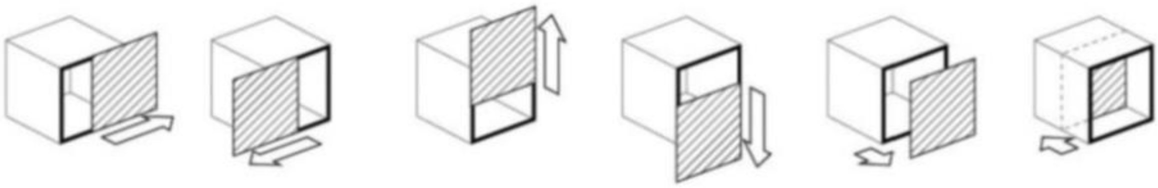


Figure II-8: The sliding movement *(SCHUMACHER, SCHAEFFER, & VOGT, 2012)*

b) The pivoting movement:

By rotating on either a horizontal or vertical axis, a pivoting device can be positioned perpendicular to the envelope. It effectively controls the amount of light input and reflects solar radiation.

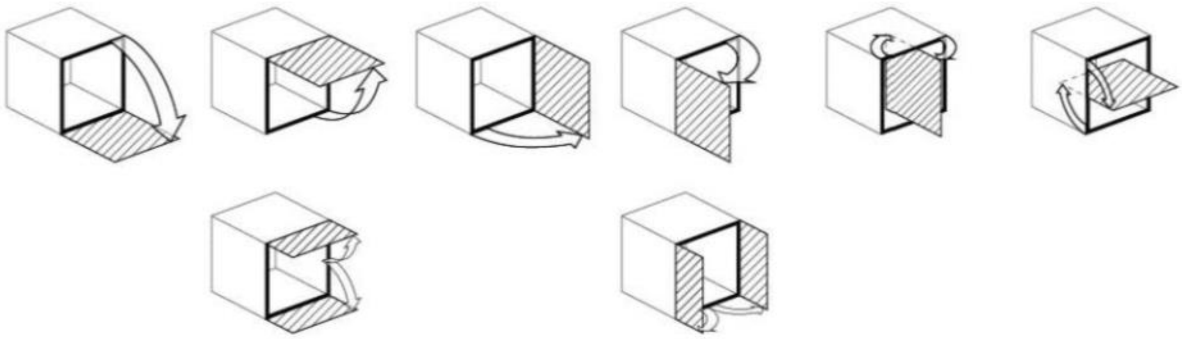


Figure II-9 : The pivoting movement *(SCHUMACHER, SCHAEFFER, & VOGT, 2012)*

c) The pliant movement:

It is similar to the pivoting movement, what sets it apart is that its four attachment points ensure great rigidity against the wind, and it takes up less space when it is open.

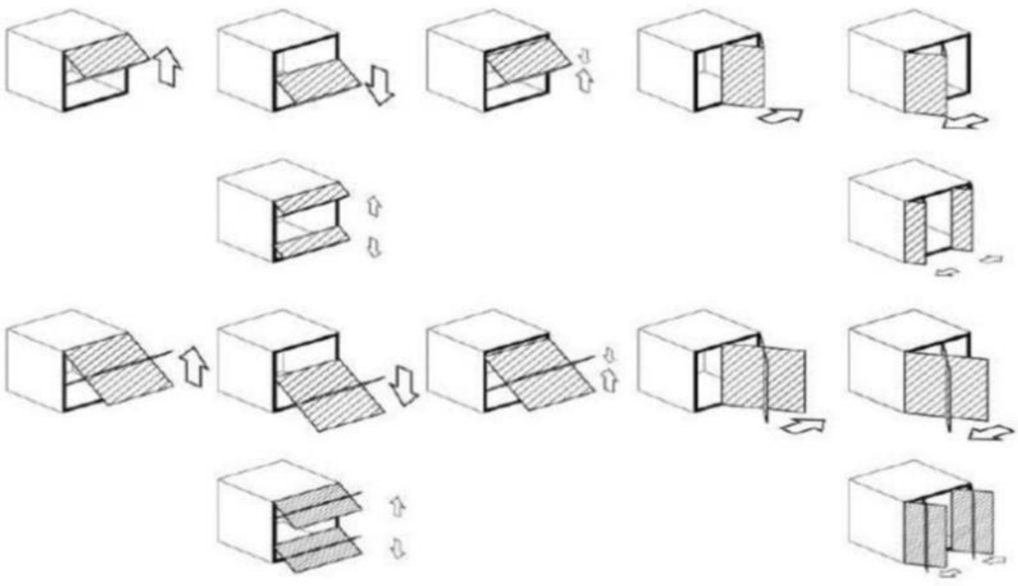


Figure II-10: The pliant movement *(SCHUMACHER, SCHAEFFER, & VOGT, 2012)*

Four other systems of movement and geometric transformations can be used in adjustable solar protection devices: Translation: the movement takes a position in the direction of a vector. Rotation: devices move around an axis. Scaling: it's the contraction and expansion of devices. The movement by deformation of materials: depends on the properties of the materials that change, like weight and elasticity.

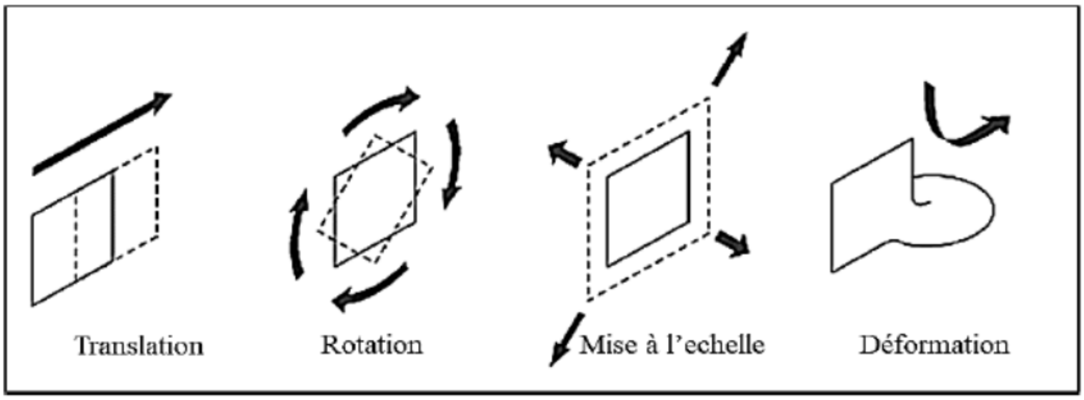


Figure II-11: The transformation movement *(SCHUMACHER, SCHAEFFER, & VOGT, 2012)*

2.5 Adaptive sun shading devises:

2.5.1 Definition of adaptive sunshades:

Adaptive sunshades can be used as high-performance, multi-parameter architectural systems. Unlike fixed shading devices, adaptive sunshades can react dynamically, mechanically or chemically to exterior climatic changes in an attempt to satisfy internal thermal loads and occupants' comfort needs (LOONEN, TRČKA, CÓSTOLA, & HENSEN, 2013).

The concept of adaptive sunshades is typically explained by a variety of comparable terms in scientific as well as professional texts. These are: active, dynamic, intelligent, interactive, kinetic, responsive, smart, or switchable, to mention but a few. Although each of them has some slight implication, they are typically applied synonymously and without any standardization. (LOLLINI, FASANO, MERONI, & ZINZI, 2010)

Traditional shading devices, however, are largely static and cannot respond to changes in the environment. The progression towards climatologically responsive sunshades is a significant advancement, offering the potential for modulating building performance according to ambient conditions. The change has immense promise for reducing energy consumption for cooling and lighting, coupled with enhanced indoor air quality, thermal comfort, and visual well-being. (OLEWNIK, LEWIS, & SIMPSON, 2004).

2.5.2 The appearance of adaptive sunshades:

The use of adaptive facades has been employed since the 1960s. as the one of the earliest examples responsive building skins of Los Angeles County Hall of Records, designed by Richard Neutra in 1962. Buckminster Fuller's façade for United States pavilion built for the 1967 Montreal Expo is another early example of automated climate-adaptive envelopes. The exterior of this geodesic dome was built using a transparent cover of acrylic panels, as seen in Fig., with interior canvas sunshades controlled by a computer program that would adjust them against the motion of the sun. (AHMED, ABDEL-RAHMAN, MAHMOUD, & SUZUKI, 2016, p. 3)

Adaptive architecture is based on an adaptive thermal comfort design, in which occupants actively participate. Thus, it gives users the freedom to adjust their comfort so that they can improve their comfort level and reduce the energy usage of the building. (CLEAR, FRIDAY, MORLEY, & BITES, 2013, p. 1)

The ability to modulate or adjust the envelope in accord with the movement of the sun shading the rays to avoid overheating and glare, or opening to exploit passive gains in heat and daylighting has given rise to what has been called the smart building envelope, a major technological development (LOONEN, TRČKA, CÓSTOLA, & HENSEN, 2013, pp. 483-493).

More recently, adaptive, resilient, and climate-responsive building envelopes have been created. Adaptive architecture increases comfort for users by optimizing energy performance through adaptability.

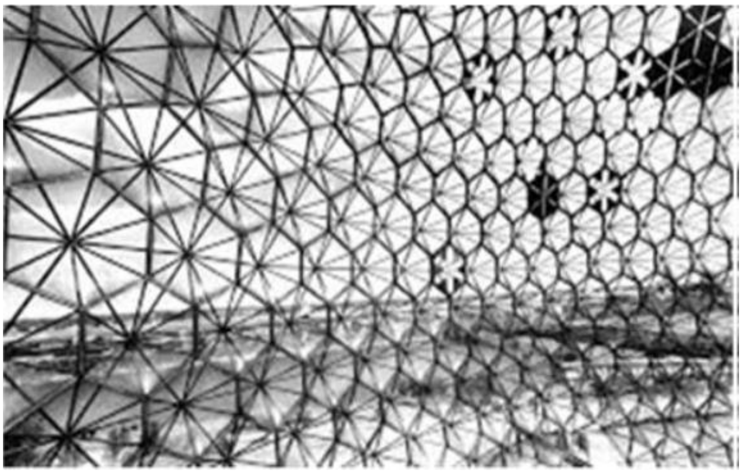


Figure II-12: The canvas sunshades in Montreal Expo Dome by Buckminster Fuller's 1967

2.5.3 The contemporary adaptive sunshades systems:

The growth of information technology has enhanced the ability to manipulate complex models of flexible sunshades, supported by more efficient energy performance calculation tools, thereby enabling the design of an optimal envelope tailored to specific conditions and contexts. The advantages of such technological progress have contributed to the emergence of new facades and envelopes with developed adaptability qualities, as demonstrated by the following examples:

2.5.3.1 Institute du monde Arabe:

this kinetic response is envisioned and illustrated by the iconic Jean Nouvel kinetic facades, Monde de Arabe (1980), where hundreds of sliding planes (25,000 photoelectric cells similar to a camera lens) were motorized and placed within the façade. Various sensors measure daylight and open or close the irises as needed to control the level of light. the system using complex motorizations and an enormous number of motorizations. (Coelho, Maes, & Pattie, 2009).

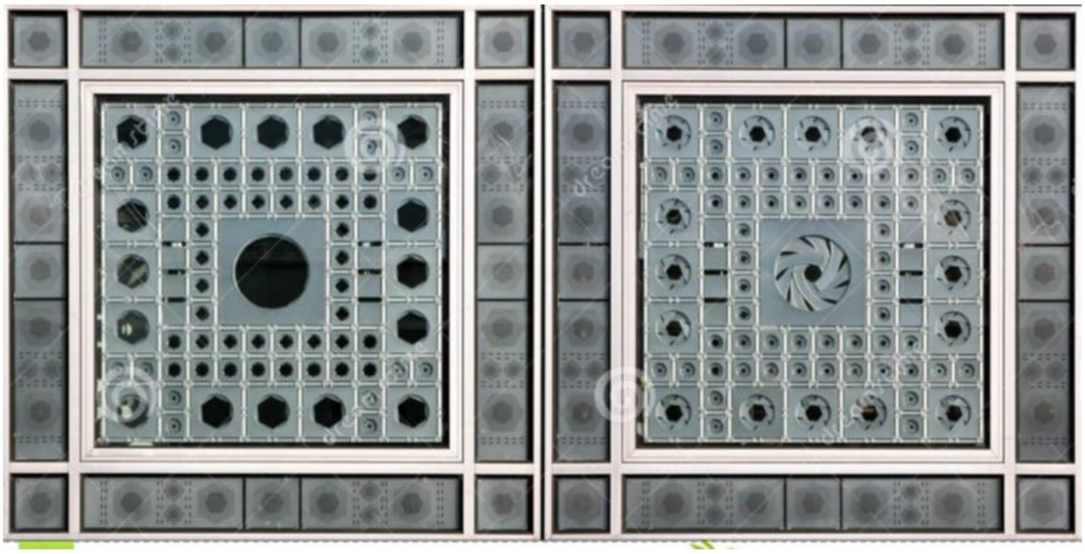


Figure II-13: The dynamic southern facade of the Arab World Institute in Paris (Source : http://www.architecture-studio.fr)

2.5.3.2 Al Bahar towers:

Inspired by the ancient "Mushrabiya," Abu Dhabi's Al Bahar Towers designed by Aedas Architects have an inventive adaptive façade that maximizes inside comfort and energy efficiency in the arid climate. 1,049 triangular PTFE (polytetrafluoroethylene) shade modules for each, mounted on motorized frames are installed on the two towers. In order to maximize natural lighting and minimize direct solar gain and glare, the modules open and shut in reaction to the path of the sun. (ARUP, 2012).

Figure II-14: The dynamic shading system at Al Bahar Towers *(ARUP, 2012)*

The system is controlled by solar tracking software that adjusts the modules' opening every 15 minutes based on the sun's angle. Sensors measure brightness and wind speed, allowing the system to react to weather conditions: in the event of strong winds or cloud cover, the modules can open to avoid excessive loads or to maximize natural lighting. (COUNCIL ON TALL BUILDINGS AND URBAN HABITAT, 2012).

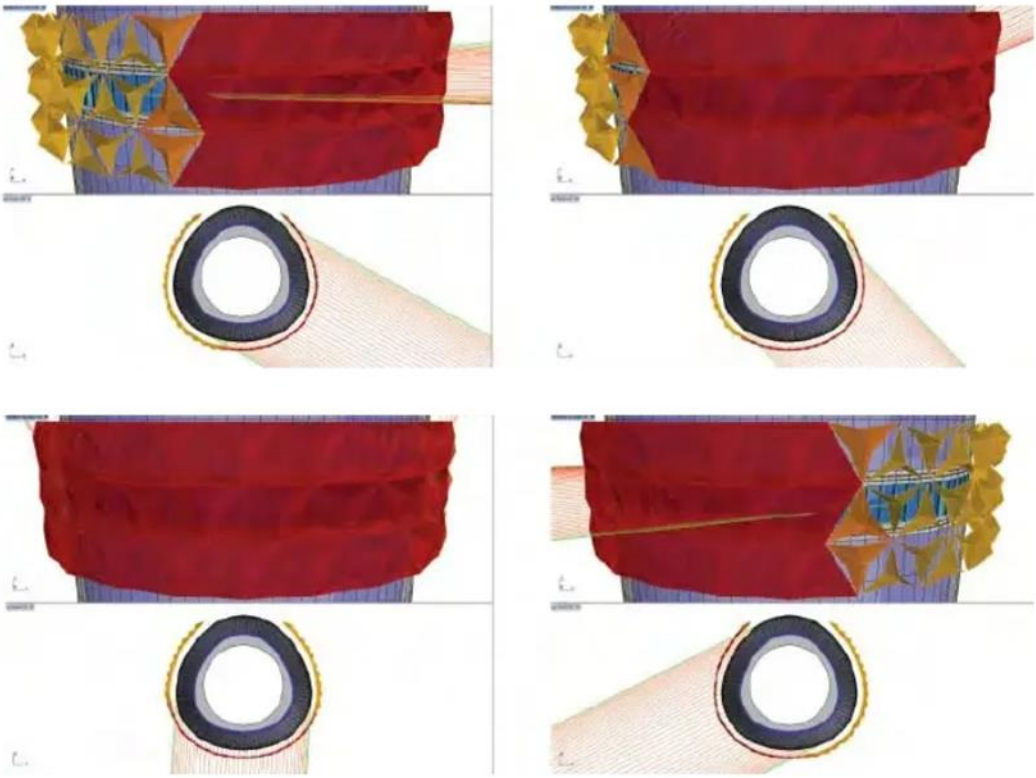


Figure II-15: Simulation of the operation mechanism of the sunshades at Al Bahar Towers *(COUNCIL ON TALL BUILDINGS AND URBAN HABITAT, 2012)*

This biomimetic approach, inspired by the mangrove flower and Islamic geometric patterns, allows for a radical reduction in energy consumption related to air conditioning while giving the towers a strong architectural presence. (ARUP, 2012)

2.5.3.3 Helio Trace Architecture Center:

The Helio Trace Architecture Center is not a physical building, but a project idea realized by Skidmore, Owings & Merrill (SOM) with the assistance of Permasteelisa Group and the Adaptive Building Initiative (ABI), a consortium between Buro Happold and Hoberman

Associates. The fascinating concept aims to develop a kinetic and adaptive façade capable of increasing the energy efficiency of buildings while providing occupants with excellent visual comfort.

Designed as part of a design competition organized by the Adaptive Building Initiative team, the "Helio Trace" façade design relies on a sophisticated kinetic curtain system that can change in real time based on its environment. The architects imagined a configuration that would optimize the control of natural light and limit the impact of glare, while cutting solar gains down by 81%. To achieve this, they developed a kinetic shading system covering the entire façade, based on their "Strata" patterned system.

The Helio Trace kinetic system can continuously track the sun's movement throughout the day and year. Unlike other mechanisms, this kinetic model is specifically designed to maximize natural light load while reducing solar heat load, thereby improving occupant comfort and reducing the building's energy consumption. (AHMED, ABDEL-RAHMAN, MAHMOUD, & SUZUKI, 2016, p. 4)

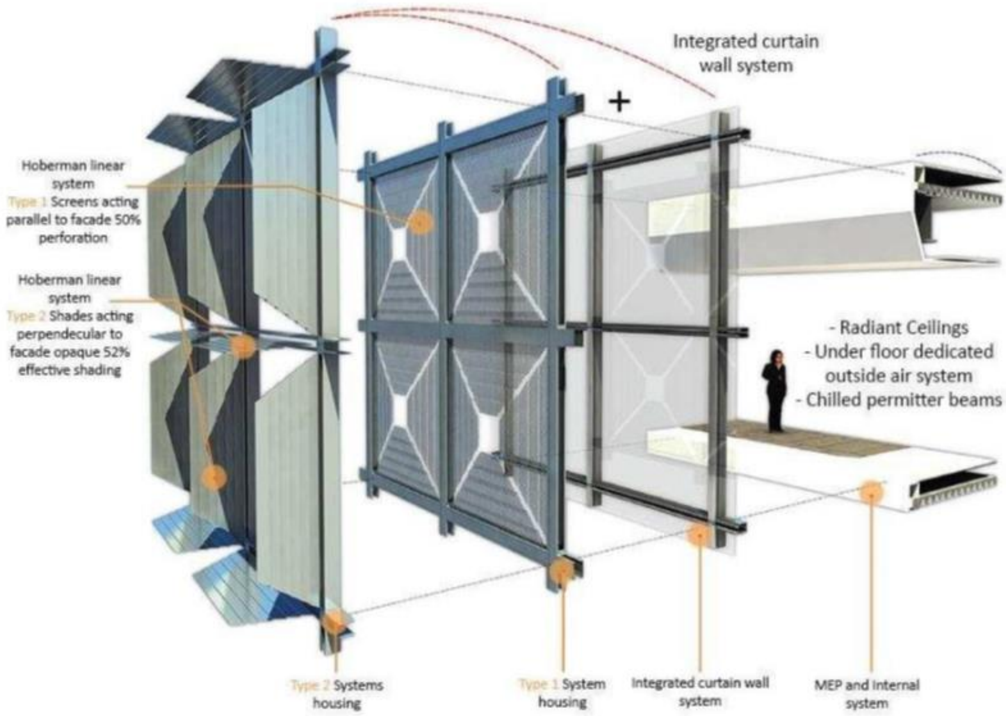


Figure II-17: The 3D section for Helio Trace Centre window unit by SOM/ABI/Permasteelisa, 2010

2.5.3.4 Q1 office building:

located in Essen, Germany, the Q1 office building designed by JSWD Architekten in collaboration with Chaix & Morel et Associés features a facade that plays a critical role in controlling solar gain as well as natural light. The facade is also equipped with an innovative 3,150 removable vertical stainless steel fin shading system. Each fin is equipped with adjustable horizontal louvers that can be oriented according to light and temperature demands, thus achieving dynamic light penetration control and avoiding glare. This system not only optimizes interior visual comfort, but also optimizes the building's energy performance by reducing air conditioning requirements. Cabling required to control these mobile elements is built into conduits hidden at the bottom and top of the façade for convenient and discreet operation of the system.

This is an optimized system that makes use of the adjustable horizontal blades and adaptive vertical parts. The vertical fins spin 180 degrees around the ducts, while the horizontal louvers function as a miniature light shelf and reflect light into the interior spaces. They create a highly sustainable and energy-efficient system by moving in accordance with the sun's angle, which lessens the need for artificial lighting and air conditioning. Additionally, this system aims to maximize user views (GREFEN, 2010, pp. 100–105).

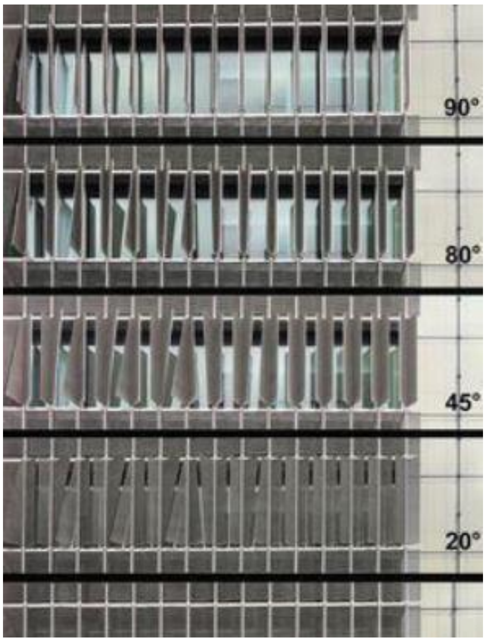


Figure II-18: The shading system of Q1 Building with removable vertical fins (Source: http:// www.tommr.de)

CHAPTER III:

parametric design of an intelligent solar control module using “Grasshopper” and “Arduino”

III. CHAPTER III: Parametric design of a smart model for solar control using "Grasshopper" and "Arduino"

Introduction

This chapter presents the methodological development of a smart sunshade system using parametric tools such as Grasshopper, Ladybug, and Honeybee. It begins by introducing parametric design principles and justifies the choice of simulation software. The chapter then describes the simulation model, a hybrid egg-crate shading system optimized for Biskra's hot-arid climate and the simulation protocol used to assess its performance

3.1 Parametric design:

Parametric architecture received considerable momentum in the past decade, greatly altering workflows within architectural design. Depending on the definition of logical relationships and modular parameters, the approach can generate complex and adaptive geometry. Unlike traditional techniques, parametric design involves sketch behavior being included in advanced modeling software, allowing access to new formal investigation and creation of innovative geometries. (SCHUMACHER P. , 2009, pp. 14–23)

Design parameterization preserves the original ideas of the designer while enabling the creation of alternatives based on particular limitations. After the relationships are established, the model can be dynamically modified to evaluate various configurations, allowing for ongoing project optimization. (TUCKER, 2014)

Figure III-1: Heydar Aliyev Center

3.2 Why parametric design?

Parametric design is a recent tendency in contemporary architecture, based on the creation of parameters and rational rules through which reactive forms, structures, or systems can be generated (JABI, 2013).Unlike traditional design, in which each object is manually defined, parametric design enables the generation of dynamic models capable of altering a response according to environmental, technical, or aesthetical constraints. (TURRIN, VON BUELOW, & KILIAN, 2011, pp. 401–420).

In kinetic façades and intelligent envelopes, parametric design plays a defining role. It not only allows the modeling of complex systems but also their behavior is simulated based on environmental inputs such as the position of the sun, temperature, or even the natural light requirements in spaces (ECHENAGUCIA, CAPOZZOLI, CASCONE, & SASSONE, 2015, pp. 577–591).For this purpose, it is a proficient tool for the development of adaptive solar control systems and energy optimization (HASSAAN, MAHMOUD, & ELGHAZI, 2016, pp. 111–127). Coupling the parametric tool Grasshopper (Rhino plugin) with Honeybee and Ladybug environmental extensions allows one to explore and print responsive shading systems (ZARI & HECHT, 2014, pp. 120–135). Architects are able to design envelopes that can respond in real time to their environment, thus opening the doors to more efficient, more sustainable architecture, and more focused on user comfort (VELASCO, MENDIVIL, & OLMEDO, 2021).

3.3 The Components of Parametric Models:

Parametric architecture is based on a logical framework consisting of interrelated components. They are the required elements for generating, managing, and modifying geometries within a design system. The basic components tend to be:

a. **Parameters:** These are variable inputs (e.g., numbers, angles, sizes, or material properties) that control and define the form of geometry. Parameters allow designers to explore a vast number of design possibilities efficiently (JABI, 2013).
b. **Geometric relationships:** They define how parts relate, constrain, or influence each other. They form dependencies within the model, for instance, alignments, proportions, or symmetry rules (TURRIN, VON BUELOW, & KILIAN, 2011).
c. **Algorithms or rule-based logic:** This refers to the name given to the logical operations or sets of operations that generate geometry from parameters. Algorithms record design intent and allow dynamic control of form through the use of computation (WOODBURY, 2010).
d. **Output geometry (generated form):** This is the outcome of the implementation of rules and parameters. The resulting geometry is not static and can be altered in real time

by modifying the input variables, making the design process interactive and iterative (JABI, 2013).

These components are parametrically controlled together in environments like Grasshopper or Dynamo, enabling the generation of intelligent architectural systems that respond to environmental, spatial, or structural constraints.

3.4 The investigative tool: (numerical simulation)

3.4.1 Rhinoceros 3D + Grasshopper:

a) Rhinoceros:

Rhinoceros (or simply Rhino) is a 3D modeling application developed by Robert McNeel & Associates to build non-uniform rational B-splines (NURBS) for generating free-form geometry. First released in 1998, the software has evolved over the years and the number of users has grown across various design disciplines like architecture, structural engineering, and industrial design. Its growing popularity reflects its usability, adaptability, and a large library of powerful add-ons and plugins.

Figure III-2: the logo of the Rhino software
(https://www.rhino3d.com)

While Rhino's strength in modeling is already firmly established, its true design capabilities are significantly enhanced by Grasshopper, a graphical programming plug-in enabling designers to define and manipulate complex shapes and systems through parametric reasoning.

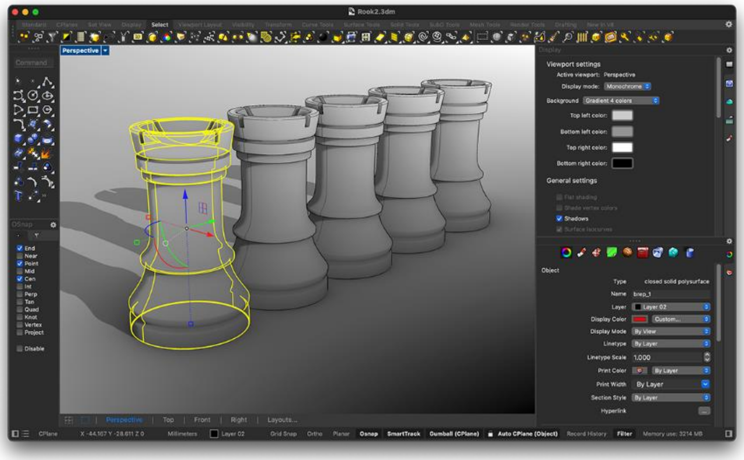


Figure III-3: the interface of the Rhino software (https://www.rhino3d.com)

The presence of Grasshopper makes Rhino a computer-intensive design tool, much valued for concept thinking and performance-based design in architectural workflows (JABI, 2013).

b) Grasshopper:

Grasshopper is a graphical programming platform that exists as a plugin within Rhinoceros 3D (Rhino). Designed by David Rutten of Robert McNeel & Associates, Grasshopper enables architects and designers to make sophisticated systems and shapes using the node-based interface—without scripting or coding. Instead of typing line after line of code, users connect nodes used to define variables, data streams, and operations and construct parametric relations and generative design logic.

Grasshopper is especially valued for its ability to analyze iterative and data-driven design issues, making it a fundamental piece of software in computational architecture, digital fabrication, structural optimization, and environmental simulation. It is also supported by a comprehensive set of extensions (e.g., Ladybug, Honeybee, Octopus, Pachyderm) that provide high-level analysis for climate response, energy performance, acoustic performance, and structural behavior. (OMID, 2019)

Figure III-4: the logo of the Grasshopper plug-in (https://www.magneticvisions.com/classes/rhino-grasshopper-course)

c) Ladybug:

Ladybug is an environmental analysis plugin for Grasshopper and Rhinoceros 3D that enables architects and designers to engage with climate-based information during the design process. Developed by Mostapha Sadeghipour Roudsari and collaborators, Ladybug translates raw weather data such as EPW (EnergyPlus Weather) files into intuitive visual outputs like radiation maps, sun paths, wind roses, and comfort graphs. These visualizations enable designers to make informed, site-specific climatic design decisions.

By making hourly climate data and environmental analysis tools accessible without coding manually, Ladybug bridges the gap between data complexity and design intuition. It is a valuable contributor to passive design strategy at an early stage, solar optimization, daylight performance, and comfort analysis, particularly in sustainable architecture and climate-responsive architecture. (SADEGHIPOUR & PAK, 2013)

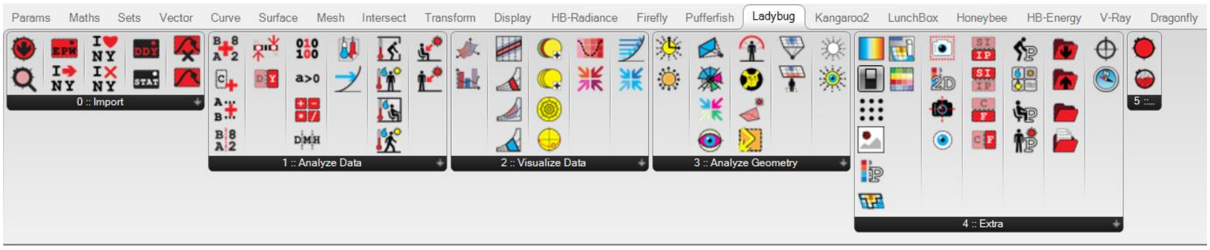


Figure III-5: Ladybug Components source: author

d) Honeybee:

Honeybee is a plugin created on top of Ladybug for Grasshopper and Rhinoceros 3D that closes the gap between design modeling and detailed environmental simulation. Created by Mostapha Sadeghipour Roudsari and colleagues, Honeybee connects parametric design environments to validated simulation engines such as EnergyPlus for building energy modeling and Radiance for lighting analysis and glare prediction. Through dynamic climate data and material definitions, users can create detailed building energy and lighting models in Grasshopper.

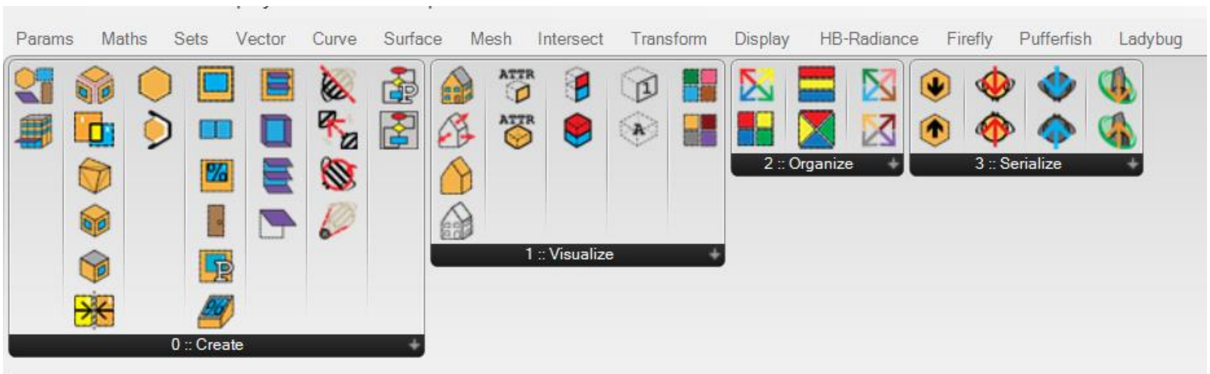


Figure III-6: Honeybee Components source: author

Whereas Ladybug is primarily used for visualization and analysis of weather data and sun exposure, Honeybee supports more quantitative and performance-oriented simulations, with detailed thermal comfort, daylight autonomy, energy consumption, and HVAC performance analyses. This makes it an essential tool to performance-based design workflows in sustainable architecture and building performance optimization. (SADEGHIPOUR & PAK, 2013, p. 3132)

3.5 Justification for the Choice of Simulation Software:

This thesis investigates the optimization of a kinetic sun-shading system for the hot arid climate of Biskra. The use of Grasshopper, in combination with the Ladybug and Honeybee plugins, was chosen because of their ability to combine parametric modeling with climate-based performance simulation.

Grasshopper allows for the modeling and controlling of adaptive sun-shading systems with intricate geometric manipulation based on solar exposure. Ladybug is utilized to investigate climatic issues such as solar radiation, sun path, and outdoor thermal comfort. Honeybee, in conjunction with EnergyPlus and Radiance, offers dynamic thermal and daylight simulation, allowing for in-depth analysis of the shading system's performance.

This integrated workflow facilitates the design, simulation, and optimization of an adaptive solar control strategy, in direct support of this research's environmental goals of this research.

3.6 PRESENTATION OF THE SIMULATION MODEL

3.6.1 General Description of the model:

In the context of this research, we designed a simplified model with the purpose of examining sunshading devices that are optimized for arid climates. The model is deliberately free of complex architectural elements such as cladding materials, finishes, or decorations. This methodological choice allows us to neutralize the aesthetic parameters, which enables us to focus more clearly on environmental factors with a direct influence on thermal comfort, including orientation, geometry, size, and efficiency of sunshading systems. The objective is to maintain the model's generalizability and transposability to a variety of architectural projects sharing similar climatic constraints. Because of its neutrality and abstraction, it is a practical comparison tool, which allows for the comparison of the performance of various configurations without bias towards form or architectural expression.

In this context, we have integrated a hybrid sunshading system with vertical exterior louvers and horizontal interior louvers. The vertical external louvers are actually designed to block low-angle solar radiation, especially from the west direction during the afternoon, while the horizontal internal louvers are oriented to control overhead sun at noon, helping to ensure even daylight distribution and low glare. This two-layer system offers improved solar control with more adaptive response to changing sun angles throughout the day, thus contributing to optimized indoor thermal comfort and improving the building's passive environmental performance.

3.6.2 Methodological Framework

3.6.2.1 Simulation parameters:

- **Location:** Biskra, Algeria (Hot-Arid Climate, Köppen BWh classification)
- **Simulation Date:** July 15th (typical summer peak condition)
- **Time Interval:** 1:00 PM to 5:00 PM (5-hour thermal cycle)
- **Sunshade Type:** Dynamic sunshading devices (rotating egg-crate louvers)
- **Orientation Analysis:** East, South, and West facades
- **Simulation Tool:** Ladybug Tools (Rhino + Grasshopper) with OpenStudio – EnergyPlus-based dynamic thermal simulation focusing on operative temperature and adaptive comfort
- **Comfort Standard:** Adaptive comfort model for hot-arid climates
- **Preferred comfort range:** 24–27°C
- **Acceptable comfort range**: 23–28°C

- **Stress threshold:** >28°C

3.6.2.2 Dimensions and geometry of the model

Length	20 meters
width	10 meters
Height	4 meters
Glazing ratio	Glazing ratio: 90% on exposed façades (South, East, South-East, West, South-West)

Table III-1: Dimensions and geometry of the model

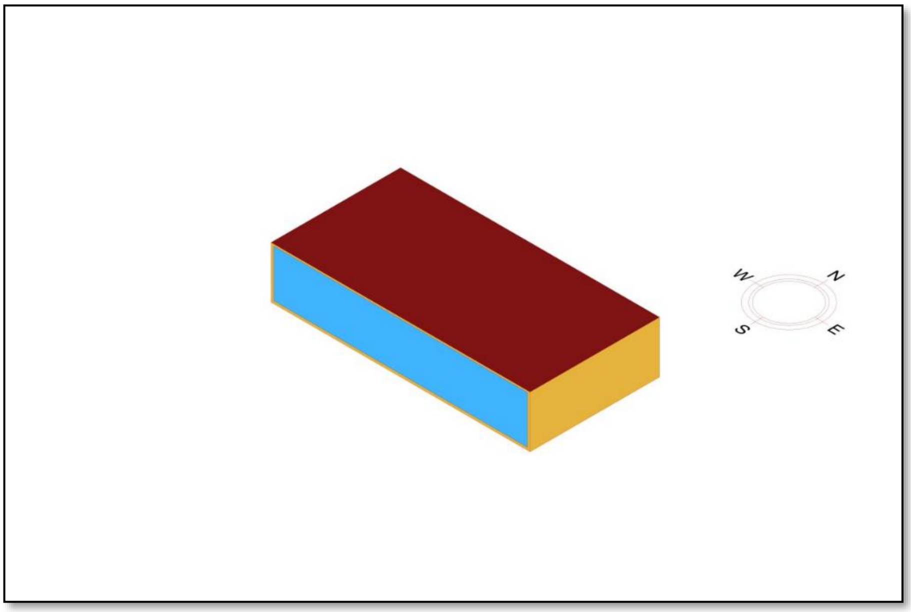


Figure III-7: the model geometry inside rhino (source: author)

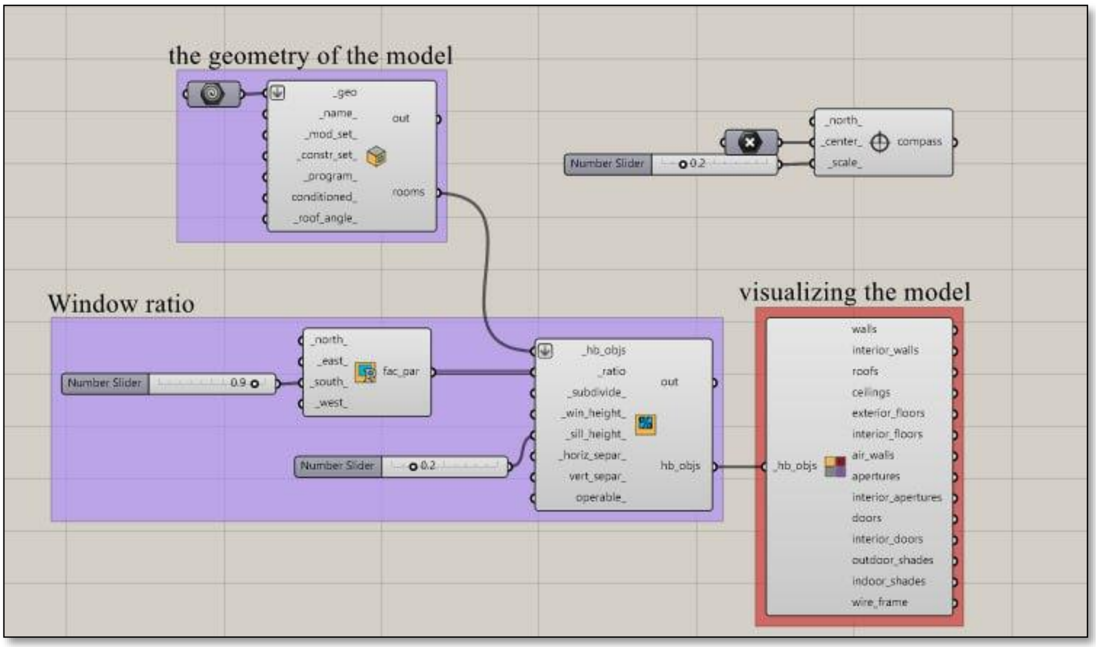


Figure III-8: the model script inside Grasshopper (source: author)

3.6.2.3 Parameters of sunshading devices:

Shading devices are of crucial role in controlling direct solar radiation, restricting unwanted heat gains, and improving indoor thermal comfort, especially in hot and dry weather conditions like Biskra. To evaluate their potential, several geometric, functional, and position parameters must be defined with high accuracy in any simulation or energy modelling process. These parameters directly influence the intercepted solar radiation and both thermal and visual performance of the building.

Parameter	**Example Values / Options**
Device Type	Louvers
Orientation	South, East, West
Placement	External vertical louvers and internal horizontal louvers
Louver Tilt Angle	0°, 30°, 45°, 60°, 90°
Louver Spacing	1m
Louver Depth	30 cm

Parameter	Example Values / Options
Louver Thickness	5 mm
Operation Mode	Manual / Motorized Rotation
Adjustment Frequency	Real-time, hourly, based on sunlight

3.6.2.4 Thermal Comfort Hypotheses:

In alignment with the adaptive comfort framework for hot-arid climates, the following hypotheses were defined to simulate a realistic indoor usage scenario within the studied cultural facility:

Metabolic Rate (Met): 1.1 met Corresponding to sedentary activity such as seated reading, based on (ASHRAE, 2020)

Clothing Insulation (Clo): 0.35 Clo reflecting typical lightweight summer clothing appropriate for the hot-arid conditions of Biskra

Air Velocity: 2.0 m/s accounting for the impact of cross-ventilation, airflow near facades, and sunshade-induced turbulence

These thermal comfort hypotheses were integrated into the Honeybee comfort model engine, in combination with OpenStudio and EnergyPlus, to compute operative temperature distributions and assess thermal comfort levels under dynamic facade behavior.

These values ensure that your operative temperature and thermal comfort calculations (including PMV/PPD or adaptive comfort evaluation) are scientifically grounded and internationally recognized.

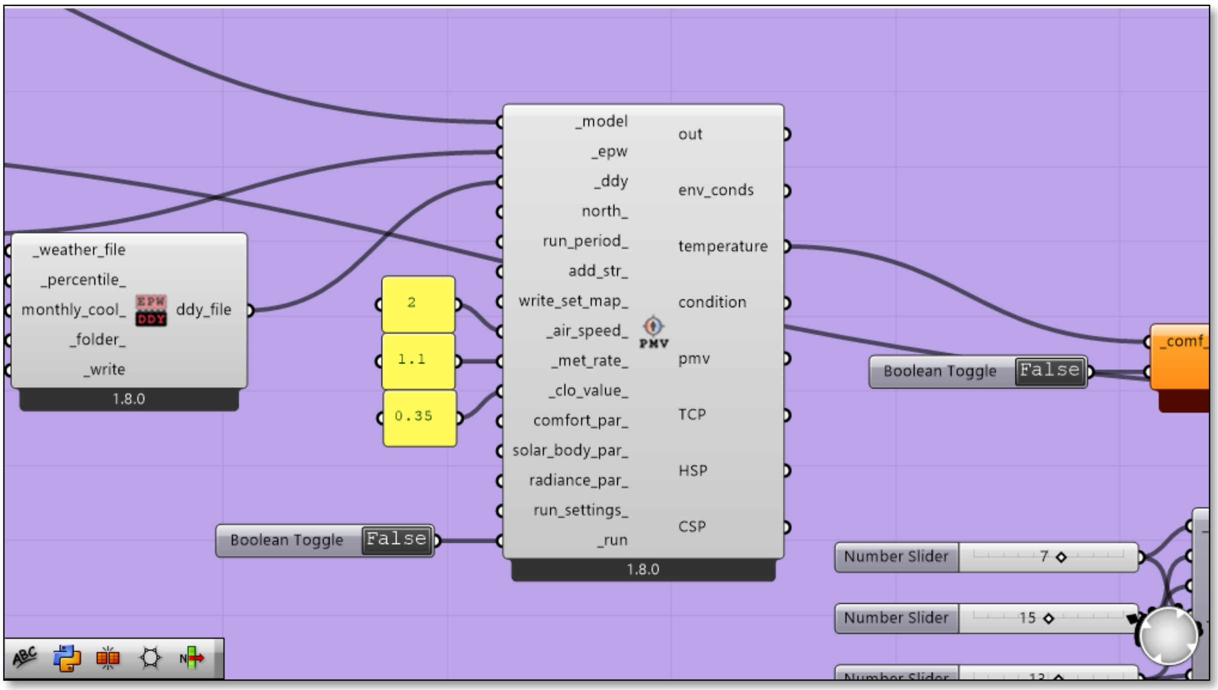


Figure III-9: Thermal Comfort Hypotheses and Parameter Inputs for PMV Simulation Using Honeybee Comfort Map (source: author)

3.6.3 Simulation Approach:

The thermal evaluation was conducted using a parametric simulation pipeline built on Rhino + Grasshopper, leveraging the Ladybug and Honeybee plugins for environmental modeling, and OpenStudio/EnergyPlus for dynamic thermal simulation.

The simulation steps followed the workflow below:

- **Climatic Data Import**: Hourly weather data for Biskra, Algeria (Köppen BWh), was imported in EPW format to define the external boundary conditions.
- **Geometric Modeling**: A simplified thermal test cell was modeled using *HB Room* components to isolate solar gain and thermal performance based solely on façade orientation and sunshade configuration.
- **Dynamic Shading Integration**: A responsive kinetic shading device (rotating egg-crate system) was modeled with sun-based conditional logic, allowing for time-specific angular adjustment based on solar position (altitude and azimuth).

- **Thermal Simulation Engine**: Simulations were performed via **Honeybee** + **OpenStudio**, interfacing with **EnergyPlus** to compute operative temperature distributions over time.
- **Output Extraction**: Hourly operative temperatures were extracted per orientation (East, South, West).

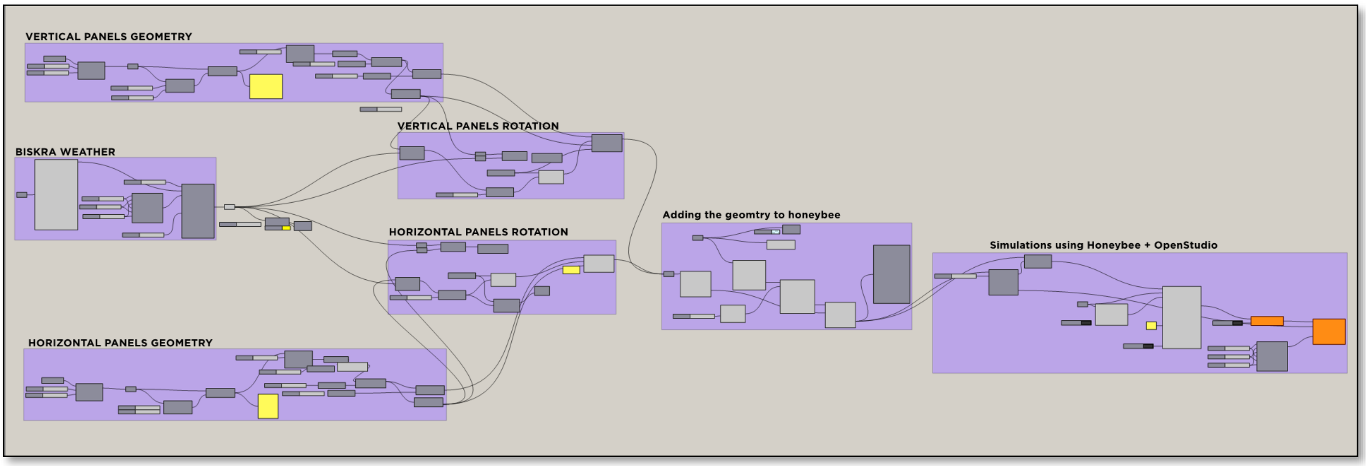


Figure III-10:the dynamic sunshading device script inside Grasshopper (source: author)

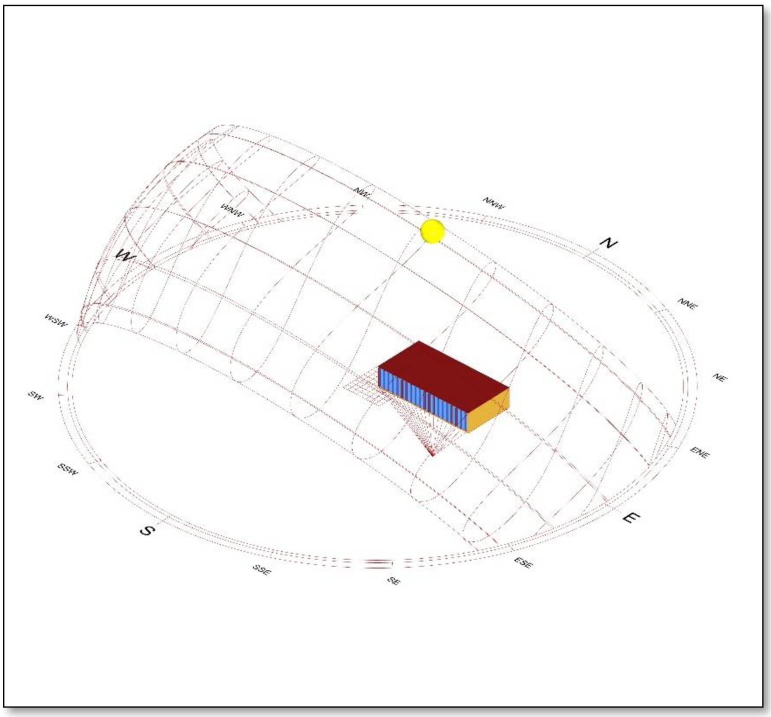


Figure III-11: Rhino Model inside Honeybee Showing Dynamic Sunshading System Oriented Toward the Sun Based on Solar Vectors (source: author)

3.6.4 Thermal Performance Results by Orientation:

Temperature Heatmaps

South orientation

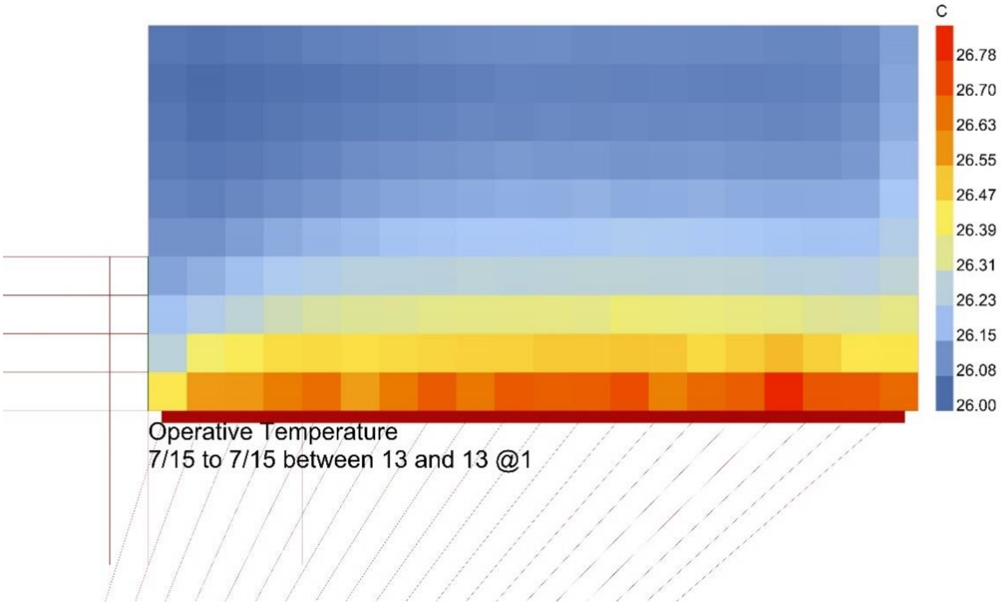


Figure III-12: Operative Temperature heatmap – South orientation (15 July, 13:00)

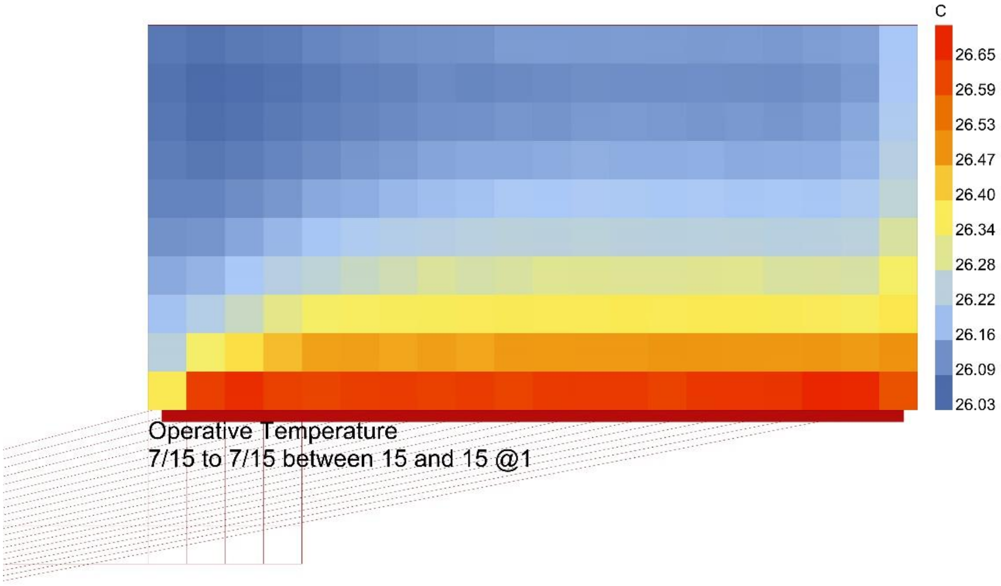


Figure III-13: Operative Temperature heatmap – South orientation (15 July, 15:00)

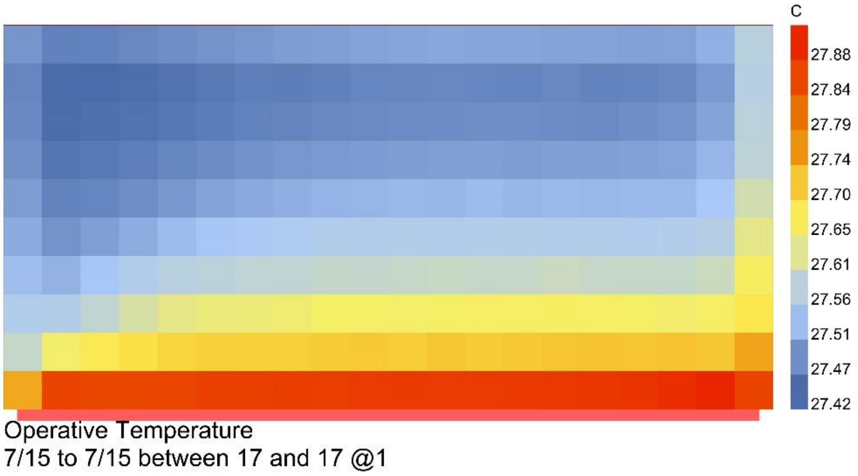


Figure III-14: Operative Temperature heatmap – South orientation (15 July, 17:00)

East orientation:

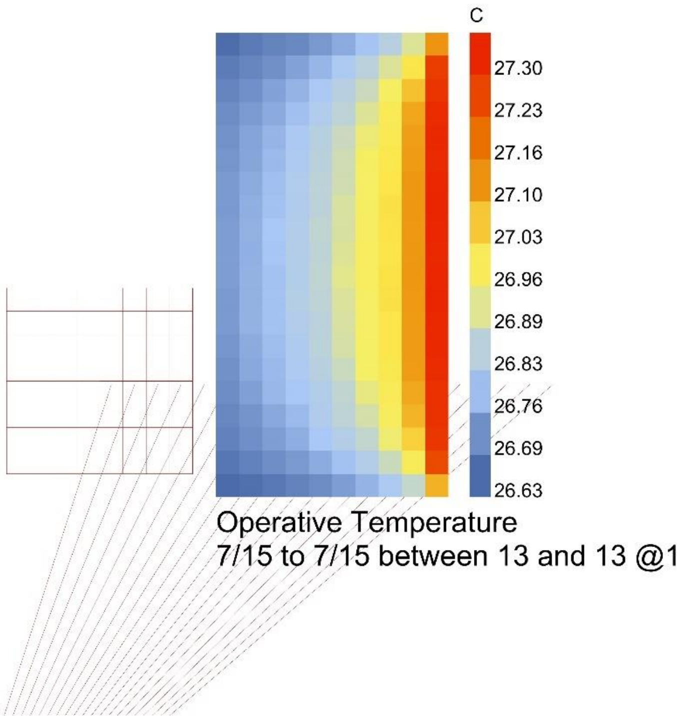


Figure III-15: Operative Temperature heatmap – East orientation (15 July, 13:00)

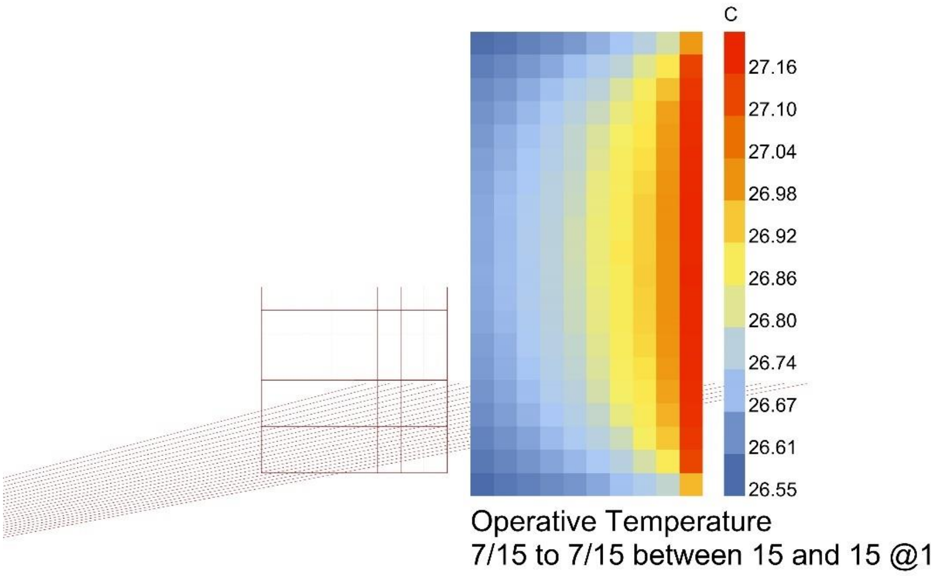


Figure III-16: Operative Temperature heatmap – East orientation (15 July, 15:00)

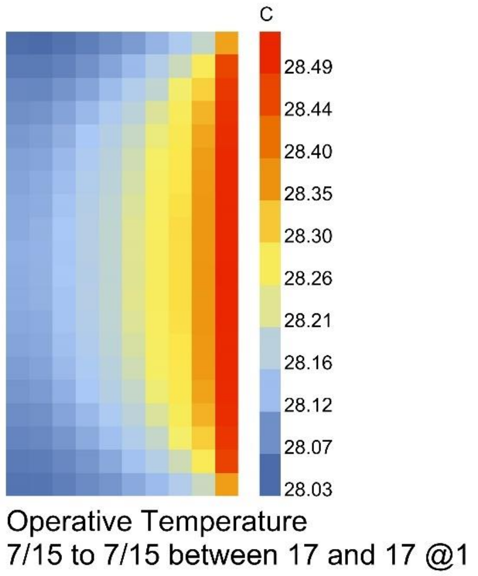


Figure III-17: Operative Temperature heatmap – East orientation (15 July, 17:00)

West orientation

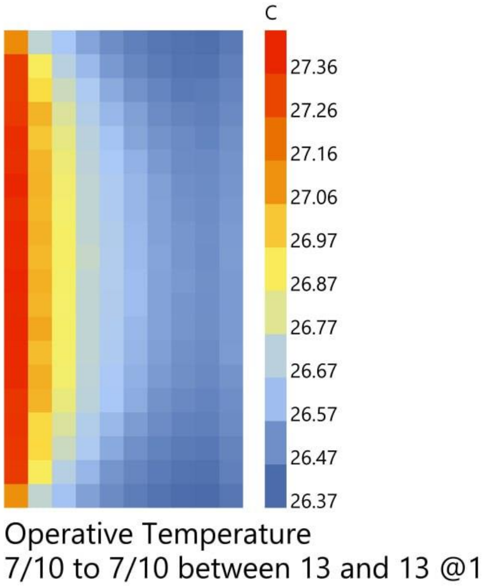


Figure III-18: Operative Temperature heatmap – West orientation (15 July, 13:00)

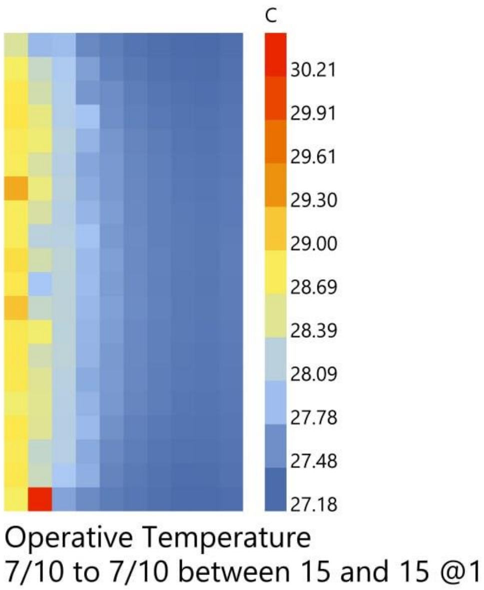


Figure III-19: Operative Temperature heatmap – West orientation (15 July, 15:00)

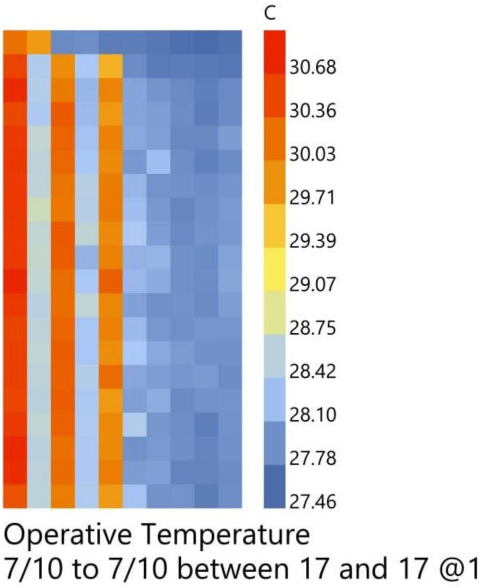


Figure III-20: Operative Temperature heatmap – West orientation (15 July, 17:00)

Tabular Summary

Thermal Comfort and Gradient Table – South Orientation

Time	Temperature Range (°C)	Thermal Gradient (°C)	% in Comfort Zone (20–27°C)
13:00	26.00 – 26.78	0.75	100%
14:00	26.03 – 27.71	1.68	72%
15:00	26.03 – 26.65	0.62	100%
16:00	26.00 – 26.56	0.56	100%
17:00	27.42 – 27.88	0.46	95%

Thermal Comfort and Gradient Table – South Orientation

Time	Temperature Range (°C)	Thermal Gradient (°C)	% in Comfort Zone (20–27°C)
13:00	26.63 – 27.30	0.67	60–70%
14:00	26.57 – 27.22	0.65	65–75%
15:00	26.55 – 27.16	0.61	70–80%
16:00	26.53 – 27.10	0.57	75–85%
17:00	28.03 – 28.49	0.46	0%

Thermal Comfort and Gradient Table – West Orientation

Time	Temperature Range (°C)	Thermal Gradient (°C)	% in Comfort Zone (20–27°C)
13:00	26.37 – 27.36	0.99	82%
14:00	26.79 – 28.20	1.41	71%
15:00	27.18 – 30.21	3.03	52%
16:00	27.45 – 29.14	1.69	58%
17:00	27.46 – 30.68	3.22	54%

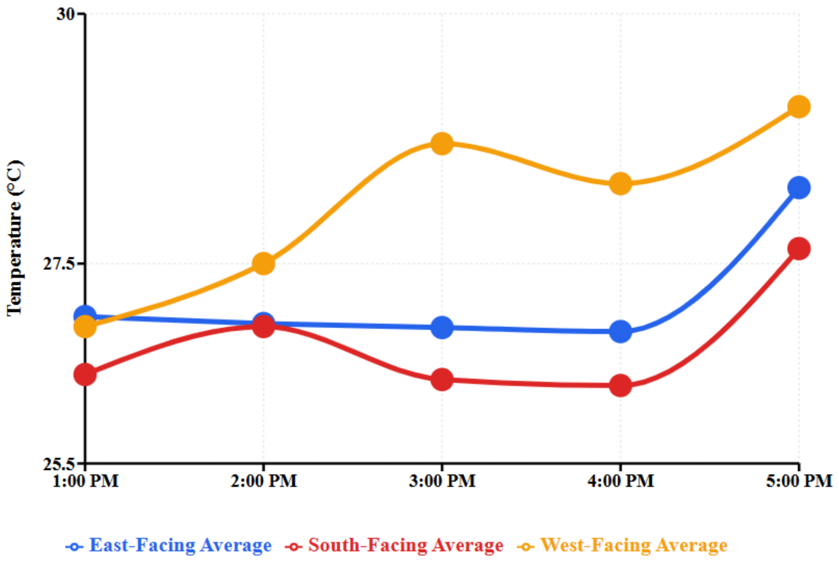


Figure III-21: Comparison of Average Operative Temperatures for East-, South-, and West-Facing Facades (July, 13:00–17:00)

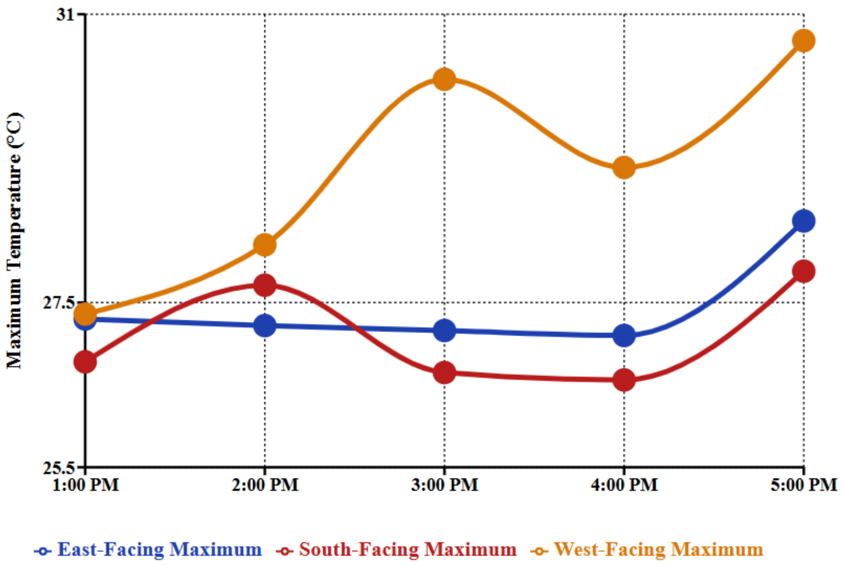


Figure III-22: Comparison of Maximum Temperatures range for East-, South-, and West-Facing Facades (July, 13:00–17:00)

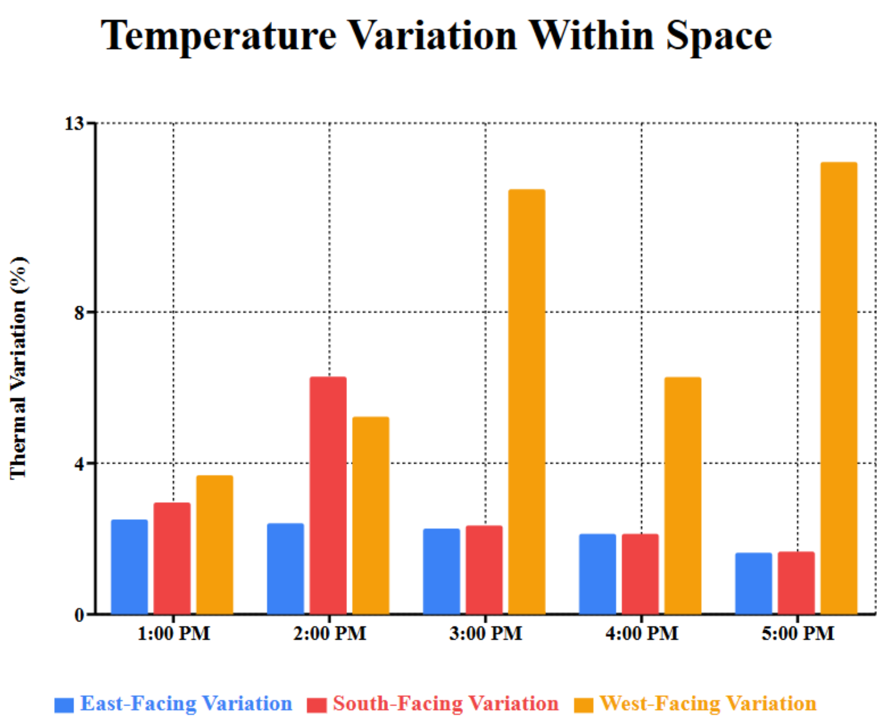


Figure III-23: Comparison of Temperatures variation within space for East-, South-, and West-Facing Facades (July, 13:00–17:00)

3.6.5 Conclusion: Dynamic Shading Effectiveness Analysis

The data confirms that indoor temperature regulation and thermal comfort are significantly improved by dynamic shading devices, with all orientations presenting performance benefits in different ways that make them suitable for specific applications.

1. Orientation-Specific Performance Excellence

All orientations have certain strengths that optimize different aspects of thermal comfort:

- East-facing systems excel in stability with minimal energy consumption (2.5-2.8% thermal fluctuation)
- South-facing systems provide the most uniform and consistent performance (27.6°C-26.7°C range)
- West-facing systems provide optimal effectiveness under challenging afternoon conditions (successfully coping with 29.8°C peaks)

2. Integrated Thermal Comfort Enhancement

All three orientations are successful at maintaining temperatures within comfortable ranges as well as addressing several comfort issues:

- **East-facing:** Prevents morning glare and gradual temperature variation (26.8°C-29.2°C)
- **South-facing:** Provides constant comfort throughout the day with minimal oscillations and constant highest temperatures of approximately 27.5°C
- **West-facing:** Actively manages the most challenging thermal loads, keeping occupants at ease despite intense afternoon solar radiation

3. Adaptability to Multitudinous Applications

The dynamic shading systems exhibit phenomenal adaptability to myriad space types:

- **East-facing:** Ideal for spaces that demand stable, low-energy performance (libraries, bedrooms, study rooms)
- **South-facing:** Ideal for applications calling for self-assured, dependable performance (exhibition spaces, meeting rooms, retail spaces)
- **West-facing:** Required for spaces with high thermal loads (workshops, afternoon-use spaces, lounges)

4. Optimized Response Adaptability

All orientations show astute response to its corresponding solar challenge:

- **East:** Gradual morning response with minimal afternoon readjustments
- **South:** Steady-state control with uniform conditions throughout the day
- **West:** Dynamic response with maximum efficiency between 3:00-5:00 PM critical period

3.7 Reduced-Scale Physical Model Construction:

3.7.1 The Components of the Model:

• Louver Slats/Blades:

Five horizontally adjustable panels that form the primary light and airflow control units. These rectangular blades are strategically positioned to allow maximum penetration of light when opened but still possess the capability to screen out light when angled.

• Main Frame Structure:

The external rectangular housing that holds and supports the entire louver assembly, providing it with structural integrity and mounting locations and maintaining an open structure that does not obstruct the light passage.

• **Pivot Mounting Brackets:**

Separate support brackets fixed on the vertical support column, with each one supporting a single louver slat at its pivot point. These compact-sized brackets are designed to minimize light obstruction while allowing complete rotation of each blade.

• **Vertical Support Column:**

The primary structural element positioned to the side of the frame and serving as the main support for all control mechanism and mounting brackets without encroaching into the center light transmission area.

• **Synchronized Control Rod Assembly:**

A horizontal linkage system which mechanically interconnects all louver slats in unison through the pivot points. This rod provides such that when one slat turns, all others turn at the same time at the same angles, keeping everything perfectly synchronized throughout the entire assembly to evenly control the light.

• **Actuator Connection Point:**

The top-of-column interface upon which the control mechanism is attached. One actuation input control the entire system through synchronized linkage.

• **Strategic Spacing Framework:**

The precise 1.0-unit spacing interval positioning maximizes the light transmission in open louvers, and the effective 0.6-unit top spacing minimizes structural interference.

This synchronized system allows all the louvers to open and close simultaneously as a group, rotating from completely open (maximum light penetration) to various angled settings for controlled lighting, with the offset column support that allows the interior space to remain unobstructed for maximum daylight penetration.

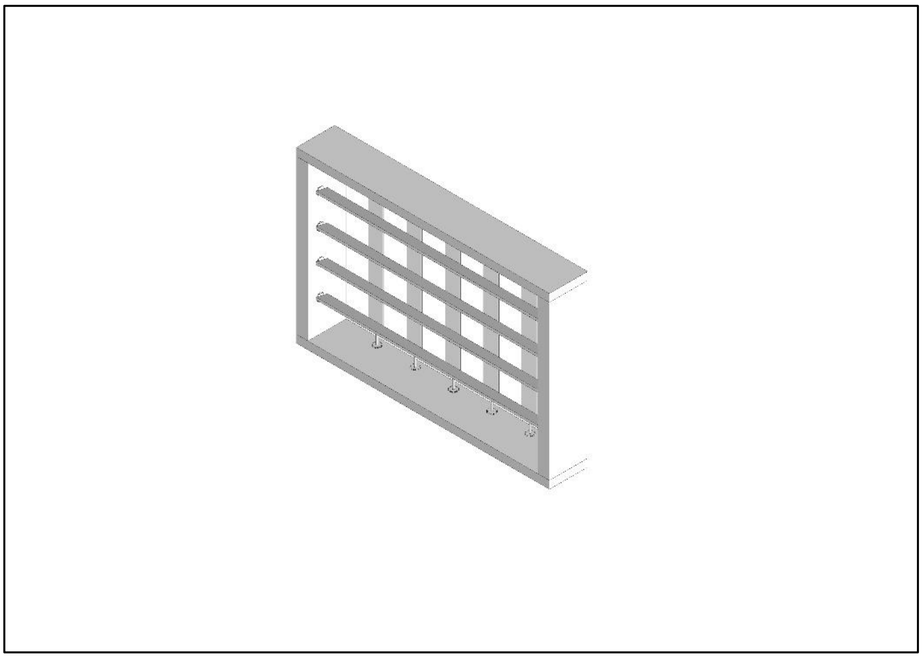


Figure III-24: 3D Isometric View of Dynamic sunshading model

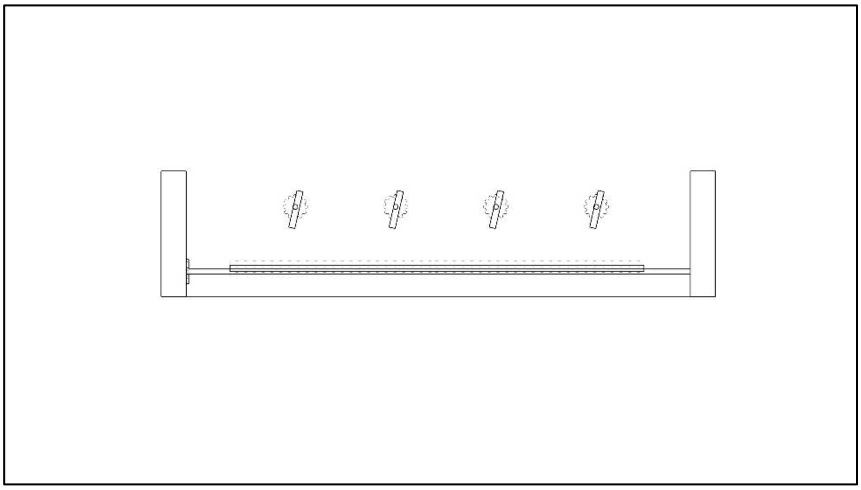


Figure III-25: Plan View of Dynamic Sunshading Model

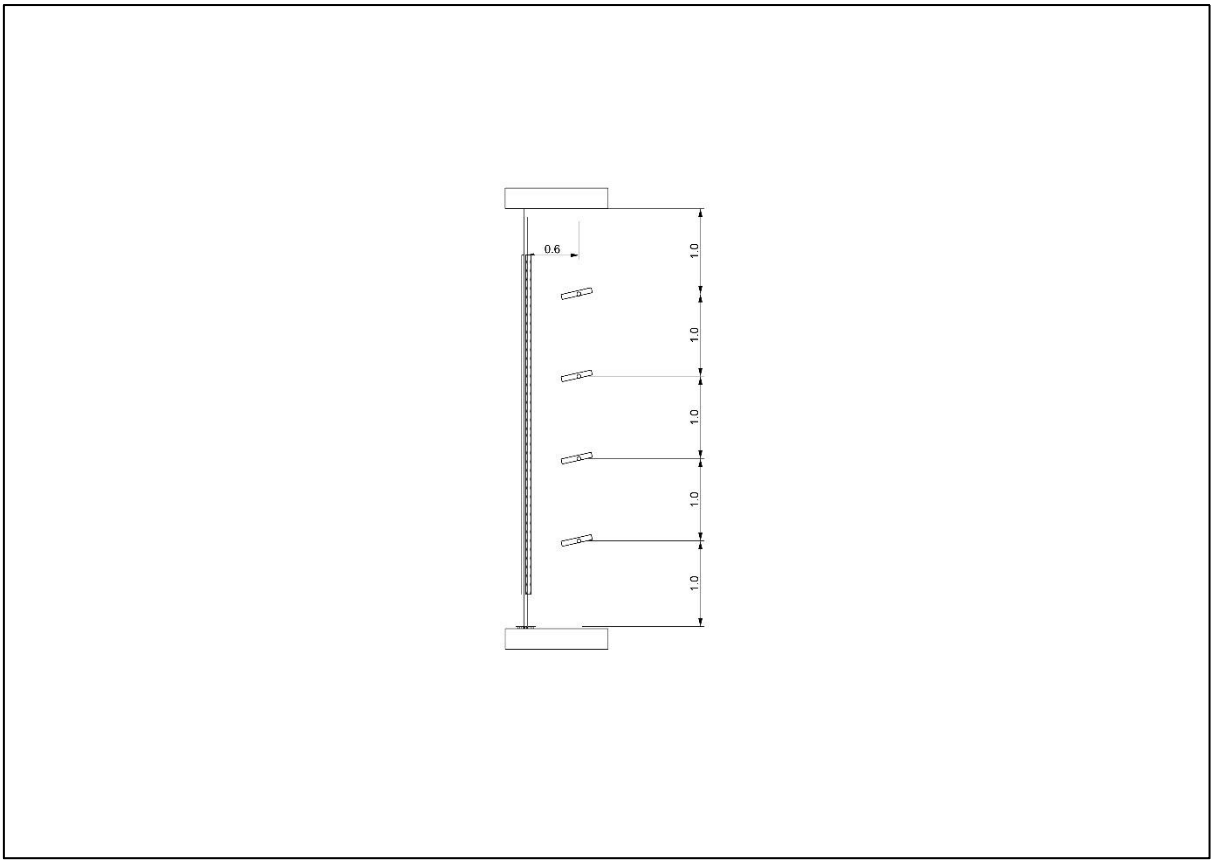


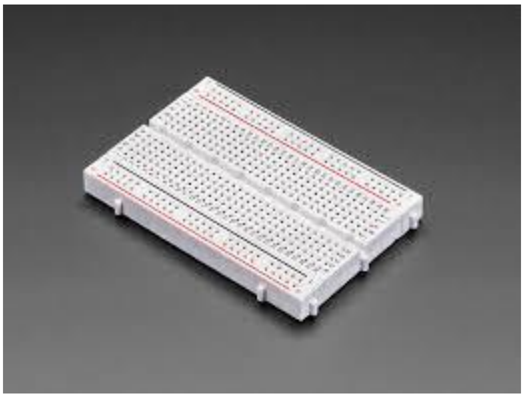
Figure III-26: Section View of Dynamic Sunshading Model

3.7.2 Arduino-Based Control System:

To develop an automated program for a movable shading system (Adaptive louvers), both hardware and software components are required. The hardware consists of sensors, actuators, and a control unit like a microcontroller (in this case, Arduino Uno), which work together to modify the louver positions according to environmental changes.

Components Required:

Arduino Uno	A microcontroller board based on the ATmega328P chip that can be programmed to control electronic components and read sensors. It's the "brain" of most beginner electronics projects.	
Servo Motor	A precise motor that can rotate to specific angles (usually 0-180 degrees) and hold that position. Commonly used for steering, robotic arms, and positioning applications.	
Jumper Wires	Flexible wires with connectors on both ends used to make temporary electrical connections between components on breadboards or between components and Arduino pins.	

LDR (Light Dependent Resistor)	A sensor that changes its electrical resistance based on the amount of light hitting it. More light = lower resistance, less light = higher resistance.	
Breadboard	A reusable board with holes and internal metal connections that allows you to build temporary circuits without soldering. Components and wires are inserted into the holes to create electrical connections.	
Lithium Battery	A rechargeable power source that provides electrical energy to your circuit. Lithium batteries are lightweight, long-lasting, and commonly used in portable electronics projects.	

3.7.3 System Operation Overview:

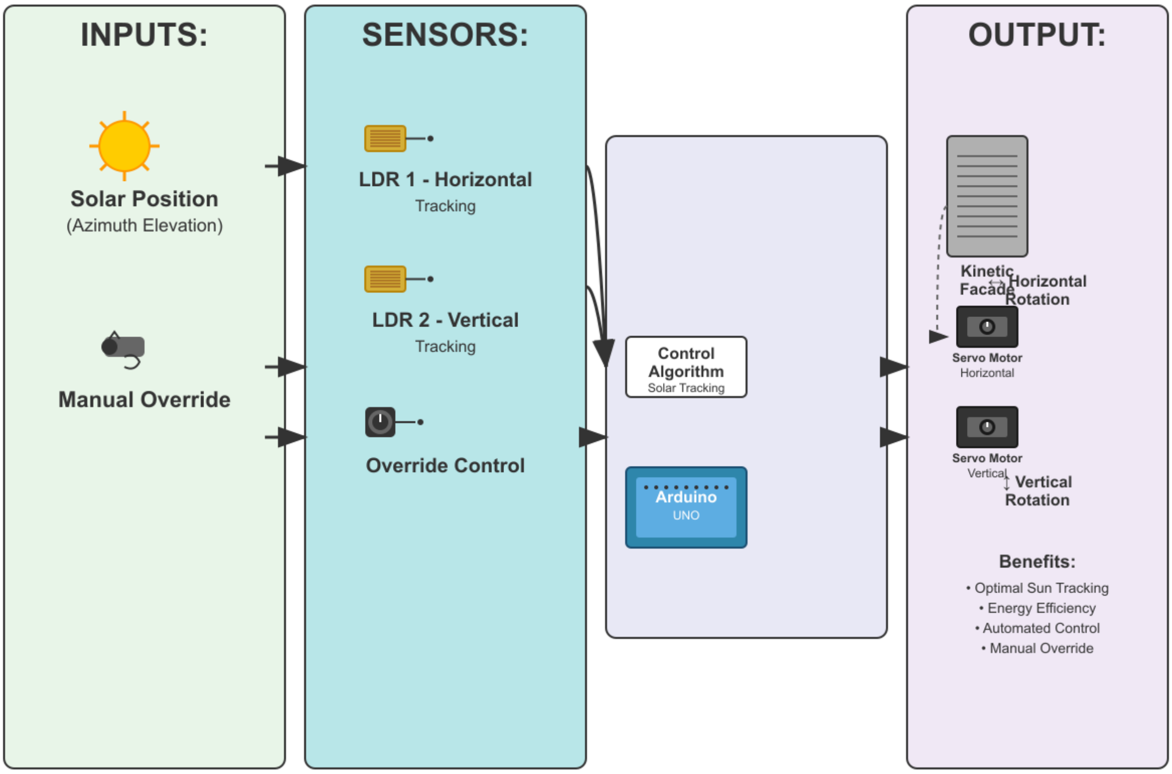
operates based on a three-step process that is used to change the shading elements automatically based on environmental factors.

Input Stage: The system is given two significant inputs - solar position data (azimuth and elevation angles) and override commands by hand as and when required. This allows the system to track the sun's movement during the daytime while simultaneously offering user control where required.

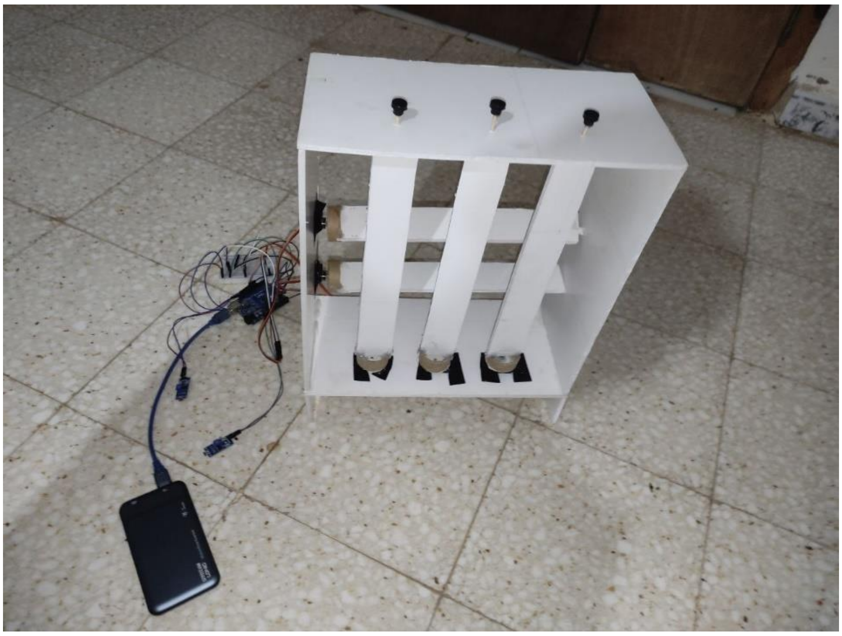
Sensing and Processing: Light is detected from different directions by multiple sensors. Horizontal and vertical tracking sensors detect changes in light intensity and an override control sensor to enable manual input. All sensor data are fed to a single central control algorithm on an Arduino microcontroller, which processes the data and determines best louver position.

Output and Control: The system responds in twin-axis movement using servo motors to rotate both horizontally and vertically. This creates a kinetic facade that adjusts automatically to maintain optimal shading or light entry based on the direction of the sun and user preference.

The system provides optimal sun tracking for energy optimization, automatic control reducing manual intervention, and manual override capability when special conditions require user intervention.



3.7.4 Prototype Development:



3.8 CASE STUDY: Cultural center in Biskra

Introduction:

This analytical framework to scrutinize three fundamental characteristics of our work. Initially, we will examine a range of literary sources and current cultural center initiatives to acquire a comprehensive understanding of the operational dynamics of such locations. Next, we will analyze the specific context of the city of Biskra through both a bioclimatic study and a site analysis. This entails assessing meteorological data and morphological characteristics of the location. This research aims to incorporate local environmental and contextual aspects into the design process, thereby informing strategic decisions that are adapted to the region's distinct characteristics.

3.8.1 The list of examples:

The Centre Pompidou

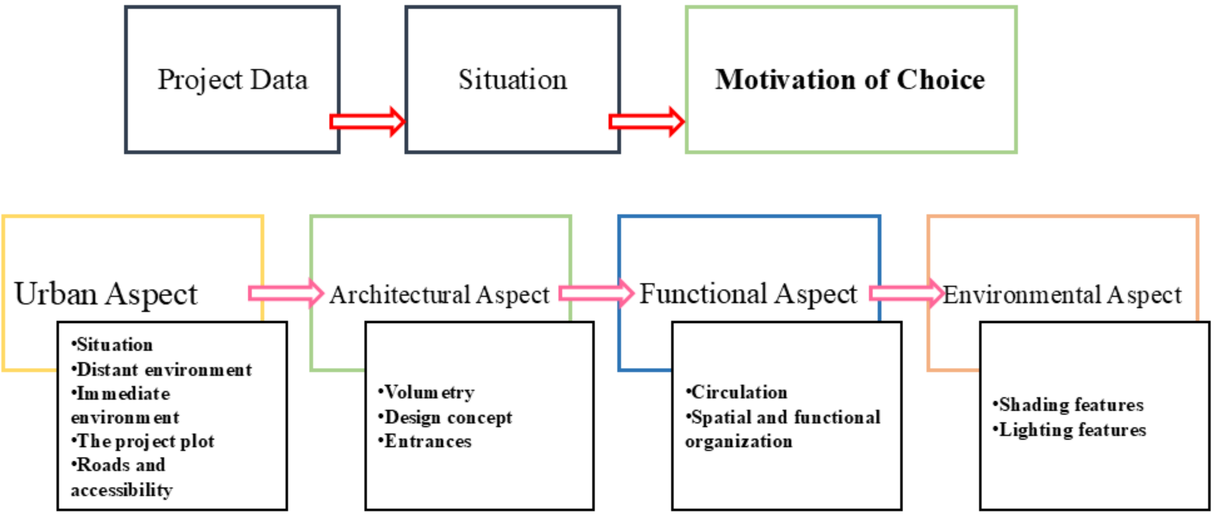
Arab World Institute

Portlantis exhibition center

Da Chang Muslim Cultural Center

Xiaopu Culture

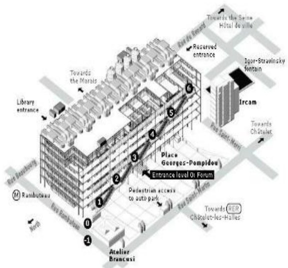
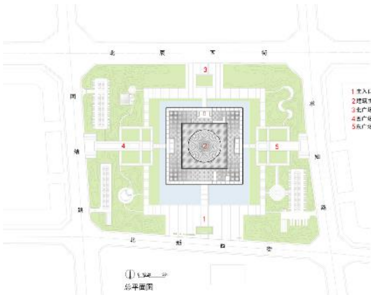
3.8.2 The analyzed elements:

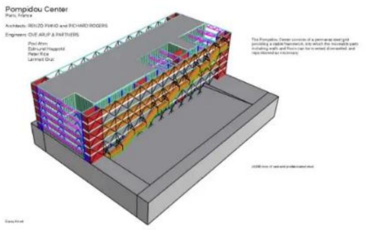
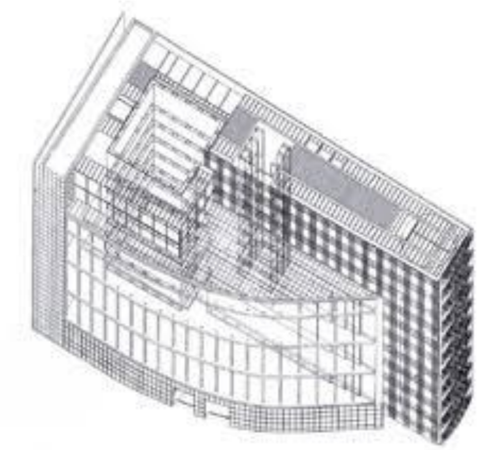
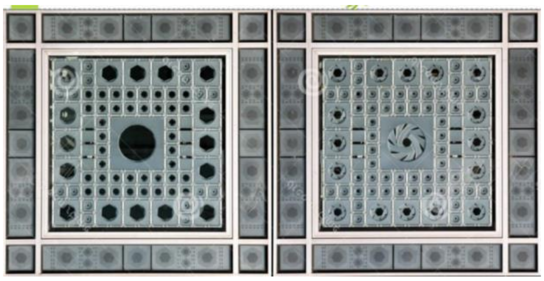


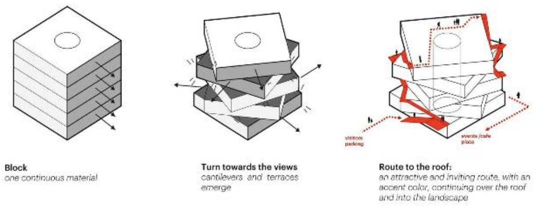
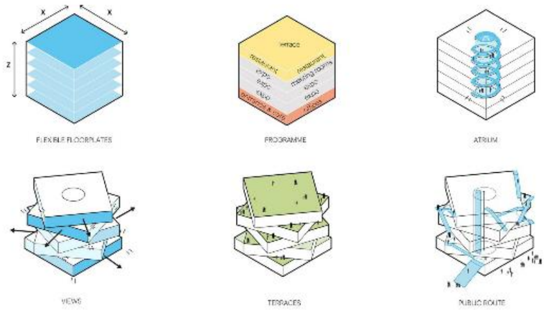
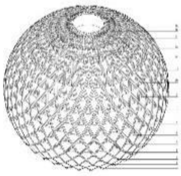
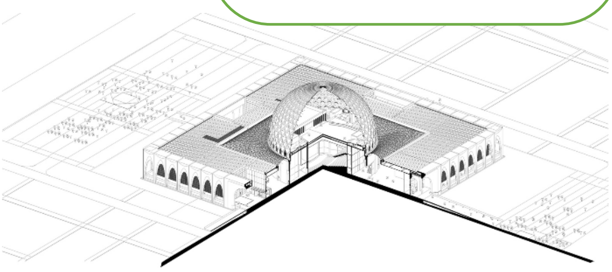
The project	Project data	Situation	Motivation of choice
	**Category:** cultural center / public library / museum **Date of realization:** 1971–1977 **Architects:** Renzo Piano & Richard Rogers **Area:** approximately 103,305 m² **N° of stories:** 10 stories (4 basement levels) **Terrace / levels:** public terrace on the top floor with panoramic views of Paris; lower ground levels include cinema, technical spaces, and storage	Situated in the **Beaubourg district** of the 4th arrondissement of Paris in **France** adjacent to Les Halles and the Marais, within the historic core of the city	The choice of the Centre Pompidou is influenced by its innovative high-tech architecture and the vibrant application of color-coded exterior components, with each functional system—circulation, structure, and services—designated by a unique color, making it exemplary for examining transparency, legibility, and urban interaction in design.
	**Category:** cultural center / museum / research institute **Date of realization:** 1981–1987 **Architects:** Jean Nouvel & Architecture-Studio **Area:** approximately 16,800 m² **N° of stories:** 11 stories (4 basement levels) **Terrace / levels:** rooftop terrace with panoramic view of Paris and the Seine; basement levels include auditorium and exhibition spaces	Situated on the left bank of the **Seine River** in the 5th arrondissement of **Paris**, adjacent to the **Jussieu University** campus and the Seine, in proximity to the **old Latin Quarter** and facing **Île Saint-Louis.**	The amalgamation of modern technology and traditional Arab motifs, especially its southern façade with light-sensitive mashrabiya-inspired openings, rendering it exemplary for examining cultural integration and responsive design in contemporary architecture.

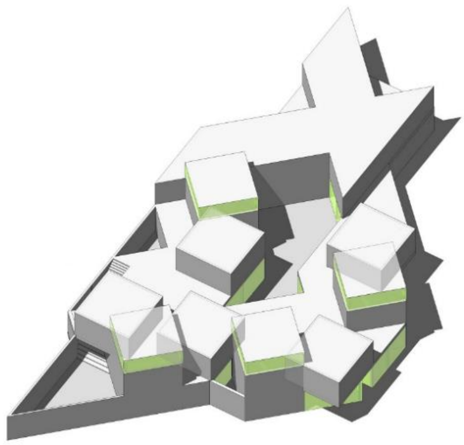
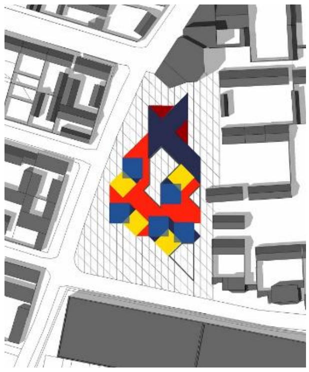
	**Category:** visitor and exhibition center / educational facility **Date of realization:** 2023–2025 **Architects:** MVRDV **Area:** 3,500 m² **N° of stories:** 5 stories (stacked exhibition levels, each rotated for different views) **Terrace / levels:** rooftop terrace offering panoramic views of the North Sea and port; interior features a 22-meter-high central atrium	situated in the westernmost extremity of **the Port of Rotterdam, on Maasvlakte 2, Netherlands** offering views of the sea, dunes, and harbor facilities	influenced by its remarkable structure, consisting of five rotational, stacked cubic volumes, each positioned to capture distinct perspectives of the port and sea. enriching the spatial experience, making it suitable for examining the interplay between architectural form, visual orientation, and environmental context in public architecture.
	**Category**: Cultural Center / Religious Architecture **Location**: Dachang Hui Autonomous County, Langfang, Hebei Province, China **Date of Realization**: Completed in 2015 **Architect**: Architectural Design & Research Institute of South China University of Technology (SCUT), led by He Jingtang **Area**: Approximately 35,000 m² **Number of Stories**: 2	situated in **Dachang Hui Autonomous County**, within **Langfang City**, **Hebei Province**, China. This location lies approximately **60 kilometers east of Beijing**, making it part of the greater Beijing metropolitan area.	examining cultural symbolism and spatial harmony in modern civic architecture because of its flowing, rhythmic form, which was influenced by classical Chinese colonnades, and its integration with the surrounding landscape.
	**Category:** Cultural Center **Location:** Xiaopu Village, Song Zhuang Town, Tong Zhou District, Beijing, China **Date of Realization:** 2007 **Architect:** DnA _Design and Architecture **Area:** Approximately 2,000 m² **Number of Stories:** 2	located in **Xiaopu Village, Song Zhuang** Town, **Tong Zhou** District, on the eastern periphery of **Beijing, China**. This region is recognized as the Song Zhuang Art District, one of China's foremost modern art hubs, housing hundreds	motivated by its creative Tangram-inspired design, which creates a relationship between art production and exhibition by interlocking artist studios and double-height galleries.

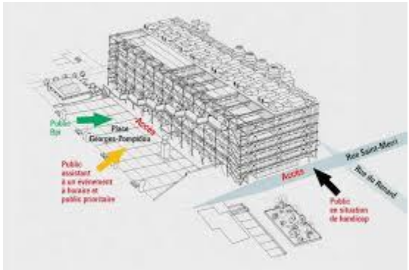
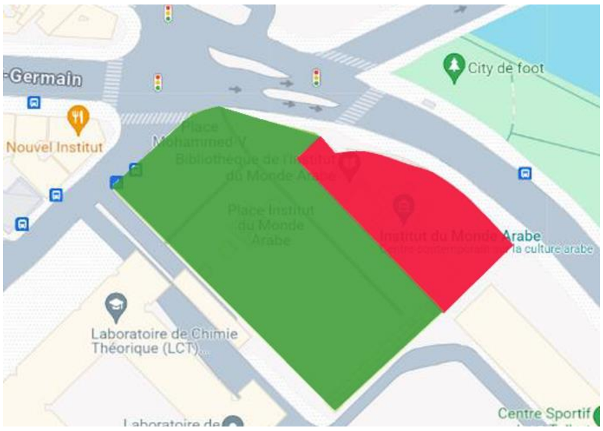
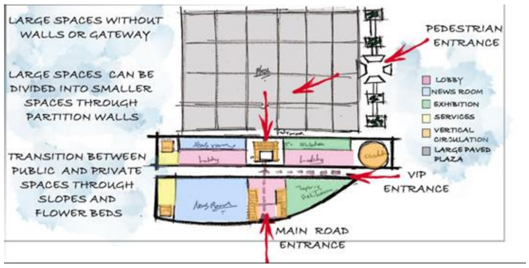
		of artists, galleries, and studios.	

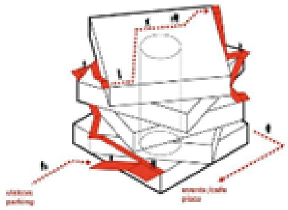
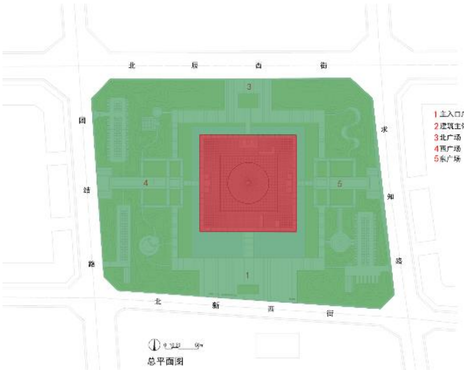
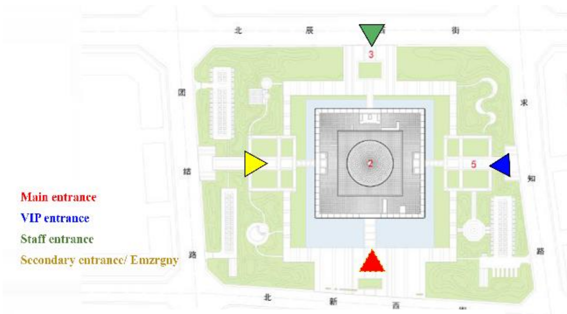
The project	The surrounding area
	 The architecture of the Centre Pompidou complements its location in the heart of Paris, providing easy access to the Hôtel de Ville, Châtelet-Les Halles, and cultural hotspots like Place Georges-Pompidou and rue Beaubourg. Easy access is provided by metro and bus lines, and discovery of Paris' history is enhanced by its proximity to historic landmarks like Atelier Brancusi.
	 The Arab World Institute mixes in perfectly with its Parisian setting, being close to the Seine and famous sites like the Jardin des Plantes and Notre-Dame. It promotes engagement with the urban fabric and Arab cultural heritage and is easily accessible from neighboring Metro stations such as Jussieu and Cardinal Lemoine.
	
	 The Da Chang Cultural Center is located in a unique Muslim enclave that's completely surrounded by Beijing and Tianjin. Positioned just 20-30 minutes from Beijing, the surrounding area serves as a cultural bridge between the capital and the local Hui community.
	

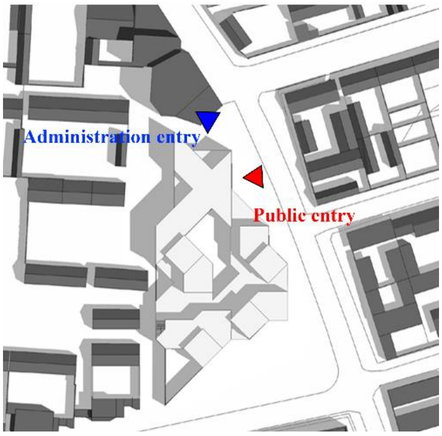
The project	**The volumetry**	**The design concept**
The Centre Pompidou	 featuring a bold rectangular volume with an exposed exoskeleton, color-coded services, and open interior floors, complemented by the expansive Place Georges-Pompidou Plaza.	 The design concept of the Centre Pompidou reflects a belief in architectural adaptability, enabling users to modify their environment as needed. It emphasizes visible structure, making the building an honest reflection of its function.
Arab World Institute	 The volumetry of the Arab World Institute blends geometric clarity with spatial intricacy, with two rectangular prisms and a curved form arranged around a central cube that creates a void.	 By utilizing kinetic sun-shading devices to recreate the Arab architectural heritage in a modern setting, the Arab World Institute, designed by Jean Nouvel, is a trailblazing example of climate-responsive design that combines technological innovation with cultural meaning.

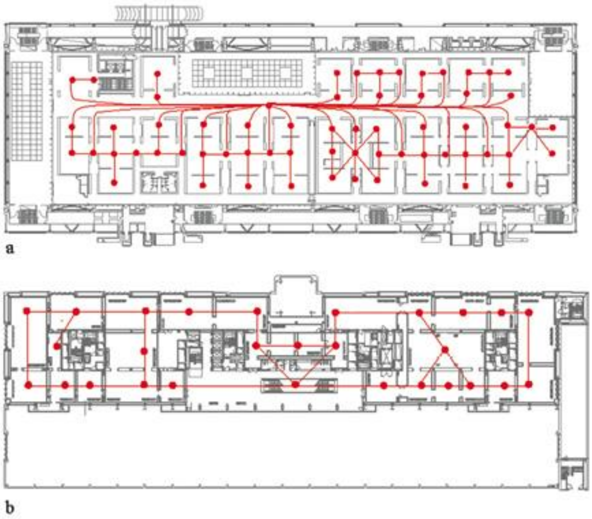
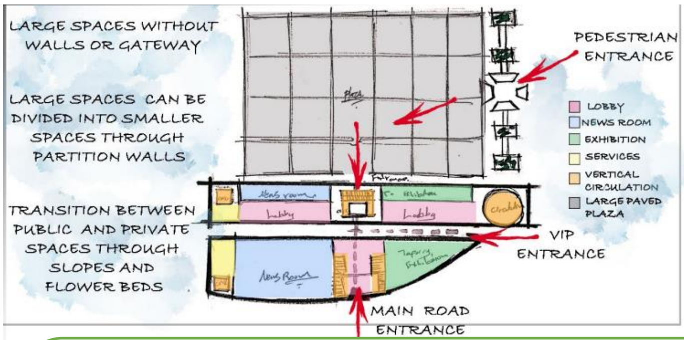
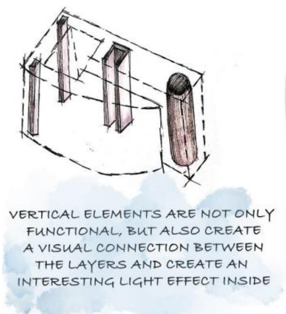
Portlantis exhibition center	 composed of five stacked, rotating volumes, each positioned to offer a different perspective of the surrounding dunes, the port, and the North Sea.	 The structure is made up of rotating, layered volumes. The terraces are incorporated into the rotating volumes and positioned thoughtfully at different heights of the structure. The mezzanine, which is situated inside the building's central atrium, offers guests a distinctive viewpoint of
Da Chang Muslim Cultural Center	 a parametric model of a dynamic dome structure formed by the intersection of a sphere and a square prism. has a dome made of petaloid shells and arches shaped like petals. 	 He Jingtang has applied his concept of "2 Views" and "3 Characters", with sustainable development concept, considering regionalism, cultural, and epochal character, thus presents us an excellent design.

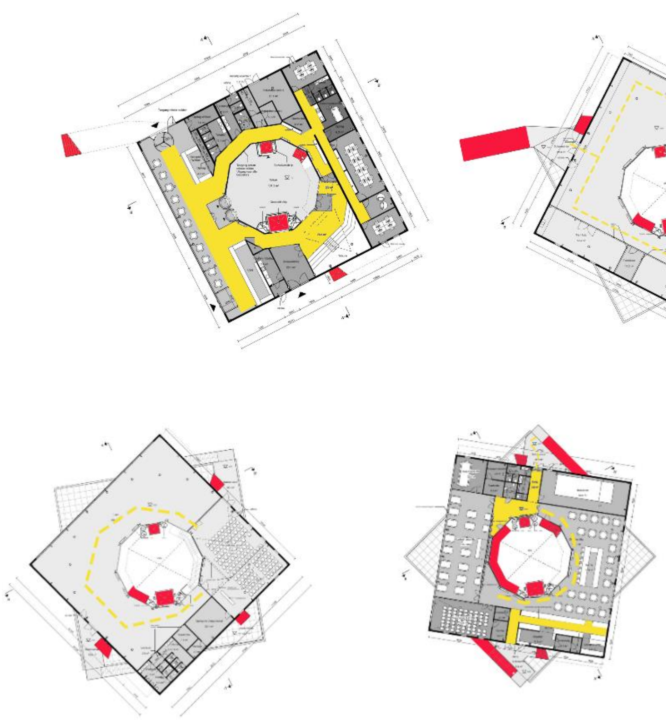
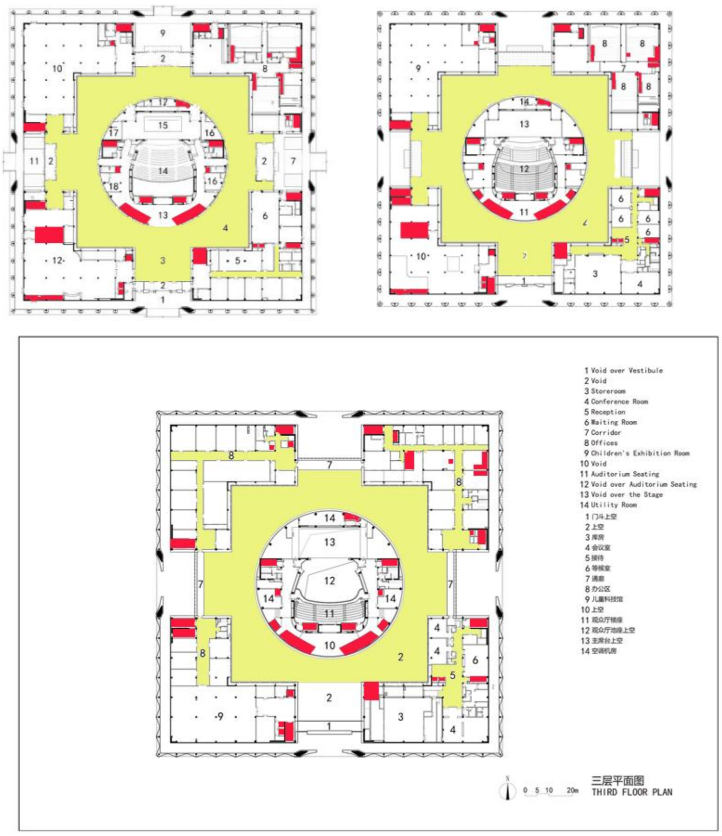
Xiaopu Culture Center	 The volumetry of the Xiaopu Culture Center is a compelling example of fragmented massing and dynamic spatial composition, which reflects both cultural symbolism and functional zoning.	  Central to the design concept is the Tangram layout, a geometric strategy that adapts to the site's irregular former industrial lot.

The project	The project plot	Entrances
The Centre Pompidou	 Built 40% Unbuilt 60%	 The Centre Pompidou features a main public entrance on the west side, opening onto Place Georges-Pompidou and leading into the central forum. Service access is located on the east, while VIP entry is discreetly integrated
Arab World Institute	 Built 40-45% Unbuilt 55-60%	 The Institute du Monde Arabe features three distinct entrances: a public entry through a spacious plaza for pedestrians, a main vehicular entrance providing direct access to the newsrooms and general lobby, and a separate VIP entrance offering a more private route to key areas like the auditorium.

Portlantis exhibition center	Built 30% Unbuilt 70% 	 Portlantis features a main public entrance on the west, opening to a beachfront plaza and central lobby, with a striking red external stairway offering rooftop access. Service and staff entrances are discreetly located to maintain smooth public circulation.
Da Chang Muslim Cultural Center	 Built 40% Unbuilt 60%	 The Da Chang Cultural Center features a public entrance on the south leading to exhibition spaces, a service entry on the north, and a VIP access on the east to private areas. The west entrance serves as a secondary or emergency exit.

Xiaopu Culture Center	 Built 40% Unbuilt 60%	 Xiaopu Culture Center features a main public entrance at ground level leading to galleries and courtyards, with a secondary staff entrance for service access. Rooftop terraces and studio openings support informal circulation and visual connectivity.

The project	Circulation
The Centre Pompidou	 The Centre Pompidou features a unique. Its most iconic element is the external glass-enclosed escalator, often called the "caterpillar," which zigzags along the façade where circulation becomes a visible and expressive element, allowing visitors to ascend while enjoying panoramic views of Paris. Inside, the building’s open-plan design promotes free and flexible movement.in the inside There are no permanent walls, allowing for flexible gallery layouts.
Arab World Institute	  Institute du Monde Arabe features a well-organized system of circulation. a pedestrian entrance via a large public plaza, a main road entrance leading directly to the newsrooms and general lobby areas, and a VIP entrance for private or official entrance, offering a more isolated route to significant spaces like the auditorium. Internally, circulation is focused on central lobby nodes, with direct connection to exhibit space, newsrooms, and vertical circulation. The organization promotes way-finding while dividing public, semi-public, and private functions unmistakably.

Portlantis exhibition center		The circulation revolves around a s 22-meter-high atrium, both visual focus and vertical link. Access is through the ground-floor lobby, from which it is possible to rise through internal staircases or lifts. There are also exterior staircases that wind around the building, giving access to each floor and terminating in a public rooftop roof garden that commands 360-degree views of the port and the
Da Chang Muslim Cultural Center		It has a longitudinal axis, with the central corridor guiding the public to different functional spaces. Public areas (like the lobby, exhibition space, and theater) are easily accessed via the main entrance. The theater, being the focal point of the cultural events, visitors can access through a main foyer that leads directly to the theater space, a buffer room where they would be able to congregate before moving on to the auditorium. The theater's symmetrical and looping circulation routes guarantee easy mobility both before and after shows.

<table>
<tr>
<td>Xiaopu Culture Center</td>
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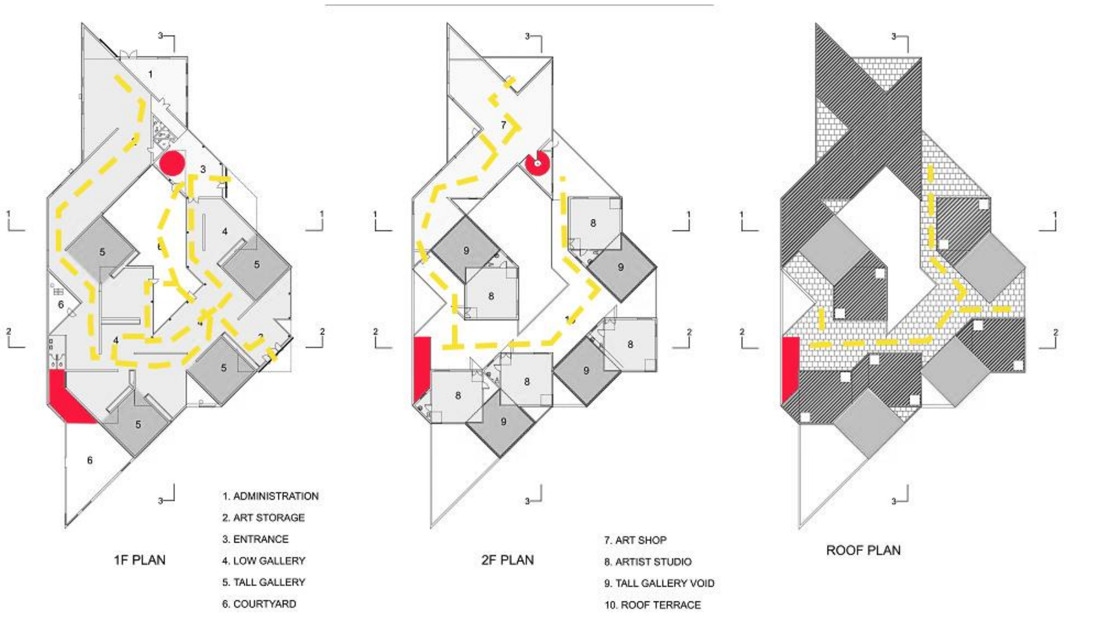

Xiaopu Culture Center gives clear and convenient flow because it has an unconventional stacked plan taken from the Tangram. Spaces such as studios, galleries, and courtyards are seamlessly connected, and free movement of people is not hindered. An inserted sculpture spiral stairway conveniently accessible at the entrance serves as a key vertical connector, both physically and visually, connecting different levels.
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<tr>
<th>The project</th>
<th>Spatial and functional organization</th>
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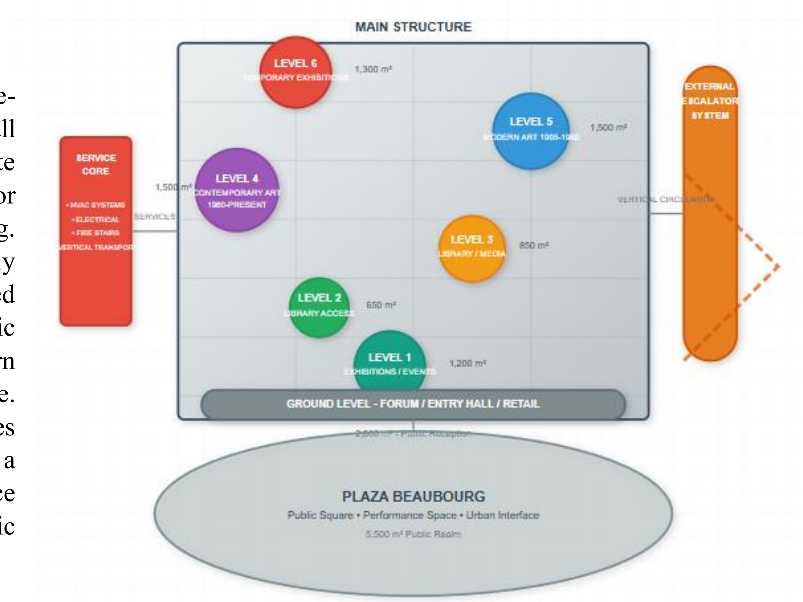
<tr>
<td>The Centre Pompidou</td>
<td>
Centre Pompidou's "inside-out" design externalizes all services and structure to create flexible, column-free interior spaces for cultural programming. The six levels stack vertically from public forum to specialized galleries, connected by dramatic external escalators that turn circulation into urban spectacle. This radical approach integrates building and plaza into a continuous cultural experience extending from interior to public realm.



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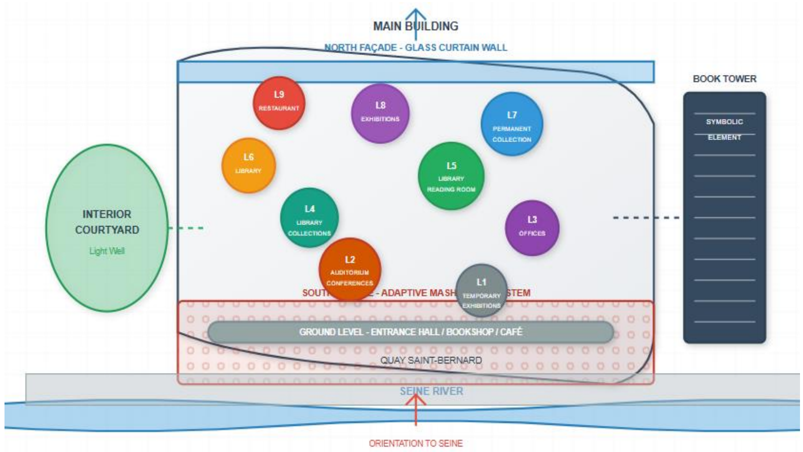
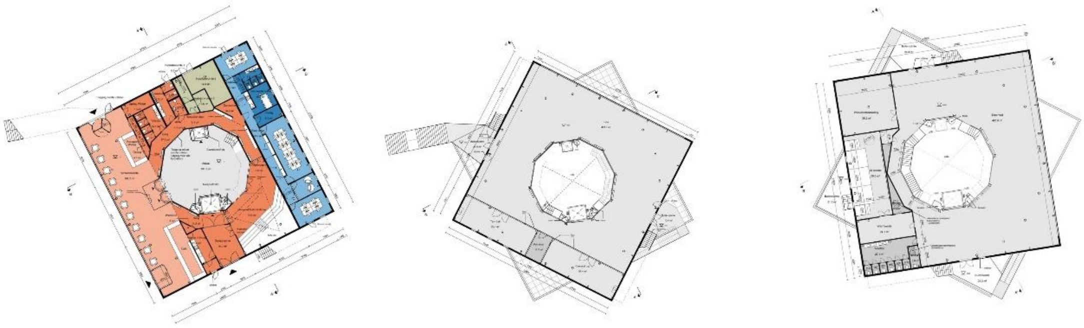
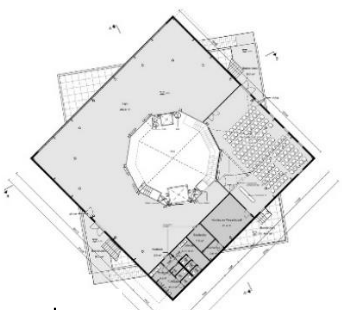
Arab World Institute



Portlantis exhibition center



Ground floor Level 1 Level 2



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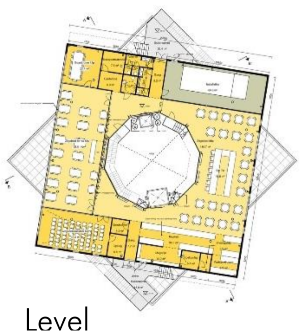
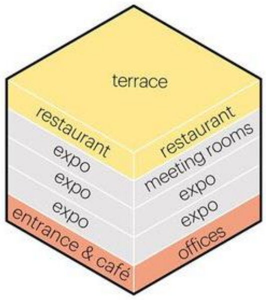


Level

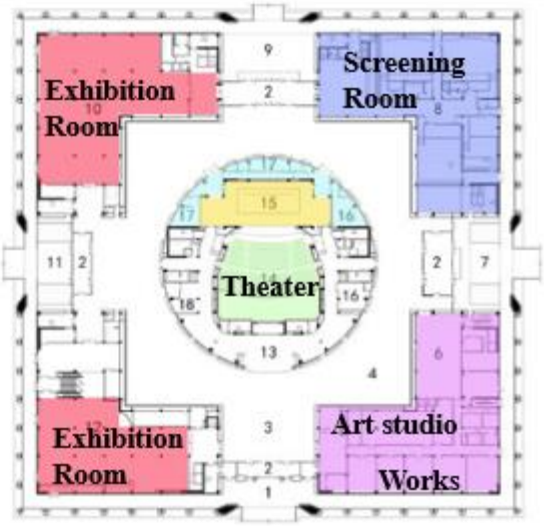


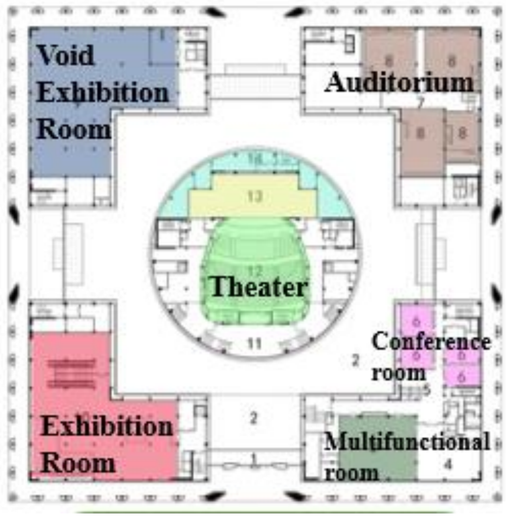
PROGRAMME

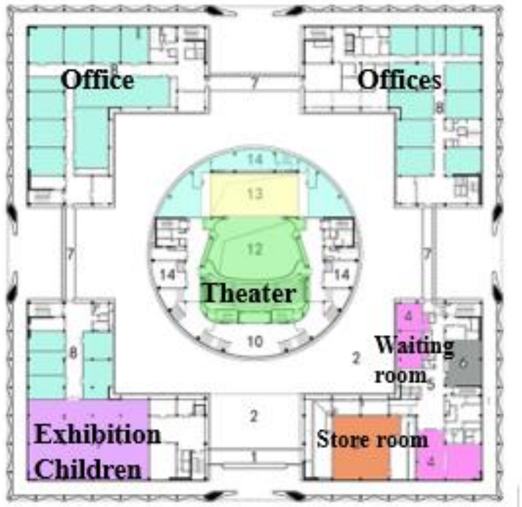
Ground Floor:
Café
Main entrance hall and ticketing counter.
Administration
Levels 1 to 3:
Exhibition Platforms
Level 4
Restaurant
Rooftop: Terrace

The three central floors are reserved for permanent exhibits, flanked below by a warm ground floor and above by an observation restaurant, crowned by a roof-open observation deck. The building integrates the shape, use, and visual boundary thoughtfully into architecture.

Da Chang Muslim Cultural Center



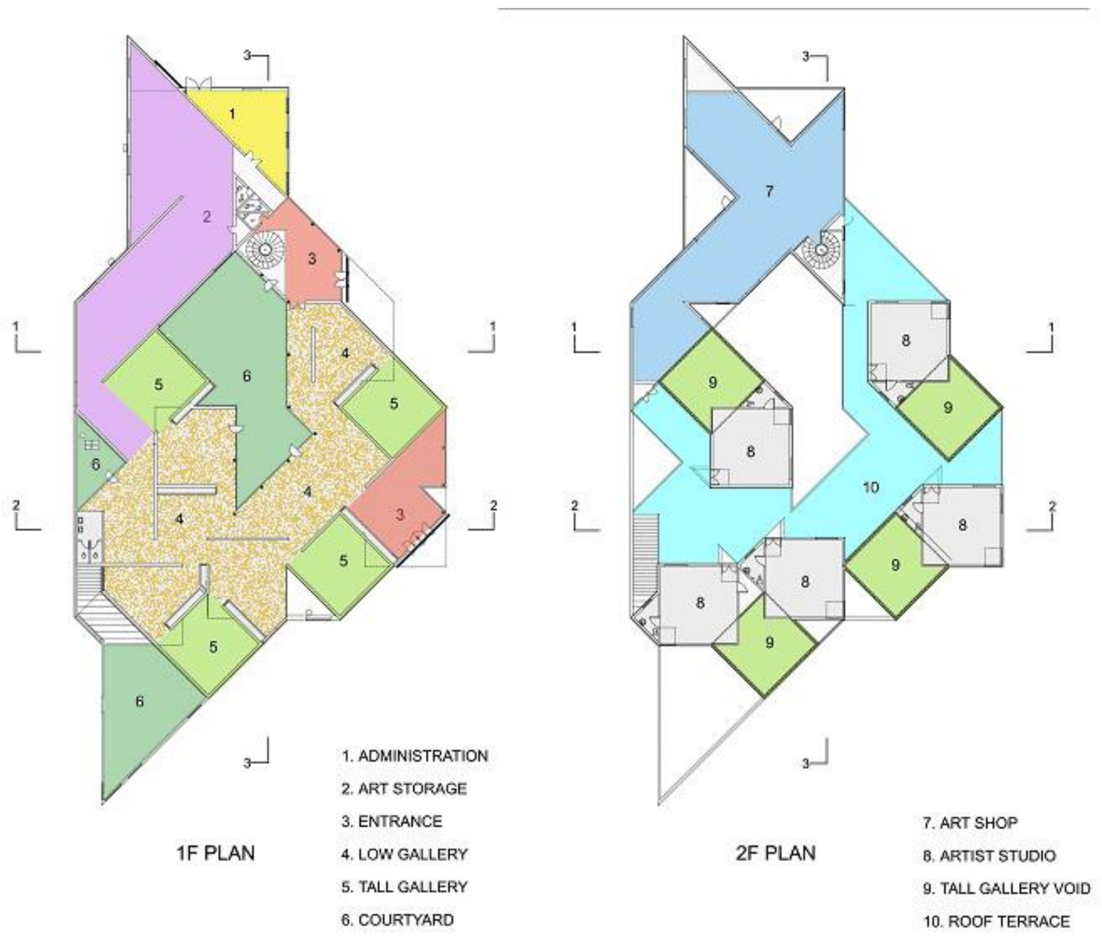


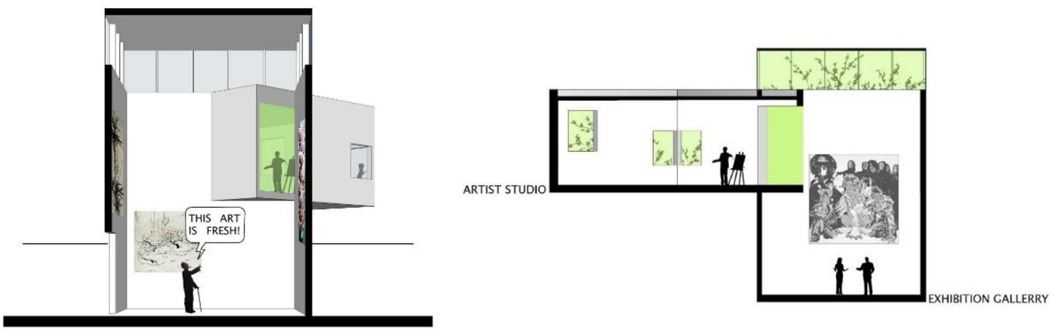


The theater is the heart of the building, connecting all the surrounding spaces radially. Circulation automatically centers around this core, with the higher levels served by stairs and elevators.

They are separate but linked zones that avoid spatial interference and facilitate smooth transitions.

Xiaopu Culture Center





The spatial design encourages a fluid visitor journey through interconnected galleries and open courtyards on the ground floor, while the upper-level artist studios, set apart for privacy, maintain visual links to the public zones below through double-height openings—fostering interaction and exchange between creators and visitors without disrupting functional separation.

Synthesis of book-related examples:

	Synthesis
Situation	The cultural centers are strategically situated along a transitional zone between the urban core and green open space, similar to Portlantis' interface between city and waterfront. This location allows it to act as both a cultural attractor and a connective public platform.
Volumetry	The volumetric form is conceived as a symbolic composition of interlocked and layered volumes, drawing inspiration from the expressive stacking of Portlantis and the Pompidou Center. Each volume is shaped in response to programmatic needs and orientation, forming a dynamic yet legible silhouette that conveys spatial hierarchy and establishes key visual axes.
Design Concept	Its architectural imagination is guided by performative and symbolic precursors. Like the Arab World Institute, it has responsive design elements, and like Da Chang, it centers on a space of unity. The building becomes a cultural must offer fixed and flexible space that responds to environmental conditions and user activity.
Accessibility	Accessibility is a key design driver. Like the Arab World Institute and Portlantis, the project offers multiple entry points that ensure permeability from various directions. The building’s position and orientation encourage walkability, public transport integration, and barrier-free access for all users.
Entrances	The building includes several entrances, each meticulously positioned over important city linkages reflecting Portlantis and Pompidou's spatial democracy. Rather than delineating a single "main" entrance, the building welcomes entry from all sides, fostering flexibility and confirming openness.
Circulation	Circulation within the center follows a clear and engaging path, inspired by Da Chang’s central vertical movement and Portlantis’ horizontal exhibition loops. Visitors are guided through a series of layered spaces, interspersed with moments of openness, views, and rest areas. Circulation is not just functional—it becomes an architectural experience.
Spatial and Functional Organization	The spatial layout is structured from a central core serving as a civic center—inspired by strong internal hearts in Da Chang and Xiaopu. The different levels accommodate permanent exhibitions and temporary ones, workshops, administrative functions, and public services. Vertical and visual interactions across floors encourage communication while maintaining clear functional zoning.

Site analysis:

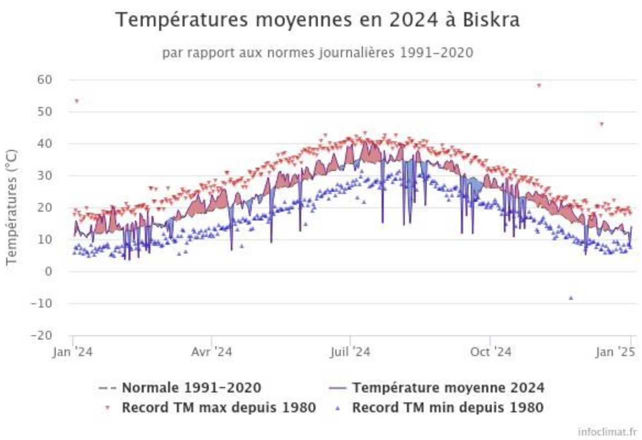
Presentation of Biskra:

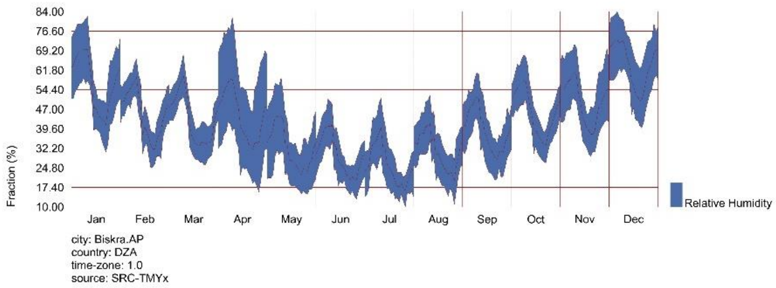
The municipality of Biskra is situated in the northeastern Algerian Sahara region in the country's southeast. With a total area of roughly 22,379.95 km², the city is situated at 34° 51' 1" N latitude and 5° 43' 40" E longitude. The urban commune alone occupies 127.53 km². At an average elevation of 120 meters above sea level. With 206,856 residents and a 3.8% population growth rate, Biskra is a strategically significant city in the area with a fast urban development.

Figure: Geographical location of the city of Biskra Source: (wilaya-Biskra.gov.dz).

Climatological data:

The subtropical desert climate of Biskra is characterized by hot, dry, and sunny summers and mild winters with the possibility of freezing nights.

The temperature		The city has a hot, dry climate with mild winters and extremely hot summers that can reach 45°C, particularly in July and August. Because of this climate, thermal comfort and sun exposure are important factors in urban and architectural design.

<table>
<tr>
<td>humidity</td>
<td>
</td>
<td>The relative humidity in Biskra shows clear seasonal variation due to its dry climate. It peaks in winter (December–January) above 70%, offering slight thermal relief, then steadily drops through spring. The driest period is summer (June–July), with levels often below 20%, causing discomfort. Humidity rises again in autumn, reaching moderate levels by November.</td>
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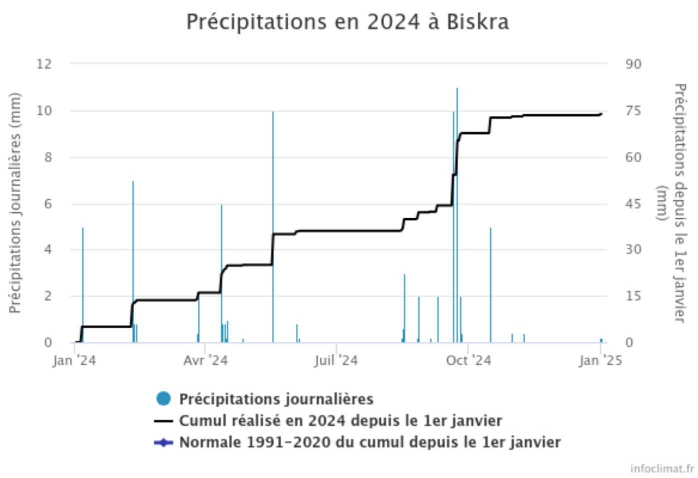
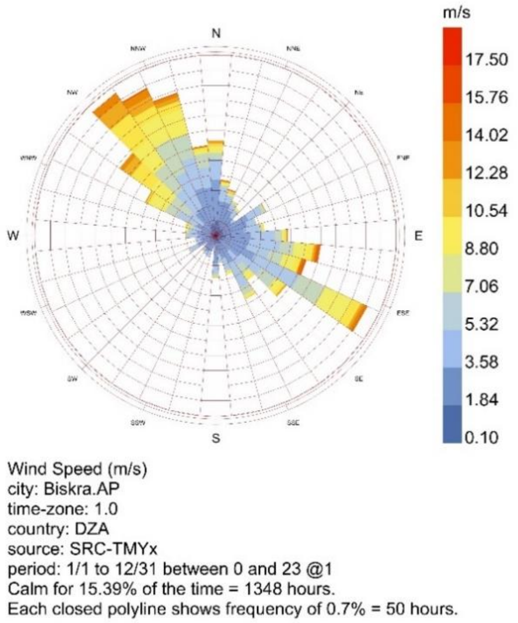
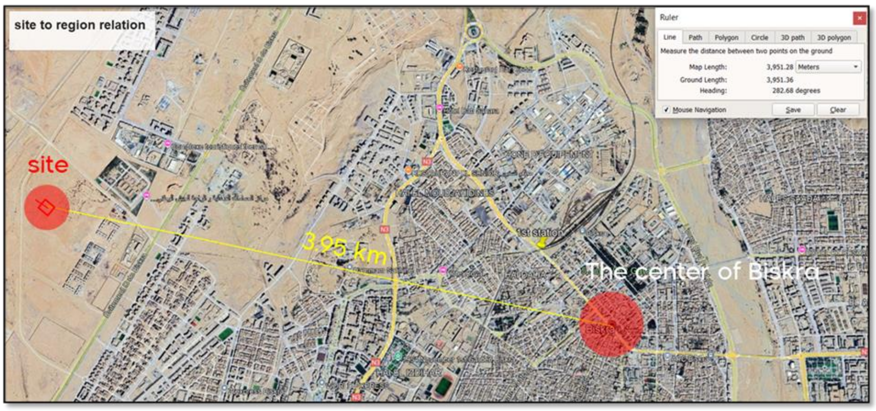
<td>
</td>
<td>This chart shows the precipitation patterns in Biskra, emphasizing the region’s arid climate. Daily rainfall events are rare. Most precipitation values range between 0.1 mm and 10 mm, with isolated peaks in March, May, and October. The highest daily recorded value appears in October, slightly above 10 mm. The cumulative precipitation progresses slowly throughout the year, reaching approximately 75 mm by December.</td>
</tr>
</table>

The winds		In Biskra, prevailing winds vary by season: in winter, they mainly blow from the northwest, bringing some humidity, while in summer, they come from the southeast in the form of the sirocco—a hot, dry wind that intensifies aridity. The average wind speed reaches 4.9 m/s in winter, particularly in January and March.

3.8.3 Site analysis:

a) site location:

The project site is located in the western expansion zone of Biskra, within what is considered the city's new urban development area. It is situated approximately 4 kilometers from the historic city center, offering both strategic accessibility and opportunities for modern growth.



The project enjoys excellent accessibility and visibility along key routes like the N46A and National Road N3 connecting Biskra to Batna and Touggourt. This strategic location creates an ideal hub for social, cultural, and commercial activities while boosting economic potential for locals and visitors.

b) Choice Justification:

- The land occupation plan for Biskra's western urban development region (Zone No. 01), which was approved in 2015, includes a Cultural Center designation for the site.
- It offers great accessibility and visibility due to its strategic location along key intercity highways.
- The location is close to residential neighborhoods, educational institutions, and university buildings in an administrative neighborhood.
- It has a lot of promise for cultural development, community involvement, and economic growth because it is situated in a new urban development zone.

c) site morphology:

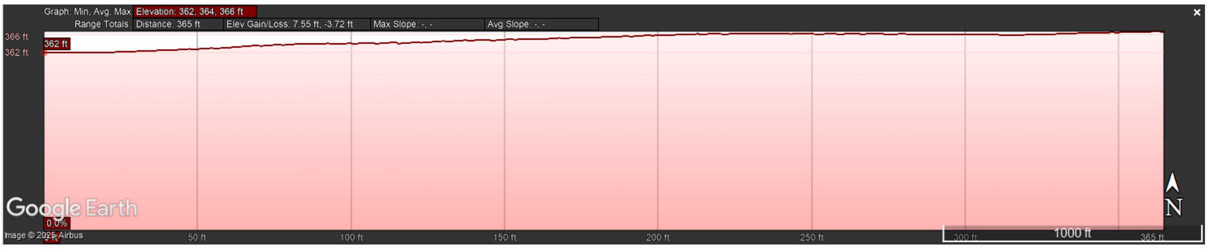


Figure III-27: Longitudinal Section of Project Site

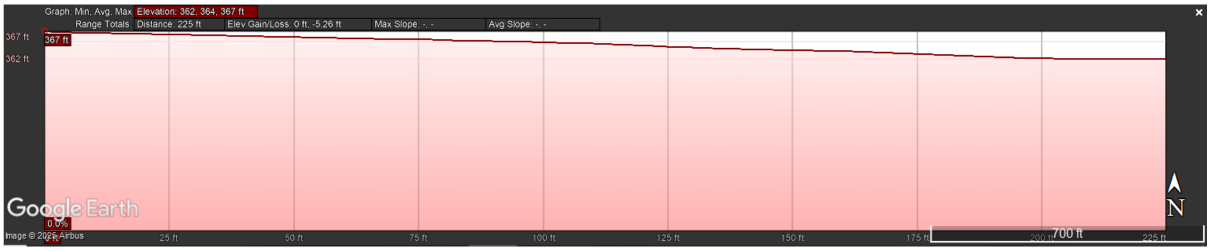


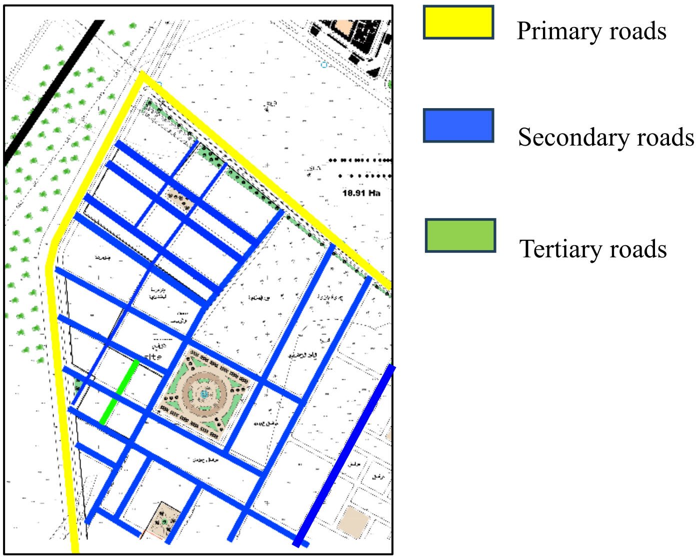
Figure III-28: Transversal Section of Project Site

The site, measuring 69 by 110 meters and covering an area of approximately 7,590 square meters, features a regular rectangular shape with naturally level terrain. Its consistent topography and geometry make it ideal for efficient and flexible architectural development, minimizing the need for excavation or expensive groundwork.

d) The site and immediate surroundings:


Municipality
Collective habitat
N
C.E.M
ECOLE PRIMAIRE
MUNICIPALITÉ
ÉTABLISSEMENT PUBLIC
ÉTABLISSEMENT PUBLIC
Collective habitat
Collective habitat

e) Roads and accessibility:

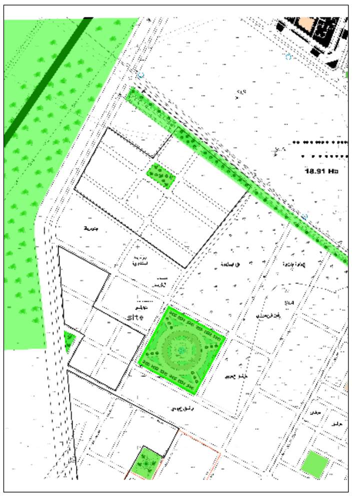


The site is served by two primary transportation corridors: the western Biskra bypass running along the western boundary and the N03 highway positioned to the north.

f) Mobility:

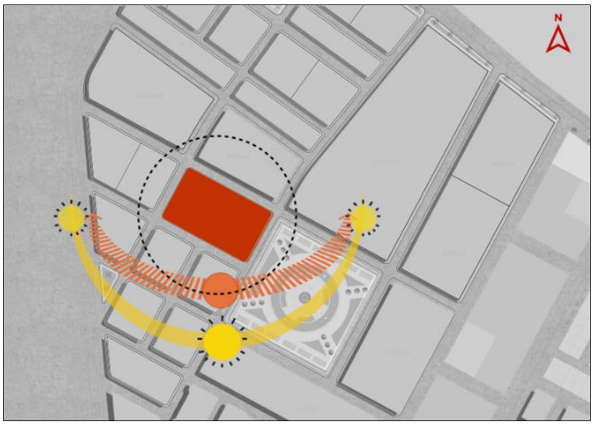
The location benefits from public transportation connectivity through bus services, providing convenient access from multiple directions.

g) Green spaces:



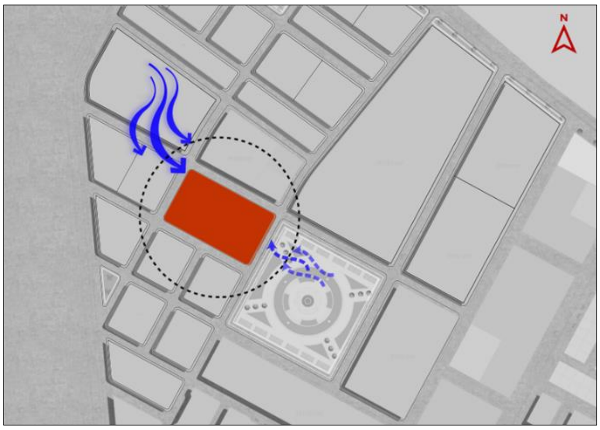
The area under study shows limited green space provision, characterized by scattered small green areas for local residents and few significant green zones, indicating insufficient overall vegetation coverage.

h) The Sun analysis:



The location takes advantage of its solar orientation relative to north, south, east, and west directions, facilitating careful management of daylight penetration and shade distribution across the site.

i) The Sun:



The main winds come from the southeast and northwest directions. These winds blow regularly throughout the year and affect how comfortable it feels outside. They also help cool down buildings naturally when planned properly.

3.8.4 Proposed program:

Function	Espace	Surface (m²)	Nombre
Entry space	Reception /security Controle	20	1
Exhibition	Exhibition Area (sensitive items)	450	1
	Exhibition Area (durable items)	450	1
Theater	Welcome hall		
	Seating	120	1
	Stage	40	1
	Projection Room	15	1
	Makeup and Dressing Room	15-20	
	Restroom facilities	36	1
	Cafeteria	50	1
Formation	Sculpture Workshop	50	1
	Ceramics Workshop	50	1
	Drawing Workshop	50	1
	Calligraphy Workshop	50	1
	Rehearsal Room	100	2

	Astronomy Club	50	1
	Media Club	50	1
	Pottery Club	50	1
	Heritage Club	50	1
	Digital Fabrication Lab	100	2
	Restroom facilities	36	2
Documentation	Reception hall + waiting area	30	1
	Storage shelving	40	
	Loan desk	20	1
	Reading room adults	100	1
	Reading room children)	150	1
Administration	Reception and waiting	36	1
	Head's Office	36	1
	Meeting room	1	
	Collaborative Offices	36	2
	Archive	20	1
	Staff room + Kitchenette	30	1
Public Spaces	Exhibition Esplanade		
	Open-air Theater		
	Exhibition Courtyard		
Parking	Visitor parking		
	Staff parking		

3.8.1 Passage elements:

a. Understanding Culture

what is culture? We define culture as the synthesis of tradition and identity - a living, breathing entity that connects our past with our present. This understanding becomes the seed from which our cultural center grows, shaping every decision that follows.

From this philosophical foundation emerges our mission: to create a space where people can learn, share experiences, exchange ideas, and exhibit cultural expressions.

c. Urban Integration and Site Strategy:

The Exhibition esplanade creates the primary public interface, establishing seamless urban continuity with the adjacent public park. This dual-function space serves as both arrival sequence and exhibition area, extending cultural activities into the urban realm.

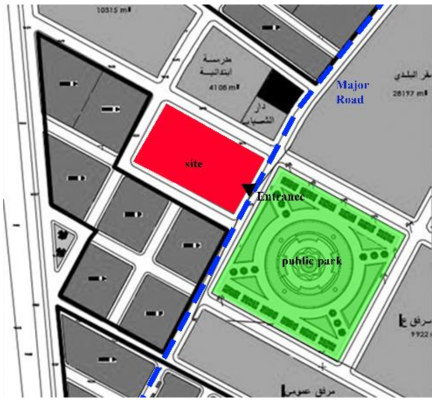


Figure III-29 : The site entrance to the surrounding area (public park)

d. Spatial Organization and Hierarchy:

A three-tier system organizes user experience: the public esplanade provides universal access, semi-private exhibition areas offer controlled cultural display, and the private central courtyard serves students and workshop participants with flexible indoor-outdoor environments for collaboration and idea exchange.

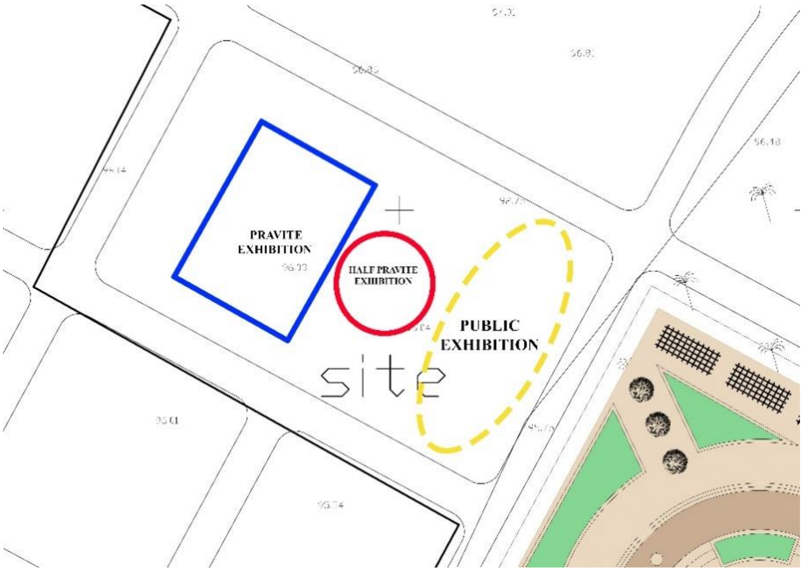


Figure III-30: Master plan hierarchy

e. Programmatic Distribution:

Four blocks emerge from this hierarchy: Exhibition spaces for cultural display, Theater for performance, Library for research, and Workshop areas for hands-on learning. Each block responds to specific functional requirements while maintaining overall project coherence.

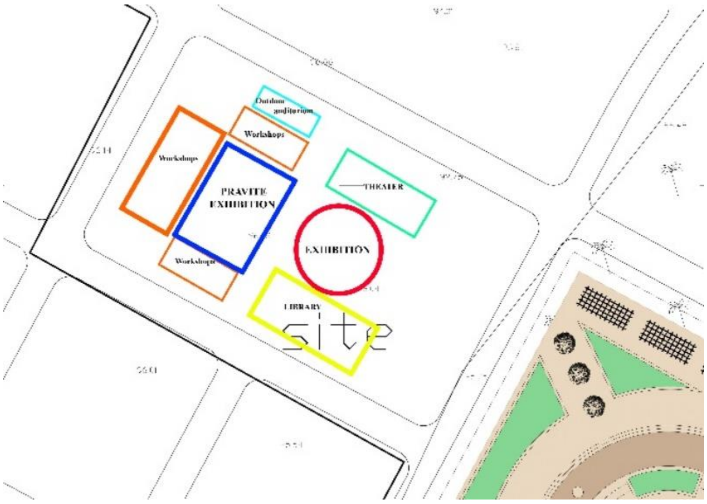


Figure III-31: Master plan functional organization

f. Environmental Strategy

Strategic orientation places the outdoor auditorium on the north (protected from solar radiation), while the administration and library occupy the south for optimal daylight. This positioning creates strong programmatic connections while responding to environmental conditions.

g. Dynamic Sunshading System

Our dynamic sunshading system represents the core environmental innovation of the project, featuring orientation-specific responses that adapt throughout daily and seasonal cycles. This system operates as an intelligent building skin that mediates between exterior climate conditions and interior programmatic requirements.

- East-Facing Exhibition Spaces need careful environmental control because they house sensitive paintings and cultural artifacts. The dynamic sunshades provide precise light control by filtering harmful UV rays to protect artwork
- South-Facing Library benefit from optimized natural daylight penetration through intelligent sunshade operation Maximizes beneficial daylight.
- West-Facing Workshop Protection The workshop spaces receive intensive solar protection from harsh afternoon radiation through Heat gain mitigation

h. Computational Optimization:

Galapagos evolutionary optimizer in Rhinoceros 3D optimizes the relationship between fenestration and sunshading with biologically-inspired algorithms that search across thousands of design variations. The approach establishes fixed sunshade parameters (materiality, structural constraints, geometry) and optimizes varying elements (size, sill height, window ratio). Various fitness functions test for lux levels, mechanical clearance, energy performance, and visual comfort per iteration. The evolutionary process creates, tests, and refines solutions until optimal sunshade configurations are reached that ensure conflict-free operation and achieve goal performance per program space.

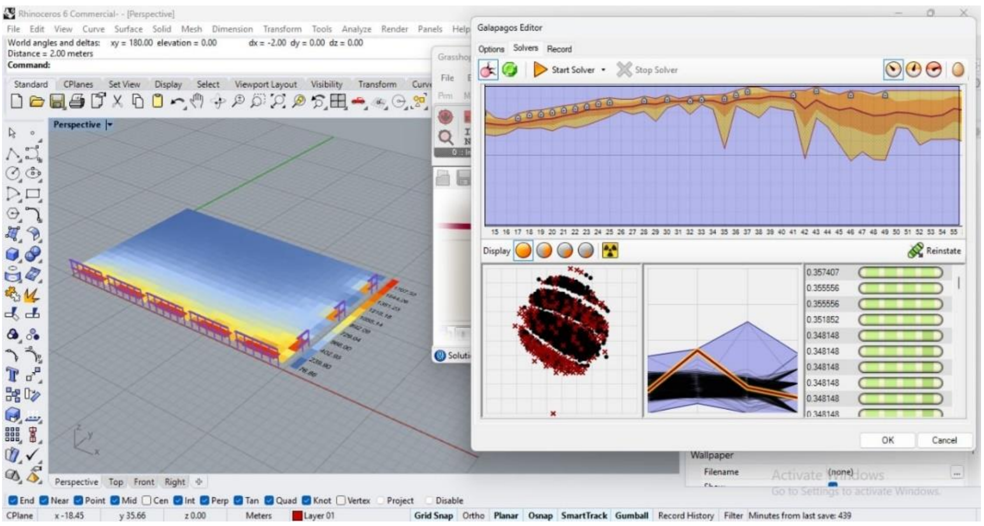


Figure III-32 : Computational Optimization for the library opening using Galapagos

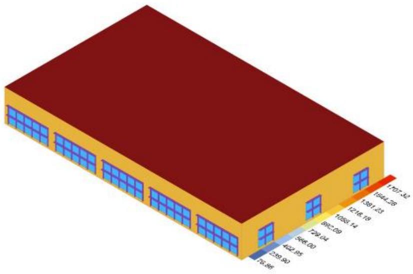


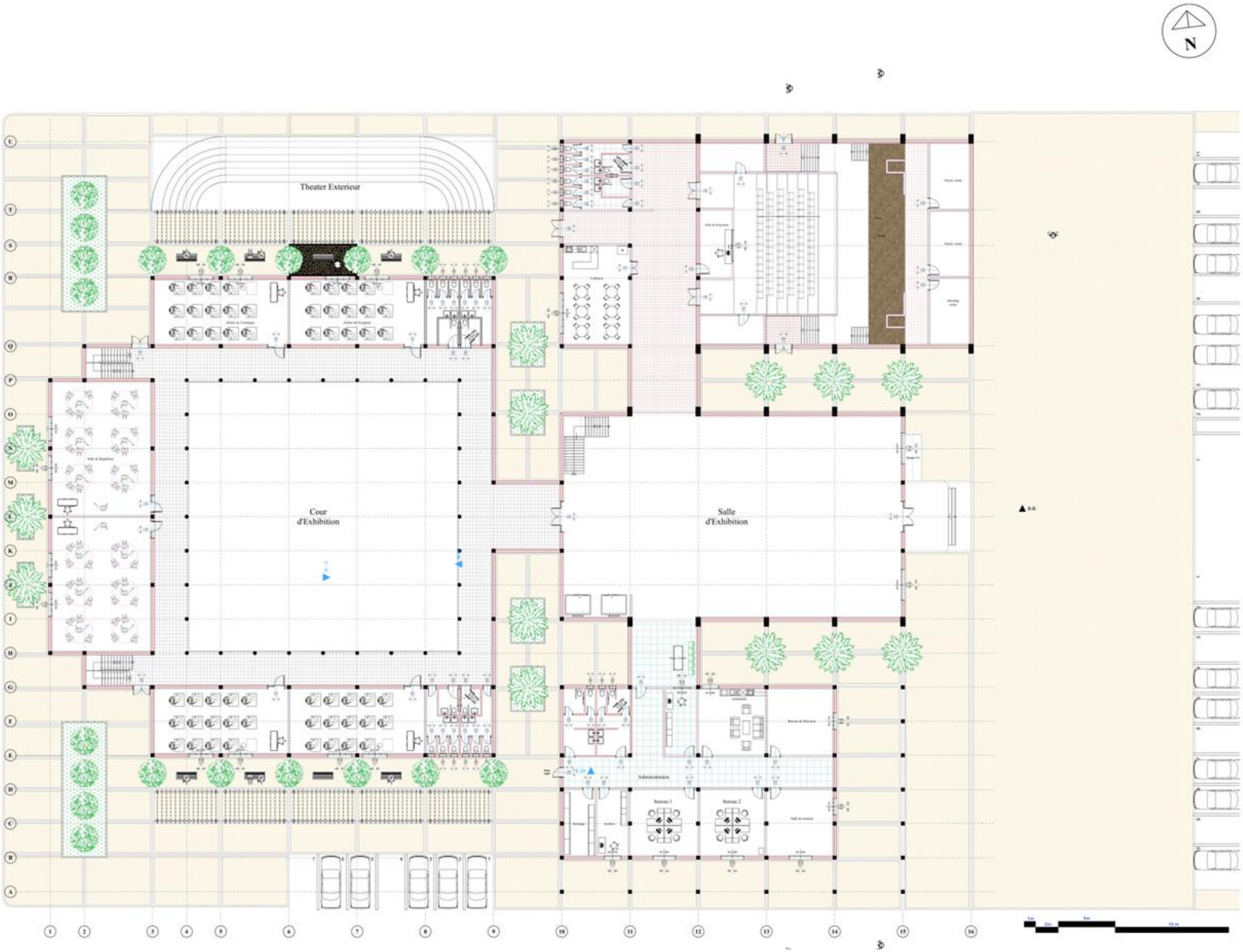
Figure III-33: The Optimal Opening Dimensions for The Library

Figure III-34: The placement of the dynamic sunshade system in the project

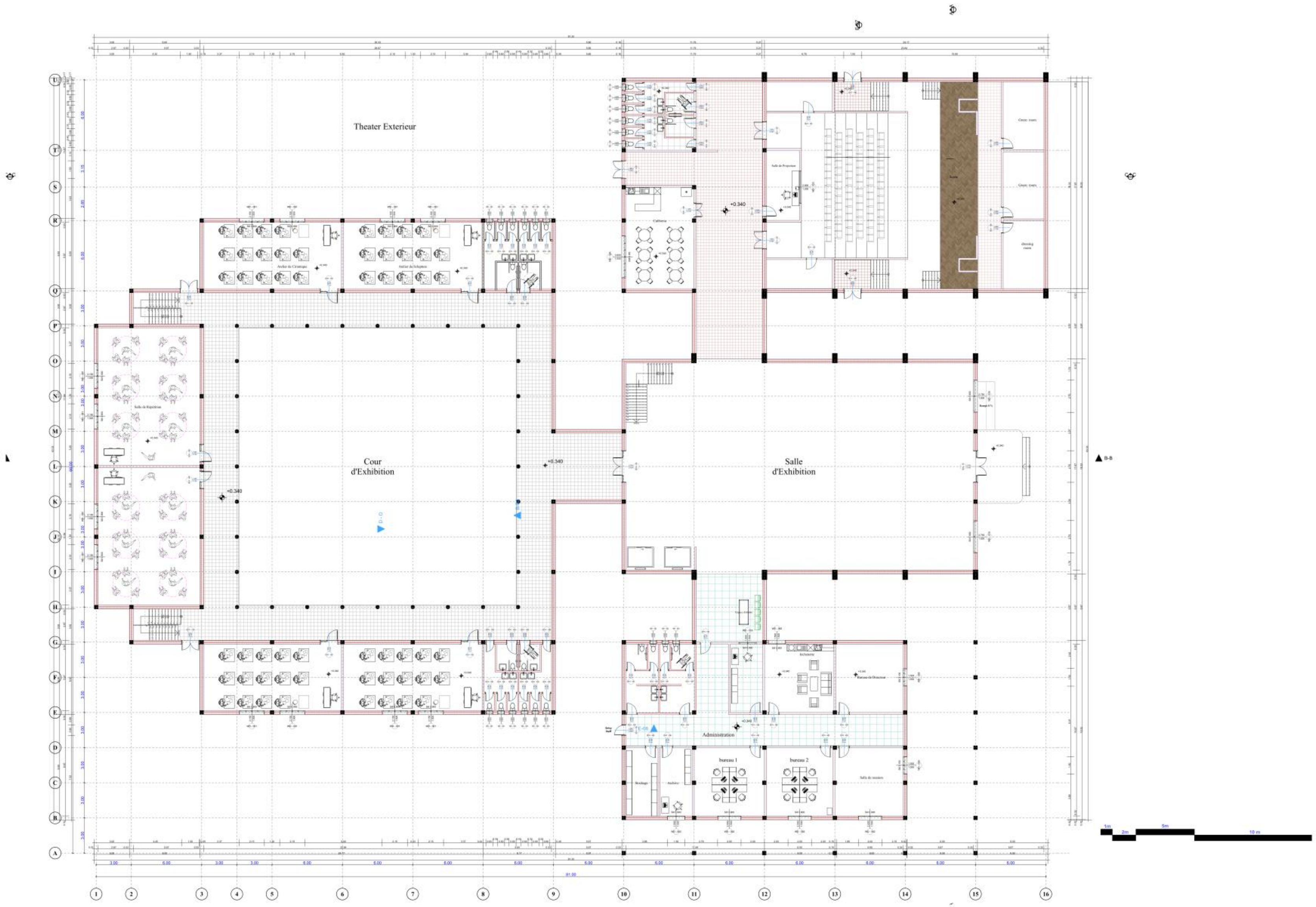
i. Circulation:

Public circulation flows from esplanade through exhibitions to courtyard. Service circulation operates separately for operational efficiency. Student circulation connects workshops, library, and courtyard spaces, facilitating academic collaboration.

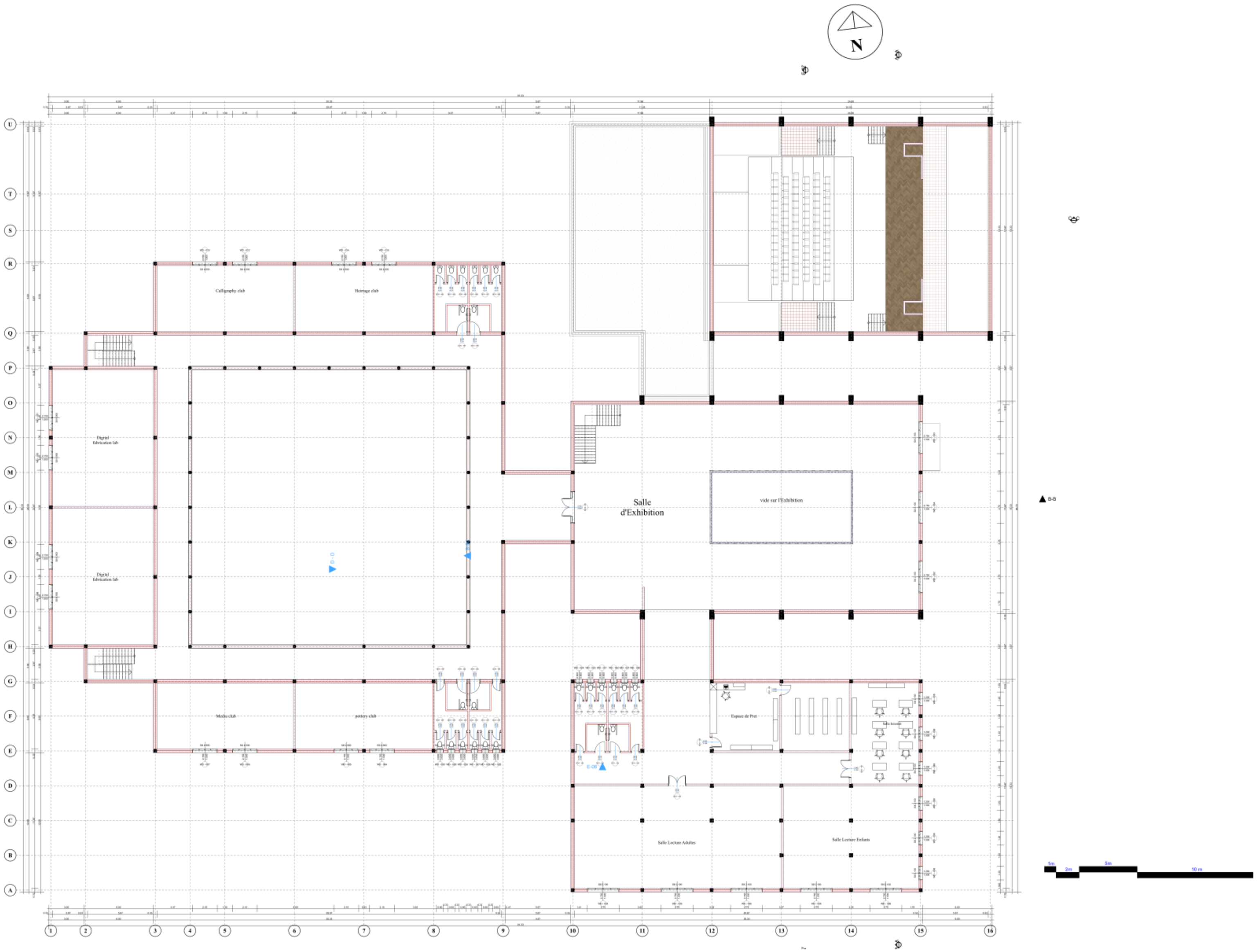
3.8.5 Architectural plans:



ASSEMBLY PLAN


Theater Exterieur
Cour
d'Exhibition
Salle
d'Exhibition
Administration
bureau 1
bureau 2
+0.340

RDC PLAN



PLAN ETAGE

3.8.6 Conclusion

In this chapter we focused on the application of our work in practice through the design of a dynamic sunshading system with adaptive louvers, integrated into the Biskra cultural center. Based on theoretical and analytical results, the system was designed to reduce solar gain and improve thermal comfort.

With Ladybug and Honeybee, simulations proved that the design effectively lowered operative temperatures and enhanced indoor conditions during the warmest summer hours. The project effectively combined passive and active strategies, confirming that dynamic sunshading may play a central part in sustainable arid climate architecture.

General Conclusion

General conclusion:

The objective of this thesis was to develop a sustainable architectural design appropriate for the climatic conditions of hot-arid regions like those around Biskra, Algeria, using dynamic sunshading devices. It sought to primarily design a cultural center with an adaptive kinetic façade system capable of enhancing thermal comfort at the lowest energy cost.

The first chapter established the theoretical groundwork, discussing the principles of thermal comfort, climate-responsive design, and advantages of smart shading systems. Thermal comfort models, the PMV/PPD model in particular, were investigated in order to identify the comfort factors that informed the design strategy.

The second chapter provided an analytical overview of architectural case studies with kinetic facades, evaluating their shading methodologies, design strategies, and technological applications to guide our adaptive system development.

The third chapter included creating and testing a dynamic sunshading prototype combining vertical and horizontal louvers. By using Ladybug and Honeybee simulations, we compared the performance of the system on east, south, and west facades in extreme summer conditions. Results showed considerable enhancements in operative temperature and thermal comfort, justifying the performance of the system in terms of the PMV model.

This phase also covered a detailed site analysis of Biskra and the preparation of the architectural program for the cultural center, so that the building effectively addresses both the climatic context and cultural heritage of the region.

Physical modeling of the adaptive shading system was conducted to experiment with its mechanical viability and illustrate its functional mode in physical space.

Lastly, the cultural center was completely designed with the dynamic sunshading devices as a primary element in the environmental and architectural approach. The final product is a project that unites energy efficiency, thermal comfort, and cultural expression, demonstrating that dynamic sunshading devices can be utilized as an efficient and sustainable architectural solution for hot-arid areas.

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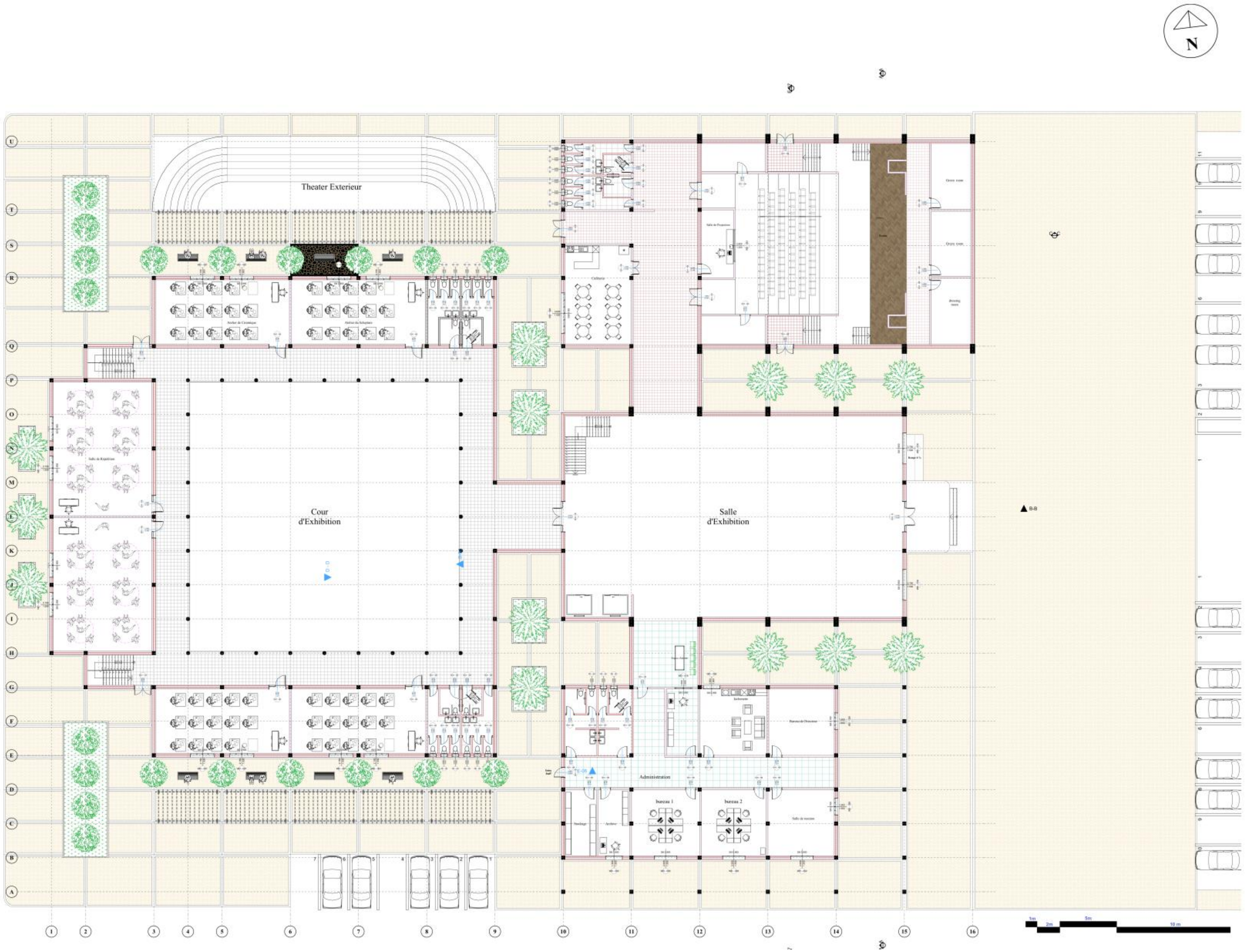
ANNEXES:



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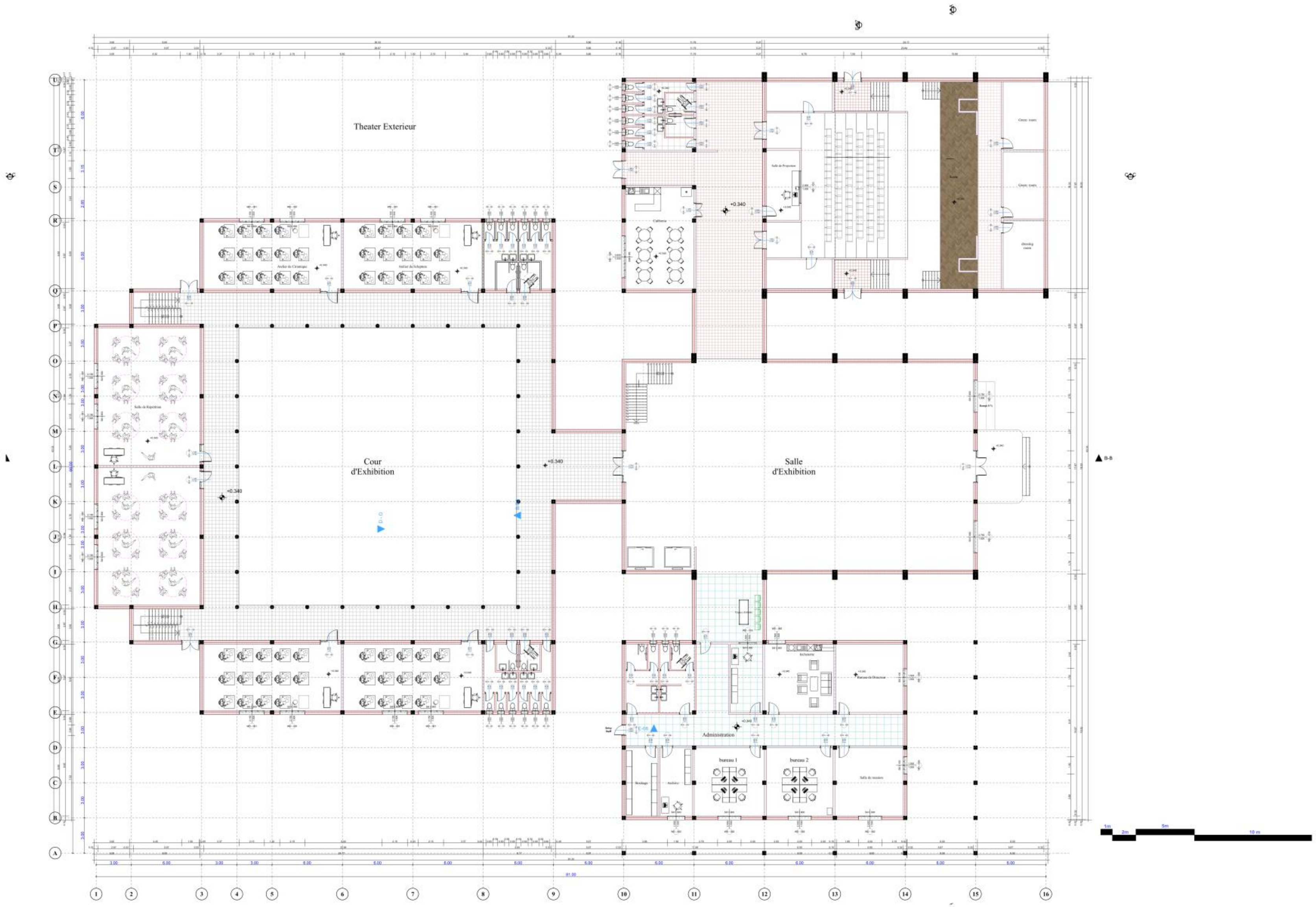
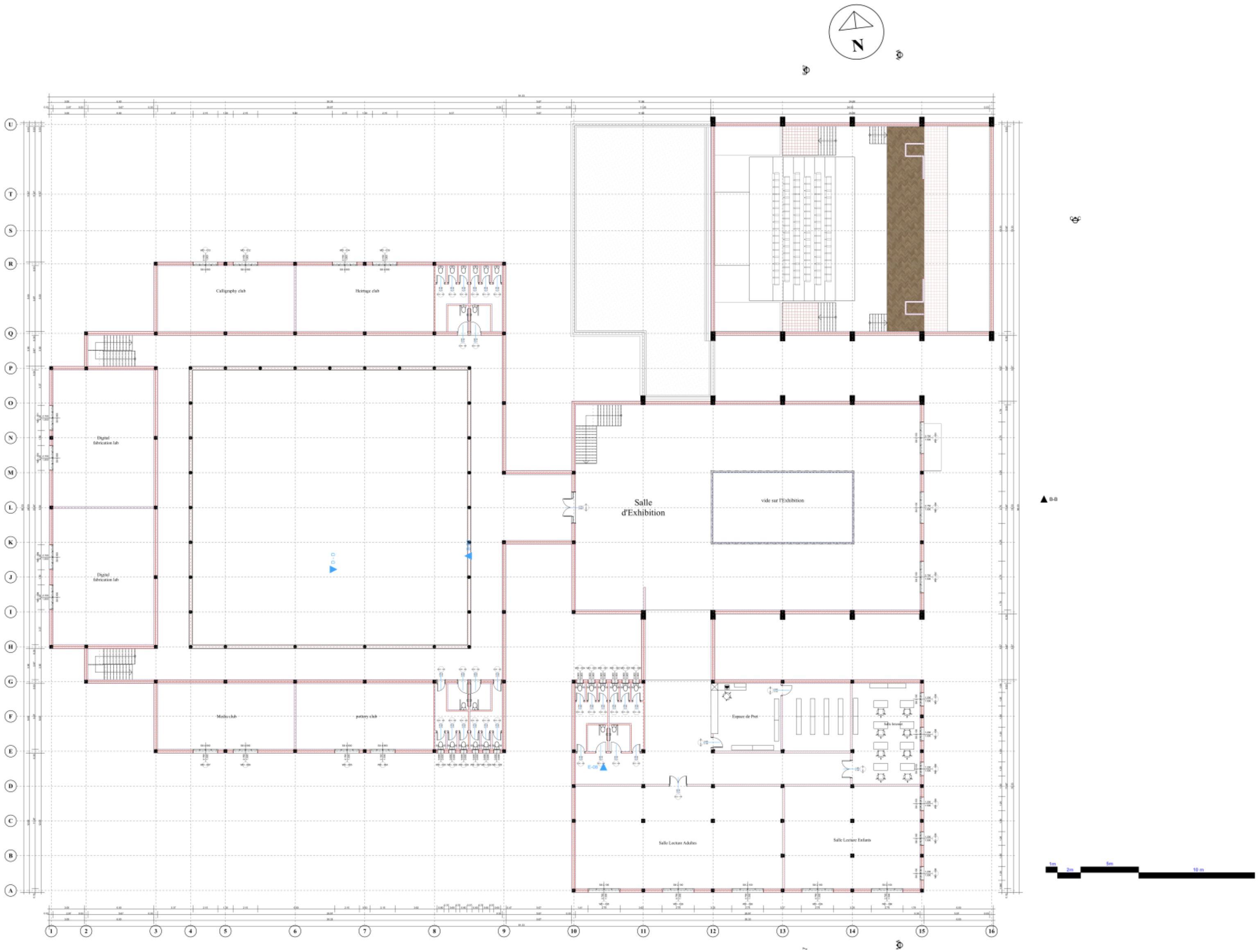


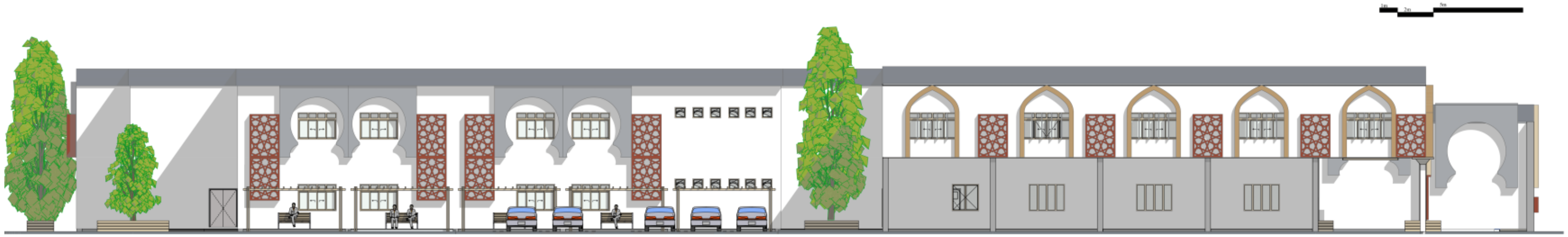
Ground Floor



1st Level plan

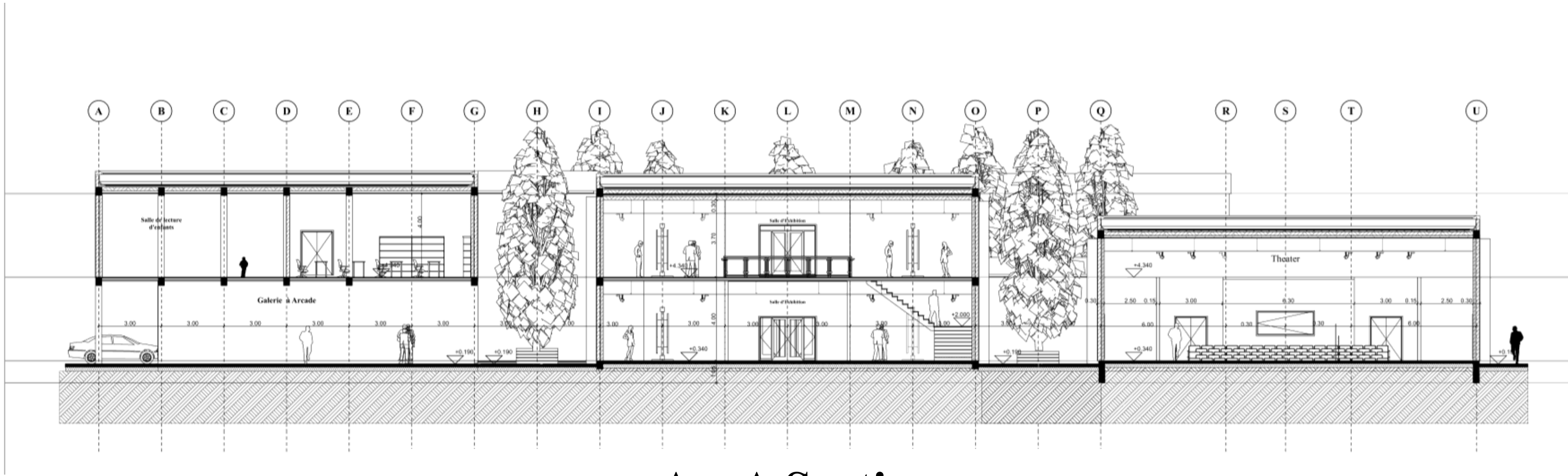
East Elevation

North Elevation

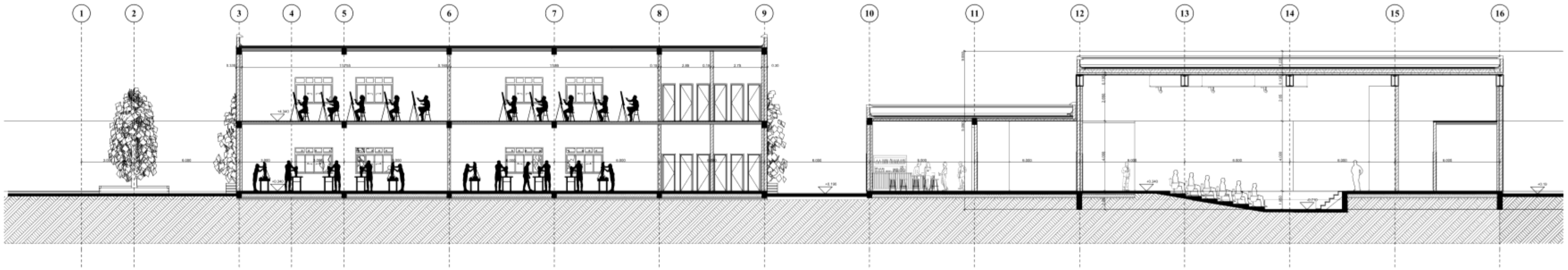


South Elevation

West Elevation



A – A Section



C – C Section

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

جامعة محمد خيضر – بسكرة

عنوان المشروع:

تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

مشروع لنيل شهادة مؤسسة ناشئة في إطار القرار الوزاري 1275

صورة العلامة التجارية

TWINSHADE

الاسم التجاري

Twinshade

السنة الجامعية

2025 _ 2024

بطاقة معلومات:

حول فريق الاشراف وفريق العمل

1- فريق الاشراف:

فريق الاشراف	
المشرف الرئيسي:	التخصص:
ميراد ياسين	هندسة معمارية

2- فريق العمل:

فريق المشروع	التخصص	الكلية
الطالب: بوغرارة محمد مرتضى	هندسة معمارية	العلوم والتكنولوجيا

عنوان المشروع: تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

فهرس المحتويات

I. المحور الأول: تقديم المشروع:

تشير الإحصائيات العالمية إلى أن قطاع السكن يستهلك ما بين 30% إلى 40% من إجمالي الطاقة المستخدمة على مستوى العالم، ويُعد من أكبر القطاعات المسببة لاستهلاك الطاقة، خاصةً بسبب الاستخدام الكبير لأجهزة التبريد في المناطق الحارة. (IEA), International Energy Agency, 2023)كما أن الطلب على الطاقة يرتفع بشكل ملحوظ في فترات الذروة الحرارية، مما يزيد من الانبعاثات الكربونية ويؤثر سلبًا على البيئة، وهو ما يستدعي إيجاد حلول تصميمية مستدامة للتحكم في استهلاك الطاقة وتحسين الراحة الحرارية في المباني.

على مستوى الجزائر، يقدّر استهلاك قطاع السكن من الطاقة الكهربائية بنسبة تقارب 35% من إجمالي استهلاك الكهرباء الوطني، مع ارتفاع واضح في فترات الصيف بسبب ارتفاع درجات الحرارة واعتماد التبريد الاصطناعي. (Ministère de l'Énergie et des Mines, Algérie, 2020)تعاني العديد من المباني السكنية والإدارية من ارتفاع درجات الحرارة الداخلية، ما يزيد من اعتماد السكان على أجهزة التكييف ويؤدي إلى زيادة تكاليف التشغيل واستهلاك الطاقة.

أما في ولاية بسكرة، فتتجاوز درجات الحرارة 45 °C خلال أشهر الصيف، مع متوسط إشعاع شمسي يومي يزيد عن kWh/m²6.5 ، ويُسجل المكان أكثر من 3,400 ساعة مشمسة سنويًا، وهو من أعلى المعدلات في الجزائر (Centre National de Météorologie, Algérie, 2023) .

هذه الظروف المناخية القاسية تزيد من الحمل الحراري على المباني، خصوصًا تلك التي تتمتع بواجهات زجاجية أو معرضة مباشرة لأشعة الشمس، مما يجعل التحكم في الكسب الحراري داخل المباني تحديًا بيئيًا وطاقيًا كبيرًا.

في هذا السياق، جاءت فكرة تصميم واجهة حركية ذكية تعتمد على كاسرات شمسية متحركة، قادرة على التفاعل مع زاوية الشمس بشكل ديناميكي من خلال برمجة زمنية أو حساسات آنية، بهدف الحد من الكسب الحراري المباشر وتحقيق توازن بين الإضاءة الطبيعية والراحة الحرارية. وقد أثبتت الدراسات في مجال التصميم البيئي أن أنظمة التظليل الفعالة يمكن أن تقلل استهلاك الطاقة بنسبة تصل إلى 30%، مع تحسين مؤشرات الراحة الحرارية داخل الفراغات المعمارية (Koenigsberger, 1974, p. 120) .

1.1 فكرة المشروع (الحل المقترح):

عنوان المشروع: تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

في هذا السياق، جاءت فكرة تصميم واجهة حركية ذكية تعتمد على كاسرات شمسية متحركة، قادرة على التفاعل مع زاوية الشمس بشكل ديناميكي من خلال برمجة زمنية أو حساسات آنية، بهدف الحد من الكسب الحراري المباشر وتحقيق توازن بين الإضاءة الطبيعية والراحة الحرارية.

يسعى هذا المشروع إلى دمج مبادئ التصميم المناخي مع البرمجة البارامترية (Grasshopper) وأدوات تحليل الأداء الحراري (Ladybug, Honeybee) لتطوير واجهة قابلة للتكيف مع الظروف البيئية المحيطة، تحقق أداءً بيئيًا عاليًا، خصوصًا في بيئة قاسية مثل بيئة بسكرة. كما يهدف إلى تقديم حل معماري تكنولوجي قابل للتطبيق في مشاريع السكن والتعليم والثقافة، ليصبح الواجهة أداة فعّالة لتحسين الراحة الداخلية وتقليل الاعتماد على التكييف الاصطناعي، وبالتالي المساهمة في البناء المستدام في المناطق الحارة الجافة.

1.2 القيم المقترحة:

يسعى مشروعنا إلى تقديم مجموعة واسعة ومتنوعة من القيم والمنافع والخدمات للعملاء، يمكن ذكرها في العناصر التالية:

- تحسين الأداء الحراري للمبنى: تساهم الواجهة الديناميكية في تقليل الكسب الحراري غير المرغوب، مما يساهم في الحفاظ على درجات حرارة معتدلة داخل الهيئة طوال اليوم.

- تقليل استهلاك الطاقة: يمكن للواجهة الديناميكية أن تخفض الحاجة إلى التكييف الاصطناعي، مما يؤدي إلى تقليل استهلاك الطاقة.

- تعزيز الراحة الحرارية: تساهم في تحقيق مستوى راحة حرارية قريب من المقياس المثالي PMV بين -0. 5 و+0. 5، مما يُحسن جودة المساحة الداخلية.

- الاستجابة الذكية للظروف المناخية: تتفاعل الكاسرات الديناميكية مع زاوية الشمس أو الإشعاع الشمسي بشكل فوري، مما يوفر تظليلًا فعالًا مع الحفاظ على دخول الضوء الطبيعي المهم.

- تحقيق الإضاءة الطبيعية المتوازنة: يسمح تصميم الكاسرات بتنظيم دخول الضوء الطبيعي وتجنب الوهج، مما يُحقق راحة بصرية ويحافظ على جودة الإضاءة الداخلية.

- إطالة عمر واجهات المبنى: يؤدي تقليل تعرض الواجهات لأشعة الشمس المباشرة إلى تقليل تدهور المواد وزيادة عمر الواجهة.

- قابلية التطبيق على أنماط معمارية متعددة: يمكن إدماج هذا النظام في المباني السكنية والتعليمية والثقافية، مما يجعله حلاً مرنًا وعمليًا في مختلف السياقات.
- تشجيع البناء المستدام: يدعم المشروع أهداف التنمية المستدامة عبر تقليل الأثر البيئي وتحسين كفاءة استخدام الموارد.
- تحسين جودة الحياة الداخلية: من خلال ضبط درجات الحرارة والإضاءة، يسهم المشروع في خلق بيئة صحية ومريحة للقاطنين في المبنى.

1.3 فريق العمل

- يتألف فريق المشروع من الطالب محمد مرتضى بوغرارة، المتخصص في التصميم المعماري، الذي قدم فكرة المشروع. حالياً طالب في السنة الثانية من ماستر تخصص العمارة والبيئة بجامعة محمد خيضر في بسكرة، وقد حصل على شهادة الليسانس في الهندسة المعمارية من ذات الجامعة.
- شارك في عدد من المشاريع المعمارية التي تركز على الجوانب البيئية، حيث قام بتطبيق استراتيجيات تتعلق بالتظليل، التحكم في المناخ، والراحة الحرارية، خصوصاً في البيئات الحارة والجافة.
- نال المرتبة الأولى في مسابقة جامعية لإعادة تصميم مسار السكك الحديدية في مدينة بسكرة وتحويله إلى ممر حضري أخضر. قدم من خلالها مشروعاً يعزز مبادئ الاستدامة الحضرية ويعمل على إنشاء مساحات عامة نشطة ومراعية للبيئة.
- كما أكمل تدريباً ميدانياً في مديرية التعمير والهندسة المعمارية والبناء بولاية بسكرة، منحته الفرصة للاطلاع العملي على ملفات تراخيص البناء، خطط التنمية العمرانية، ونظم العمل الإدارية والميدانية ضمن السياق العمراني المحلي.
- في سياق جهود نشر المعرفة الرقمية، تولى محمد مرتضى مسؤولية تقديم دورة تدريبية لأعضاء هيئة التدريس في قسم الهندسة المعمارية، تركزت على استخدام أدوات Ladybug و Honeybeeلتحليل المناخ والحرارة ضمن برنامج .Grasshopper خلال هذه الدورة، تم تناول تقنيات محاكاة الإشعاع الشمسي، تحليل فترات الراحة الحرارية، واستراتيجيات التظليل الفعالة.

- علاوة على ذلك، حصل على شهادات في برمجة المشاريع الإلكترونية باستخدام منصة Arduino، وكذلك على شهادات في التصميم ثلاثي الأبعاد والعرض المعماري، كما تمكن من الحصول على شهادة B2 في اللغة الإنجليزية.

1.4 أهداف المشروع:

- مشروعنا الحالي يهدف إلى الوصول إلى عدد من الأهداف الأساسية التي تساهم في نجاحه واستمرار تأثيره الإيجابي على الناس والبيئة العمرانية. كما يسعى أيضًا لتقوية مهارات الفريق القائم على التنفيذ.

- من أهم الأهداف هو تلبية احتياجات المستخدمين المحليين بشكل فعال عن طريق تقديم نظام تظليل ذكي يساعد على تحسين الراحة الحرارية ويقلل من استهلاك الطاقة في المباني. هذا يكون مهمًا بشكل خاص في المناطق ذات المناخ الحار والجاف مثل ولاية بسكرة. يعتمد هذا الهدف على فهم عميق للتحديات المناخية والبيئية المحلية بالإضافة إلى رغبات السكان في الحصول على فضاءات عمرانية مريحة.

- بالإضافة إلى ذلك، يسعى المشروع لتحقيق أرباح مستمرة ونجاح تجاري للفريق الذي ينفذه. يتطلب ذلك وضع خطط مالية قوية وإدارة دقيقة، مما يضمن وجود تنافس قوي وثابت في السوق.

- يمكننا أن نصنفها إلى أهداف قصيرة، متوسطة وبعيدة المدى:

1.4.1 أهداف قصيرة المدى:

- تطوير النظام: إنشاء نموذج أولي متكامل لكاسرات الشمس المتحركة مع نظام تحكم أوتوماتيكي ويدوي.

- اختبار وتحسين الأداء: تقييم أداء النظام من خلال المحاكاة الرقمية والتجارب الفعلية.

- جذب العملاء: تقديم المشروع لمكاتب الدراسات، المهندسين المعماريين، والمستثمرين العقاريين لإثبات فعاليته.

- بناء شراكات استراتيجية: التعاون مع شركات البناء وموردي المواد لضمان التطبيق العملي وتوسيع نطاق الاستخدام.

1.4.2 أهداف متوسطة المدى:

- تنفيذ النظام في مشاريع تجريبية حقيقية لاختبار فعاليته عمليًا.
- توسيع نطاق التطبيق ليشمل أنواع مختلفة من المباني مثل الجامعات، المكاتب، والمباني التجارية.

1.4.3 أهداف بعيدة المدى

- تسويق النظام على المستوى الوطني والدولي والتوسع في الأسواق العالمية عبر شراكات مع شركات البناء.
- دمج تقنيات إضافية مثل الألواح الشمسية والطاقة المتجددة لتحسين كفاءة النظام.
- تطوير إصدار أكثر تقدمًا لتحقيق الاعتراف بالنظام كمعيار في المباني المستدامة والعمل على إدراجه في لوائح البناء الأخضر مثل LEED وBREAM.
- تطوير إصدار أكثر تقدمًا يعتمد على التعلم العميق لزيادة قدرة النظام على التكيف مع الظروف الجوية المتغيرة.

1.5 جدول زمني لتحقيق المشروع:

المرحلة	النشاط	المدة الزمنية	النتائج المتوقعة
المرحلة 1	تحليل السوق والتخطيط	من الشهر 1 إلى الشهر 2	تحليل المنافسين، تحديد القيمة المضافة، الاستبيانات، تحديد المستخدمين المستهدفين
المرحلة 2	التصميم الأولي للنظام	من الشهر 2 إلى الشهر 4	التصميم الأولي للنظام اختيار المحركات والحساسات، المحاكاة الحرارية والمعمارية،

			تصميم النظام الإلكتروني
المرحلة 3	النمذجة والتصنيع	من الشهر 6 إلى الشهر 8	تقييم الأداء في بيئة حقيقية وجمع الملاحظات
المرحلة 4	التعديلات بعد الاختبار	من الشهر 9 إلى الشهر 10	ضبط النظام، تحسين الأداء والمتانة
المرحلة 5	التطوير التجاري وبدء البيع	من الشهر 11 إلى الشهر 12	تصميم الشعار والموقع، الكتيب التقني، خطة التسعير، عرض تجريبي والبدء في تسويق المنتج وتحقيق أولى المبيعات
المرحلة 6	تطوير خطة التوسع الجغرافي	السنة الثانية	التوسع في ولايات أخرى داخل الجزائر
المرحلة 7	تطوير المنتج ودمج تقنيات جديدة	السنة الثالثة	تقديم إصدار مطور مع إمكانيات تحكم ذكية جديدة

II. المحور الثاني: الجوانب الابتكارية

التصميم الديناميكي المتكيف مع المناخ:

يتجلى الابتكار الأساسي في هذا المشروع من خلال تطوير واجهة ديناميكية متكيفة مع الظروف المناخية المحلية، حيث يستخدم النظام الذي يتحرك وفقاً لمسار الشمس عبر اليوم والفصول. هذا التصميم الثوري يمثل نقلة نوعية من الواجهات الثابتة التقليدية إلى نظام حي ومتجاوب، خاصة في البيئة الصحراوية القاسية حيث تصل درجات الحرارة إلى مستويات عالية. يعمل النظام على تقليل اكتساب الحرارة بنسب كبيرة مع تعزيز الراحة البصرية للمستخدمين، مما يخلق بيئة داخلية مريحة دون الإفراط في استخدام أنظمة التكييف الاصطناعي.

تعزيز جودة الراحة الحرارية والبصرية:

يساهم النظام الديناميكي المقترح في تحسين كل من الراحة الحرارية والبصرية داخل الفضاءات المعمارية، من خلال التحكم المتواصل والآني في كمية الإضاءة والحرارة الداخلة إلى المبنى. وتُنفَّذ هذه العمليات بشكل ذكي ومتزامن مع التغيرات المناخية الخارجية، مما يضمن بيئة داخلية مريحة وصحية، سواء في السياق المعيشي أو المهني. كما ينعكس هذا التحكم الدقيق إيجابيًا على الرفاهية النفسية للمستخدمين، عبر تقليص مصادر الإزعاج الحراري أو البصري، وتحقيق توازن بيئي يتماشى مع متطلبات الراحة المستدامة.

قابلية التكيّف مع مختلف الأنماط المعمارية

تتميّز التكنولوجيا التي نعتمدها بقدرٍ عالٍ من المرونة، ما يتيح إمكانية تكييفها مع مختلف أنواع المباني،كما يمكن تعديل التصاميم والأحجام وفقًا لخصوصيات كل مشروع على حدة، مما يمنح المهندسين المعماريين حرية كبيرة في دمج النظام ضمن تصاميمهم بسهولة وبدون تعقيد.

المساهمة في التنمية المستدامة

يُسهم هذا المشروع بفعالية في تحقيق أهداف التنمية المستدامة من خلال ابتكار أنظمة تظليل متطورة تعزز من كفاءة استخدام الطاقة وتحد من الاعتماد على أجهزة التكييف في المباني. هذا يدعم المساعي الرامية إلى تقليل الانبعاثات الحرارية وخفض الأثر البيئي، بالإضافة إلى تخفيض نفقات الكهرباء.

III. المحور الثالث: التحليل الاستراتيجي للسوق

1 تحليل PRESTEL :

عنوان المشروع: تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

المحور	سياسي	اقتصادي	اجتماعي
التحليل	– التشريعات والسياسات الحكومية المتعلقة بالبناء والتطوير العقاري – وجود حوافز حكومية للاستثمار في الحلول المستدامة. – -السياسات البيئية والاستدامة التي تشجع على استخدام تأثير بيئي إيجابي.	– ارتفاع تكاليف الطاقة الكهربائية والغاز يجعل السوق أكثر إقبالاً على المنتجات الموفّرة للطاقة مثل أنظمة التظليل الذكية. – توفر تمويلات وقروض بدون فوائد (مثل كناك وأناد) يدعم انطلاق المشروع وتطوير النموذج الأولي. – توفر المواد الأولية محليًا (ألمنيوم، خشب) يخفض من تكاليف الإنتاج. – إمكانية التوسع في السوق الجهوي ثم الوطني تدريجيًا، خصوصًا في المناطق الحارة. – السوق المحلي يعاني من غياب منتجات مماثلة، ما يمنح المشروع ميزة تنافسية قوية.	– ارتفاع وعي المجتمع الجزائري عامة وسكان الجنوب خاصة بأهمية الراحة الحرارية داخل المباني. – المشروع يستهدف مناطق ذات كثافة سكانية مرتفعة ومناخ صحراوي، حيث الحاجة ملحّة لحلول التظليل. – ازدياد اهتمام المعماريين والمطورين بالحلول البيئية التفاعلية القابلة للدمج بسهولة في المشاريع.

المحور	قانوني	بيئي	تقني

التحليل	– الامتثال للقوانين المحلية الخاصة بسلامة واجهات المباني – متابعة التغيرات في التشريعات واللوائح لضمان الامتثال الكامل – حماية حقوق الملكية الفكرية للتطبيق وضمان عدم انتهاكها من قبل المنافسين – التزامات التشريعات البيئية والبنائية المتعلقة بجودة المواد وسلامتها	– المساهمة في تقليل الأثر البيئي من خلال تخفيض الكسب الحراري وتقليل التكييف الصناعي. – استخدام مواد مقاومة وقابلة للتدوير (ألمنيوم، خشب) يعزز من الجانب البيئي للمشروع. – تقليل استهلاك الطاقة وانبعاث الغازات الضارة – يتماشى المنتج مع المعايير البيئية الحديثة في مجال التظليل وتقنيات التحكم السلبي في الحرارة	– اعتماد نظام تحكم ديناميكي مزوّد بحساسات ضوء وحرارة ومحرك كهربائي يضع المشروع ضمن الحلول الذكية – توفر آلات وتقنيات إنتاج – إمكانية التحديث البرمجي المستمر للنظام لتحسين الاستجابة وتحليل البيانات المناخية.

2 تحليل SWOT :

نقاط القوة(S)	نقاط الضعف(W)
- منتج مبتكر وغير متوفر في السوق الوطني. قلة المنافسين في السوق المحلية. - يجمع بين التصميم الجمالي والوظيفة التقنية (راحة حرارية وبصرية). - يعتمد على مواد متوفرة محليًا (ألمنيوم، خشب بتكلفة مناسبة. - استجابة ذكية آنية للمعطيات المناخية بفضل نظام الاستشعار والتحكم. -	- الوعي السوقي: قلة الوعي بين العملاء المحتملين حول فوائد النظام يمكن أن يؤثر على التبني السريع. - ارتفاع تكلفة النظام مقارنة بالحلول التقليدية. -
الفرص(O)	**التهديدات (T)**
- توسع السوق في المناطق ذات المناخ الصحراوي. - توفر اليد العاملة المؤهلة. - توفر المواد الأولية. - دعم السياسات البيئية في الجزائر لتقنيات تقلل من استهلاك الطاقة. - المشاركة في معارض وطنية ودولية لجذب المستثمرين. - إمكانية التصدير إلى بلدان ذات ظروف مناخية مشابهة.	- المنافسة: دخول منافسين جدد إلى السوق يمكن أن يقلل من الحصة السوقية. - الوضع الاقتصادي: تقلبات الوضع الاقتصادي يمكن أن تؤثر على القدرة الشرائية للعملاء. - وتيرة التطور التكنولوجي المتسارعة قد تُفقد النظام الحالي قدرته التنافسية على المدى الطويل.

3 تحليل PORTRER:

تهديد دخول منافسين جدد	**بالرغم من أن السوق المحلي لا يحتوي حاليًا على منتجات تظليل ذكية مماثلة، إلا أن سهولة الوصول إلى المكونات الأساسية وسرعة التقليد قد تُشجع على ظهور منافسين مستقبليين، خصوصًا في حال غياب حماية فكرية قوية. الكلفة الاستثمارية لبدء مشروع مماثل متوسطة، ما يُسهّل على آخرين دخول السوق.**
قوة تفاوض الموردين	**يعتمد المشروع على مزيج من الموردين المحليين للمواد الأساسية (الألمنيوم، خشب) وموردين دوليين للمكونات الإلكترونية. أي اضطراب في التوريد أو الأسعار قد يؤثر على التكاليف والإنتاجية.**
قوة تفاوض العملاء	**الزبائن لا يملكون خيارات بديلة مماثلة محليًا، مما يقلّل من قوتهم التفاوضية. العملاء في البداية بحاجة إلى توعية بمنافع النظام الجديد.**
المنتجات البديلة	**لا توجد أنظمة تظليل ذكية مشابهة في السوق الوطني. لكن البدائل التقليدية مثل الستائر الثابتة أو الزجاج العاكس قد تُستخدم كحلول مؤقتة.**
حدة المنافسة داخل القطاع	**المنافسة المحلية شبه منعدمة في مجال التظليل الذكي ,لكن على المدى المتوسط، قد تظهر شركات ناشئة مشابهة خاصة في المناطق الحارة.**

1 المزيج التسويقي:

المنتجات / الخدمات	خصائص ومميزات منتجنا/ خدماتنا	الاحتياجات التي تلبيها
أنظمة تظليل ديناميكية تعزز الراحة الحرارية عبر تقليل التعرّض لأشعة الشمس المباشرة وتوفير تظليل مستمر.	- توفير أكبر قدر من الظل في الأوقات الحرجة لتحسين الراحة الحرارية داخل الفضاءات المعمارية. - نظام تشغيل ذكي يعمل يدويًا أو أوتوماتيكيًا حسب تفضيلات المستخدم وخصوصية المشروع. - قابلية التخصيص الكاملة من حيث الشكل، الحجم، اللون، وآلية الحركة، لتلبية متطلبات كل مشروع.	– تحسين جودة الحياة من خلال تعزيز الراحة الحرارية والبصرية داخل المباني، خصوصًا في المناطق الحارة والجافة. – توفير الوقت والمال عبر نظام ذكي يتفاعل تلقائيًا مع المتغيرات المناخية

- تحليل البيئة الخارجية المحيطة بواجهة المبنى (الاتجاه، زاوية الشمس) لتعديل التظليل بدقة).

2 السعر:

سيتم اعتماد سياسة التسعير المبنية على التكلفة كأساس لتحديد سعر بيع منتج Twinshades، وذلك مع مراعاة الأسعار المقترحة من قبل المنافسين في السوق المحلي والدولي، بهدف ضمان القدرة التنافسية وتحقيق هامش ربح مستدام.

- تشمل التكلفة الوحدوية جميع المصاريف المرتبطة بتصنيع وحدة واحدة من النظام (مواد أولية، أجور، طاقة، نقل، تركيب، إلخ).
- يتم تحديد هامش الربح وفقًا لهدف الربحية والاستدامة المالية للمؤسسة، مع الحفاظ على تسعيرة مقبولة للزبائن المستهدفين.

ويتم حساب السعر كما يلي:

سعر المنتج = التكلفة الوحدوية لإنتاج النظام + هامش ربح محدد مسبقًا

المنتجات / الخدمات	السعر المقترح
أنظمة تظليل ديناميكية	35000 دج/وحدة

3 الترويج:

وسيلة الترويج	التفاصيل	التكلفة
حملات إعلانية رقمية	حملات على وسائل التواصل الاجتماعي ومحركات البحث، تستهدف الفئات المهتمة بالعمارة المستدامة والتظليل الذكي.	مجاني

العرض المباشر (المقابلات)	الترويج المباشر من خلال الزيارات الميدانية للمؤسسات، حيث يتم عرض النظام بشكل عملي أمام الهيئات المستهدفة.	2000دج
لوحات إعلانية	تصميم بطاقات عمل احترافية تحمل الهوية البصرية للمشروع (الشعار، الألوان، البيانات الأساسية)، وتُوزّع خلال الزيارات الميدانية، المعارض، أو اللقاءات.	500*8=4000 دج
فتح موقع خاص	فتح موقع خاص بالمؤسسة لتسهيل العملية	10000 دج
المجموع		16000دج

4 **التوزيع:**

1. التوزيع المباشر

يتم تسويق وتركيب النظام مباشرة من طرف فريق المشروع إلى الزبائن (أفراد أو مؤسسات)، خاصة في الولايات الجنوبية (مثل بسكرة، ورقلة، غرداية) حيث الحاجة ملحّة إلى التظليل الذكي.

2. شراكات مع مكاتب الدراسات والمقاولين

يتم عقد اتفاقيات مع مكاتب دراسات ومهندسين معماريين لاقتراح دمج النظام ضمن مشاريعهم الجديدة، مما يوفّر قناة توزيع مهنية ومباشرة نحو المشاريع قيد الإنجاز.

3. التوزيع عبر الطلب الإلكتروني

من خلال موقع إلكتروني رسمي (أو صفحة ترويجية)، يمكن للعملاء إرسال طلبات التثبيت أو التزويد، مع توفير خيارات التخصيص حسب المشروع.

5 عرض القطاع السوقي

السوق المحتمل:

جميع المناطق ذات المناخ الحار والجاف في الجزائر، والتي تتسم بارتفاع درجات الحرارة وشدة الإشعاع الشمسي على مدار العام. وتُعد هذه المناطق من أكثر الجهات حاجة إلى حلول تظليل ذكية وفعّالة لتحسين جودة البيئة الداخلية للمباني.

السوق المستهدف:

من حيث الفئة الجغرافية:

- الولايات الصحراوية ذات الإشعاع الشمسي المرتفع (مثل بسكرة، ورقلة، غرداية، تمنراست، الوادي، أدرار...).
- المدن الكبرى التي تعرف توسعًا عمرانيًا واهتمامًا بالحلول المستدامة (الجزائر العاصمة، وهران، قسنطينة...).

من حيث نوع العملاء:

- المؤسسات ومحلات بيع الجملة لولاية بسكرة وما جاورها

6 تحليل السوق:

الزبائن المستهدفون:

نوع الزبون
مؤسسات البناء والترقية العقارية
المهندسون المعماريون والمصممون

الموردون:

عنوان المشروع: تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

اسم المورد	الموقع	السلعة	معيارالمفاضلة
مصنع جزائرية للألمنيوم	**المنطقة الصناعية المسيلة-صندوق البريد رقم 758 مسيلة الجزائر**	**-الألمنيوم**	توفر الاحتياجات سعر
Sarl The Original Wood Company Import	**Zone Industrielle, Beni Tamou, 09100 W. Blida, Algérie**	**- الخشب**	توفر الاحتياجات سعر
DIGIKOM	**-العلمة، سطيف**	**-مستلزمات الدارة**	توفر الاحتياجات سعر الخبرة
AliExpress	/	-مستلزمات الدارة	توفر الاحتياجات

الاستراتيجية التسويقية:

1 **استراتيجية الانطلاق (مرحلة التأسيس):** خلال هذه المرحلة الأولى، سيتم اعتماد استراتيجية السيطرة على التكاليف من أجل تقليص نفقات الإنتاج إلى الحد الأدنى دون التأثير على جودة المنتج، وذلك بهدف تقديم منتج عالي الأداء بسعر منافس مقارنةً بالحلول التقليدية أو المستوردة.

بالتوازي، سيتم تبنّي استراتيجية التركيز من خلال التركيز على السوق الجهوي فقط، وتحديدًا الولايات الجنوبية ذات المناخ الصحراوي (مثل بسكرة، ورقلة، غرداية)، حيث الحاجة إلى حلول تظليل ذكية ملحّة وواقعية.

2 **استراتيجية التوسّع (مرحلة النمو):** توسيع النطاق الجغرافي ليشمل مختلف ولايات الجنوب والوسط ذات نفس الظروف المناخية.

IV. المحور الرابع: خطة الإنتاج والتنظيم

مخطط الإنتاجي:

الموقع:

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

صورة I1.موقع المشروع

سبب اختيار الموقع: تم اختيار موقع المشروع في منطقة صناعية نظرًا لابتعادها عن الكثافة السكانية، مما يوفّر بيئة ملائمة للأنشطة الصناعية دون التأثير على راحة السكان. كما أن الأرض المختارة تندرج ضمن أملاك الدولة المخصصة لمشاريع المؤسسات المصغّرة، مما يتيح استغلالها بمبلغ رمزي يُقدّر بـ 1 دج للمتر المربع، وهو ما يساهم

بشكل كبير في تقليص التكاليف العقارية وضمان انطلاقة اقتصادية للمشروع، مع سهولة الوصول إلى شبكات النقل والتوزيع القريبة.

الجانب العمر اني للمشروع:

المكان	المساحة	الاستعمال
المستودع 1	200م^2	مكان الإنتاج والتصنيع
المستودع 2	150 م^2	مكان وضع الآلات
الإدارة	150 م^2	خاص بمكتب المديرة والعمال مع مرحاضين وحمامين
مخزن	150 م^2	مخصص للمنتوجات الجاهزة للبيع
مخزن	150 م^2	تخزين المواد الأولية (ألمنيوم، حساسات...)
مركز الحراسة	50 م^2	مخصص لعمال الحراسة
فضاء للراحة مزود بمر افق أساسية	100 م^2	تتكون من غرفة استراحة العمال وقت الغداء +حمامين +مصلى
موقف سيارات الموظفين والزوار	60 م^2	يستوعب 4–6 سيارات تقريبًا

احتياجات المشروع:

الجهاز	المهمة الرئيسية	السعر (دج)
منشار مزدوج الرأس لقص الألمنيوم	لقطع المقاطع بأبعاد دقيقة للهيكل	1.400.000

عنوان المشروع: تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

منشار طاولة كهربائي لقص الخشب	قص الألواح الخشبية حسب التصاميم المطلوبة لتشكيل أجزاء النظام.	150,000 – 90,000
آلة صنفرة كهربائية (صقل الخشب)	تنعيم أسطح الخشب بعد القص والتحكم في التشطيب النهائي	15,000 – 30,000
آلة لحام TIG (AC/DC)	لحام دقيق لهيكل الألمنيوم الحامل للكاسرات الشمسية، مع ضمان متانة التوصيلات.	400.000
آلة ثقب وتشكيل الألمنيوم	تنفيذ ثقوب تثبيت وربط الأجزاء المعدنية بدقة وسرعة.	250.000
معدات تشطيب تثبيت الخشب	قص حواف الألواح ودقّتها وإزالة الزوائد	150.000
المجموع	2,380,000– 2,305,000	

المعدات المكتبية:

اسم العتاد	الكمية	السعر(دج)	السعر الإجمالي (دج)
مكتب المدير	**1**	**60.000**	**60.000**
مكتب المسير	**1**	**40.000**	**40.000**
مكتب المصمم	**1**	**40.000**	**40.000**
مكتب	**12**	**10.000**	**120.000**
كراس ي	**20**	**45.00**	**90.000**
خز ائن	**20**	**9000**	**180.000**
مكيف هو ائي	**10**	**80.000**	**800.000**
مدفئة	**10**	**70.000**	**700.000**
حاسوب	**10**	**50.000**	**500.000**

طابعة	**10**	**25.000**	**250.000**
هاتف فاكس	**10**	**2000**	**20.000**
ثلاجة	**1**	**80.000**	**80.000**
راوتر انترنت	**2**	**3.400**	**6.800**
المجموع: 2.886.800 دج			

احتياجات المواد الأولية

المادة	الكمية السنوية	سعر الوحدة دج	التكلفة السنوية دج
ألمنيوم	1,280متر	2500	12,800,000
خشب MDF أو معالج	1,500كغ	1,200	1,800,000
لوحة تحكم إلكترونية	160وحدة	4000	640,000
حساس ضوء (Light Sensor)	160وحدة	500	80,000
سيرفو موتور	160وحدة	8000	1,280,000
مستلزمات تثبيت (أسلاك، براغي...)	160وحدة	3000	480,000
المجموع			17,080,000

الطاقة والكهرباء:

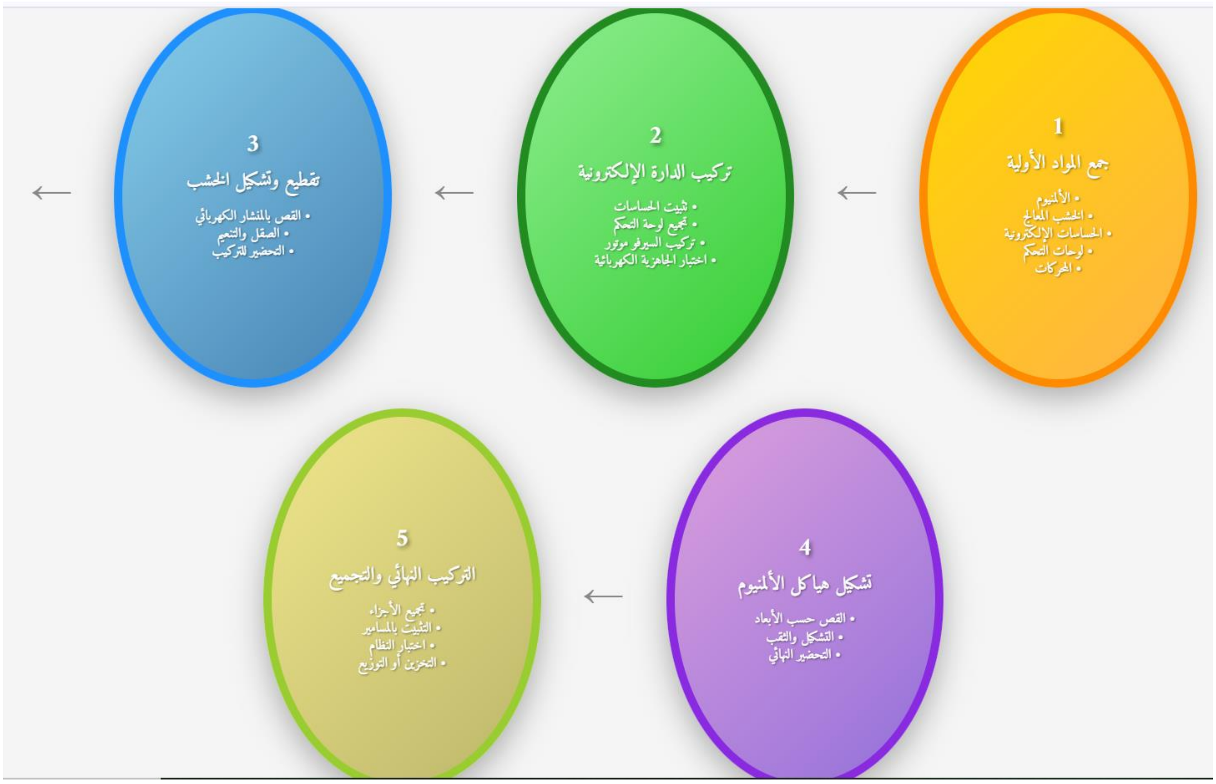
الخدمات	احتياجات الثلاثي الزيادة ب 1%	تكلفة سنة 1
الماء	1600m3	**31200دج**
الكهرباء والغاز	5 00.000 kw	**13.000.000دج**
انترنت وهاتف	غير محدود	**38.400دج**
صيانة	/	**700.000دج**

المجموع	14.469.600دج

طقم البسة العمال:

الاحتياج	الكمية	السعر(دج)	*السعر الإجمالي (دج)*
طقم البسة خاص بعمال الورشات	6	2500	*15.000*
طقم البسة خاص بعمال الجمع	3	2000	*6.000*
قميص الحارس	2	600	*1.200*
احذية	11	1800	*19.800*
قفازات	11	500	*5.500*
المجموع			***47.500 دج***

نظام الإنتاجي: خطوات الإنتاج



احتياجات اليد العاملة والأجور:

منصب	العدد	التخصص	الوظيفة	الأجور (دج)
المسير	1	ماستر تسيير موارد بشرية	مراقبة سير العمل وضبطه التعامل مع الموردين والزبائن	**70.000**
محاسب	1	شهادة ماستر في المحاسبة	جمع تحليل البيانات المالية واعداد ميزانية المؤسسة	**45.000**
المصمم	1	شهادة ماستر في الهندسة المعمارية	تحديد تصاميم و تموضع الكاسرات حسب المشروع	**50.000**
مدير الإنتاج	1	شهادة ماستر الكترونيك	الاشراف على عملية الانتاج ضمان سيرورة الإنتاج الجيد	**50.000**
عامل انتاج	6	شهادة ليسانس في الهندسة إلكتروميكانيكية	تنظيم الإنتاج وتشغيل الات الضغط والتجفيف	**40.000**
حارس	2	/	حراسة المصنع ومراقبة الافراد الداخلة والخارجة من المؤسسة	**25.000**
عاملة نظافة	2	/	الحفاظة على نظافة المؤسسة	**25.000**

المجموع = 555.000دج

التموين:

1. **الآلات والمعدات الصناعية :**

يتم اقتناء المعدات الثقيلة (مثل آلات القص واللحام والتشكيل) مرة واحدة فقط في بداية المشروع، مع إمكانية شراء تجهيزات إضافية مستقبلًا عند الحاجة فقط.

تتم عملية الشراء إما بالدفع عند الاستلام أو عبر حساب CCP، حسب الاتفاق مع المورد.

2. المواد الأولية:

يُعتمد في تموين المواد الأولية على نظام الشراء حسب الطلب، وذلك لتجنّب التخزين المفرط وتحقيق مرونة في التوريد حسب نوعية كل منتوج (خشب، ألمنيوم، حساسات، إلكترونيات...).

3. التجهيزات المكتبية واللوازم:

يتم اقتناء هذه التجهيزات (مكاتب، كراسي، طابعة، كمبيوتر...) مرة واحدة فقط في بداية النشاط، باعتبارها تجهيزات ثابتة لا تُستهلك يوميًا، مع مراجعة دورية للحاجات الثانوية مثل المستلزمات الورقية والأدوات المكتبية.

الشركاء:

اسم الشريك	أهمية الشريك
الموردون المحليون والدوليون	لأهميتهم في انجاح المشروع بتوفير كافة مستلزمات المشروع من الات وتجهيزات والمواد الأولية
البنوك	دور الكبير في تمويل المشروع وذهاب لتجسيده في ارض الواقع
الزبائن	يُشكلون قاعدة أولية لاختبار المنتج، والحصول على تغذية راجعة حقيقية تساعد على التطوير المستمر.

V. المحور الخامس: الخطة المالية PLAN FINANCIER

عنوان المشروع: تطوير أنظمة التظليل الشمسي الحركية المتكيفة مع البيئة

تكاليف المشروع واستهلاك الاستثمار:

الأصول	**التكلفة**
المباني	**500,000** *(تهيئة فقط)*
الآلات والمعدات	**2,380,000 دج**
الأثاث	**300,000 دج**
رأس المال العامل	**17,500,000 (تقديري)**
المجموع	**20,680,000 دج**

التكاليف التشغيلية:

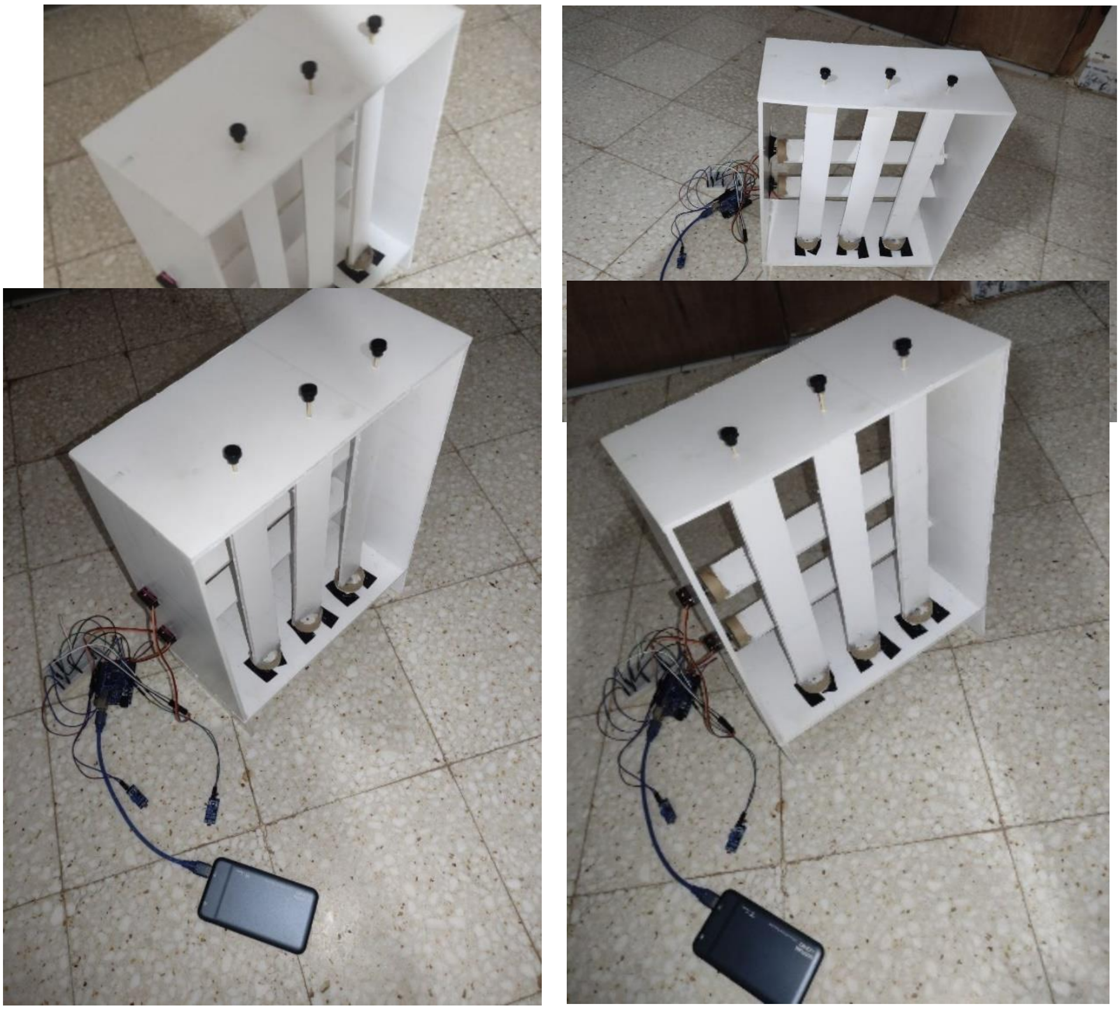
الأصول	**التكلفة**
مواد أولية	**2,209,292.00دج**
أجور	**555.000دج**
الهاتف والانترنت	**5,256 دج (438 دج × 12 أشهر)**
الكهرباء والماء	**14.469.600دج**
المجموع	**2,784,017.60دج**

تقدير المبيعات:

العام	يناير	فبراير	مارس	أبريل	مايو	يونيو	يوليو	أغسطس	سبتمبر	أكتوبر	نوفمبر	ديسمبر	المجموع السنوي (دج)
2026	5,250,000	6,300,000	7,700,000	9,800,000	12,250,000	14,700,000	16,800,000	19,250,000	21,700,000	23,800,000	26,250,000	28,700,000	192,500,000
2027	7,000,000	8,750,000	10,500,000	13,300,000	15,750,000	18,200,000	21,000,000	23,800,000	26,250,000	28,700,000	31,500,000	33,250,000	238,000,000
2028	8,750,000	11,200,000	13,300,000	15,750,000	18,200,000	21,000,000	23,800,000	26,250,000	28,700,000	31,500,000	34,300,000	36,750,000	269,500,000
2029	10,500,000	13,300,000	15,750,000	18,200,000	21,000,000	23,800,000	26,250,000	28,700,000	31,500,000	34,300,000	36,750,000	39,200,000	299,250,000
2030	12,250,000	14,700,000	17,500,000	20,300,000	22,750,000	25,200,000	28,000,000	30,800,000	33,250,000	35,700,000	38,500,000	41,300,000	320,250,000
2031	14,000,000	16,800,000	19,250,000	21,700,000	24,500,000	27,300,000	29,750,000	32,200,000	35,000,000	37,800,000	40,250,000	42,700,000	341,250,000
إجمالي المبيعات خلال 6 سنوات													1.660,750,000

VI. المحور السادس: النموذج الاولي التجريبي

الصور الاتية تمثل شكل النموذج الأولي:



صورة: نموذج العمل التجاري

شرائح العملاء

- المؤسسات المقاولتية
- شركات البناء
- زبون فردي

العلاقات مع العملاء

- خدمات ما بعد البيع
- محتوى توعوي وتثقيفي
- دعم تقني وتفاعل عبر الهاتف أو الموقع
- برامج إحالة للمستخدمين الأوائل
- خصومات في السعر عند طلب كمية كبيرة (علاقة طويلة المدى)

القنوات

- زيارات ميدانية للمؤسسات
- موقع إلكتروني رسمي
- شبكات التواصل الاجتماعي
- المعارض المتخصصة في البناء والبيئة

القيم المقترحة

- نظام تظليل ذكي يوفر الراحة الحرارية ويقلل من استهلاك الطاقة
- تصميم محلي باستخدام مواد طبيعية (خشب وألمنيوم)
- تكلفة منخفضة وسهولة التركيب

الانشطة الرئيسية

- انتاج مواد بناء عازلة للحرارة
- انتاج اثاث مركب
- التسويق للمواد البينية

موارد الرئيسية

- انتاج مواد بناء عازلة للحرارة
- انتاج اثاث مركب
- التسويق للمواد البينية

الشركات الرئيسية

- شركات التوصيل
- البنك
- الموردون :
- شركة جزائرية للألمنيوم
- Sarl The Original Wood Company Import
- DIGIKOM
- AliExpress

المصادر والارادات

- بيع النظام كوحدات جاهزة
- تركيب وخدمة ميدانية
- عروض بيع بالجملة لمشاريع كبرى

هيكل التكاليف

- تكاليف ثابتة: اجار العاملين، تكاليف تهيئة المقر، تكاليف شراء الآلات والمعدات .
- تكاليف متغيرة: تكاليف المواد الاولية، تكاليف الماء والغاز والكهرباء.