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

MASTER'S DISSERTATION

Domain: **Architecture, urbanism and city professions**
Field: **Architecture**
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Theme: **Housing**

Presented and defended by:
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Theme:

Intelligent opening devices adapted to arid climate individual housing

The project:

Project of 51 Villas

Examiner's committee

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الاهداء

الحمدلله الذي بنعمته تتم الصالحات وبشكره تدوم النعم اهدي هذا العمل

الى مكملتي اختي, سندي اخوتي, من مارستا الامومة معي على أكمل وجه ومن مارس الابوة أيضا فكان السبب في وجودي هنا اليوم, الى عشيرات العمر و رفيقات الدرب...

إلى من علّمني أن الحلم يبدأ بخطوة، وإلى من ساندني حين أثقلني التعب، وأشرق في قلبي الأمل بدعواتهم الصادقة، أهدي هذا العمل.

إلى كل روح كنت أسكن دعواتها، وإلى عطائكم اللامحدود الذي مهد لي طريق العلم، أهدي إليكم بذور هذا الإنجاز الذي لا يستحقه الا تعبكم وحده.

وإلى كل من آمن بي قبل أن أؤمن بنفسي، إلى زملائي وكل من ساهم بزغبةٍ أو كلمة دعم، أخصكم جميعًا بأجمل عبارات الامتنان والتقدير.

لستم مجرد أسماء في صفحة، بل أنتم مصدر الإلهام ، ودعاؤكم رفيقي في مسيرة العلم. هذا الإهداء لكم، فبارك الله فيكم وحقق على يديكم كل خير.

الشكر والتقدير

الحمد لله رب العالمين، والصلاة والسلام على أشرف الأنبياء والمرسلين، سيدنا محمد، وعلى آله وصحبه أجمعين

أتقدم بجزيل الشكر والامتنان إلى أستاذتي "ايناس العوني"، مشرفة هذه المذكرة، على توجيهاتها القيمة وإشرافها الدقيق الذي كان له الأثر الكبير في إخراج هذا العمل على النحو الذي يليق به.

وأخص بالشكر لجنة المناقشة الموقرة، أستاذتي مريم ماضوي، والاستاذة منال ناصري، على ملاحظاتهم البنّاءة واقتراحاتهم الثمينة التي أثرت البحث وأضافت إليه بعداً علمياً رفيع المستوى

كما أتقدم بجزيل العرفان إلى كلية العمارة بجامعة محمد خيضر –بسكرة-، ومنسقي قسم الهندسة المعمارية، لتوفير بيئة أكاديمية محفزة على الابتكار والتفكير النقدي

ولا يفوتني أن أوجه شكري وامتناني إلى زملائي الطلبة في مختلف المستويات الدراسية، لإثرائهم المناقشات العلمية ودعمهم الدائم طوال مسيرة البحث

أخيراً، أتقدم بالشكر لكل من قدم لي عوناً مباشراً أو غير مباشرٍ في سبيل إنجاز هذا البحث، سائلاً الله أن يجعل هذا العمل خالصاً لوجهه الكريم، وأن يكون عوناً لمن ينهلون من علمه في المستقبل.

والحمد لله رب العالمين

الملخص بالعربية

في ظل التحديات البيئية المتزايدة والتأثيرات المتسارعة لتغير المناخ، أصبحت الحاجة إلى حلول معمارية ذكية ومستدامة أكثر إلحاحًا، خصوصًا في المناطق الجافة التي تتميز بدرجات حرارة مرتفعة، ورطوبة منخفضة، وندرة الموارد المائية. تهدف هذه المذكرة إلى دراسة إمكانية دمج أنظمة الفتح الذكية في السكنات الفردية ضمن المناخات الحارة والجافة، مع التركيز على الاستفادة من هذه الأنظمة في تحسين جودة البيئة الداخلية وتقليل استهلاك الطاقة، من خلال التحكم التلقائي في التهوية والإضاءة والتظليل.

يتكوّن العمل من ثلاثة محاور رئيسية: نظري، تحليلي، وتطبيقي. في الجزء النظري، تم تناول الخلفية المفاهيمية والتاريخية لتقنيات الفتح الذكي، وأنواعها وآليات تشغيلها، إضافةً إلى تحليل مزاياها وتحدياتها. كما تمت دراسة الفتحات المعمارية في السكنات الفردية ضمن المناطق الجافة، ومقارنة خصائصها مع البيئات المناخية الأخرى، مع التركيز على تكامل هذه الحلول مع العناصر المعمارية التقليدية مثل المشربية.

أما في الفصل التحليلي، فتم تحليل أربعة مشاريع معمارية ذات صلة مباشرة بموضوع البحث، وقد تم اختيار هذه الأمثلة لما تمثله من تنوع مناخي، واستخدامات متقدمة للفتحات الذكية، وتوازن بين الحلول التكنولوجية والمعمارية. كما تم إجراء تحليل ميداني لأرضية المشروع المقترحة في مدينة بسكرة (الجزائر)، لتحديد خصائصها المناخية والعمرانية والاجتماعية، والفرص والتحديات التي تقدمها.

انطلاقًا من نتائج التحليل، تم تطوير فكرة تصميمية مستوحاة من نظام المشربية الذكية، حيث تمت إعادة توظيف هذا العنصر التقليدي في إطار معاصر وتفاعلي، يعزز التهوية الطبيعية، ويوفر التظليل، ويضمن الخصوصية، مع مراعاة البعد الجمالي والوظيفي. وقد تم تقديم تصور شامل للمشروع يدمج هذه الفكرة ضمن لغة معمارية متكاملة، تستجيب للواقع المناخي والاجتماعي للمنطقة.

تهدف هذه المذكرة إلى تقديم نموذج معماري تجريبي يجمع بين الذكاء البيئي، والهوية المحلية، والراحة الحرارية، ما يجعلها مساهمة في النقاش المعماري حول السكن المستدام في المناطق الجافة.

Summary

Amid increasing environmental challenges and the accelerating impact of climate change, the need for smart and sustainable architectural solutions has become more urgent—particularly in arid regions characterized by high temperatures, low humidity, and limited water resources. This thesis investigates the integration of intelligent opening systems into individual housing within hot and arid climates, with a focus on improving indoor environmental quality and reducing energy consumption through automated control of ventilation, daylight, and shading.

The research is structured around three main components: theoretical, analytical, and applied. The theoretical section explores the conceptual and historical background of intelligent openings, classifies their types and operating mechanisms, and analyzes their benefits and limitations. It also examines how openings function in individual houses located in arid zones, comparing their characteristics with those in other climatic contexts, while emphasizing the potential synergy between smart systems and traditional architectural elements such as the mashrabiya.

The analytical chapter includes a detailed study of four architectural case studies directly related to the research theme. These examples were selected for their climatic diversity, advanced use of intelligent openings, and their balance between technological innovation and architectural expression. Additionally, a contextual analysis of the project site in Biskra, Algeria was conducted, assessing its climatic, urban, and social characteristics, as well as the opportunities and constraints it presents for residential design.

Building on the results of the analysis, the conceptual design phase proposes a project inspired by the smart mashrabiya system, reinterpreting this traditional element in a modern and responsive way that enhances natural ventilation, ensures solar protection and privacy, and aligns with both aesthetic and functional needs. The design proposal integrates this concept into a coherent architectural language tailored to the environmental and social context of the site.

Ultimately, this thesis aims to present an experimental architectural model that combines environmental intelligence, local identity, and thermal comfort, contributing to the broader discourse on sustainable housing in arid regions.

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Conceptual chapter : Conceptual Design of the Project (Applied Phase)

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I. General Introduction

The climate challenges that characterize dry and desert areas are among the most prominent factors that greatly affect the design of residential buildings. The architect faces the need to develop innovative solutions that keep pace with harsh climatic conditions, while at the same time ensuring the comfort and well-being of residents. In this context, the role of smart technologies emerges since we are in the age of technology, which effectively contributes to improving the environmental performance of buildings, especially in areas with a dry climate characterized by high temperatures and scarce water resources.

Intelligent opening devices that adapt to these climatic conditions are an essential solution in achieving optimal natural ventilation and regulating lighting and temperature inside the home. This helps reduce reliance on artificial cooling systems and reduce energy consumption. The importance of these devices lies in their ability to interact intelligently with climate changes, such as high temperatures and winds, through automatic control mechanisms that ensure the ideal balance between indoor comfort and external environmental conditions in order to achieve thermal comfor

From here, we aim to study how to integrate intelligent technologies into the design of individual housing openings to suit the dry climate, with a focus on providing sustainable environmental solutions that contribute to reducing energy consumption and improving the thermal efficiency of the building. By using itelligent opening devices that monitor environmental changes, residents will be able to benefit from natural ventilation and reduce the effects of the scorching sun, contributing to improving the quality of life in hot and dry areas.

II. Problematic:

Arid and desert areas are among the most challenging areas in the design of residential buildings, as this environment requires innovative architectural solutions that are compatible with harsh climatic conditions that include high temperatures, scarcity of water, and strong winds. These challenges prompt architects to think of solutions that balance the comfort of the residents and reduce energy consumption in residential buildings.

One of the most important problems facing housing design in arid climates is heat management and ensuring adequate natural ventilation, and exploiting the necessary natural lighting in addition to taking advantage of the surrounding weather conditions to reduce reliance on artificial cooling systems that consume huge amounts of energy. In this context, the importance of intelligent opening devices (such as smart windows and smart doors, etc.) emerges, which can contribute significantly to the sustainability of buildings through intelligent interaction with climate variables.

With the advancement of intelligent opening device technologies, architectural challenges remain regarding the integration of these devices with individual housing designs in arid areas.

From the above, we find ourselves facing the following Problematic:

how can intelligent opening devices adapted to arid climates be integrated and implemented in individual housing to achieve a balance between natural ventilation, Thermal regulation, and low energy consumption?

III. Objectives:

- Analysis of the role of intelligent opening devices in improving ventilation and thermal comfort.
- Studying the impact of intelligent opening devices on energy consumption.
- Exploring the integration of intelligent opening devices with architectural design.
- Comparing smart architectural solutions with traditional solutions.
- Studying the impact of the local environment on the use of intelligent opening devices.
- Proposing innovative solutions for ventilation and heat using intelligent opening devices.
- Enriching scientific research in the field of architectural technology.

IV. Methodology:

A collection and organization of relevant information, documents, visual materials, and references concerning intelligent openings, individual housing, and hot climates is conducted in order to deepen the knowledge base and enrich the research content.

The theoretical research phase: In this phase, the focus is on exploring intelligent openings in individual housing located in hot and arid regions. It includes a detailed explanation of smart opening systems, as well as an analysis of openings in individual houses situated in both cold and hot climates, highlighting their specific characteristics. Additionally, this section addresses the general features of hot and arid zones, with particular emphasis on the hot and arid climate in Algeria.

The analytical research phase: This phase involves the study of selected architectural examples that are directly related to the research topic. These case studies serve as a foundation for collecting relevant data and extracting recommendations and guidelines that can inform the design process.

Following this, an analytical study of the project site is conducted with the aim of developing housing solutions that are adapted to the specific characteristics of the region. The analysis seeks to leverage the strengths of the site while proposing creative solutions to address its weaknesses, in order to ensure architectural integration and climatic responsiveness.

Design Implementation Phase : In this final phase, the theoretical and analytical findings are translated into a concrete architectural proposal. The design process begins with the definition of the general concept, followed by the integration of the thesis topic into the proposed project. The goal is to create housing solutions that respond effectively to the climatic characteristics of the site and incorporate intelligent opening systems in a meaningful and functional way.

V. Structure of the dissertation:

Main Entrance: It includes a general introduction, the definition of the research problem and the formulation of the main research question, the establishment of the research objectives, the adopted methodology, and finally the structure of the thesis.

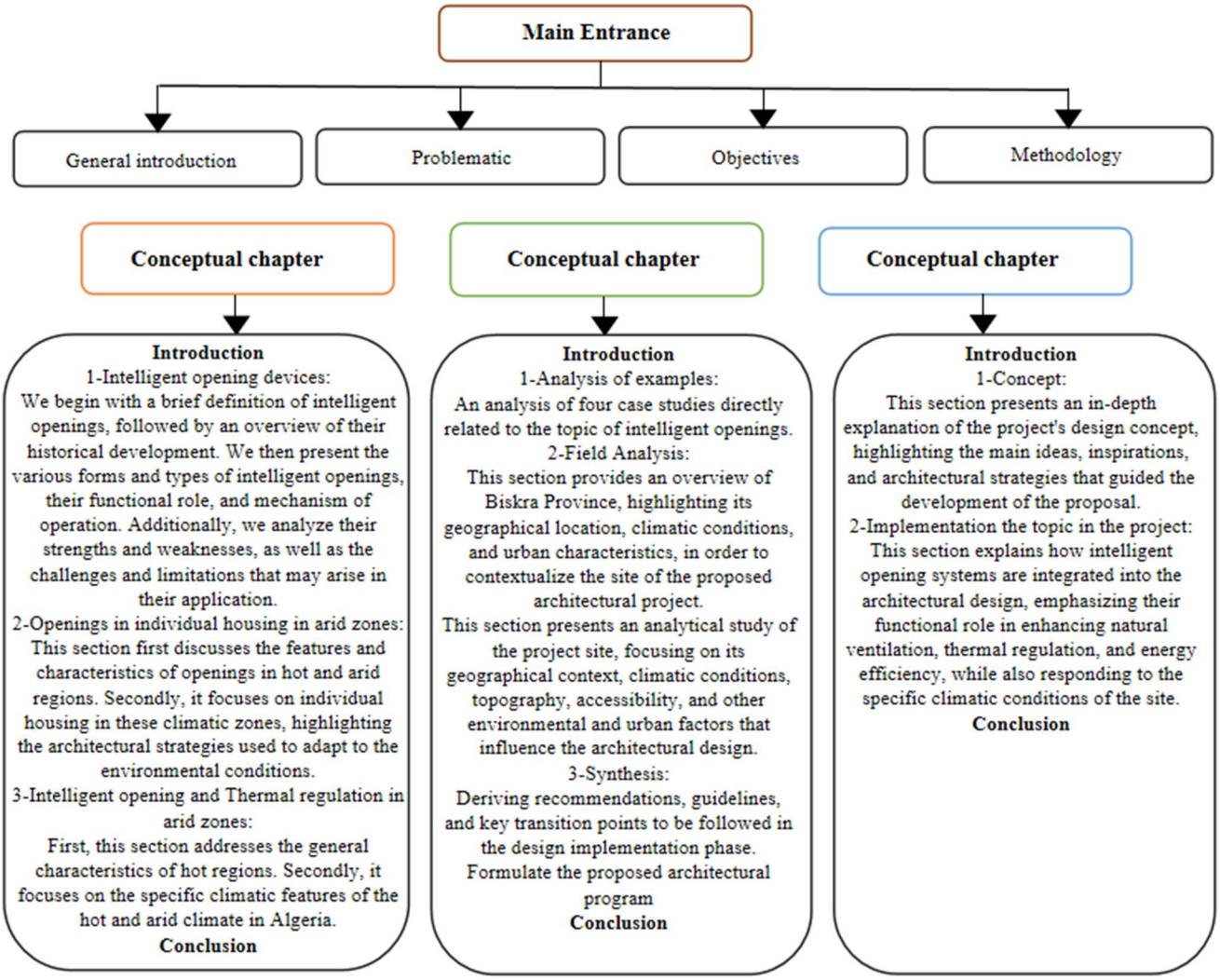
Theoretical Chapter: We first address the concept of intelligent openings, focusing specifically on their definition, historical background, forms, and different types. We also examine their functional role, mechanism of operation, strengths, weaknesses, and the challenges they may face.
Secondly, we explore the concept of openings in hot and arid regions, followed by a discussion on individual housing in hot and arid climates.
Thirdly, we examine the concept of hot and arid zones, their characteristics and specific features. Finally, we present an overview of the hot and arid climate in Algeria.

Analytical Chapter: We analyze a selection of case studies, some of which implement smart opening systems, while others are situated in hot and arid climates, allowing for a comparative understanding of both technological integration and climatic adaptation in architectural design.Then, we move on to the site analysis of the project. First, we provide a general introduction to Biskra Province, followed by a detailed study of the specific project site. Finally, we draw conclusions regarding the key strengths and limitations of the project site.

Synthesis: We derive a set of solutions to be applied to the project and present relevant recommendations and guidelines. Finally, we formulate the proposed architectural program.

Conceptual chapter: The overall architectural concept is first introduced, then the focus shifts to illustrating how the core subject of the research is embedded within the design proposal. In light of the conclusions drawn from the theoretical study.

Dissertation Structure Outline:


Main Entrance
General introduction
Problematic
Objectives
Methodology
Conceptual chapter
Introduction
1-Intelligent opening devices:
We begin with a brief definition of intelligent openings, followed by an overview of their historical development. We then present the various forms and types of intelligent openings, their functional role, and mechanism of operation. Additionally, we analyze their strengths and weaknesses, as well as the challenges and limitations that may arise in their application.
2-Openings in individual housing in arid zones:
This section first discusses the features and characteristics of openings in hot and arid regions. Secondly, it focuses on individual housing in these climatic zones, highlighting the architectural strategies used to adapt to the environmental conditions.
3-Intelligent opening and Thermal regulation in arid zones:
First, this section addresses the general characteristics of hot regions. Secondly, it focuses on the specific climatic features of the hot and arid climate in Algeria.
Conclusion
Conceptual chapter
Introduction
1-Analysis of examples:
An analysis of four case studies directly related to the topic of intelligent openings.
2-Field Analysis:
This section provides an overview of Biskra Province, highlighting its geographical location, climatic conditions, and urban characteristics, in order to contextualize the site of the proposed architectural project.
This section presents an analytical study of the project site, focusing on its geographical context, climatic conditions, topography, accessibility, and other environmental and urban factors that influence the architectural design.
3-Synthesis:
Deriving recommendations, guidelines, and key transition points to be followed in the design implementation phase.
Formulate the proposed architectural program
Conclusion
Conceptual chapter
Introduction
1-Concept:
This section presents an in-depth explanation of the project's design concept, highlighting the main ideas, inspirations, and architectural strategies that guided the development of the proposal.
2-Implementation the topic in the project:
This section explains how intelligent opening systems are integrated into the architectural design, emphasizing their functional role in enhancing natural ventilation, thermal regulation, and energy efficiency, while also responding to the specific climatic conditions of the site.
Conclusion

Theoretical Chapter :

❖ Introduction:

In the face of increasing environmental challenges and the accelerating impact of climate change, the demand for smart and sustainable architectural solutions has become more urgent—particularly in arid regions characterized by high temperatures, low humidity, and water scarcity. Among the most notable innovations in contemporary architecture are intelligent opening devices, such as smart windows, doors, and adaptive façades. These technologies play a crucial role in enhancing indoor environmental quality by promoting natural ventilation, optimizing daylight, and reducing the reliance on conventional cooling systems.

This chapter explores the theoretical foundation of intelligent opening devices, beginning with their definition and historical development, followed by an in-depth look at their various types, forms, and mechanisms of operation. It also highlights their contribution to improving building performance, thermal comfort, energy efficiency, and user convenience. Moreover, the chapter addresses the advantages and limitations of integrating these technologies, particularly within the architectural context of arid climates.

The purpose of this theoretical study is to establish a solid knowledge base that will inform the analytical and practical chapters of this research, and to support the development of innovative architectural strategies that are climate-responsive, user-oriented, and environmentally sustainable.

1. Intelligent opening devices:

1.1. Definition: Intelligent opening devices in architecture are dynamic building elements, such as doors, windows, gates, and shading systems, that utilize advanced technologies – including sensors, actuators, microprocessors, and network connectivity to automate their operation, respond to environmental conditions, user needs, and security protocols, and integrate seamlessly with other building systems to enhance the building's functionality, energy efficiency, comfort, and safety.[1]

1.2. Historical: The history of smart home devices is linked to the development of smart home technology, and this development began in the 1990s with the emergence of connected home appliances. Here is a look at some of the major milestones in the history of these devices:

1.1.1. Late 1990s - Early 2000s:

- **1990s:** Smart home technology began to emerge with the development of remote control systems for home appliances. These systems were simple and used technologies such as infrared.

1.1.2. 2000 - 2010: Advances in communication:

[1] https://www.intelligentopenings.com/en/partner-area/ https://www.sciencedirect.com/ / https://scielo.org/en/ /https://www.scribd.com/document/294968571/Sensors-In-Intelligent-bulidings /https://mu.ac.in/wp-content/uploads/2022/10/User-E1-Internet-of-Thing.pdf

- **2000:** This period saw the emergence of the first devices that could be controlled via the Internet, allowing users to control their home appliances remotely.
- **2005:** Protocols such as Zigbee and Z-Wave began to be used to facilitate communication between different devices in the home.

1.1.3. 2010 - 2020: The smart revolution:

- **2010:** Many smart products were launched such as smart locks and security cameras that could be controlled via smartphones.
- **2014:** Voice assistants such as Amazon Echo increased in popularity, which helped promote the use of smart home devices.

2020 and Beyond: Integration and Expansion:

- **2020:** Smart opening devices have evolved to include advanced features such as facial recognition and voice control, making them more secure and easy to use.
- **2023:** Smart opening devices have become an integral part of smart home systems, integrating with security, air conditioning, and lighting systems.[2]

Technology continues to evolve, making smart opening devices more efficient and suitable for the needs of users in different climates.[3]

1.2. Types and shapes: Smart Door Locks-Smart Garage Door Openers-Smart Gate Opener-Smart Window-Smart Facades

Figure 01: Smart Door Locks

Source:https://www.yalehome.com/

Figure 02: Smart Garage Door Openers

source:https://www.houseopedia.com/

[2]https://www.smartest-home.com//https://www.bridgecable.com//https://mammothsecurity.com//https://thereader.mitpress.mit.edu/ /https://itcombine.com/ /https://iotmktg.com/ / https://www.itechdigital.com//https://www.ibm.com/ / https://www.mdpi.com// https://www.matteralpha.com//https://www.powerfleet.com/ /https://canadiandoorautomation.com/.

[3]https://ec.europa.eu/programmes/erasmus-plus/project-result-content/4df4e928-8958-4552-80da-146977e666b9/Smart_Home_systems_FINAL.pdf/https://www.smartest-home.com/en/history-of-smart-home/ https://www.matteralpha.com/explainer/smart-home-technology-in-depth-history

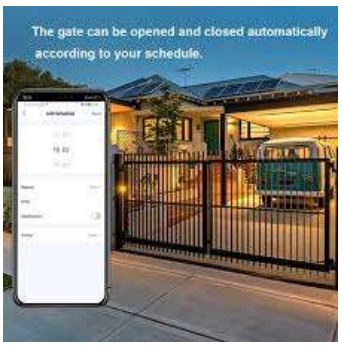


Figure 03: Smart Gate Opener

Source:https://www.ebay.com/__

Figure 04: Smart Façade

Source : Book: Eco-friendly: building facade.

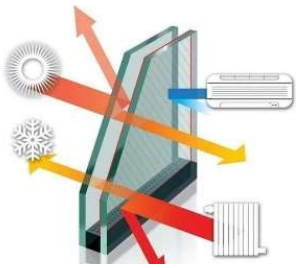


Figure05: Smart Window

Source:https://www.arquitecturar.com/

1.3.1. Smart Windows (Automated or Responsive): Sliding Windows – Bi-folding Windows – Pivot Windows

Figure06: Sliding Window

Source:https://stock.adobe.com/

Figure 07: Bi-folding Window

Source:https://almashur.id/pintu-pivot-aluminium/

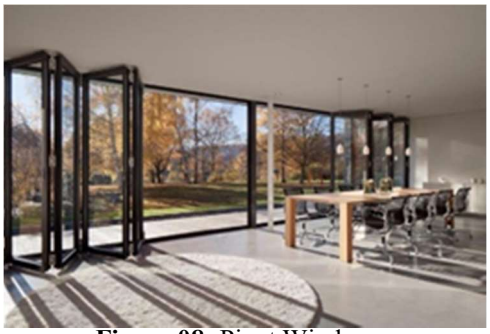


Figure 08: Pivot Window

Source :https://sa.made-in-china.com/

1.3.2. Smart Doors (Automatic or Secure Entry): Sliding Doors – Swing Doors – Rotating or Revolving Doors – Dutch Doors

Figure 09 : Sliding Door

Source:https://www.directdoors.com/

Figure 10 : Swing Door

Source : https://impalaglass.blogspot.com/

Figure 11 : Revolving Doo

Source : https://www.gettyimages.com/

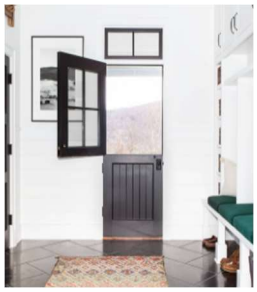


Figure 12 : Dutch Door

Source :https://www.houzz.com/

1.3.3. Intelligent Façades (Dynamic and Adaptive Panels): Smart Shutters or Louvers – Responsive Curtain Walls – Folding Façades

Figure 13 : Smart Shutter

Source: https://www.gettyimages.com/

Figure 14 : Responsive Curtain Walls

Source: https://asmartbuild.en.made-in-china.com/

Figure 15: Folding Façades

Source: https://www.researchgate.net/

1.3.4. **Motorized Garage Doors:** Roll-up Garage Doors - Sectional Garage Doors

Figure 16: Roll-up Garage Door

Source: https://smartgarage.ca/residential-door/gallery/

Figure 17: Sectional Garage Door

Source: https://www.thegaragedoorcentre.co.uk/

1.3.5. Sensor-Activated Panels: Shape-based Activation

Figure 18: Smart bedside panel

Source: https://photo.kommersant.ru/

1.3.6. Futuristic and Artistic Shapes: Curved or Organic Forms - Panel-Based Designs

Figure 19: Organic Form

Source: https://www.gettyimages.com/

Figure 20: Panel-Based Design

Source: https://bhys.medium.com/_

1.3.7. Retractable or Hidden Openings: Concealed Doors – Retractable Glass Walls.[4]

Figure 21: Concealed Door

Source: https://www.houzz.ie/

Figure 21: Retractable Glass Wall

Source: https://www.nanawall.com/

1.5. How do smart opening devices work?

Smart opening devices operate through a combination of sensors, connectivity, data processing, and actuators to enable automated, secure, and remote-controlled access to doors, windows, or gates.

1.5.1. Sensors Capture Environmental Data: These devices use various sensors such as:

"Sensors" These devices are equipped with different types of sensors to gather information. Examples include:

• **Motion sensors:** Detect movement for automated opening or security alerts.

[4] https://www.sciencedirect.com/ /

• **Contact sensors:** Determine if an opening is open or closed.

• **Light sensors:** Measure ambient light levels for automated shading adjustments.

• **Temperature and humidity sensors:** Monitor indoor climate for automated ventilation.

• **Rain sensors:** Detect precipitation to automatically close windows or retract awnings.

• **Biometric scanners:** Recognize fingerprints or facial features for secure access.

• **User Input:** Users can interact with smart opening devices through various methods:

• **Smartphone apps:** For remote control, scheduling, and receiving notifications.

• **Keypads:** For entering PIN codes.

• **Voice assistants:** Like Amazon Alexa or Google Assistant, for voice commands.

• **Physical buttons or touchscreens:** For local control.

• **Key fobs or smart cards:** Using RFID or other communication technologies.

1.5.2. Data Transmission and Processing: Sensor data is transmitted wirelessly or via wired connections to a central control unit or smart hub.

• **Microcontroller/Microprocessor:** This acts as the "brain" of the device. It receives data from sensors and user inputs, processes it according to pre-programmed logic or user-defined settings, and then sends commands to the actuators.

• **Embedded Software/Operating System:** This software on the microcontroller manages the device's functions, communication protocols, and security features.

1.5.3. Command Execution via Actuators: Based on the processed data, the control unit sends commands to actuators-mechanisms that physically open, close, lock, or unlock the device. For example, a smart door may unlock when an authorized fingerprint is recognized or open automatically when motion is detected nearby.

"Actuators" These are the mechanical components that perform the physical action of opening, closing, locking, or adjusting the device. Examples include:

• **Motors:** To move doors, gates, windows, or shading elements.

• **Solenoids:** To engage or disengage locking mechanisms.

• **Electronic hinges or mechanisms:** For specialized movements.

1.5.4. Integration with Building Systems and Remote Control: Smart opening devices are often integrated into broader building management systems (BMS), allowing centralized monitoring and control. Users can remotely operate them via smartphones or building dashboards, enhancing convenience and security.

• **Wireless Communication Modules:** Smart opening devices connect to networks and other devices using various wireless protocols:

• **Wi-Fi:** For direct connection to home or building networks and internet access.

• **Bluetooth/Bluetooth Low Energy (BLE):** For short-range communication with smartphones or hubs, often used for initial setup or direct control.

• **Zigbee and Z-Wave:** Low-power mesh network protocols commonly used for smart home devices, offering reliable communication and the ability to extend range through interconnected devices.

• **Cellular (LTE/5G):** For remote access and control where Wi-Fi isn't available.

• **NFC (Near-Field Communication):** For very short-range communication, sometimes used for keyless entry.

1.5.5. Power Source: Smart opening devices require a power source to operate their electronic components and actuators. This can include:

• **Mains power:** Direct connection to the electrical grid.

• **Batteries:** Often used for wireless devices or as a backup power source.

• **Low-voltage DC power:** Supplied through adapters.

• **Power over Ethernet (PoE):** For devices connected via Ethernet cables.

• **Energy harvesting:** Some advanced devices may explore solar power or other ambient energy sources, though this is less common for primary operation.[5]

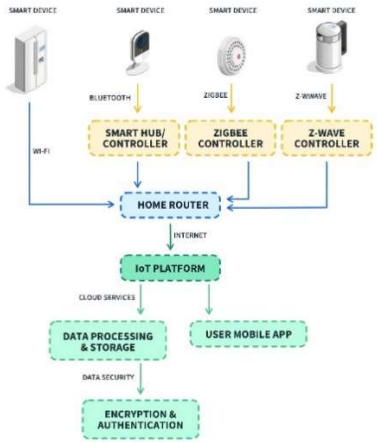


Figure 23 : Illustration about how do smart opening devices work

Source: https://www.cbtnuggets.com/

[5] https://www.wbdg.org/FFC/DOD/UFGS/UFGS%2028%2010%2005.pdf / /https://open.alberta.ca/dataset/0ce39a94-7c58-49d5-9183-32332ed50315/resource/eb3b9a40-9951-4d8b-afcd-3d2e8cd892db/download/ccht-roadmap-chapter4.pdf /https://www.researchgate.net/publication/391313096_Smart_Buildings_and_Digital_Twin_to_Monitoring_the_Efficiency_and_Wellness_of_Working_Environments_A_Case_Study_on_IoT_Integration_and_Data-Driven_Management /https://telecomworld101.com/iot-sensors-and-actuators-a-guide/

Figure 24: Smart home infographic

Source: https://www.vectorstock.com/

1.6. Advantages of using intelligent opening devices:

1.6.1. Ease of Use: The devices can be controlled via user-friendly applications.

1.6.2. Customization: The settings can be customized to suit your needs.

1.6.3. Reliability: These devices are durable and reliable.

1.6.4. Sustainability: They contribute to preserving the environment by reducing energy consumption.

1.6.5. Enhance security and comfort.

1.7. Challenges Facing Intelligent Opening Devices:

1.7.1. Cost: These devices can be expensive to purchase and install.

1.7.2. Cyber security: These devices are vulnerable to hacking, so choose devices that use strong encryption.

1.7.3. Complexity: Setting up and connecting these devices together can be complicated for some users.

1.7.4. Software Glitches: Like any software-driven device, smart locks can experience glitches or bugs that might temporarily prevent proper operation.

1.7.5. Dust and Sand: The environment in arid zones might expose smart locks to more dust and sand, potentially affecting the mechanical parts or sensors over time.

1.7.6. Power Outages: While some smart locks have battery backups, prolonged power outages, which might occur, could limit their functionality if they primarily rely on mains power.[6]

[6] https://www.researchgate.net/search?q=Challenges+Facing+Intelligent+Opening+Devices / https://search.open.ac.uk/search/search.shtml?q=Challenges%20Facing%20Intelligent%20Opening%20Devices&pg=1

✓ Synthesis:

In modern architectural design, intelligent opening devices are a core component of intelligent or smart buildings. These buildings leverage interconnected systems to provide enhanced user experiences, operational flexibility, and resource management. The open architecture approach-where hardware and software from different suppliers can seamlessly integrate-enables these devices to play a dynamic role in the built environment.

2. Openings in individual housing in arid zones :

2.1. Openings in individual housing in arid zones:

2.1.1. Minimizing Solar Heat Gain:

2.1.1.1. Orientation: Orienting buildings to minimize east and west-facing windows, which receive intense morning and afternoon sun. Prioritizing north and south-facing windows, as they receive less direct sunlight, especially the north-facing side in the Northern Hemisphere. and easier to shad

Figure 25: Building orientation in Oued Souf

Source: جريدة التحرير الجزائرية

2.1.1.2. High-Level Openings: Incorporating small, high-level openings allows hot air to escape while preventing direct sunlight from entering. This design helps maintain a cooler indoor environment by facilitating natural ventilation

Figure 26: Ventilation openings in old buildings in Oued Souf

Source: https://www.imago-images.com/

2.1.1.3. Shading: Using deep overhangs, awnings, and louvers to block direct sunlight from entering windows. Employing external shading devices that are more effective than internal ones.

Figure 27: Shading in old buildings in Oued Souf

Source: https://x.com/

2.1.1.4. Window Size and Type: Reducing the size of windows, especially on east and west-facing walls.Using high-performance windows with low solar heat gain coefficients (SHGC) and reflective coatings.

Figure 28: Window Size and Type –Oued Souf

Source: https://ouadisoufnew.blogspot.com/

2.1.2. Maximizing Natural Ventilation:

2.1.2.1. Cross Ventilation: Designing buildings to promote cross ventilation, allowing breezes to flow through the interior. Placing windows and vents on opposite walls to create airflow.

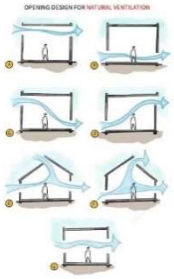


Figure 29: Opening design for natural ventilation

Source: https://www.arkitectureonweb.com/

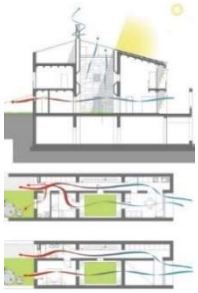


Figure 30: Longitudinal and cross section to illustrate Cross Ventilation

Source: https://www.researchgate.net/

2.1.2.2. High-Level Openings: Incorporating high-level windows or vents to allow hot air to escape.

This utilizes the principle of hot air rising.

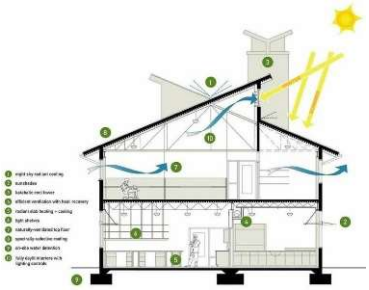


Figure 31: High-Level Openings for natural ventilation

Source: Saleh et al, Babylonian Journal of Machine Learning Vol.2024, 1–14

2.1.2.3. Courtyards: Designing homes with courtyards to create shaded outdoor spaces and promote

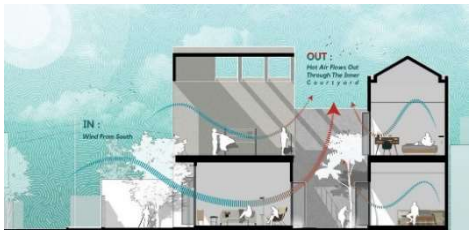


Figure 32 : home with courtyard

Source : 16621-Article Text-56442-1-10-20240327.pdf

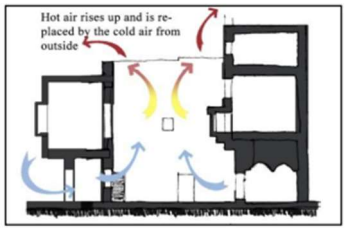


Figure 33 : Ventilation through the courtyard

Source : [PDF] NATURAL VENTILATION IN OLD ISLAMIC HOUSES

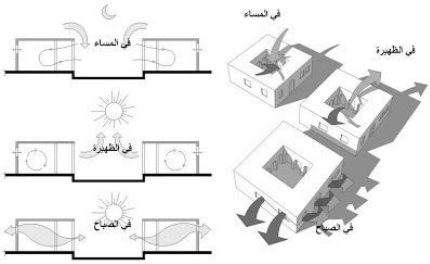


Figure 34 : The effect of the yard on the house in terms of ventilation

Source : https://isawi-bookmark.blogspot.com/

2.1.3. Material Choices:

2.1.3.1. Adobe (Sun-Dried Mud Bricks): Adobe is widely used in arid climates due to its excellent thermal insulation properties and high thermal mass. It effectively slows heat transfer, keeping interiors cool during the day and releasing stored heat at night. Adobe also limits heat penetration during intense sunlight hours. Its local availability and low embodied energy make it a sustainable choice.

Figure 35: Adobe (Sun-Dried Mud Bricks)

Source: https://stock.adobe.com/dz/

2.1.3.2. Stone: Stone is durable, resistant to weathering, and has high thermal inertia, which helps moderate indoor temperatures by absorbing heat during the day and releasing it slowly at night. Stone walls also provide excellent resistance against harsh winds and sandstorms common in deserts.

Figure 36 : Picture of different types of stone

Source : https://klesarstvo-bregovic.hr/proizvodi/zidovi-od-kamena/

2.1.3.3. Concrete and Hollow Concrete Blocks: Concrete is commonly used for structural walls and foundations. When combined with hollow blocks and insulation layers (e.g., polyurethane), it improves thermal resistance and reduces cooling loads. Concrete's thermal mass contributes to stabilizing indoor temperatures but requires additional insulation to prevent heat gain.

Figure 37: Concrete Blocks

Source: https://concretefeliz.com/

2.1.3.4. Rammed Earth: Rammed earth construction uses compacted soil layers to form thick walls with high thermal mass. It is sustainable and well-suited for arid climates, providing natural insulation and humidity regulation.

Figure 38: Rammed Earth

Source: https://www.shutterstock.com/

2.1.3.5. Clay and Baked Clay Tiles: Clay materials, including baked clay bricks and tiles, are used for walls and roofing. They offer good insulation and thermal mass, and support flat earthen roofs typical in arid architecture.

Figure 39: Baked Clay Tiles

Source: https://www.publicdomainpictures.net/

2.1.3.6. Insulation Materials: Adding insulation such as polyurethane foam or natural insulating materials (e.g., date palm waste) improves the thermal performance of walls and roofs by reducing heat transfer. Studies show that even thin insulation layers can significantly reduce cooling energy demand.

Figure 40: common thermal insulation materials

Source: https://www.refmon.hu/

2.1.3.7. Natural Plasters (Clay or Lime): Natural plasters are applied to walls to protect from erosion and help regulate moisture by absorbing and releasing humidity, which is beneficial in dry climates. They also contribute to thermal comfort by moderating surface temperatures.

Figure 41: Natural Plaster

Source: https://www.omorovicza.eu/pages/manage-my-subscriptions

2.1.3.8. Light-Colored Paints and Reflective Coatings: Exterior surfaces are often finished with light colors or reflective coatings to reduce solar heat absorption, lowering wall surface temperatures and indoor heat gain.[7]

[7] / https://www.sciencedirect.com/topics/social-sciences/place-of-residence / journals.lagh-univ.dz / Connections By Finsa/ whereisthenorth.com/ Hippo Enterprises Inc./ Housing for Health - the guide/

2.2. Individual housing in arid zones: It is usually defined as a stand-alone building intended for use by a single owner as a single dwelling unit. These homes typically do not share walls with other dwellings and are located on their own land, allowing for private entrances and direct access to the street.

2.2.1. Type of individual housing: This type of housing can be classified into two main types:

2.2.1.1. Pure individual housing: This is a single-family detached home that is the result of a construction process and contains only one dwelling.

Figure 42: Pure individual housing

Source: https://www.squareyards.com/

2.2.1.2. Grouped individual housing: This includes single family homes that may consist of several single dwellings or one dwelling with additional spaces, but still maintain the individual character of each unit.[8]

Figure 43: Grouped individual housing

Source: https://www.lowincomehousing.us/det/

2.2.2. Characteristics: Single-family homes, especially single-family homes, have distinct characteristics that set them apart from other types of residential property. Here are the most important characteristics:

2.2.2.1. Self-contained structure: Single-family homes typically consist of a stand-alone building that does not share walls with neighboring units, providing greater privacy compared to houses or apartments

Figure 44 : Self-contained structure

Source : https://makazi.in/

[8] insee.fr/ scispace/ ArchitectureAu/ Careers Building Communities/ Investopedia/ suw.biblos.pk.edu/

2.2.2.2. Single-family kitchen: These homes typically have a full-sized kitchen, setting them apart from multi-family units that may have shared or multiple kitchens

Figure 45: Single-family kitchen

Source: https://www.homesandgardens.com/

2.2.2.3. Land ownership: When purchasing a single-family home, the owner acquires the entire plot of land on which the home is located, including any outdoor spaces such as gardens or yards

2.2.2.4. Private access: Single-family homes provide private access points to the street, unlike apartments or condominiums that share common hallways or entrances

Figure 46: Private access

Source : https://dutumgroup.com/

2.2.2.5. Space and expandability: Single-family homes often come with more space, including additional storage options such as basements and attics. They also offer expansion opportunities, allowing homeowners to adjust their living space as needed.

Figure 47: Basement storage

Source: Pinterest

Figure 48: Exploiting the attic for storage

Source: Pinterest

2.2.2.6. Location and environment: These homes are often located in less densely populated areas, which contributes to a quieter living environment. They may also be located on the outskirts of urban areas, which can result in less traffic and a quieter environment.

Figure 49: single family residences

Source : https://www.property24.com/articles/sectional-title-vs-clusters-whats-the-difference/24614

2.2.2.7. Higher Maintenance and Costs: In general, single-family housing costs and maintenance expenses may be higher than multifamily housing options due to their size and the responsibilities associated with owning the land.

2.2.2.8. Customization Freedom: Homeowners have more control over their property, allowing them to make changes to the exterior and landscaping without the need for approval from a homeowner's association or similar entity.

These characteristics make single-family housing particularly attractive to families looking for privacy, space, and the ability to customize their living environment.[9]

✓ Synthesis:

In arid regions, openings in individual houses are designed to minimize heat gain by reducing window size and orienting them away from direct sunlight, while enhancing natural ventilation especially at night for passive cooling.

3. Intelligent opening and Thermal regulation in arid zones

3.1. Arid zones: Arid areas are those characterized by water scarcity and high temperatures, which greatly affects life and ecosystems in them.[10]

3.1.1. Characteristics of arid areas: Climatic characteristics:

3.1.1.1. Rainfall scarcity: Rainfall in these areas is irregular, often less than 100 mm per year, making agriculture difficult.

Figure 50: water crisis

Source: https://www.greenplanetplumbing.com.au/

[9] https://www.wbdg.org/FFC/VA/VADEGUID/dg_small_house_model.pdf
https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=144257&CVD=144258&CLV=0&MLV=2&D=1

[10] https://www.mdpi.com/2220-9964/10/11/720 /

3.1.2.2. High temperatures: Dry areas often record high temperatures of up to 42°C during the summer, with sharp drops in temperatures at night[11]

Figure 51: Mapping the hottest temperatures around the world

Source: https://www.aljazeera.com/

3.1.2. Natural causes of drought: Natural causes of drought include the region's distance from sources of moisture, the presence of stable air masses, and the lack of rainstorm systems. The continental location and mountain barriers also play a role in reducing rainfall.[12]

3.1.3. Types of arid areas: Arid areas are generally classified based on their precipitation levels, vegetation cover, and climatic characteristics. The main types of arid zones include:

3.1.3.1. Hyper-Arid Zones:

- Receive less than 100 millimeters of rainfall annually.
- Characterized by extremely sparse or no vegetation except for scattered shrubs.
- Rainfall is infrequent and irregular, sometimes with several years without rain.
- These areas cover about 4.2% of the Earth's land surface.
- True nomadic pastoralism is often practiced here.

3.1.3.2. Arid Zones:

- Receive between 100 and 300 millimeters of rainfall annually.
- Vegetation is sparse but more than in hyper-arid zones, often supporting pastoralism.
- Cover approximately 14.6% of the Earth's land area.

3.1.3.3. Semi-Arid Zones:

- Receive between 300 and 600 millimeters of rainfall annually.
- Vegetation includes low rainfall woodland savanna and grasslands.
- These zones cover about 12.2% of the Earth's land area.

3.1.3.4. Dry Subhumid and Evergreen Scrub Zones:

- Receive more than 500 millimeters of rainfall annually but still experience dry periods.
- Vegetation is denser, including evergreen scrub.[13]

3.1.4. Challenges facing arid zones:

3.1.4.1. Water Scarcity: Limited water resources, over-extraction, saltwater intrusion

[11] WorldAtlas/ fao.org/ Sciencing/ Biology Discussion/ sciencedirect/ api.pageplace/ GRIDArendal/

[12] BBC Bitesize/usgs/hondapowerproducts.co.id/scijinks/Entrenosotros | Consum/Aquaread/Seneca Learning Ltd./

[13] https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SOD_CCP3.pdf /

3.1.4.2. Climate Change: Rising temperatures, reduced rainfall, increased drought frequency

3.1.4.3. Land Degradation: Soil salinization, erosion, desertification due to unsustainable land use

3.1.4.4. Biodiversity Loss: Habitat destruction, reduced ecosystem resilience

3.1.4.5. Socioeconomic Pressure: Population growth, resource conflicts, poverty[14]

3.2. Hot and arid climate in Algeria:

3.2.1. Overview: Algeria is characterized by a great diversity of climates, but the hot and dry climate dominates vast areas of it, especially in the southern and central regions. This climate has profound effects on the daily lives of the population and economic activities in the country.[15]

3.2.2. Causes of the hot and arid climate in Algeria:

3.2.2.1. Geographical location: Algeria is located in North Africa, a region generally characterized by a hot and dry climate.

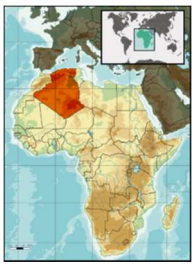


Figure 52: Map of Algeria's location

Source: https://topwar.ru/101954-cherez-saharu-na-orbitu.html

3.2.2.2. Air currents: Algeria is dominated by dry and hot air currents coming from the Sahara Desert.

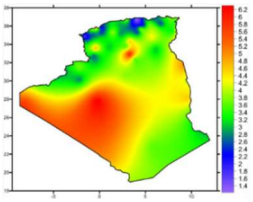


Figure 53: Air currents in Algeria

Source: https://biblio.univ-annaba.dz/ingeniorat/wp-content/uploads/2018/10/Chouabbi-Amar.pdf

3.2.2.3. Terrain: The mountainous terrain in Algeria contributes to the variation in temperatures and the distribution of rainfall.

[14] https://www.mdpi.com/2073-4441/17/5/633 / https://www.fao.org/4/i2096e/i2096e.pdf / /

[15] https://climateknowledgeportal.worldbank.org/country/algeria / https://cgbrussels.mfa.gov.dz/discover-algeria-1/about-algeria-1 /

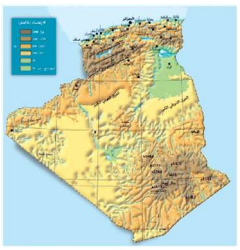


Figure 54 : A map showing the topography of Algeria

Source : https://dspace.univ-ouargla.dz/jspui/bitstream/123456789/12987/4/Mechri-Mohammed%20Laid.pdf

3.2.2.4. Lack of rainfall: Algeria experiences small amounts of rainfall, especially in the southern regions.[16]

3.2.3. Characteristics of the hot and arid climate in Algeria:

3.2.3.1. High temperatures: Algeria experiences a significant rise in temperatures during the summer, especially in the interior and southern regions.

3.2.3.2. Lack of rainfall: Annual rainfall in Algeria ranges from less than 100 mm in the desert to more than 1000 mm in the northern mountainous regions.

3.2.3.3. Low humidity: The dry areas in Algeria are characterized by low humidity, which increases the feeling of heat.

3.2.3.4. Temperature differences between night and day: very large in desert areas.[17]

3.3. Thermal regulation:

Thermal regulation focuses on maintaining comfortable indoor temperatures while optimizing energy efficiency.

3.3.1. Key Concepts of Thermal Regulation:

3.3.1.1. Thermal Comfort: Thermal comfort refers to the condition where the ambient temperature does not negatively impact the occupants, providing a satisfactory environment. Achieving this involves understanding the balance between heat gain and loss within a building, and is generally assessed subjectively.

[16] https://assafirarabi.com/en/48562/2022/11/05/climate-change-in-algeria-and-its-impacts/ /

[17] https://www.adaptation-fund.org/wp-content/uploads/2025/03/3_AFB.PPRC_.35.22.Rev_.1-Proposal-for-Algeria-1.pdf / https://nomadseason.com/climate/algeria/index.html / https://assafirarabi.com/en/48562/2022/11/05/climate-change-in-algeria-and-its-impacts/ /

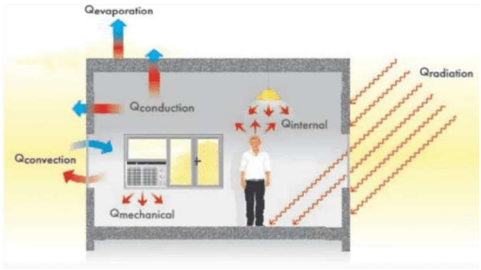


Figure 55: human body perception towards thermal comfort

Source: TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf

• Conduction

• Convection

• Radiation

Effective thermal regulation requires managing these processes to minimize unwanted heat loss or gain[18]

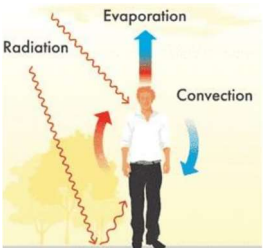


Figure 56: The heat exchange between the human body and its environment

Source: TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf

3.3.1.4. Phase Change Materials (PCMs): PCMs are innovative materials that absorb and release thermal energy during phase transitions (e.g., solid to liquid). Integrating PCMs into building envelopes can enhance thermal inertia, reducing temperature fluctuations and improving energy efficiency.

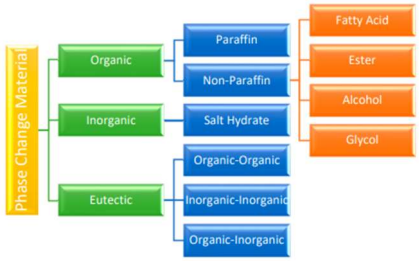


Figure57: Flow.chart.of.different.types.of.phase change materials

Source: pdf. Incorporation of Phase Change Materials in Buildings(MDPI)

[18] TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf/ https://www.researchgate.net/publication/322305734_Optimizing_Thermal_Comfort_Considerations_with_Electrical_Demand_Response_Program_Implementation / https://www.mdpi.com/2071-1050/13/22/12425 /

3.3.1.5. Adaptive Facades: Modern architectural designs often incorporate adaptive facades that adjust to environmental conditions. These facades can enhance natural ventilation, control solar gain, and improve overall thermal performance.

Use high performance windows with multi-panes, low-e coatings and gas filling to reduce heat transfer.

Use intelligent opening

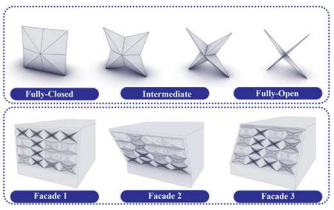


Figure 58: Examples of adaptive Facades

Source: University of Stuttgart

3.3.1.6. Airtightness: Sealing air leaks in the building envelope to prevent unwanted air infiltration, which can significantly impact energy consumption.

3.3.2. Strategies for Effective Thermal Regulation (Passive Design Techniques): Passive solar design utilizes natural resources (like sunlight and wind) to regulate indoor temperatures without mechanical systems. This includes strategic placement of windows, overhangs, and thermal mass materials that absorb heat during the day and release it at night

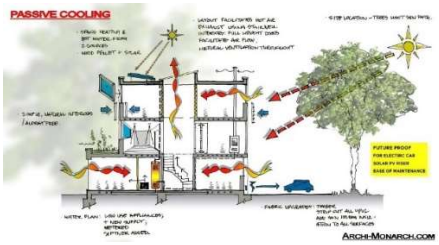


Figure 59: Passive cooling

Source: https://www.re-thinkingthefuture.com/

Passive Design Techniques :

3.3.2.1. Strategic Building Orientation: The building is oriented to receive the maximum amount of sunlight during the winter to warm the interior, and to minimize exposure to the sun during the summer to reduce heat gain, which contributes to reducing the need for cooling and heating systems.[19]

[19] https://www.sciencedirect.com/topics/social-sciences/passive-design#:~:text=Passive%20design%20refers%20to%20the%20optimization%20of,promote%20natural%20ventilation%2C%20and%20enhance%20energy%20efficiency.

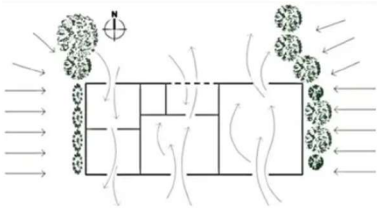


Figure 60 : The rectangular shape and north-south orientation achieve the best ventilation and least direct sunlight

Source : .استراتيجيات التصميم السلبيpdf

3.3.2.2. Insulation: Insulation materials are essential for reducing heat flow through building envelopes. High-quality insulation minimizes thermal bridging, which occurs when heat flows through conductive materials, compromising energy efficiency.[20]

Figure 61: Techniques for improving thermal insulation in buildings

Source: (مشرق علي حيدر) شركة "ستاير ليمتد" الامارات-البيان

3.3.2.3. Ventilation Systems: Proper ventilation is crucial for maintaining air quality and thermal comfort. Natural ventilation can be enhanced through operable windows and strategically designed openings that allow for cross-ventilation.[21]

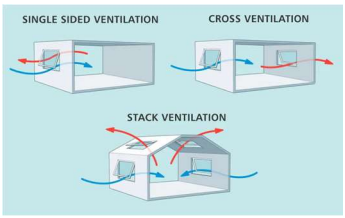


Figure 62: Natural ventilation

Source: https://repository.unika.ac.id/26745/6/17.A1.0093-Novena-BAB%20V_a.pdf

3.3.2.4. Use of Thermal Mass: Materials with high thermal mass (like concrete or brick) can store heat during the day and release it at night, helping to stabilize indoor temperatures throughout fluctuating daily conditions.[22]

[20] https://www.mdpi.com/2071-1050/16/24/11076 / https://www.yourhome.gov.au/passive-design/orientation

[21] surrey.ca/ archiroots.com/ energy.gov

[22] surrey.ca/ energy.gov

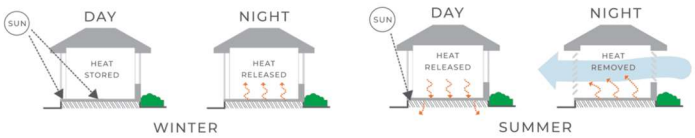


Figure 63: Thermal mass work

Source: TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf

3.3.2.5. Solar Control Strategies (Shading): Implementing shading devices, such as awnings or louvers, can significantly reduce solar heat gain during hot months while allowing sunlight in during cooler periods

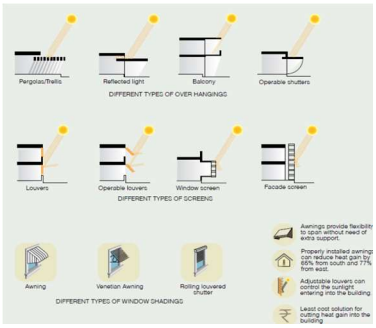


Figure 64: Exterior shading devices

Source: TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf

To prevent summer overheating and glare, a good shading device strategy should be used with glazed openings.[23]

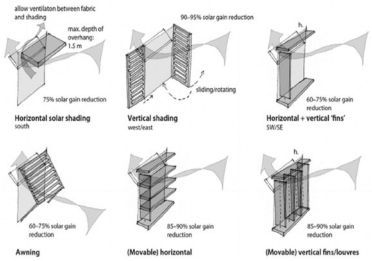


Figure 65: Most effective shading

Source: TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf

3.3.2.6. Cool Roofs: Using reflective materials on roofs reduces the absorption of solar heat, lowering the building's temperature and reducing the need for cooling.[24]

[23] TRAINING 'A' PRESENTATION ON THERMAL COMFORT AWARENESS.pdf/ archiroots.com/ frontiersin.org

[24] archiroots.com

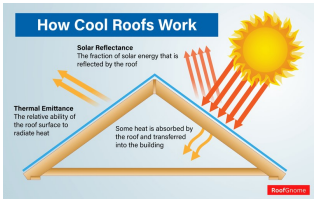


Figure 66: Houw cool roofs work

Source: https://roofgnome.com/

3.3.2.7. Green Roofs and Waterbodies: Adding green roofs or water bodies helps with insulation, ventilation, and ambient temperature reduction.[25]

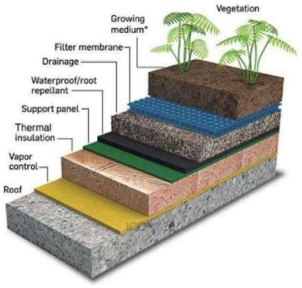


Figure 67: cross section of green roof

Source: https://en.idei.club/

3.3.2.8. Use of Local Materials: Choosing building materials suitable for the local climate reduces the environmental impact and helps adapt to climatic conditions.[26]

3.3.3. Key benefits of effective thermal regulation:

3.3.3.1. Improved occupant comfort: Maintaining a comfortable indoor temperature throughout the year.

3.3.3.2. Reduced energy consumption: Lowering heating and cooling costs.

3.3.3.3. Increased sustainability: Minimizing environmental impact by reducing reliance on fossil fuels.

3.3.3.4. Enhanced indoor air quality: Improving ventilation and reducing the risk of mold and mildew.

3.3.3.5. Cost Savings: Reduced energy consumption leads to lower utility bills over the building's lifetime.

3.3.3.6. Using local: Natural materials with high thermal mass (e.g., adobe, stone) supports sustainable construction practices.[27]

[25] archiroots.com

[26] archiroots.com

[27] irbnet/sciencedirect/tandfonline/NUTEC/fujielectric/yourhome.gov/Revise/Monga/icecleaning.co.uk/Thermtest/building.govt

3.3.4. Role of intelligent opening devices in thermal regulation:

optimizing the exchange of heat and light between indoor and outdoor environments. Here's how:

• Natural Ventilation

• Helps to cool the indoor environment during hot weather and expel stale air.

• Solar Heat Gain Control

• Nighttime Cooling

• Improved Indoor Air Quality

• Enhanced Comfort.[28]

✓ Synthesis:

Thermal regulation is essential for creating sustainable, comfortable living environments in architecture. By employing a combination of insulation, advanced materials like PCMs, passive design strategies, and effective

❖ Conclusion :

This theoretical chapter has provided a comprehensive understanding of intelligent opening systems and their architectural relevance in hot and arid climates. Through the examination of their definitions, evolution, types, and functional mechanisms, it has become evident that these systems offer valuable solutions for improving indoor environmental quality, enhancing thermal comfort, and reducing energy consumption. The findings emphasize that intelligent openings, when carefully integrated into architectural design, can act as efficient tools for climate-responsive strategies—especially when combined with passive design principles and culturally rooted elements such as the mashrabiya. Despite their advantages, challenges related to contextual adaptation, user interaction, and technical maintenance must be considered to ensure long-term effectiveness.

Based on the insights gained, it is recommended that intelligent openings be treated not as isolated technological features, but as integral components within a holistic sustainable design approach—particularly in individual housing located in arid regions. Their integration should be sensitive to local climate, user behavior, and cultural identity, encouraging a balance between performance and tradition.

These conclusions lay the groundwork for the next chapter, which shifts from theoretical reflection to practical analysis. The upcoming analytical study will examine real architectural examples where intelligent opening systems have been implemented, in order to evaluate their effectiveness and extract applicable strategies. This transition will help identify design principles and contextual solutions that can inform the development of a climate-adapted housing model suited to the Algerian arid environment.

[28] Sciencedirect/ mdpi/ Bachofen AG/ geze.ae/ wiley/ ACS Publications/ bpie/ tandfonline/ pmc.ncbi.nlm.nih/ advanced.onlinelibrary.wiley/ spie.org/ ACS Publications/ oaepublish.com/ journal.umy.ac

Analytical Chapter:

❖ Analysis of examples

Introduction:

Building on the theoretical foundations established in the previous chapter, this analytical section aims to translate conceptual knowledge into practical architectural understanding. The chapter begins with a detailed analysis of four architectural case studies, each selected for its relevance to the research theme and its capacity to demonstrate context-sensitive strategies for integrating intelligent openings in hot and arid climates—or in environments facing similar thermal challenges.

The first example, The Address Hillcrest Villas (Dubai Hills Estate), was chosen for its high-end residential design that integrates smart technologies within a desert climate context, showcasing how luxury housing can still prioritize passive and active environmental solutions. The second case, Ventura House in Brazil, despite its location outside the arid belt, was selected for its innovative use of adaptable façade elements and natural ventilation strategies, offering valuable transferable concepts. The third example, Nawayef Homes in Hudayriyat Island, Abu Dhabi, was included due to its contextually responsive housing typology designed for extreme heat, combining smart openings with orientation and form-based environmental control. Finally, the fourth case, The Sustainable City in Yas Island, presents a large-scale urban model where intelligent environmental strategies—including responsive openings—are applied to create an energy-efficient and livable community in a desert environment.

Each case is examined through architectural, climatic, and functional lenses, allowing for a comparative evaluation that highlights best practices, limitations, and contextual adaptability. Following the case studies, the chapter presents an analytical study of the proposed project site in Biskra, focusing on its geographic location, climatic characteristics, urban context, and environmental constraints. This site analysis is essential in identifying both the opportunities and challenges that will influence the architectural response.

The final section of this chapter synthesizes the findings into a set of strategic recommendations and design guidelines. These conclusions will serve as transition points into the design phase, where the insights drawn from both the case studies and the site analysis will inform the development of a climate-responsive housing model that integrates intelligent opening systems in a contextually appropriate and sustainable way.

1. First example: The Address Hillcrest Villas Dubai Hills Estate :

Figure 68 : The Address Hillcrest Villas Dubai Hills Estate

Source : https://vision-ary.com/

1.1. Technical sheet:

Developer	Emaar Properties
Project Type	Residential Complex
Design	138 villas: 51 villas with a classic design 87 villas with a modern design
Areas	from 6,983 to 10,805 square feet
Number of rooms	5 bedrooms
Facilities and services	Multipurpose room, Fully equipped gym, Community Center, Children's pool and water play a Yoga platforms and health and educational facilities
Opening	It was launched in the third quarter of 2022
Number of floors	04 floors

Table 01: Technical sheet

Source: https://www.bayut.com/

1.2. Reason for choice: This project was chosen firstly because it is a residential complex and secondly because it is in arid zone.

1.3. Situation and Accessibility: The project is located in Mohammed Bin Rashid City near Al Khail Road and Umm Suqeim Street.

Figure 69: Master plan

Source: https://www.bayut.com/

It is strategically located between Downtown Dubai and Dubai Marina. The community also provides easy access to the city's most popular areas and attractions:

Al Maktoum International Airport, Dubai International Airport, Dubai Marina, Downtown Dubai, Dubai Hills Park, Dubai Hills Mall, Dubai Hills Golf Club.

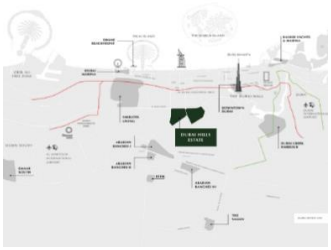


Figure 70: Location Map of most popular areas

Source: https://dubai-immo.com/

Figure 71: Dubai Hills Park

Source:https://www.bayut.com/

Figure 72: Dubai Hills Mall

Source:https://realtree.ae/apartments-for-sale/dubai-hills-estatemain-feed-card-text

Figure 73: Dubai Hills Golf Club

Source: https://www.mohamedalabbar.com/

1.4. The idea: The design concept of the "Address Hillcrest Villas" project in Dubai Hills Estate revolves around providing a blend of luxury and modernity in a comfortable and integrated residential environment. The project features :

• Two architectural styles: classic and modern, allowing for a variety of options to meet the tastes of different residents.

	Classic	**Modern**
Street View	 **Figure 74:** main facade of classic villas	 **Figure 75:** main facade of modern villas
Garden View	 **Figure 76:** secondary facade of classic villas	 **Figure 77:** secondary facade of modern villas

Table 02: facades of the modern and classic villas

Source: https://opr.ae/ar/areas/dubai-hills-estate

• Relies on clean lines and an innovative architectural style, with the use of high-quality materials.

• The modern design focuses on exploiting open spaces to achieve interaction between the interior and exterior.

Figure 78: open spaces

Source: https://www.edgerealty.ae/

Figure 79: interaction between inter& exter

Source: https://www.edgerealty.ae/

• Large windows allow for abundant natural lighting and stunning views of the surrounding green spaces.

Figure 80 : Large windows natural lighting

Source : https://www.edgerealty.ae/

Figure 81: Views of the green spaces

Source : https://www.edgerealty.ae/

Sustainability

• There are vast green spaces throughout the project, children's play areas, outdoor recreational facilities andpedestrian walkways to encourage outdoor activities.

Figure 82 : Pool

Source : https://www.dubizzle.com/

Figure 83: Green spaces throughout and children's play areas

Source : https://www.dubizzle.com/

Figure 84: Outdoor recreational facilities

Source: https://www.dubizzle.com/

Figure 85: Pedestrian walkways

Source: https://www.dubizzle.com/

1.6. Plans and circulation:

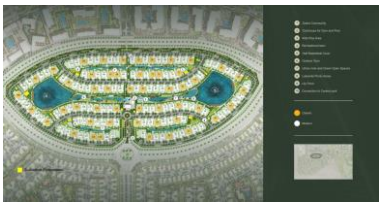


Figure 86: Ground plan

Source: فلل_أدريس_هيلكريست.pdf

The Plans:

Shape 01	Shape 02	Space
 **Figure 87:** Plan 01	 **Figure 88:** Plan 02	9918.29square footage
Shape 03	**Shape 04**	**Space**
 **Figure 89:** Plan 03	 **Figure 90:** Plan 04	10371.45square footage

Table 03: architectural plans design

Source: فلل_أدريس_هيلكريست.pdf

1.8. The Lightning: Natural lighting and artificial lighting were combined

Figure 91: Natural lighting through the large opening
Source: https://www.edgerealty.ae/ar/_

Figure 92: Smart lighting and warm colors
Source: https://opr.ae/ar/

➢ Transitional Points :

✓ Architectural Plans Design:

• Floor Organization: A clear separation between reception, living, and sleeping areas.

• Spacious and Open Areas: The layouts focus on providing generous and open living spaces, enhancing comfort and flexibility in use.

• Design Variety: Two architectural styles (Classical and Modern) with differences in balcony sizes and detailing, allowing for diverse tastes while maintaining a luxurious character.

Architectural Facades:

• Simple and Elegant Design: The facades rely on clean lines and natural neutral colors that reflect a contemporary and refined character, with the use of high-quality materials that give a cohesive and serene appearance.

• Panoramic Windows and Wide Balconies: Allow abundant natural light and reinforce the connection between interior and exterior spaces.

• Integration with Nature: The presence of private gardens and green areas surrounding the villas contributes to creating a comfortable microclimate and protection from direct sunlight, while enhancing privacy.

• Spacious Car Parking: Garage designs accommodate up to 3 cars, reflecting attention to comfort and practicality.

Sustainability and Comfort :

• Consideration of the Hot and Arid Local Climate: The villa designs take into account sun and heat protection through natural shading and green spaces, reducing the need for mechanical cooling.

✓ Synthesis:

The Address Hillcrest Villas project presents an advanced architectural model that combines luxury, functionality, and environmental comfort through flexible interior layouts and elegant facades that integrate nature with modern design. The emphasis on natural lighting, ventilation, and green spaces enhances quality of life and achieves an environmental and social balance within the Dubai Hills community.

2. Second example: Ventura House: A Modern Architectural Gem in Brazil

Figure 93: Ventura House

Source: https://cristinaivanec.wordpress.com/

2.1. Technical sheet:

Location	Xangri-là, South Brazil
Architects	National Architecture
Area	600 square meters
Floors	Open ground floor + private upper floor
Number of bedrooms	04 bedroom suites
Facade materials	White rotatable GRC units
Project Type	Individual house

Table 04: Technical sheet

Source: Arch Daily

2.2. Reason for choice: The intelligent openings

2.3. Situation: Located in a gated community in the municipality of Xangri-Lá, on the coast of Rio Grande do Sul.

Figure 94: Situation plan

Source: https://www.architonic.com/

2.4. Plans:

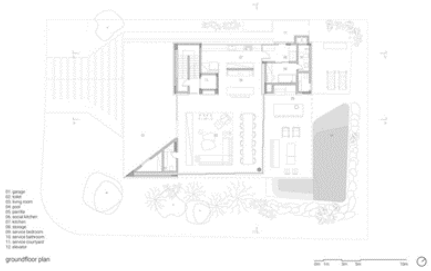


Figure 95: Ground floor plan

Source: https://www.architonic.com

Figure 96: First floor plan

Source: https://www.architonic.com

2.6. The facades:

Figure 97: Adaptive Façade Sud

Source: https://cristinaivanec.wordpress.com/

Figure 98: Adaptive Façade Nord

Source: https://cristinaivanec.wordpress.com/

2.7. The intelligent openings:

Key GRC (Glass Fiber Reinforced Concrete) Facade:

The upper floor facade is covered with 390 GRC units (80 x 80 cm), specially designed to gently and evenly direct daylight into the interior while providing privacy. Some of these units are rotatable to allow for open views and ventilation.

Figure 99: Rotatable GRC unit to allow for open views ventilation

Figure 100: Evenly direct daylight into the interior while and

Source: https://cristinaivanec.wordpress.com/

GRC units are lightweight, custom-made, concrete panels mounted on a supporting structure, providing durable, flexible, and aesthetically pleasing architectural facades with high weather resistance and light weight.

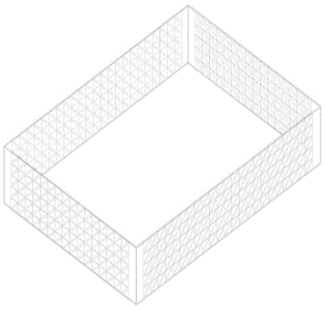


Figure 101: Adaptive Façade

Figure 102: Detail GRC façade

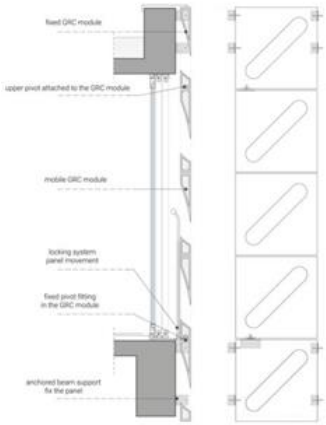


Figure 103: GRC units

Source : https://www.architonic.com/

➢ Transitional Points :

Architectural and Functional Characteristics of the Facade:

• **Design of Controllable Units:** Allows regulation of visibility and ventilation as needed, while maintaining privacy. This creates a dynamic facade that responds to user needs and climatic conditions.

• **Natural Light Orientation**: The shape and design of the units aim to direct daylight into the interior in a soft and well-distributed manner.

• **Materials:** The use of white GRC (Glass Reinforced Concrete) with fiberglass offers high resistance to weathering, reduced weight compared to traditional concrete, and a sleek modern appearance that aligns with the overall design elements.

Synthesis:

The upper-floor facade of Ventura House represents an advanced model of adaptive intelligent facades, which interact smartly and aesthetically with both the environment and the user. It embodies the principles of sustainability and thermal comfort.

3. Third example: Nawayef Homes At Hudayriyat Island, Abu Dhabi

Figure 104: first view from Nawayef Homes

Source: fYJ7vJleEZAgu2KUmUaZ.pdf

Figure 105: secande view from Nawayef Homes

Source: fYJ7vJleEZAgu2KUmUaZ.pdf

3.1. Technical sheet:

Developer	Modon Properties
Location	Al Hudayriat Island, Abu Dhabi, UAE
Property Type	Villas
Residential Units:	Villas: 3 to 5 Bedrooms.
Areas	from 344.00 sqm to 436.00 sqm
Facilities and Services	Extensive green areas, Recreational areas, Sports facilities, Access to sandy beach, Children's playground, Large landscaped garden.

Table 05: Technical sheet

Source: fYJ7vJleEZAgu2KUmUaZ.pdf

3.2. Reason for choice: This project was chosen firstly because it is a Residential Complex and secondly because it is in arid zone.

3.3. Situation: Located on Al Hudayriat Island in the Emirate of Abu Dhabi, it is divided into 3 sub-residential projects. They are : Nawaif West Homes, Nawaif West Palaces and Nawaif Heights West.

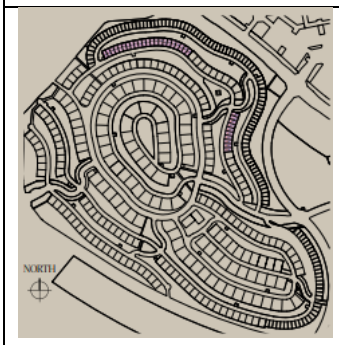
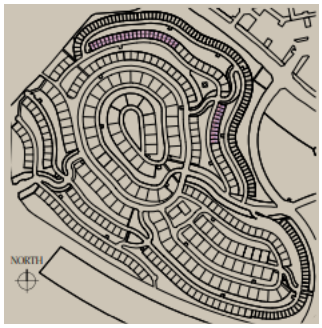
Each offering homes with a variety of architectural designs. The complex occupies a prime location close to Al Hudayriat Tower, which connects to the southern coast of the emirate.

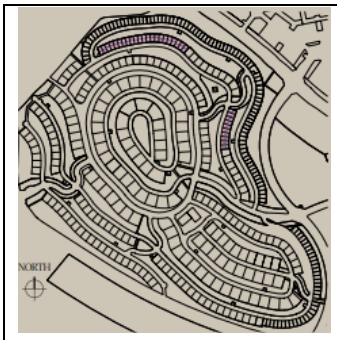
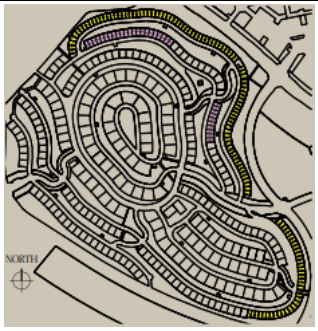
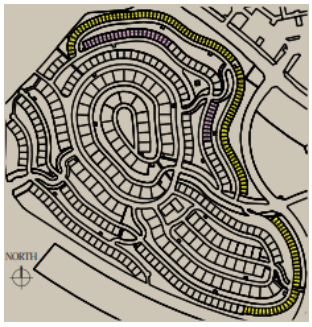
Set amidst rolling hills that rise up to 45 metres, it offers stunning views of the Abu Dhabi skyline and the azure waters of the Arabian Gulf. The villas are located on the eastern hill in Nawaif and are medium sized villas.

Figure 106: fYJ7vJleEZAgu2KUmUaZ.pdf

Source: fYJ7vJleEZAgu2KUmUaZ.pdf

3.4. Plans and facades: Consisting of a ground floor and a first floor, and residents can choose from six different designs available.

Situation	Plan	Façade	Space
 **Figure 107:** Situaton of Plan type 01	 **Figure 108:** Plan type 01	 **Figure 109:** Facade type 01	436.00s
 **Figure 110:** Situaton of Plan type 02	 **Figure 111:** Plan type 02	 **Figure 112:** Facade type 02	399.00s

 **Figure 113:** Situaton of Plan type 03	 **Figure 114:** Plan type 03	 **Figure 115:** Facade type 03	400.0sq
 **Figure 116:** Situaton of Plan type 04	 **Figure 117:** Plan type 04	 **Figure 118:** Facade type 04	378.00s
 **Figure 119:** Situaton of Plan type 05	 **Figure 120:** Plan type 05	 **Figure 121:** Facade type 05	344.00s

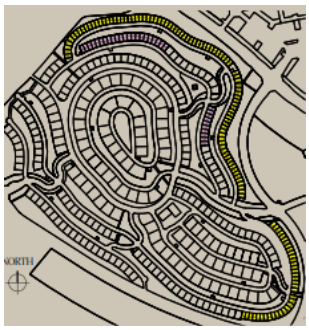
			348.00s
Figure 122: Situaton of Plan type 06	**Figure 123:** Plan type 06	**Figure 124:** Facade type 06	

Table 06: architectural plans disign

Source: fYJ7vJleEZAgu2KUmUaZ.pdf.

➢ Transitional Points :

Architectural Plans Design:

• Spacious villas with 3 to 5 bedrooms.

• Flexible and open interior spaces that allow ample natural light and effective ventilation.

• The design prioritizes privacy and offers a comfortable living environment.

Architectural Facades:

• Based on modern, clean lines with the use of high-quality materials and natural colors that blend harmoniously with the surrounding environment.

• Large windows provide generous natural lighting and improved ventilation, complemented by shading elements that reduce the impact of the region's intense sunlight.

• The facades are designed to balance aesthetics and functionality, with a focus on thermal insulation and energy efficiency.

Sustainability and Comfort:

• The elevated location on the hills offers excellent natural ventilation and panoramic views, contributing to enhanced thermal comfort and reduced energy consumption.

• Integration of green spaces enhances environmental quality.

✓ Synthesis:

The Nawayef Homes project features a luxurious and well-balanced architectural design that merges elegance with comfort, while respecting the natural surroundings of Al Hudayriyat Island hills. With its contemporary facades, the development creates a sustainable residential community that ensures thermal comfort and high levels of privacy.

4. Fourth example: Sustainable City Yas Island

Figure 125: Sustainable City Yas Island

Source: The-Sustainable-City-1.pdf

4.1. Technical sheet:

Developers	Aldar Properties
Total .	Approximately 25 square kilometers
Project concept	A sustainable and environmentally friendly residential community Relying on clean energy and renewable resources.
Location	Yas Island, Abu Dhabi
Unit Type	Apartments (1-3 bedrooms), Townhouses (3-4 bedrooms)
Number of Units	864
Areas	721-3,358 sq ft for apartments, 2,551-3,358 sq ft for townhouses
Sustainability	Solar energy, water recycling, urban agriculture, electric transmis
Amenities	Parks, lakes, swimming pools, sports fields, health club, horse riding center, mosque
Lifestyle	Car-free community, healthy and active environment
Construction begins	in May 2023

Table 07: Technical sheet

Source: The-Sustainable-City-1.pdf

4.3. Reason for choice: This project was chosen firstly because it is a Residential Complex and secondly because it is in arid zone.

4.4. Situation:

City: Yas Island

Geographical location: Abu Dhabi, United Arab Emirates, specifically in Yas North.

Distance: It is located 30 minutes from Abu Dhabi city and its location is characterized by easy access to Abu Dhabi International Airport and the main areas of the city.

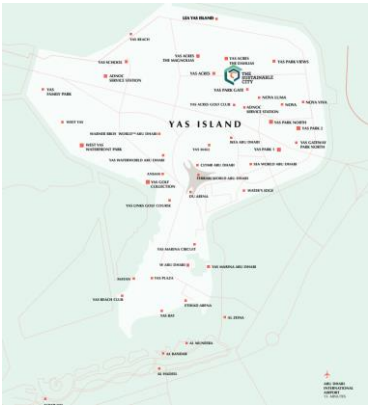


Figure 126: Location Map

Source: The-Sustainable-City-1.pdf

4.6. Plans:

Figure 127: Master plan

Source: The-Sustainable-City-1.pdf

1 to 3 bedroom apartments, 3 to 4 bedroom townhouses

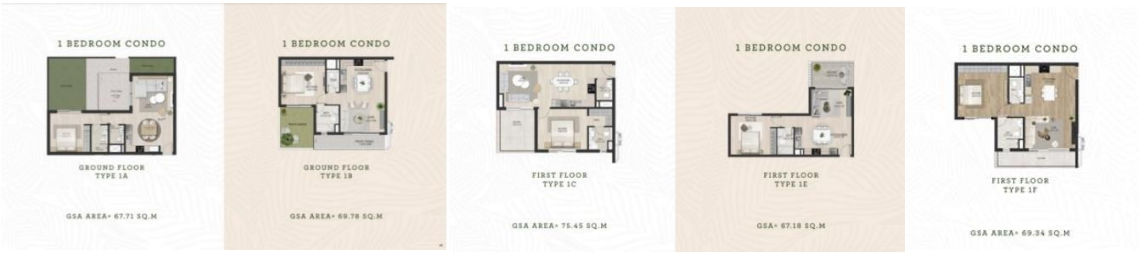


Figure 128: Plan 01 bedroom conbo

Source: The-Sustainable-City-1.pdf

Figure 129: Plan 02 bedroom conbo
Source: The-Sustainable-City-1.pdf

Figure 130: Plan 03 bedroom conbo
Source: The-Sustainable-City-1.pdf

Figure 131: Plan 03 besroom townhouse
Source: The-Sustainable-City-1.pdf

Figure 132: Plan 04 besroom townhouse
Source: The-Sustainable-City-1.pdf

4.7. The facades:

Figure 133: type facade N01
Source: The-Sustainable-City-1

Figure 134: type facade N02
Source: The-Sustainable-City-1.pdf

Figure 135: type facade N03
Source: The-Sustainable-City-1.pdf

4.8. The Roofs:

Clean energy: s'region climate is an opportunity, rooftop solar panels power the whole city to meet most of the community 's needs.

Figure 136: view of rooftop solar panels power

Source: The-Sustainable-City-1.pdf

4.9. Color selection:

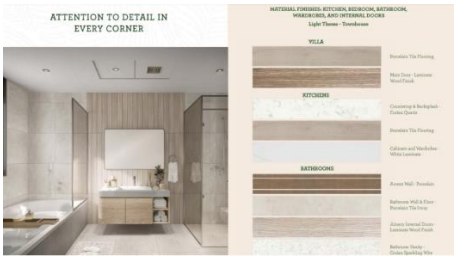


Figure 137: Light theme-townhouse
Source: The-Sustainable-City-1.pdf

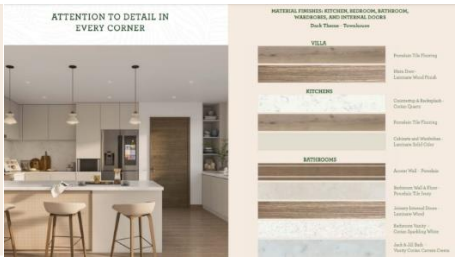


Figure 138: Dark theme-townhouse
Source: The-Sustainable-City-1.pdf

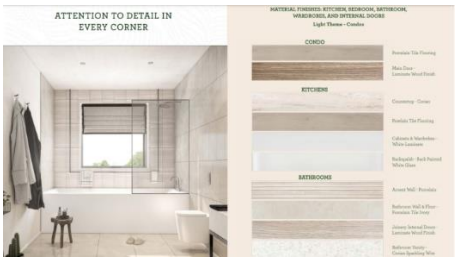


Figure 139: Light theme-condos
Source: The-Sustainable-City-1.pdf

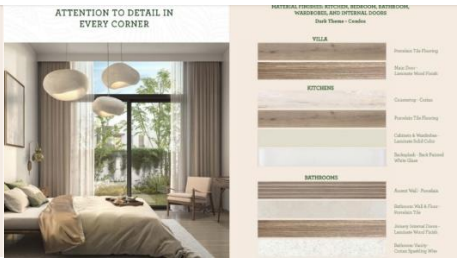


Figure 140: Dark theme-condos
Source: The-Sustainable-City-1.pdf

➢ Transitional Points :

Architectural Plans design:

• A variety of residential units including apartments and townhouses (3–4 bedrooms) with flexible spaces.

• Space distribution focuses on sustainability and comfort.

• High levels of natural lighting and ventilation are provided.

• The residential clusters are designed to be car-free, with dedicated walking and cycling paths to promote clean mobility.

Architectural Facades:

• Integration of smart technologies such as solar panels for energy generation.

• Large windows allow for abundant natural light, combined with shading systems to reduce heat gain.

• The facades strike a balance between aesthetics and functionality, with an emphasis on reducing the carbon footprint.

Roof Systems:

• Equipped with solar panels for renewable energy generation and district cooling systems to minimize energy use for air conditioning.

• Use of green roofs and planted surfaces enhances thermal insulation and helps mitigate the urban heat island effect.

✓ Synthesis :

The Sustainable City – Yas Island represents an integrated model of sustainable architectural design, combining smart space planning, high-performance facades, and renewable energy roof systems. The project achieves significant savings in energy and water consumption, while enhancing residents' quality of life in a healthy and eco-friendly environment.

Synthesis :

	Theoretical Chapter	Analytical Chapte	Recommendations	Transitional Points
Urbain Side	-Individual housing are often located in densely populated areas -Customization Freedom - Climate impact:Rainfall scarcity and high temperatures -Pure and Grouped individual housing	-Integration with Nature:The presence of private gardens and green areas surrounding the villas contributes to creating a comfortable microclimate and protection from direct sunlight -Sustainability and Comfort -Consideration of the Hot and Arid Local Climate: The villa designs take into account sun and heat protection through natural shading and green spaces, reducing the need for mechanical cooling. - Architectural Facades: natural colors that blend harmoniously with the surrounding environment.	- The residential clusters are designed to be car-free, with dedicated walking and cycling paths to promote clean mobility. - Integration of smart technologies such as solar panels for energy generation. - shading systems to reduce heat Gain - Utilizing the surrounding Landscape environment, and facilities to create stunning views - Combating the dry and hot climate through green spaces, fountains, and more.	- Role of intelligent opening Devices in thermal regulation: optimizing the exchange of heat and light between indoor and outdoor environments. Here's how - Use of green roofs and planted surfaces enhances thermal insulation and helps mitigate the urban heat island effect.

Architectural Side	-Smart systems aim to make buildings more sustainable, energy-efficient, andcapable of providing comfortable and healthy indoor environments for users. - How do smart opening devices work: Sensors Capture Environmental Data Data Transmission and Processing Command Execution via Actuators Integration with Building Systems and Remote Control Power Source - small, high-level openings and reflective coatings. -Using deep overhangs, awnings, and louvers - Designing homes with courtyards -Pure and Grouped individual housing	-separation between reception, living, and sleeping areas -Spacious and Open Areas -façade modern -Simple and Elegant Design for Facades -Wide Balconies -Spacious Car Parking -Sustainability and Comfort - Flexible and open interior Spaces - The design prioritizes privacy - Large windows provide generous natural lighting and improved ventilation - Roof Systems:Equipped with solar panels for renewable energy generation and district cooling systems to minimize energy use for air conditioning.	- Passive Design Techniques: Strategic Building Orientation ,Insulation,Ventilation Systems,Use of Thermal Mass, Solar Control Strategies (Shading) ,Cool Roofs,Green Roofs and Waterbodies,Use of Local Materials - Space distribution focuses on sustainability and comfort. - Integration of smart technologies such as solar panels for energy generation. - shading systems to reduce heat gain - Materials	- The role of Smart opening devices: Improved Security,Remote control, Integration with smart home systems, Emergency assistance ,Convenience - Intelligent opening devices: Ease of Use,Reliability, Sustainability ,Enhance security and comfort - Challenges Facing Intelligent Opening Devices:Cost,Cyber security ,Complexity,Software Glitches, Dust and Sand,Power Outages - Intelligent opening provide Thermal Comfort

Intelli-gent Opening Devices	**Type**	-Smart Door,Smart Garage Door, Smart Gate,Smart Window,Smart Facades - Adaptive Facades	- Panoramic Windows - Adaptive Facades -Intelligent mechrabiya - The use of white GRC (Glass Reinforced Concrete) with fiberglass offers high resistance to weathering, reduced weight compared to traditional concrete , and a sleek modern appearance that aligns with the overall design elements.	- Design of Controllable Units	- creates a dynamic facade that responds to user needs and climatic conditions.
	Orienta-tion	- Orienting buildings to minimize east And west-facing windows, which receive intense morning and afternoon sun. Prioritizing north and south-facing windows, as they receive less direct sunlight, especially the north-facing side in the Northern Hemisphere. And easier to shad - Placing windows and vents on Opposite walls to create airflow - The building is oriented to receive the maximum amount of sunlight during the winter to warm the interior, and to minimize exposure to the sun during the summer to reduce heat gain, which contributes to reducing the need for cooling and heating systems.	- shading elements that reduce the impact of the region's intense sunlight. - Natural Light Orientation	- shading systems to reduce heat gain - Natural Light Orientation: The shape and design of the units aim to direct daylight into the interior in a soft and well-distributed manner.	- The shape and design of the units aim to direct daylight into the interior in a soft and well-distributed manner

	Forme	-Smart Windows:Sliding,Bi-folding Pivot -Smart Doors:Sliding,Swing,Revolving, Dutch -Intelligent Façades:Shutters ,Responsive Curtain Walls,Folding -Motorized Garage Doors:Roll-up ,Sectional -Sensor-Activated Panels -Retractable or Hidden Openings: Concealed -Doors,Retractable Glass Walls	- Large windows	- Large windows	- The shape and design can direct and distribute light and ventilation well.

Table 08: Synthesis

Program:

The speces	F05,V01	F05,V02	F04,V01	F04,V02
Garage	35m²	33m²	28m²	25m²
Back yard	140m²	100m²	59m²	54m²
Living-room	50m²	40m²	35m²	34m²
Kitchen	30m²	30m²	28m²	27m²
Lounge	45m²	44m²	37m²	30m²
Bath room	15m²	13m²	10m²	9m²

Guest room	24 m²	23m²	22m²	19m²
Laundry	9m²	8m²	8m²	7m²
Master room	44m²	44m²	35m²	35m²
Bath room	15m²	10m²	7m²	9m²
Bedroom 01	40m²	32m²	30m²	30m²
Bedroom 02	30m²	25m²	/	/
Loggia	30m²	30m²	30m²	30m²
Total	**507m²**	**432m²**	**329m²**	**309m²**

Table 09: Program

❖ Field Analysis

1. Definition of the state

1.1. The site: The state of Biskra is located in the southeast of Algeria, and is considered a link between the east and the west and the north and the south. It is called the bride of Ziban, which is the plural of the word Zab, which means palm oasis. Its area is: 1,024,600 km.

The state's borders :

It is bordered to the north by Batna State

To the northeast by Khenchela State

To the southwest by Ouled Djelal State

To the south by El Oued State

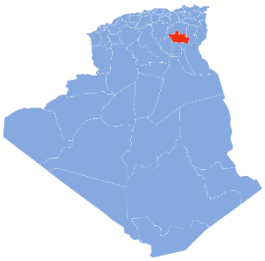


Figure 141: Map showing the location of Biskra in Algeria

Source : المعرفة

Figure 142: Map of Biskra

Source : المعرفة

Figure 143: Aerial photo of Biskra

Source: googleearth

1.2. City limits:

North: Municipality of Al-Wataya and Branis

South: Municipality of Oumache

Southeast: Municipality of Sidi Okbi

East: Municipality of Chtma

West: El Hajeb

1.3. Climate data: The city of Biskra has a hot and arid climate, characterized by very hot summers, which are usually accompanied by winds, and a cold and dry winter.

1.3.1. Temperatures: The average temperature is approximately 23°C, the average maximum temperature is 34.9°C and the average minimum temperature is 11°C (recorded in Biskra in 2018)

months	01	02	03	04	05	06	07	08	09	10	11	12	Average
Temperatures	13	16.2	16.9	22.3	27.4	25.1	36.4	36.7	31.9	23.5	16.4	12.5	24

Table 10: Temperatures in Biskra

Source: Monograph of Biskra Province 2021

1.3.2. Precipitation: Regarding rainfall rates over the last 25 years, Biskra is located in the 200-0 mm zone, except for mountainous areas or rainy years.The following is the amount of rainfall that fell during the year 2021, estimated at 48.8 mm, which is a small amount when compared to previous years.

months	01	02	03	04	05	06	07	08	09	10	11	12	Average
Amount of rainfall (mm)	0. 2	0	2	11	15	1. 4	0	1. 6	6	4. 4	5. 2	2	48. 8

Table 11: Average rainfall in Biskra

Source: Monograph of Biskra Province 2021

1.3.3. Humidity: The highest humidity rate is recorded in December, which does not exceed 50 (daily humidity rate), and the lowest humidity rate is recorded in July, with a value of 19

months	01	02	03	04	05	06	07	08	09	10	11	12	Average
Humidity ratio	43	38	38	35	36	20	19	21	32	39	53	49	35

Table 12: Humidity Rate in Biskra

Source: Monograph of Biskra Province 2021

1.3.4. Winds: The Biskra region experiences several types of winds throughout the year. We find strong winter winds coming from the northwest which come from the high plains (causing an increase in humidity), and seasonal winds (the prevailing winds) which are represented by hot sandy winds in the spring coming from the south or southwest, in addition to the sirocco winds in the summer which are hot winds coming from the southeast.

months	01	02	03	04	05	06	07	08	09	10	11	12	Average
Wind force (m/s)	4. 4	4. 3	3. 4	3. 9	3. 4	4. 5	3. 6	3. 6	3. 6	3. 1	3. 8	3. 4	3. 7

Table 13: Average wind speed in Biskra

Source: Monograph of Biskra Province 2021

2. Ground:

2.1. The location of the land in relation to the city: The project land is located in the western region of the city of Biskra, specifically in the new urban pole (a new urban expansion area), near National Road No. (3) which connects the state of Batna and the center of the city of Biskra, and it is a land designated for a commercial center according to the land use plan.

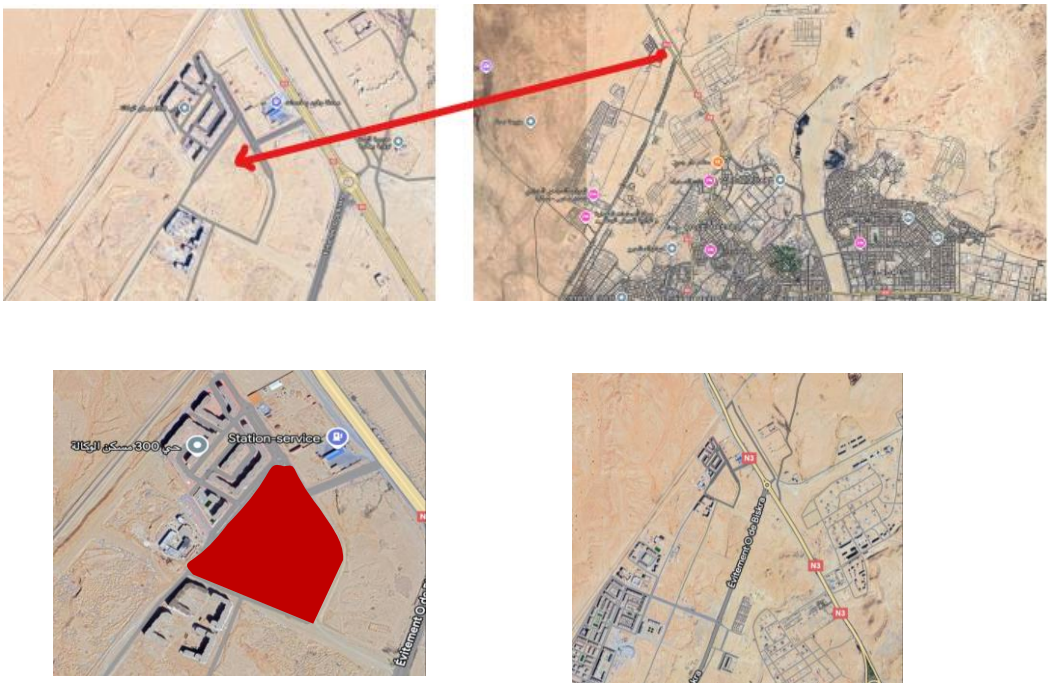


Figure 144: Aerial photo of site

Source: googleearth

2.2. The land and the surrounding area: The site is located in an urban area that is considered strong. To the north there is a gas station and services

A neighborhood of 300 housing units

Figure 145: The gas station

Figure 146: 300 housing units

In the west, there is an elementary school and a collective housing complex.

Figure 147: housing units

Figure 148: 300 housing units

Figure 149: primary schools

2.3. Accessibility: The land has direct access, as we can reach it from National Road No (03)

Figure 150: Aerial photo of site

Source: googleearth

Main Road (National Road No. 03)

Secondary road

Figure 151: Aerial photo of site

Figure 152: Actual photos from the project site

Figure 153: Aerial photo of site

Source: googleearth

Figure 154: Actual photos from the project site-1-

Figure 155: Aerial photo of site

Source: googleearth

Figure 156: Actual photos from the project site-2-

Figure 157: Aerial photo of site

Source: googleearth

Figure 158: Actual photos from the project site-3-

Figure 159: Aerial photo of site

Source: googleearth

Figure 160: Actual photos from the project site-4-

2.4. Morphological and topographical study of the soil:

Floor shape: The floor has an irregular shape

Nature of the floor: There is a slight slope in the floor (Almost flat)

Area: 38000 m²

2.5. Solarization: The floor is completely exposed to the sun throughout the day, due to the absence of urban barriers, in addition to the absence of natural barriers.

Figure 161: Aerial photo of Biskra

Source: googleearth

2.6. Wind: The ground is exposed to harmful winds throughout the year.

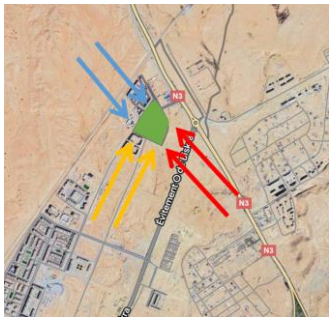


Figure 162: Aerial photo of Biskra

Source: googleearth

Cold wind

Hot wind

Sand wind

2.7. Perimeter Facades of the Site:

Figure 163: The southern façade of the project site

Figure 164: The northern façade of the project site

Figure 165: The eastern façade of the project site

Figure 166: The western façade of the project site

2.8. Advantages:

• Direct access to the land (National Road No. (03

• The topography of the land is good and almost flat, which facilitates the project design process.

• The site is located in a newly developed urban expansion area.

• The site is located in an area that has recently seen the development of several collective housing complexes.

• As a result, public facilities such as primary schools, football fields, and other amenities have been provided.

• The area includes commercial shops that cater to daily needs and enhance the livability of the neighborhood.

2.9. Disadvantages:

• Climatic factors (the land is completely exposed to the sun and wind)

• Absence of green spaces and the preparation of external areas for the study area

Conclusion:

This analytical chapter has provided a critical examination of four diverse architectural projects—The Address Hillcrest Villas (Dubai Hills Estate), Ventura House (Brazil), Nawayef Homes (Hudayriyat Island, Abu Dhabi), and The Sustainable City (Yas Island)—all of which demonstrate contextually adapted strategies involving intelligent openings and climate-responsive design. Through this comparative analysis, key principles have emerged, such as the importance of orientation, the integration of passive and active systems, the balance between privacy and openness, and the role of intelligent façades in enhancing environmental performance. Despite differences in geographic location and scale, all examples reveal how smart openings—whether motorized louvers, dynamic shading, or operable façades—can be leveraged to improve thermal comfort and reduce energy demand, especially when adapted to specific climatic and cultural contexts.

The analysis of the project site in Biskra further reinforced the relevance of these strategies. By understanding the site's climatic conditions, urban surroundings, and functional potentials, a clear vision began to emerge regarding the types of architectural interventions most suitable for a hot and arid Algerian environment. Key strengths such as solar exposure and spatial openness were identified as

opportunities, while challenges like high temperatures and privacy constraints were addressed through informed architectural decisions.

Based on the findings, several recommendations can be drawn: the need to prioritize passive ventilation enhanced by smart systems, the potential of integrating locally inspired elements such as mashrabiyas into modern design, and the importance of user-oriented adaptability in housing. These conclusions provide a strong foundation for transitioning into the design phase of the research. The next chapter will translate these analytical insights into a comprehensive architectural proposal, exploring how intelligent openings can be effectively embedded in a housing model tailored to the specific climatic, cultural, and spatial realities of arid regions like Biskra.

❖ Conceptual chapter

Introduction:

Following the analytical phase of this research, which identified key strategies and contextual requirements for integrating intelligent openings in individual housing within arid regions, this chapter presents the development of the architectural concept for the proposed project. The design idea emerges as a direct response to the climatic, cultural, and functional parameters explored previously, while also drawing inspiration from two emblematic architectural precedents that exemplify the successful integration of responsive façade systems.

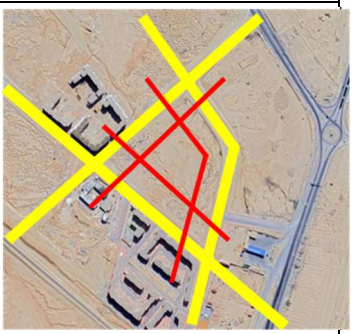
The first source of inspiration is the Arab World Institute in Paris, renowned for its innovative use of mechanical mashrabiyas—a modern reinterpretation of the traditional Islamic screen—capable of adjusting to light conditions through a dynamic diaphragm system. The second is the Al Bahr Towers in Abu Dhabi, where a kinetic façade based on the mashrabiya principle enhances solar control and energy efficiency while reflecting regional identity. These two references offered not only technical insight but also a conceptual foundation for bridging tradition and technology in a meaningful architectural language.

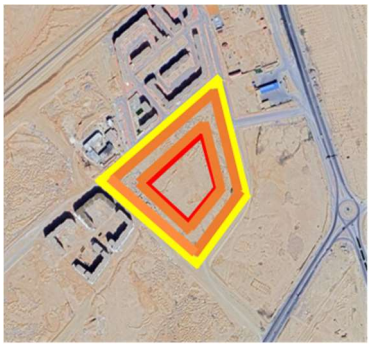
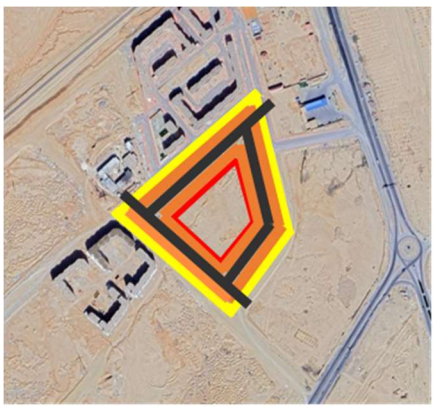
In this chapter, the conceptual design is presented in a structured and detailed manner. The idea is rooted in the reinterpretation of the mashrabiya as a smart environmental interface, adapted to the domestic scale and reimagined through geometry, movement, and materiality. The design responds to the local context of Biskra, aiming to optimize passive cooling, control solar exposure, and maintain privacy—while offering a spatial experience that is both contemporary and culturally resonant.

This section details the evolution of the concept, from its conceptual genesis to its architectural translation, through diagrams, sketches, and narrative explanations that clarify the design logic and its relation to the research objectives.

1. Conceptual design

Table 14 : Conceptual design

Phase	Conceptual design	Layout
01	The project has been well integrated into the urban fabric in which it is located, This was achieved by creating axes that run parallel to the surrounding urban grid lines of the project site, as illustrated in the site plan.	  **Figure 167:** The existing site axes **Figure 168:** The axes we created

02	A central space was created at the heart of the site to serve as the main courtyard of the project, intended to accommodate the landscape design	 **Figure 169:** The central courtyard
03	The villas were positioned along the site's existing outer axes, and additional villas were placed along the newly generated axes derived from those original ones. These were arranged in a mirrored layout, resulting in the villas occupying the perimeter of the site.	 **Figure 170:** Peripheral placement of villas
04	As for circulation, mechanical circulation was restricted to the areas between the villas only, ensuring that the central zone of the site remains free from mechanical traffic. This strategy was implemented to enhance safety, maintain a clean environment, and create a pedestrian-friendly core where only foot traffic is allowed.	  **Figure 171:** Mechanical circulation **Figure 172:** Pedestrian circulation
05	Regarding the entrances, their orientation was based on the surrounding road network. The main entrance was directed towards the access road that connects to National Road No. 03. Additionally, two secondary roads were designated to reduce pressure on the main entrance and to facilitate circulation. Each of	 **Figure 173:** The entrances

	the two secondary entrances was oriented toward a separate secondary road.	

2. Concept :

2.1. First: at the level of urban planning (the overall massing of the project):

2.1.1. Prior to the pre-defense presentation:

2.1.1.1. Fenced plot: Fencing is used to clearly define the plot boundaries, enhance security, control access points, and preserve residents' privacy. It also serves as a first barrier against harsh climatic conditions in arid zones, such as wind and sand."

Figure 174: A massing plan indicating the fenced plot

2.1.1.2. The central courtyard as a unifying element: The central courtyard of the complex featured a mechanical circulation system enabling vehicles to reach the inner core of the site.

Vehicle access was allowed into the heart of the complex through a controlled mechanical movement system integrated within the central courtyard.

Figure 175: A massing plan indicating the mechanical circulation and pietone

2.1.1.3. Orientation of the main entrances of the villas: They were uniformly directed toward the site's central courtyard.

Figure 176: A massing plan indicating the orientation of the main entrances of the villas

2.1.2. Following the pre-defense presentation:

2.1.2.1. Intelligent Security Fence: The intelligent security fence is an integrated protection system used to secure sensitive or private sites. It is not merely a physical barrier, but rather incorporates advanced technology capable of detecting any intrusion attempts or unusual contact.

Figure 177 : Intelligent Security Fence

Source : https://www.perimtec.com/

2.1.2.2. Roads and entrances:

• The main entrance is oriented toward the primary road (National Road No. 3), giving the complex a clear identity.

Figure 178: The main entrance

• Secondary entrances are placed along secondary roads to serve residents, improve circulation, and reduce pressure on the main entrance.

Figure 179: Secondary entrances

2.1.2.3 Peripheral placement of villas:

Figure 180: Peripheral placement of villas

• Allows inward openness toward the courtyard without compromising privacy.

• Reduces noise from surrounding roads.

• Keeps the project's core free for a shared central courtyard for nature and communal activities.

• Maximizes space efficiency with minimal waste.

• Creates a functional and visual transition from public to private spaces.

2.1.2.4. The central courtyard as a unifying element:

Figure 181: The central courtyard of project

• Helps create a pleasant microclimate by enhancing thermal comfort, shade, humidity, and greenery.

• Strengthens the sense of community and reduces isolation within the gated complex.

• The central courtyard are designed to be car-free, with dedicated walking and cycling paths to promote clean mobility.

Figure 182: Pedestrian and mechanical circulation of the project

• Reconfiguring the main villa entrances to be positioned opposite one another.

Figure 183: The main villa entrances

2.2. Secondly: At the scale of the villas (housing blocks):

• Avariety of villa types meets the diverse needs of residents in terms of family size and lifestyle (F4/F5).

• Tow design variations per type help maintain visual balance and architectural diversity, avoiding monotony.

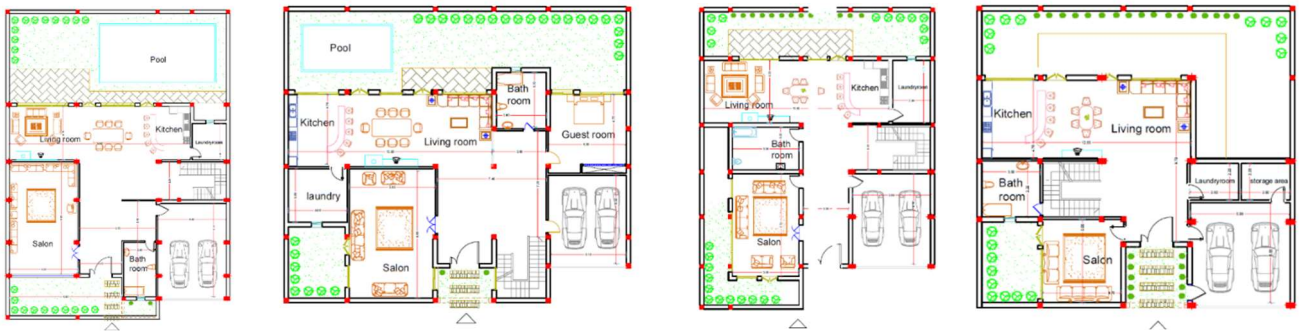


Figure 184: Architectural plans design

• Local or culturally inspired design elements such as mashrabiyas can be integrated.

Figure 185: Mashrabiya

Source: https://www.scribd.com/

• Narrow façades facing the sun, strategically placed windows, deep shading, and balconies enhance climate response.

• Use of consistent materials and color palette

• The integration of traditional and modern forms.

• To maintain facade coherence and project unity, the same architectural elements will be employed across the various elevations of the project. These elements will be strategically reinterpreted and differently distributed on each facade to preserve a consistent architectural language while introducing visual diversity

. This approach enhances the aesthetic appeal, reinforces the project's identity, and ensures a harmonious integration of all built components within a unified design framework.

Figure 186: Modern style of Mashrabiya (Intelligent Mashrabiya)

Source : https://www.ahr.co.uk/

3. Implementation the topic in the project: we inspired from 2 examples (Kinetic Architecture)

3.1. "Institut du Monde Arabe" designed by Jean Nouvel:

Figure 187: Institut du Monde Arabe

Source : https://www.alquds.co.uk/

3.1.1. General Concept of the Facade:

• The south-facing facade of the building is inspired by the Mashrabiya (Moucharabieh), a traditional Arabic architectural element used to control the entry of light and air while preserving privacy.

• This tradition has been transformed into a contemporary intelligent system composed of 240 movable diaphragms, each measuring 180×180 cm, forming a complex lattice that entirely covers the glazed facade.

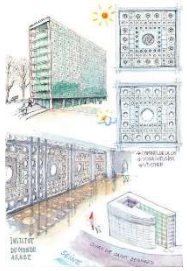


Figure 188: Sketch of the details of façade

Source: https://www.flickr.com/photos/aidibus/

3.1.2. Smart Operating Mechanism:

• Each Mashrabiya unit functions as a mechanical aperture, similar to a camera lens, that opens and closes to regulate the amount of light entering the building.

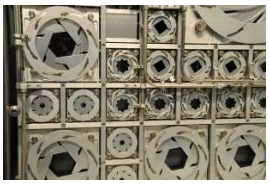


Figure 189: A close-up of the mashrabiya units from the inside

source: https://mjaf.journals.ekb.eg/article_20441_c1ac774b3ebecfeb5e97321f08f2df9a.pdf

Figure 190: A close-up of the mashrabiya units from the outside

source: https://moremorexless.blogspot.com/2017/01/arab-world-institue.html

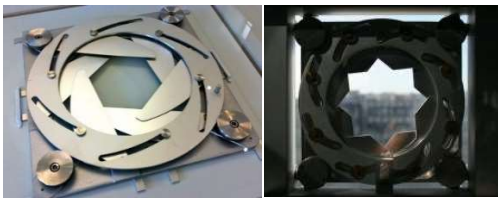


Figure 191: Form of a unit of mashrabiya

Source: https://www.researchgate.net/

• These apertures are controlled by small electric motors linked to light sensors that monitor the intensity and direction of solar radiation.When solar intensity is high, the diaphragms close to reduce heat gain and glare.

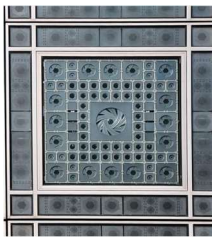


Figure 192: The shape of the facade from the inside when the diaphragms are closed

Source: https://www.aaciaegypt.com/

Figure 193: The shape of the facade from the outside when the diaphragms are closed

Source: https://seaf.journals.ekb.eg/article_383989_aaab7d6973a0fcf0046daa5ec2689605.pdf

• When intensity drops, they open to allow natural daylight in, creating a pleasantly lit interior environment.

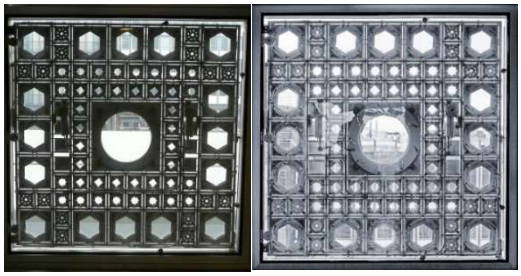


Figure 194: The shape of the facade from the inside when the diaphragms are opened

source: https://arch-news.net/

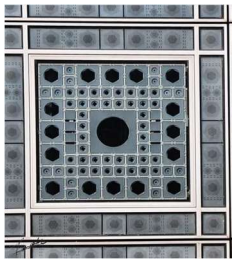


figure 195: The shape of the facade from the outside when the diaphragms are opened

source: https://www.aaciaegypt.com/

• This system achieves an ideal balance between natural lighting, thermal comfort, and privacy, while reducing the need for mechanical cooling and artificial lighting.

Figure 196: The effect of this opening on the distribution of natural lighting in the spaces of the institute

Source: https://www.arc.ulaval.ca/files/arc/Jean_Nouvel.compressed.pdf

3.1.3. Visual and Architectural Impact:

• The facade is constantly in motion throughout the day. The diaphragm shapes shift between squares, circles, and octagons, creating a dynamic and aesthetic visual effect that reflects Arab cultural heritage in a contemporary expression.

• This movement adds vitality to the building, making it an architectural landmark that harmonizes modernity with tradition.

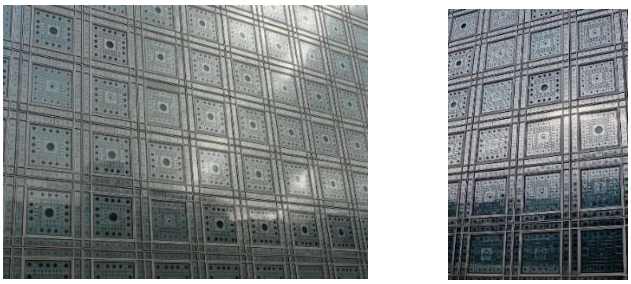


Figure 197: The facade during the day

Source: https://www.arc.ulaval.ca/files/arc/Jean_Nouvel.compressed.pdf

Figure 198: The facade in the evening

Source: https://www.arc.ulaval.ca/files/arc/Jean_Nouvel.compressed.pdf

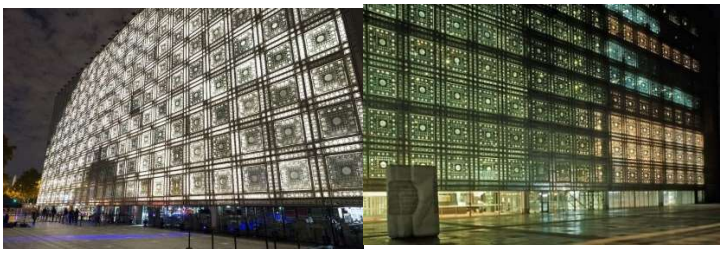


Figure 199: The facade photo at night

Source: https://blogdabilokaeblogdaarte-biloka.com/

3.1.4. Materials and Technologies:

• The Mashrabiya units are made of aluminum, chosen for its lightweight, weather resistance, and high manufacturing precision, ensuring smooth and reliable movement.

Figure 200: The Mashrabiya units

Source : https://www.arc.ulaval.ca/files/arc/Jean_Nouvel.compressed.pdf

• The glazed facade behind the Mashrabiya is double-glazed, offering high thermal and acoustic insulation, which enhances the building's energy efficiency.

Figure 201: The glazed facade behind the Mashrabiya

Source: https://www.archdaily.com/

3.1.5. Environmental and Functional Benefits:

• Energy Efficiency: Significant reduction in solar heat gain, leading to lower cooling energy consumption.

• Enhanced Light Quality: Even distribution of natural light within indoor spaces, reducing glare and improving visual comfort.

• Privacy: Effective shielding from external views while maintaining outward visibility.

• Natural Ventilation: A design that allows airflow while controlling heat penetration.

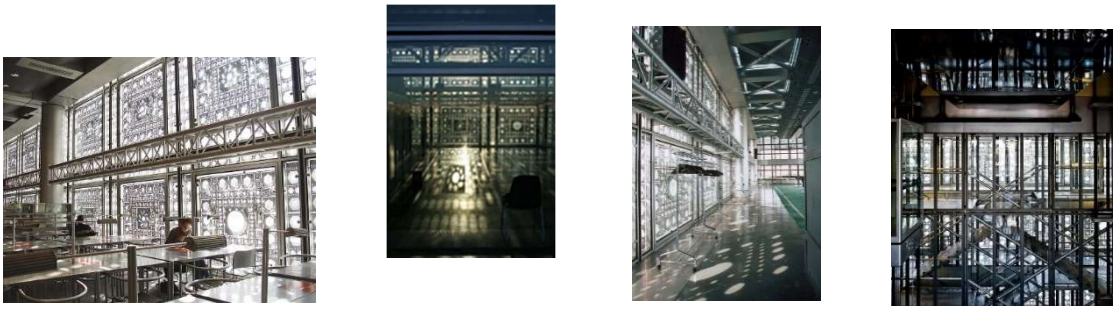


Figure 202: The effect of this opening on the spaces of the institute

Source: https://blogdabilokaeblogdaarte-biloka.com/

✓ **Synthesis:**

The facade of the Institut du Monde Arabe represents a unique integration of Arabic heritage and modern architectural technology. It utilizes an intelligent Mashrabiya system composed of automated diaphragms that control light and heat penetration, achieving high thermal comfort, privacy, and energy savings, while delivering a distinct architectural identity with a dynamic visual effect.

3.2. The Al Bahr Towers project in Abu Dhabi:

3.2.1. Concept and Architectural Design of the Facade:

• The façade of Al Bahr Towers draws inspiration from the "mashrabiya", a traditional Arabic architectural element consisting of intricately carved wooden screens that provide shading and privacy while allowing the passage of light and air.

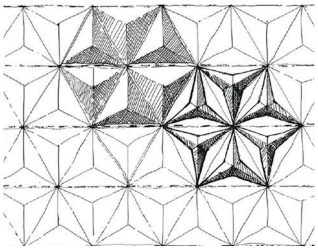


Figure 203: Mashrabiya diagram

Source: https://www.ahr.co.uk/projects/al-bahr-towers

• The facade is a secondary skin, set approximately two meters away from the primary glazed envelope of the building. It consists of around 2,000 triangular units, each covered with perforated fiberglass panels.

Figure 204: Close-up of the façade

Source : https://www.ahr.co.uk/projects/al-bahr-towers

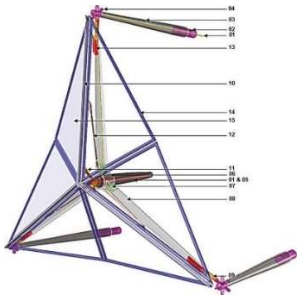


figure 205: Triangular unit

Source : https://www.ahr.co.uk/projects/al-bahr-towers

(This concept was also mentioned earlier in the Ventura House example.)

3.2.2. Smart Operational Mechanism (Dynamic Shading Elements):

• Each triangular unit functions as an automated shading device, capable of opening and closing in response to the sun's position and intensity. These shading panels move along the tower's surface to provide real-time solar protection and reduce direct solar gain.

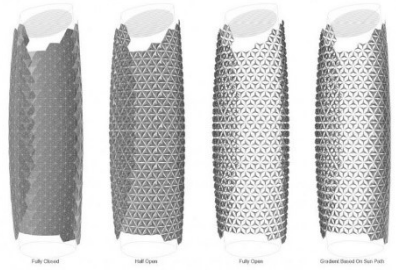


Figure 206: Schematic diagram showing the closing and opening of the triangular facade units.

Source: https://www.scribd.com/

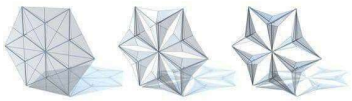


Figure 207: A diagram showing the closing and opening of a triangular unit close up

Source: https://www.scribd.com/

• The movement of these units is controlled by the Building Management System (BMS), which relies on sensors that monitor the intensity and direction of sunlight.
During the day, the units open to reduce solar heat gain by up to 50%, thereby minimizing the need for mechanical cooling and reducing energy consumption.

Figure 208: Realistic photo showing an open unit

Source: https://www.ahr.co.uk/projects/al-bahr-towers

Figure 209: Realistic photo showing an open unit up close

Source: https://www.ahr.co.uk/projects/al-bahr-towers

- At night or when the sun is not present, the units retract to fully expose the glazed façade, offering unobstructed views and allowing natural light to enter.

Figure 210: Realistic photo showing a closed unit

Source: https://www.ahr.co.uk/projects/al-bahr-towers

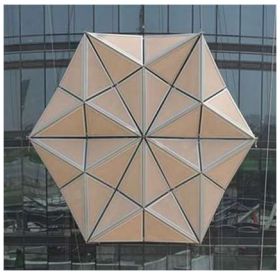


Figure 211: Realistic photos showing a closed unit up close

Source: https://www.ahr.co.uk/projects/al-bahr-towers

- The facade changes shape every 15 minutes.

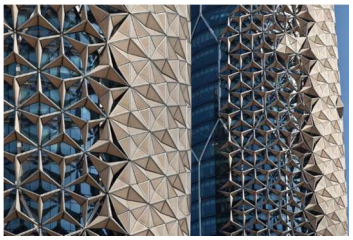


Figure 212: Realistic image of the facade shape change

Source: https://www.ahr.co.uk/projects/al-bahr-towers

Figure 213: Realistic image showing the units opening towards the sun and the units closing towards the shade

Source: https://www.ahr.co.uk/projects/al-bahr-towers

3.2.3. Environmental and Functional Benefits:

• Heat Gain Reduction: The dynamic shading system helps minimize internal temperature rise, enhancing thermal comfort and reducing energy loads for air conditioning.

• Improved Daylight Quality: The façade diffuses daylight softly throughout the interior spaces, reducing reliance on artificial lighting and minimizing glare.

• Privacy and Ventilation: The system enhances privacy while allowing air to circulate, promoting natural ventilation.

• Integration of Renewable Energy: The south-facing roof areas are equipped with photovoltaic panels, generating around 5% of the building's total energy needs, mainly for domestic hot water production.

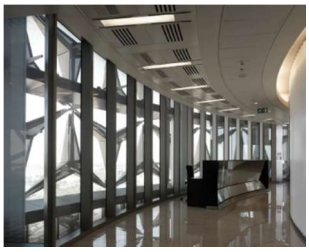


Figure 214: The effect of this kinetic facade on the spaces of the institute

Source: https://www.ahr.co.uk/projects/al-bahr-towers

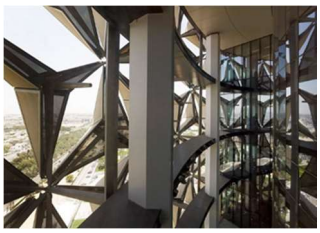


Figure 215: The effect of this kinetic facade on the spaces of the institute

source: https://www.ahr.co.uk/projects/al-bahr-towers

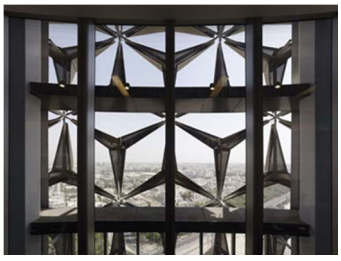


Figure 216: The effect of this kinetic facade on the spaces of the institute

source: https://www.scribd.com/

3.2.4. Components of the External Envelope:

• Dynamic Shading Elements: Made of perforated fiberglass panels, each unit is motorized for precise movement.

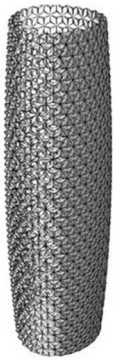


Figure 217: Dynamic Shading Elements

Source: https://www.scribd.com/

• Independent Support Frame: Holds the shading elements separately from the main glass façade, maintaining structural integrity and enabling free movement.

Figure 218: Independent Support Frame

Source: https://www.scribd.com/

Figure 219: Independent Support Frame up close

Source: https://www.scribd.com/

• Primary Glazing: A double-glazed curtain wall system, providing high thermal and acoustic insulation.

Figure 220: Primary Glazing

Source: https://www.scribd.com/

3.2.5. Architectural Outcome:

• The integration of traditional design principles with advanced technology in the dynamic façade system makes Al Bahr Towers a pioneering example in sustainable architecture.

• The building envelope achieves a balance between aesthetics, thermal performance, and environmental functionality, contributing to significant energy savings while enhancing user comfort.

Figure 221: View of the facade during the day

Source: https://www.ahr.co.uk/projects/al-bahr-towers

Figure 222: View of the facade during the evening

Source: https://www.ahr.co.uk/projects/al-bahr-towers

✓ **Synthesis**:

The Al Bahr Towers envelope is a smart, dynamic façade system inspired by the traditional mashrabiya, composed of thousands of responsive glass elements that open and close automatically to regulate sunlight and internal heat. This innovative approach results in significant energy savings, improved thermal comfort, and enhanced privacy, while preserving the project's architectural identity and elegance.

4. In my project:

• In "loggia" the concept of the intelligent mashrabiya from the Bahrein Towers project will be applied to the bedroom windows and glazed façades.

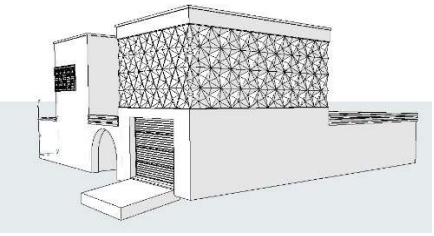


Figure 223: A 3D view illustrating the integration of the mashrabiya into the project. In the loggia

• For the bedroom windows and glass façades, the smart mashrabiya system inspired by the Institut du Monde Arabe will be implemented.

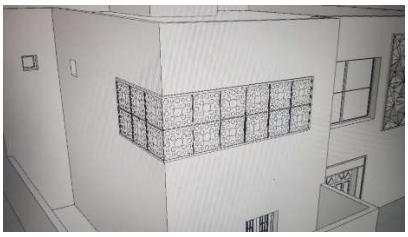


Figure 224: A 3D view illustrating the integration of the mashrabiya into the project. In the villa windows

• As for the bathroom windows, they will be integrated into the wall,

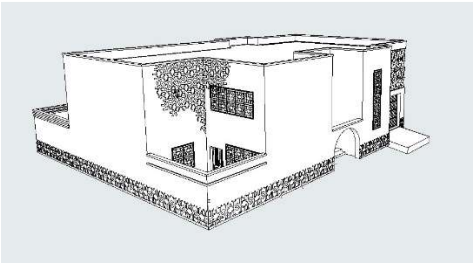


Figure 225: A 3D view illustrating the integration of the mashrabiya into the project. In the bathroom windows

• Avariety of villa types meets the diverse needs of residents in terms of family size and lifestyle (F4/F5).

• Two design variations per type help maintain visual balance and architectural diversity, avoiding monotony.

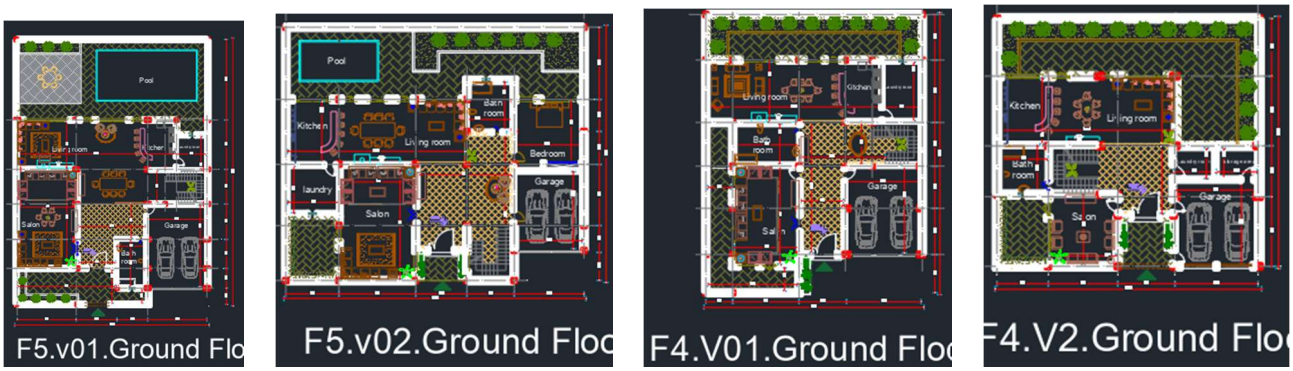


Figure 226: Different architectural drawings

• Integrating traditional and modern forms by combining contemporary architectural elements with design features inspired by local culture, such as mashrabiyas and arches.

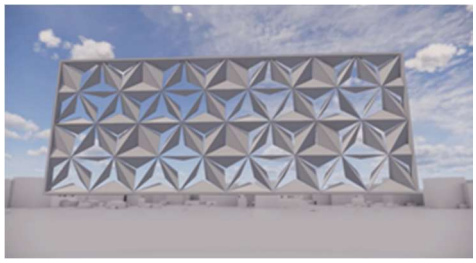


Figure 227: A 3D view of the mashrabiya used in the loggia

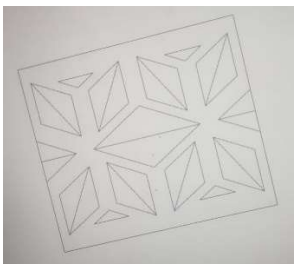


Figure 228: The mashrabiya used in the windows

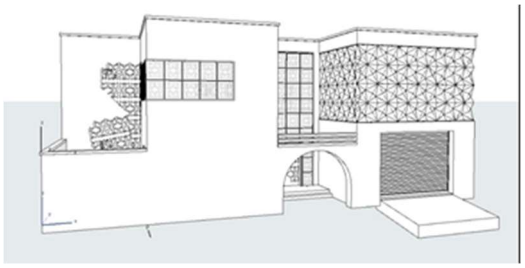


Figure 229: A 3D view of the integrated elements in the project

• **The materials:**

In the intelligent mashrabiya of "loggia": The Mashrabiya units are made of aluminum, chosen for its lightweight, weather resistance, and high manufacturing precision, ensuring smooth and reliable movement.

"Due to its Lightweight":

Aluminum is one of the lightest structural metals, which helps reduce the load on the façade or the mounting system. It also facilitates the mechanical movement of the mashrabiya, whether it slides, rotates, or opens and closes. This lightweight property also eases installation and maintenance processes.

"Weather Resistance":

Aluminum is corrosion-resistant and can withstand harsh environmental conditions, such as:

Intense solar radiation

Rain and humidity

Wind and dust

This makes it ideal for exterior applications, especially in arid or extreme climates.

"High Manufacturing Precision":

Aluminum can be precisely fabricated and shaped using advanced techniques like laser cutting, casting, or CNC machining. This precision is crucial in smart mashrabiya systems to ensure that:

Each unit operates smoothly without friction or malfunction.

There is no unintended infiltration of light or air when closed.

The geometric form remains consistent and aesthetically refined.

"Ensuring Smooth and Reliable Movement":

All the above characteristics contribute to a system that functions efficiently, without frequent breakdowns or resistance. Smooth movement refers to easy, uninterrupted operation, while reliability means long-term performance with minimal maintenance requirements.

For the bedroom windows and glass façades: GRC (Glass Fiber Reinforced Concrete) is a composite material made of a cementitious mix reinforced with alkali-resistant glass fibers. It is widely used in contemporary architectural applications, especially for building façades and intricate decorative elements.

Properties of GRC:

"Lightweight":

Significantly lighter than traditional concrete, making it ideal for façade applications without overloading the structure.

"Strength and Durability":

Despite its lightweight nature, GRC offers good mechanical strength and can withstand various environmental stresses.

"Flexibility in Molding":

It can be easily molded into complex shapes, allowing for creative and detailed architectural designs—such as mashrabiya units.

"Weather Resistance":

It resists humidity, heat, UV rays, and wind, making it suitable for exterior applications, especially in hot and arid climates.

"Sustainable and Eco-Friendly":

GRC contains low cement content and is recyclable, contributing to a reduced environmental footprint.

Conclusion :

This chapter has outlined the conceptual framework of the proposed architectural project, developed in direct response to the environmental, cultural, and functional challenges identified in previous chapters. The design draws inspiration from exemplary projects such as the Arab World Institute in Paris and the Al Bahr Towers in Abu Dhabi, where the reinterpretation of the traditional mashrabiya as a smart, dynamic system has proven both environmentally effective and culturally expressive.

Through this concept, the project aims to integrate intelligent opening systems not merely as technological features, but as architectural elements embedded in the overall spatial and environmental strategy. The reinterpretation of the mashrabiya within the design ensures privacy, regulates light and ventilation, and reinforces a regional identity adapted to the contemporary domestic context of Biskra.

The detailed explanation of the design intent, its spatial logic, and its environmental responsiveness lays the foundation for the next chapter, which will translate this concept into architectural reality through detailed plans, sections, façades, and technical systems. The following phase will demonstrate how the

conceptual idea evolves into a coherent architectural proposal that fulfills the research objectives of sustainability, thermal comfort, and cultural integration in arid-zone individual housing

Annex :

The plans :

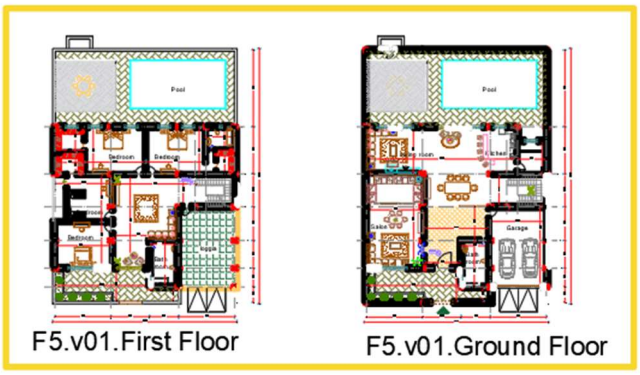


Figure 01 : architectural design for F5 V1

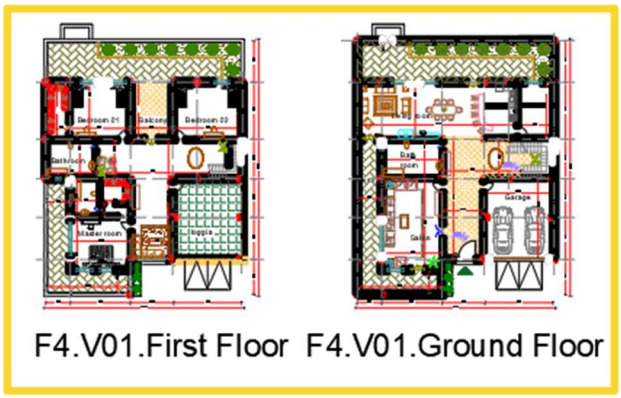


Figure 02 : architectural design for F4 V1

Figure 03 : architectural design for F5 V2

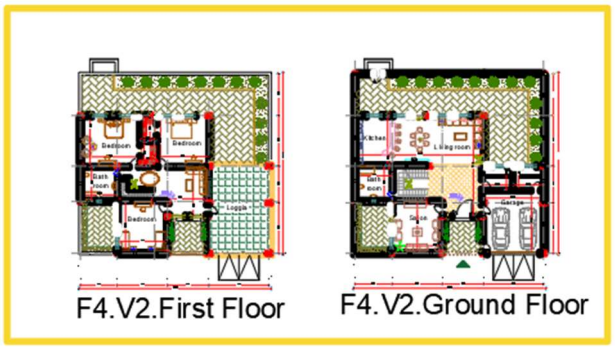
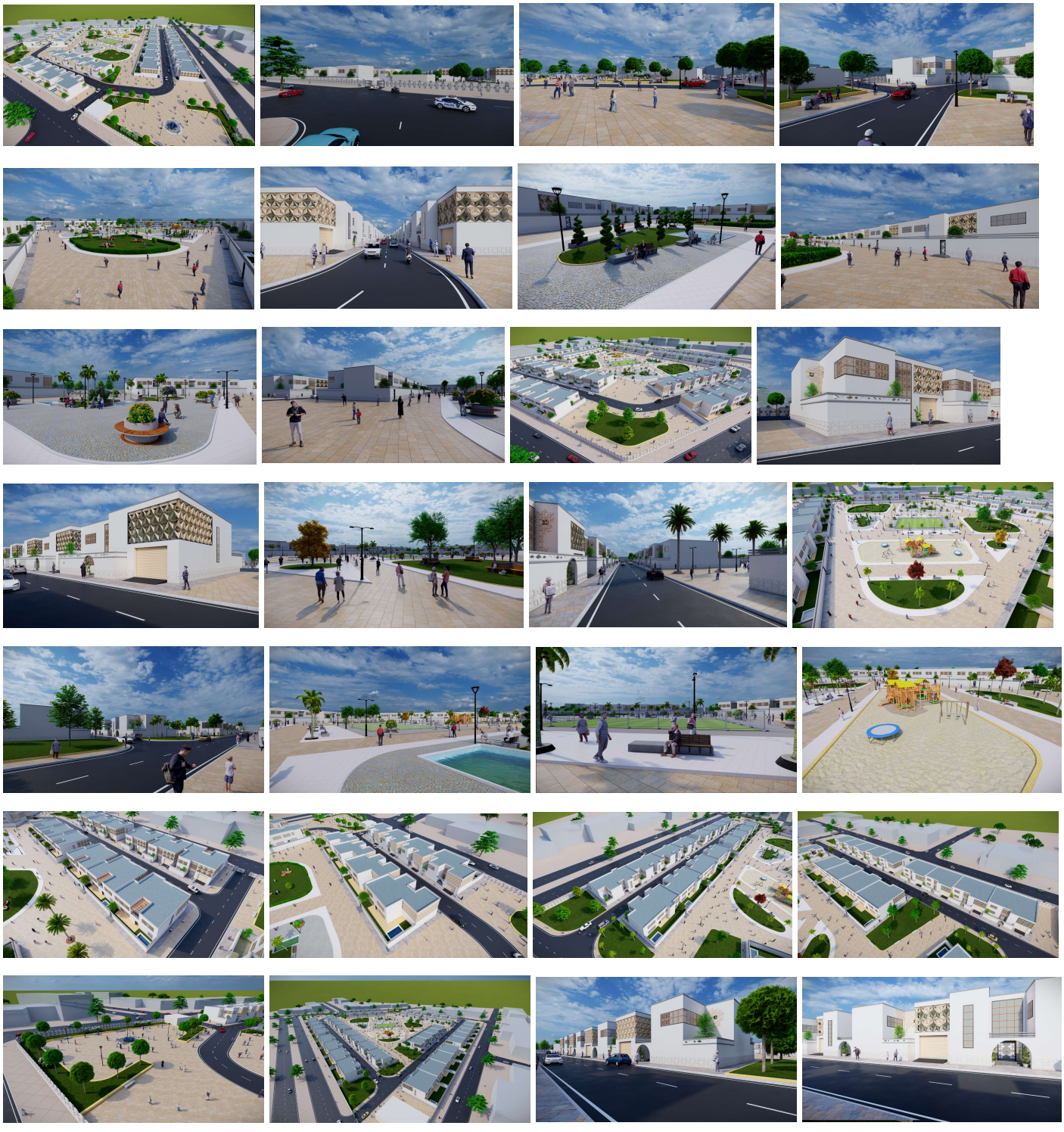


Figure 04 : architectural design for F4 V2

Figure 05 : massing plan

Exterior views :



Interior views :

Figure 06 : the shape of the mashrabiyah from the inside

Figure 07 : views interior from the villas

The facades :

Figure 08 : principal facades

Figure 09 : secondry facades

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