ALGERIAN DEMOCRATIC AND PEOPLE'S REPUBLIC
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

SAAD DAHLEB UNIVERSITY OF BLIDA - 01 -
ARCHITECTURE AND URBAN PLANNING INSTITUTE
Department of Architecture

Master's thesis in Architecture

Workshop theme: Environment, technology and architecture

Designing a commercial and entertainment center with a cultural souk experience, by achieving sustainable development through ensuring thermal comfort and cultural preservation in arid regions. Case of Laghouat city

Presented by:
BENELHOCINE Naïda Mey, 161632034436
BENOUARED Lina Ikram, 0918141BE01

Group: 01
Supervised by:
Dr. BOUKARTA Soufiane Dr.
ATTIK Tarek
Jury members:
Dr. KHELIFI Lamia (MCB)
Mme. DROUCHE Aicha (MAA)

Academic year: 2022/2023

Acknowledgment

I am immensely grateful to my family, friends, our and Laghouat's Architecture and Urban planning Institute professors (Pr. BOUKARTA. S, Pr. ATIK. T, and all professors we had the chance to meet in Laghouat) , mentors, and staff for their unwavering support throughout my studies, and especially this year. Your love, encouragement, and guidance have been instrumental in my success. The camaraderie, shared experiences, and diverse perspectives of my classmates and study groups have enriched my education. I am also thankful to the authors, researchers, and scholars whose work has expanded my knowledge.

Lastly, I want to extend a special thank you to myself and my partner and my friend BENOUARED L.I, for believing in ourselves. Through the ups and downs of this journey, we have persevered, remained dedicated, and pushed myself to achieve our goals. The self-belief we have cultivated has been a driving force in our accomplishments, and I am proud of the person, me and her, have become.

Completing my university studies has been transformative, and I am honored to have had such incredible individuals, including myself, by my side.
With heartfelt appreciation,

BENELHOCINE Naïda Mey

I would like to express my sincere gratitude to my supervisors, Dr. Boukarta Soufiane and Dr. ATTIK Tarek for their constant support and guidance throughout this project. Their expertise, knowledge, and patience have been invaluable to us. I am also grateful to those who were involved in this project, directly or indirectly especially from the Institute of Architecture and Urbanism of Blida and also from the department of Architecture of Laghouat Dr. Benarfa Kamal, for their helpful feedback and suggestions.

I am also grateful to Mr. Benkali Mustapha and all the participants in our study for their time and insights on the site of the project. Their willingness to share their experiences has been invaluable to my research.

I would like to thank my parents, family and friends for their love and support throughout this journey. Their encouragement and understanding have helped us to persevere when things got tough.

Finally, I would like to express my heartfelt gratitude to my partner BENELHOCINE. N.M, for her exceptional support, contributions, and unwavering dedication throughout our journey together.

This project would not have been possible without the help and support of all of these peo-ple. I am deeply grateful to them all.

BENOUARED Lina Ikram

Abstract

In order to effectively address the spatial needs and propose of innovative green solutions that align with the societal dynamics of Laghouat, an arid city in Algeria, a comprehensive research has been undertaken. A comprehensive examination of the various factors influencing energy optimization in building design, including everything from the surrounding environment to the intricate details of the building envelope in order to develop new and suitable solutions that cater to the unique socio-cultural context of Laghouat, while promoting sustainable environmentally responsive design that is resilient to the arid zone.

Based on the typo-morphological and sensorial approach enhanced with questionnaires and interviews along with a SWOT analysis, gave us the theme of the project: sustainable commercial and entertainment center with souk experience in Laghouat. The thematic research was therefore divided into 3 sections: the souk, commercial and entertainment center, and urban park.

The project of the integrated souk with commercial and entertainment spaces was based on the linear spatial organization of the traditional souk experience that encompasses local culture and practices creating a heritage ambiance that seeks to rejuvenate the city's unique identity, particularly the "Kser," by honoring its history, preserving its authenticity, and incorporating its distinct architecture and urban characteristics into various sensorial experiences within a sustainable environment that avoids the urban heat island effect. An urban park was added to strengthen this approach to leverage the oasis's micro-climate effects.

At the end, and to refine our design in terms of sustainability responses, we used several softwares, like Meteonorm, climate consultant, Envi-met and DesignBuilder.

Keywords: sustainability, energy optimization, resilience, Laghouat, Algeria, arid zones, kser, urban analysis, SWOT analysis, souk, traditional souk, commercial center, urban park, heritage, history, Meteonorm, climate consultant, Envi-met, DesignBuilder

Résumé

Afin de répondre efficacement aux besoins spatiaux et de proposer des solutions vertes innovantes qui s'alignent sur la dynamique sociétale de Laghouat, une ville aride d'Algérie, une recherche approfondie a été entreprise. Un examen complet des différents facteurs influençant l'optimisation énergétique dans la conception des bâtiments, allant de l'environnement environnant aux détails complexes de l'enveloppe du bâtiment afin de développer des solutions nouvelles et adaptées qui répondent au contexte socioculturel unique de Laghouat, tout en favorisant conception durable respectueuse de l'environnement et résiliente à la zone aride.

Notre recherche s’est basée sur l'approche typo-morphologique et sensorielle enrichie de questionnaires et d'entretiens accompagnés d'une analyse SWOT pour nous donner le thème du projet : centre commercial et de divertissement durable avec l'expérience du souk à Laghouat. La recherche thématique a donc été divisée en 3 sections : le souk, centre commercial et de divertissement, et le parc urbains.

Le projet du souk intégré avec des espaces commerciaux et de divertissement était basé sur l'organisation spatiale linéaire de l'expérience du souk traditionnel qui englobe la culture et les pratiques locales créant une ambiance historique qui cherche à rajeunir l'identité unique de la ville, en particulier le "Kser", en honorant son histoire, en préservant son authenticité et en incorporant son architecture et ses caractéristiques urbaines distinctes dans diverses expériences sensorielles dans un environnement durable qui évite l'effet d'îlot de chaleur urbain. Un parc urbain a été ajouté pour renforcer cette approche afin de tirer parti des effets microclimatiques de l'oasis.

Au final, et pour affiner notre conception en termes de réponses durables, nous avons utilisé plusieurs logiciels, comme Meteonorm, Climat Consultant, Envi-met et DesignBuilder.

Mots clés : durabilité, optimisation énergétique, résilience, Laghouat, Algérie, zones arides, kser, analyse urbaine, analyse SWOT, souk, souk traditionnel, centre commercial, parc urbain, patrimoine, histoire, Meteonorm, consultant climat, Envi-met, DesignBuilder

ملخص

من أجل تلبية الاحتياجات ا الفضائية بفعالية واقتراح حلول خضراء مبتكرة تتماشى مع االحركية المجتمعية لمدينة الأغواط ، وهي مدينة جافة في الجزائر ، تم إجراء بحث مكثف و فحص شامل للعوامل المختلفة التي تؤثر على تحسين الطاقة في تصميم المباني ، بما في ذلك كل شيء من البيئة المحيطة إلى التفاصيل المعقدة لغلاف المبنى من أجل تطوير حلول جديدة ومناسبة تلبي البيئة الاجتماعية والثقافية الفريدة للأغواط ، مع االتشجيع لتصميم مستدام مستجيب بيئيًا ومرنًا للمنطقة الجافة.

استنادًا إلى منهجية التصنيف الشكلي والحسي المعزز بالاستبيانات والمقابلات الميدانية جنبًا إلى جنب مع تحليل SWOT ، توصلنا إلى موضوع المشروع: مركز تجاري وترفيهي مستدام يتمتع بتجربة السوق في الأغواط. لذلك تم تقسيم البحث الموضوعي إلى 3 أقسام: السوق والمركز التجاري والترفيهي والحديقة الحضرية.

استند مشروع السوق المتكامل مع المساحات التجارية والترفيهية إلى التنظيم الفضائي الخطي الطولي متأثرا من تجربة السوق التقليدي التي تشمل الثقافة والممارسات المحلية لخلق أجواء تراثية تسعى إلى تجديد الهوية الفريدة للمدينة ، ولا سيما "القصر" من خلال ارفع شأن تاريخها ، والحفاظ على أصالتها ، ودمج هندستها المعمارية المتميزة وخصائصها الحضرية في تجارب حسية مختلفة داخل بيئة مستدامة تتجنب تأثير جزيرة الحرارة الحضرية. تمت إضافة حديقة حضرية لتعزيز هذا النهج للاستفادة من تأثيرات المناخ الجزئي للواحة.

الكلمات المفتاحية: الاستدامة ، تحسين الطاقة ، المثابرة ، الأغواط ، الجزائر ، المناطق االجافة ، التحليل الحضري ، السوق ، السوق التقليدي ، المركز التجاري ، الحديقة الحضرية ، القصر، التراث ، التاريخ

Figures list

Table list

Abbreviations

APRUE	Agence Nationale pour la Promotion et la Rationalisation de l’Utilisation de l’Énergie
CSEB	Compressed Stabilized Earth Blocks
EPA	Environmental Protection Agency
FEB	Fired earth brick
HTC	Human Thermal Comfort
IEA	International Energy Agency
LAI	Leaf Area Index
NBS	Nature Based Solutions
OECD	Organization for Economic Co-operation and Development
PCI	Park Cool Island
PET	Physiological Equivalent Temperature
PCM	Phase change material
SVF	Sky View Factor
UHI	Urban Heat Island
UCI	Urban Cool Island
WRF	Weather Research Forecasting

Content

INTRODUCTION

CHAPTER 01

1.1. General introduction

The Industrial Revolution, with its various phases and regional manifestations, stands as a pivotal point in any discussion of environmental consciousness. This transformative period brought about a significant shift in energy consumption patterns across the globe, leading to profound environmental and social consequences (Stearns, 1998).

At its core, the Industrial Revolution marked an international transition from an agrarian, land-based society characterized by small-scale rural communities and self-sufficiency to a fast-paced industrial society (Keeler, Vaidya, 2016). This infrastructure created by the Industrial Revolution can be likened to a massive steamship like the Titanic, propelled by the use of fossil fuels, nuclear reactors, and chemicals (Keeler, Vaidya, 2016).

The reliance on fossil fuels as the primary energy source during the Industrial Revolution dramatically altered the planet's energy consumption landscape. As industrial processes expanded and transportation systems developed, the demand for energy skyrocketed (Smil, 2017). Consequently, the growth of energy consumption over a specific time frame has garnered considerable attention, with a striking 102% increase observed within a 41-year period from 1973 to 2014 (Georges Andrieux, 2015).

Furthermore, a significant disparity in global energy consumption exists between highly industrialized nations and emerging economies. OECD countries, known for their advanced industrialization, hold a substantial share of 39.8% in global energy consumption. In contrast, emerging countries like China, as a primary consumer, account for 19.1% of global energy consumption. Meanwhile, the African continent represents a modest 6% share, and Latin America contributes 5.2% (Lezreg at al, 2016).

Based on information provided by the International Energy Agency, it was found that fossil fuels constituted 86% of the overall energy consumption in 2002. On the other hand, renewable energy sources, which are considered environmentally friendly, have witnessed limited growth in recent years. Specifically, solar and wind energy accounted for 1%, hydropower for 2%, and biomass for 11% (Key Figures for Energy, 2016). This resulted in higher CO2 emissions and the accumulation of greenhouse gases in the atmosphere, contributing to the warming of the planet and climate change (Intergovernmental Panel on Climate Change IPCC, 2014)

And if we focus on the architecture and building industry, it is evident from statistics that the building sector consumes around 50% of extracted materials and generates 60% of waste. This sector is also responsible for soil sealing and the growing energy demand for heating, air conditioning, and mechanical ventilation. Furthermore, the annual global energy consumption of the building sector amounts to 46% (Agence Natioanle pour la Promotion et la Rationalisation de l'Utilisation de l'Enegrie. APRUE: 2021).

As an action for this matter, the first documented awareness of sustainable development was in 1987 with the publication of the Brundtland Report. This report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The report emphasized the importance of understanding the Earth's ecological limits and highlighted the three pillars of sustainable development: economic, social, and environmental (The World Commission on Environment and Development,1987).

Preserving non-renewable natural resources has emerged as a critical challenge in the pursuit of sustainable development. This recognition prompted global political powers to address the issue at the 2nd Earth Summit in Rio in 1992. Subsequent international meetings and conferences, such as the Berlin Summit, Geneva meeting, and Kyoto Protocol, translated the commitment to sustainability into legally binding targets. This was followed by additional events, including the Buenos Aires meeting, Hague conference, Montreal meeting, and Copenhagen Summit (Keeler, Vaidya, 2016).

Algeria participated in the recent Conference on Climate Change in Paris (COP 21), pledging decisive action to reduce global warming. Algeria has developed a clear strategy to reduce fossil fuel dependence and promote renewable energy. The country has invested in projects such as solar thermal equipment manufacturing and aims for a 50% integration rate by 2020. Plans for 2021-2030 include expanding mirror manufacturing, enhancing energy storage, and developing wind energy, with a target integration rate of 50% from 2014 to 2020 and aims to achieve an integration rate of over 80% by 2030 (Abderrahmane Mebtoul, 2015).

Algeria recognizes the significant potential for reducing electricity and gas consumption in the building sector. In line with this, the country has launched various programs under the National Energy Management Program (PNME) from 2007 to 2011, such as Eco-bat, Propair, Top industrie, Alsol, and Eco-lumière. These initiatives form part of Algeria's ambitious plan to create equal opportunities for renewable energy and energy efficiency until 2030 (Abderrahmane Mebtoul, 2015).

Despite these ambitious plans, Algeria faces challenges in fully implementing them. The country's economic dependence on oil and gas, combined with its vulnerabilities to aridity, and desertification, retard the effective execution of these initiatives. Insufficient support, technological limitations, and financial constraints further contribute to the obstacles Algeria encounters in its environmental preservation and climate change efforts.

The question remains whether Algeria can overcome these obstacles and successfully implement its plans. Additionally, concerns arise regarding the adequacy of Algeria's national initiatives in contributing to the global goal of reducing global warming, which impacts the entire planet.

1.2.General problematic

Climate and weather are related yet different things. Weather refers to short-term atmospheric conditions in a specific place at a given time. Climate, on the other hand, is the long-term average of the weather patterns in a specific region. Climate studies show that the earth's temperature is warming. Therefore, Climate change refers to long-term changes in the average weather patterns that have come to define Earth's local and global climates (Keeler, Vaidya, 2016).

The primary cause of climate change is the increased amount of greenhouse gases in the atmosphere, which is produced by human activities such as burning fossil fuels and deforestation (Kuppaswamy Iyenger, 2015). These gases trap more of the sun's heat, leading to a rise in global temperatures. This increase in illnesses such as heat stress and respiratory problems due to poor air quality (Keeler, Vaidya, 2016). Climate change not only affects health through heat, but also through sea-level rise, increased rainfall, flooding, and other extreme weather events.

In recent years, the global population has been steadily increasing, leading to negative consequences for Earth's biodiversity and its ability to sustain productivity and manage waste. The concept of the "ecological footprint," introduced in 1990 at the University of British Columbia, measures the land, water, and natural resources needed by individuals, cities, countries, or humanity as a whole to meet their resource consumption demands. Since 1980, humanity has been in a state of ecological overshoot, depleting resources at a faster rate than they can be replenished (Kuppaswamy Iyenger, 2015).

In this context, the emergence of green building design has led designers and architects to prioritize passive design strategies from the early stages of the design process. These strategies aim to minimize the environmental impact of buildings by reducing the energy required for their operation. Additionally, renewable energy sources such as solar energy and wind energy are incorporated to further decrease the reliance on non-renewable energy sources. The goal is to create buildings that are energy-efficient and have a minimal ecological footprint.

Laghouat, located in the southern region of Algeria, is known as the gateway to the Sahara Desert and renowned for its arid and dry climatic conditions. The city derives its name from the Arabic language, specifically from the plural form of "Ghaout" or "Ghouta," which signifies a space characterized by the presence of water and trees or a house encompassed by a garden (Almaany website).

Prior to French colonization, Laghouat boasted a fortified village known as a Ksar, enveloped by a flourishing oasis. However, the arrival of French colonizers and subsequent urbanization driven by natural gas discovery led to the emergence of a phenomenon focused on housing provision for the growing population.

Regrettably, this led to the development of large-scale collective housing projects that inadequately integrated with the environment and lacked spatial quality such as public and entertainment equipment, neglecting the challenges posed by the region's climate and resulting in a high demand for cooling energy. During our visit to Laghouat, the city's residents expressed their longing for the former traditional typology of the city as a Ksar, as well as the preservation of urban green spaces. The conversion of these areas into building plots has left only the botanical garden as the sole remaining green space, which is insufficient to mitigate the higher temperatures. Consequently, this has contributed to the phenomenon known as the Urban Heat Island effect, whereby cities experience significantly higher temperatures compared to surrounding rural areas (Rupard, 2019).

Furthermore, our survey revealed the citizens' dissatisfaction with the limited availability of public and entertainment amenities. This has resulted in an increase in mechanical mobility due to the lack of proper facilities. The survey also demonstrated the community's fervent desire for multifunctional spaces that seamlessly incorporate entertainment, commerce, and cultural elements while thoughtfully considering the local micro-climate. These spaces aspire to provide a refuge from residential environments, offering a diverse range of amenities within a cohesive setting.

Today, tourism plays a vital role in driving employment and development, making a significant contribution to local economic growth and social well-being. This sector employs millions of people worldwide in diverse positions and at various levels, thereby playing a crucial role in fostering local economic growth and enhancing social welfare.

In the case of Laghouat, the city holds significant tourism potential as it features eight renown archaeological sites. By restoring these historical sites, the city can not only attract more tourists but also revitalize its economy and promote sustainable growth, reducing its dependence on gas energy.

Given the context of Laghouat's unique climatic conditions, urbanization challenges, and the importance of tourism for economic growth, the following problematic can be identified:

How can we design a sustainable public and entertainment facility in the city of Laghouat with an integrated park that address the region's climate challenges, enhance energy efficiency, and create a more sustainable and resilient city that promotes tourism, preserves cultural heritage, and improves the well-being of its residents?

1.3. Specific problematic

Resilient architectural design plays a crucial role in improving both outdoor and indoor thermal comfort by implementing resilient strategies. These strategies encompass design resistance, redundancy, resource efficiency, and passive design principles, which collectively enhance the resilience and sustainability of the built environment (Keeler, Vaidya, 2016).

When we reflect on the practices of local ancestors, we can observe their deep connection with the environment, as their survival depended on utilizing available resources for shelter, food, farming, and travel. Laghouat's old city, known as "ksar," exemplifies such practices. Interviews conducted have revealed the city's self-sufficiency through local farming practices and compacted living arrangements. The integration of vegetation and "seguia" (irrigation) systems played a vital role in providing comfort and adapting to the challenging climatic conditions of the region..

Regrettably, these valuable lessons from the past have been neglected and lost due to rapid urbanization and the prioritization of quick construction. Consequently, there is now a disconnection between the built environment and the site's climatic conditions. This disconnection is worsened by the use of modern construction materials, such as concrete and asphalt, which lack thermal inertia. The disappearance of traditional features like patios and "rahbat" has had a significant social impact. Patios, in particular, have a thermal efficiency as they provide natural ventilation and light. Additionally, the abandonment of vegetation and palm trees has led to soil deforestation, resulting in the neglect of "seguia" systems that were once used for irrigation. These systems have now become sources of greywater, causing unpleasant- ant odors and sensory experiences in the city.

The neglect of these essential local passive strategies has consequently led to an imbalanced lifestyle, forcing city residents to seek refuge outdoors during the nighttime. Also, it has created a heightened demand for cooling systems to cope with the elevated temperatures experienced in the region.

As previously mentioned, Laghouat has the potential for tourism due to its rich material and immaterial heritage. In-depth interviews conducted as part of our study emphasize the urgent need to preserve and safeguard the neglected heritage and culture of the area, as they face the risk of disappearing. The appearance of non-adaptable typologies in the city, which neither represent the city nor the society, has further highlighted the importance of preserving the cultural identity. Cultural preservation has always been a fundamental pillar of sustainable development and should be prioritized to ensure the long-term sustainability and vitality of Laghouat.

Considering everything mentioned above, the following issue arose for us:

> **1. What are the effective strategies involved in reflecting and restoring the lost cultural identity of Laghouat within a public and entertainment facility, while ensuring its functional requirements and providing a sense of authenticity to visitors?**
>
> **2. How can we effectively reduce energy consumption in a public and entertainment facility by identifying the optimal microclimatic conditions for outdoor thermal comfort**

1.4. Hypothesis

To respond to ours problematics presented above, we suggest the following hypothesis:

1- By strategically integrating vegetation, water features, and urban geometry, along with utilizing local materials, shading options, and natural ventilation, it is possible to significantly reduce energy consumption in a public and entertainment facility in the city of Laghouat. This integration will create optimal microclimatic conditions outdoor thermal comfort and contribute to achieving an optimal level of indoor thermal comfort, thus addressing the region's climate challenges, and enhancing energy efficiency.

2- Through a sensitivity analysis of multiple dynamic thermal simulations, we hypothesize that the implementation of passive strategies will have a significant effect on improving thermal comfort in the public and entertainment facility.

3-By incorporating elements of Laghouat's cultural heritage, such as traditional architectural features, design motifs, and materials, alongside modern amenities and facilities, a sustainable and resilient city could be created that promotes tourism, preserves cultural heritage, and improves the well-being of its residents.

1.5. Objectives

- Identification of elements that symbolize the local identity of Laghouat.
- Minimize energy consumption through the implementation of appropriate architectural passive and active concepts.
- Recognize the significance of designing an environmentally friendly and sustainable project.
- Incorporate the project into its surroundings and link it to the human perspective and experience.

1.6. Theme choice criteria

The criteria for choosing the theme revolve around reviving the lost identity of the city. Looking back in time, Laghouat was established as a vital commercial hub, connecting the north and south regions due to its strategic location. In this context, the goal is to revitalize the city's commercial potential by establishing a multifunctional center that offers commerce, entertainment, leisure activities, culinary experiences, and cultural events, while providing a traditional Souq experience. This undertaking seeks to rejuvenate the city's unique identity, particularly the "Kser," by honoring its history, preserving its authenticity, and incorporating its distinct architecture and urban characteristics into various sensorial experiences. Additionally, the revival of the city's natural surroundings, particularly its palm grove land, is pursued, while also striving to strike a balance between the city's daytime and nighttime lifestyles by leveraging the oasis's micro-climate effects.

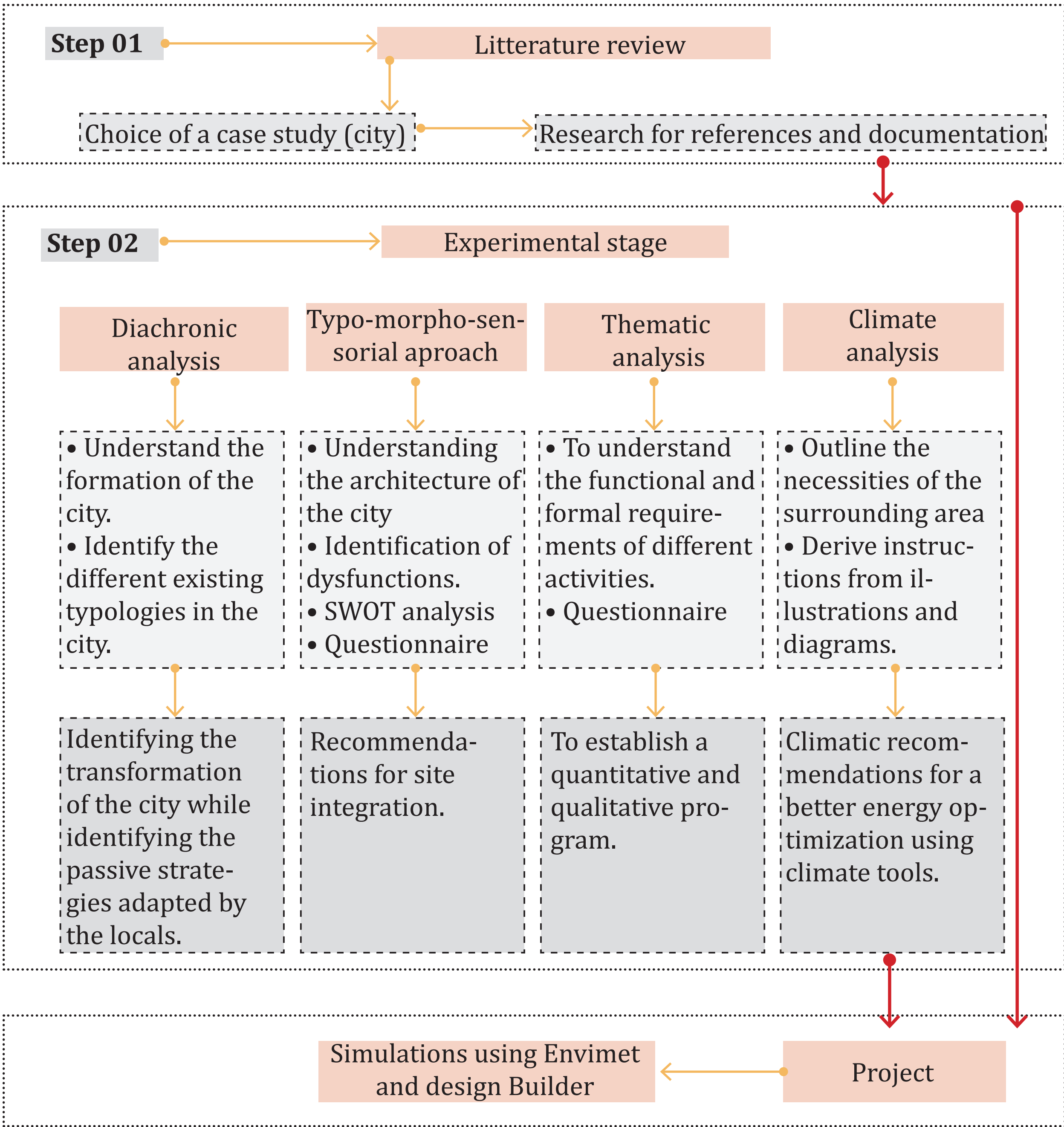
1.7. Research methods

There are always two main steps to conduct a research:

(i) **The literature review** with the main goal is to understand concepts, methods, and results obtained with other authors to be able to discuss our results with their results. Also, within the same stage, identify our method that could help us to verify our hypothesis. And also, within a thematic analyses and to be able to understand needed activities that could help us to design our project. Hence, the second chapter is totally dedicated to these purposes.

(ii) **The experimental stage**. It is the second step. It has to help us to conduct the research based on the orientations obtained from the first step. In our case, we have combined a typo-morphological with sensorial approach with questionnaires and interviews to get what is matter in the intervention site, a Swot analysis was used to synthetize the analysis work and get in the same time the main strategy that could organize our design process. To refine our design in terms of sustainability responses, we used several softwaress, like Meteonorm, climate consultant, Envi-met and DesignBuilder.

1.8. Research structure



STATE OF THE ART

CHAPTER 02

2.1. Introduction

In order to effectively address the spatial needs and propose of innovative green solutions that align with the societal dynamics of Laghouat, an arid city in Algeria, comprehensive research becomes indispensable. This research process begins with a comprehensive examination of the various factors influencing energy optimization in building design, encompassing everything from the surrounding environment to the intricate details of the building envelope. By acquiring a comprehensive understanding of these elements, we, as students, can develop new and suitable solutions that cater to the unique socio-cultural context of Laghouat, while promoting sustainable environmentally responsive design that is resilient to the arid zone.

Moving on to the thematic research, it is divided into three key sections: the souk, commercial and entertainment center, and urban parks. Through a meticulous exploration of their urban, architectural, and programmatic concepts, we aim to establish a quantitative and qualitative program for our project. Moreover, we seek to uncover the valuable contributions each component can make to our project.

This chapter serves as an essential and preliminary clarification of concepts and definitions, drawing upon a range of reference works and articles related to our project's objectives and problematic. By establishing a robust theoretical framework, we came out with a comprehensive list of outputs and foundations that form a solid basis for the project's reflection.

2.2. Concepts definition

2.2.1. Sustainable architecture

Sustainability in architecture prioritizes meeting present-day needs without compromising future generations' ability to meet theirs (Kuppaswany Iyengar., 2015). According to American Institute of Architects, sustainable or green architecture aims at minimizing negative environmental impacts while promoting social equality and economic prosperity through its life cycle from design till eventual demolish or reuse stage structures with eco-friendly practices that are resource efficient aesthetically appealing while socially equitable.

2.2.2. Energy efficiency

Energy efficiency, according to the International Energy Agency (IEA), is the correlation between the amount of usable energy produced and the amount of energy used. By reducing energy demand and associated emissions, it is essential for advancing sustainability and combating climate change. Energy efficiency is further described by the United States Environmental Protection Agency (EPA) as the capacity to produce the same service or result while requiring less energy.

2.2.3. Nature based solutions

The European Commission defines nature-based solutions (NBS) as solutions that take inspiration and support from nature. These solutions are affordable and offer environmental, social, and economic benefits, all while helping to increase resilience.

2.2.4. Thermal comfort

When considering variables like temperature, humidity, ventilation, and garment insulation, thermal comfort refers to the individual's subjective impression of comfort in a given thermal environment. It is the subjectively assessed condition of being happy with the thermal environment, according to ASHRAE.

2.2.5. Typo-morphological approach

The term "typo-morphology" was originally used by urbanist Savierio Muratori, 1952 and developed by Kevin Lynch in his 1960 book "The Image of the City." Lynch argued that the physical characteristics of urban regions had a significant impact on how people perceive, interact with, and use cities. The typo-morphological technique, which has been developed and applied by academics and urban designers, builds on Lynch's ideas.

2.2.6. Sensory approach in Architecture

According to Juhani Pallasmaa's "The Eyes of the Skin: Architecture and the Senses," it highlights the significance of utilizing not just visual sense but also touch, hearing, smell, and kinesthetic experiences. This method seeks to create meaningful and comprehensive settings that evoke emotional and physical reactions, so improving the entire human experience by activating numerous senses.

2.2.7. Multi-functional building

A multifunctional building, according to the American Institute of Architects, is an adaptable structure that serves several purposes and can adapt to varied usage throughout time. It combines several utilities into a single structure, encouraging sustainability and efficiency in the built environment.

2.3. Algeria's energy policy

Algeria has prioritized energy management and conservation efforts, implementing measures such as daylight saving time and establishing institutions to coordinate energy policies. Environmental concerns and reducing greenhouse gas emissions have become significant priorities. The government aimed to reduce national energy consumption by 16% by 2020, focusing on measures like improving insulation and promoting renewable energy sources. However, low energy prices and a lack of awareness hinder progress in energy conservation. Moreover, the country plans to expand its energy capacity by adding 35,505 MW, including 5,539 MW from renewable sources, by 2023 (APRUE 2014). Furthermore, the government has set a target of reducing its own CO_2 emissions by 7%, and up to 20% if it receives external funding (Chaker, 2023). Currently, the national energy management policy is implemented through three main tasks:

- **Introduction of energy efficiency standards and requirements**, particularly thermal insulation standards for new buildings, as well as energy efficiency and energy-saving standards applicable to devices operating on electricity, gas, and petroleum products.
- **Control of energy efficiency,** including buildings, devices operating on electricity, gas, and petroleum products, vehicles, and motorized equipment.
- **Mandatory and periodic energy audits** for high energy-consuming establishments in the industrial, transportation, and tertiary sectors.

2.4. Optimization of building energy performance
2.4.1. Introduction

As discussed earlier, optimizing building energy performance is crucial for achieving a sustainable future, and integrated design ensures that early design decisions do not compromise later ones. Energy performance goals should be established from the outset, and passive design, which reduces reliance on active systems, should be maximized early in the process. Each surface of a building is influenced by a unique set of factors, and by manipulating these factors, a more environmentally friendly design can be achieved.

To achieve sustainable design goals, it is essential to research the various factors that impact the energy performance of a building, including orientation, implantation, building shape, and envelope. Additionally, by analyzing the distinct characteristics of each region and researching the specific environmental conditions, effective strategies for improving building energy performance can emerge.

To facilitate this research, we have organized a study that outlines the relevant research areas, as shown in the figure below (Figure 2.1). Ultimately, the aim is to create energy-efficient and environmentally friendly buildings that meet the needs of their users.

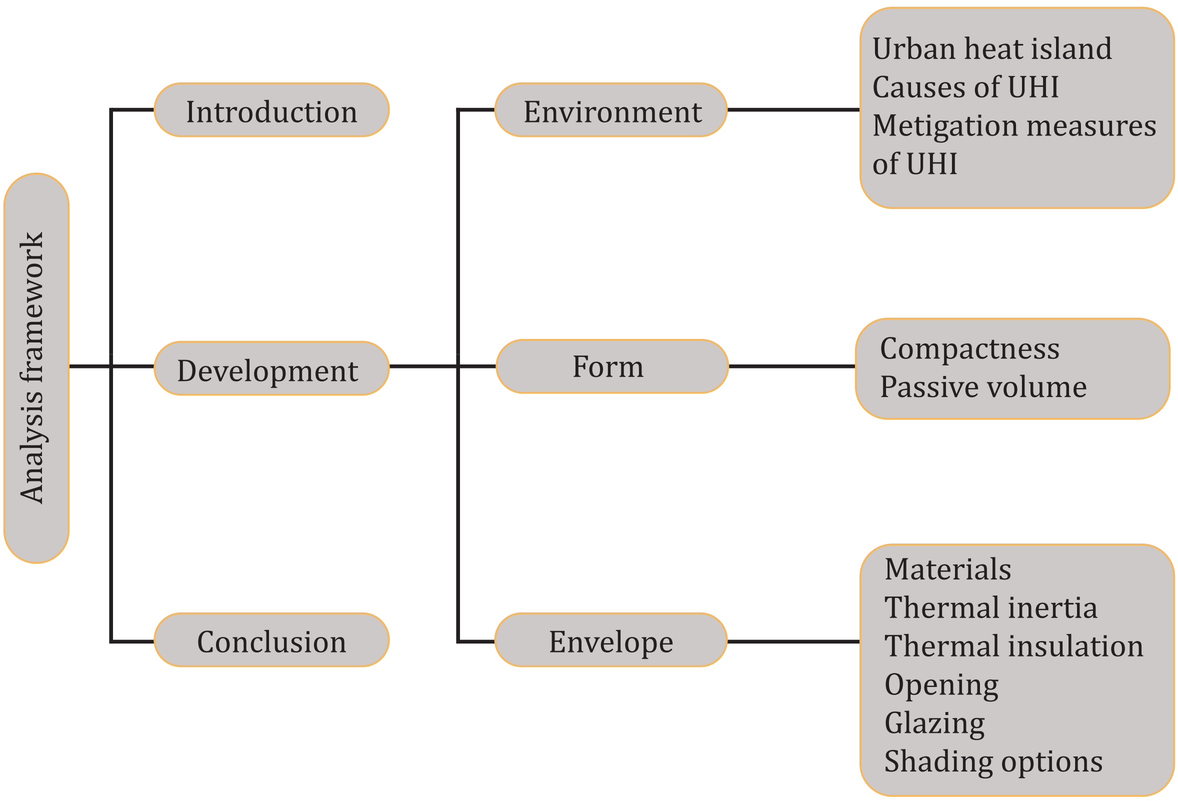


Figure 2.1: Analysis framework. Source: author

2.4.2. Environment

The surrounding environment can affect how a building performs. Reflective surfaces reduce heat absorption, while greenery and geometric design help to control temperature and optimize natural light and ventilation.

2.4.2.1 Urban heat island (UHI)

The rapid urbanization in modern society leads to a significant demand for energy to sustain cities. As buildings and roads replace open spaces and vegetation, the urban heat island phenomenon emerges due to the decrease in vegetation and evapotranspiration and the increase in dark surfaces and anthropogenic heat generation (Rupard, 2019).

Definition: The urban heat island (UHI) effect is a phenomenon where cities are significantly warmer than surrounding rural areas (figure 2.2) (Rupard, 2019). This is due to darker urban surfaces, less vegetation, and building and street materials with high heat capacities that store and release heat slowly (Wang, Akabri, 2016, Oke, 1988).

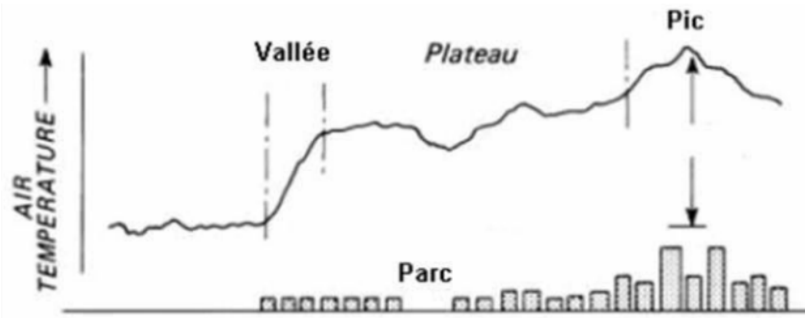


Figure 2.2: Presentation of urban heat island. Source: Oke, 1988

2.4.2.2. Key causes of Urban heat Island (UHI)

The urban heat island effect is caused by changes in urban environments. Based on our research on UHI phenomenon, we have identified three principal factors that contribute to its occurrence:

A. Urbanization and urban sprawl, which is caused by increased heat-absorbing surfaces and reduced vegetation. As the world's population continues to increase, environmental issues and UHI will worsen, leading to more heatwaves. (Stone et al. 2010; Grimmond, 2007).

B. The use of manufactured materials and reduction in native vegetation in cities. Modern construction materials have different characteristics from natural elements, leading to distinct urban climate conditions compared to the past. This, combined with anthropogenic heat, pollution, and increased urban density, exacerbates the UHI effect (Landsberg, 1981; Oke, 1997; cited in Grimmond, 2007).

C. Technological advancements such as air conditioning systems. The higher density of modern cities results in more air conditioners, affecting human well-being and emitting more greenhouse gases (Grimmond, 2007). A 1°C temperature increase due to UHI results in a significant increase in electricity demand for heating and cooling, with a range of 2-4% (Akbari et al., 2001).

2.4.2.3. Key mitigation measures

The UHI effect can be mitigated with various measures that have been well-studied and documented. Cool pavements, increased utilization of green spaces, and harnessing the cooling effects of wind and water are some of the key measures to mitigate the UHI effect. We outlined these measures in Figure 2.3.

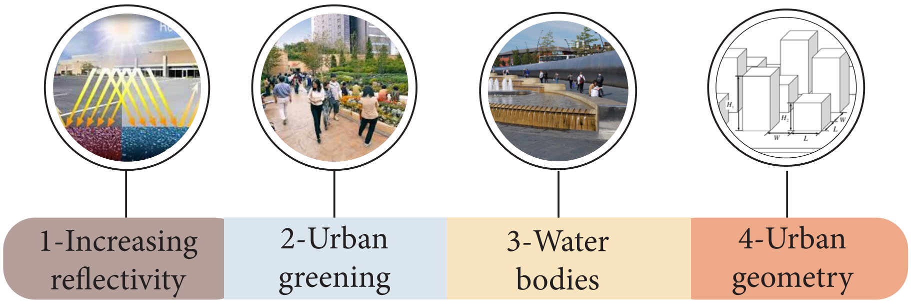


Figure 2.3: Representation of key mitigation measures. Source: authors

1. Increasing the reflectivity of urban materials: Urban materials, such as buildings and roads, absorb and store energy during the day, causing local warming at night. The use of "cool" coatings that reflect heat can potentially reduce energy storage and lower urban temperatures in summer (Heaviside, 2020). Our research evaluated studies on the impact of reflective surfaces on mitigating the urban heat island effect. See the summary in Table 2.1.

A. Cool pavements, including reflective and permeable pavements, reduce heat absorption and lower surface temperatures. Solar reflective pavements use reflective aggregate, binder, or coating to stay cooler. Lighter-colored pavements and permeable pavements are efficient ways to mitigate the UHI effect by reflecting sunlight and allowing air and water to keep the pavement cool (Santamouris, 2013b).

B. Albedo, the spectral and broadband properties of a material determine its absorptivity and reflectivity. A material's reflectivity is based on its color and surface roughness, with lighter colors reflecting more visible spectrum solar radiation. Absorptivity to infrared radiation is not dependent on color, and the roughness of a surface also affects its absorptivity of solar radiation, according to Santamouris (2013b).

Table 2.1: Summary of reflective surfaces' impact on UHI mitigation. Source: author

Indicator	***Researcher***	***Study***	***Result***
Albedo	Morinia.E et al, 2019	This research employed the Weather Research and Forecasting (WRF) mesoscale model to replicate the weather conditions of Rome in an urban setting. The study evaluated four distinct situations in which the albedo is increased.	Raising the albedo results in a reduction of air temperature during the day and night in the urban area. leading to a temperature decrease of up to 4°C during the day and a slight increase of up to 1°C in specific locations during the night. ***Synthesis:*** Improving the reflective qualities of urban surfaces presents a highly encouraging solution to mitigate the urban heat island effect.

Table 2.1: Summary of reflective surfaces' impact on UHI mitigation. Source: author

Indicator	***Researcher***	***Study***	***Result***
Color	Synnefa A, Santamouris M, Livada.I 2006	The study examined how different colors of thin-layer bituminous materials responded to solar radiation by measuring their surface temperature. The aim of the study was to explore how the reflectivity of colors affected outdoor thermal comfort.	Off-white asphalt with a visible spectrum albedo of 0.45 demonstrated a nearly 12 °C lower maximum surface temperature than black asphalt with a visible spectrum albedo of 0.03. Yellow, beige, green, and red asphalt materials had a maximum surface temperature of 9.0, 7.0, 5.0, and 4.0 °C lower than black asphalt. ***Synthesis:*** It is evident that the surface temperature is influenced almost proportionally by the specific reflectivity of materials.
	Georgakis wwmouris M 2006	During the summer period, comprehensive experiments were conducted in a deep canyon located in Athens.	Data collected in street canyons indicated that the surface temperature of black asphalt approached 65°C during the summer, while gray stone reached 48°C. ***Synthesis:*** The darker the surface, the greater its capacity for absorption, while the lighter the color, the more significant the reflection.
Pavement materials	Takebayashi, H., Moriyama, M., 2012	The study examines the potential of various pavement materials for mitigating (UHI) effects. By analyzing the surface heat budget of five different pavements materials, including asphalt concrete,cement concrete,-photo catalytic cement concrete, resin cement, and water-permeable pavement	Water-permeable pavement and photo catalytic cement concrete are effective in reducing urban heat island effects, while AC pavements have significantly higher temperatures than grass surfaces up to 20 C. ***Synthesis:*** water permeable pavement can play a significant role in mitigating UHI effects in urban areas.

Improving the thermal performance of pavements :

1- To increase the albedo of the paving surfaces in order to absorb less solar radiation.

2- To increase the permeability of the surfaces, in vegetated and non-vegetated pavements, in order to decrease their surface temperatures through evaporation processes.

3- To increase the thermal storage capacity of the surfaces by adding ingredients of high thermal capacitance or materials of latent heat storage. Contribute to reduce surface temperatures during daytime and decrease sensible heat release to the atmosphere.

2. Urban greening: Urban vegetation, such as green roofs, walls, pavements, parks, and trees, can mitigate UHI by regulating temperature through various means like water vapor transport, shading, and wind effects. Combining different types of vegetation is most effective in reducing UHI. Vegetation can also improve air quality by acting as a barrier to pollutant transport and collecting pollutants through deposition, absorption, and adsorption. Studies have shown that trees can reduce peak cooling load by 2-10% (Santamouris, 2007) and cooling load by 21-53% in California (Akbari, 2002). Our investigation reviewed the impact of greenery on UHI, and Table 2.2 summarizes our findings.

A. The urban/park cool islands (UCIs/PCIs): refers to areas with lower temperatures due to the presence of green spaces compared to impervious surfaces. While UCIs are influenced by urban morphology characteristics, PCIs are solely related to green infrastructure. UCIs/PCIs are important for Human Thermal Comfort, and several reviews have evaluated the contribution of urban greening to HTC (Human Thermal Comfort) and heat stress reduction. Cooling effects of green spaces are substantial, with maximum reported PCI magnitudes ranging between 1.5 and 9.5°C. These findings are from studies conducted in several European and Mediterranean countries, including Chen et al. (2014), Oke (1998), Yang et al. (2017).

B. Green roofs – facade: can mitigate the UHI effect by enhancing a building's thermal insulation, which ultimately reduces the demand for air conditioning and heating, leading to energy conservation.

C. Street trees: Trees play a crucial role in mitigating UHI and reducing summer air temperatures by altering solar and terrestrial radiation through shading (Sawka et al., 2013). In general, it is considered that of the incoming radiation on a leaf, around 50% is absorbed, 30% is reflected, and 20% is transmitted (Figure 2.4). The shading and evapotranspiration rate of a tree depend on its height, canopy geometry, foliage characteristics, and mature shape, which vary among species. Urban trees are classified based on their size, type, and arrangement of leaves, which affect radiation filtration and are measured by "Leaf Area Index" (LAI) (Elmira et al., 2016).

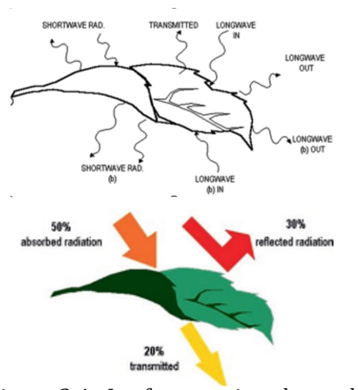


Figure 2.4: Leaf properties: thermal exchange. Source: Gustavo, 2019

D. Urban parks: Urban parks have a considerable impact on reducing the UHI effect and improving pedestrian thermal comfort through the phenomenon of park cool island (PCI), first introduced by Oke. The cooling efficiency of urban parks depends on their size, plant type, sky obstruction level, and irrigation frequency, as well as the characteristics of the surrounding urban area such as density, anthropogenic heat, and prevailing climate (Feyisa et al., 2014).

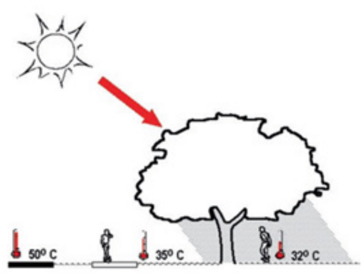


Figure 2.5: Microclimate differences. Source: Gustavo, 2019

To gain a deeper comprehension of the microclimate effect created by trees and their potential as a mitigation strategy in hot and dry climates, we conducted a comprehensive research study. The research investigation was structured into five distinct sections, as follows in (figure 2.6):

1-Trees and evapotranspiration	2-Solar radiation and trees	3-Tree shading	4-Energy saving by tree	5-Trees and air quality

Figure 2.6: The research conducted in trees, which is dived into 5 section. Source author

1. Trees and evapotranspiration: Trees play a crucial role in cooling through evapotranspiration, which involves the absorption and release of water through leaves. Large trees can evaporate up to 3000 gallons of water daily, influencing cooling by lowering temperatures and increasing humidity. This process follows Boyle's law, where the conversion of water from liquid to vapor removes one calorie of heat per gram of water. As a result, air conditioning costs can be reduced by 10% to 50% due to the cooling effect provided by trees (Willeke, 1989, as cited in Gustavo Cantuaria, 2019).

2. Solar radiation and trees: Trees can assist attenuate radiation by intercepting and reflecting it through changes in material and color (figure 2.7). The capacity of different tree species to intercept radiation varies according to their height, canopy transmissivity, seasonability, foliation, and defoliation. A research done in Nanjing City, China, discovered that streets with deciduous trees had a summer microclimate up to 7°C cooler and a relative humidity up to 20% greater than streets with mixed trees (Gustavo Cantuaria, 2019).

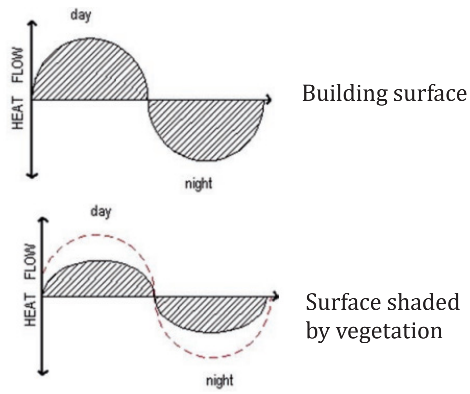


Figure 2.7: Effects of vegetation on a surface. Source: Oke 1990 cited in Gustavo, 2019

3. Tree shading: Shading from vegetation plays an essential role in the microclimate. Makzhoumi's studies in Baghdad showed that different tree types vary in their shading efficiency. Surprisingly, palm trees, despite their height, provided the least ground shade. However, when trees were arranged in a rectangular enclosure with longer sides facing east/west, shading efficiency increased (Gustavo Cantuaria, 2019).

4. Energy saving by tree: a single 7.5-meter-tall tree can cut annual cooling and heating expenses for a residence by 8-12% (Gustavo Cantuaria, 2019). Tree shade reduces solar heat gain, while evapotranspiration further cools the environmen. Studies show that air conditioning savings range from 25% to 80%, with denser and larger tree canopies providing greater benefits. More foliage area (LAI) leads to increased evapotranspiration, enhancing the cooling effect (Gustavo Cantuaria, 2019).

5. Trees and air quality: Urban trees, especially young and fast-growing ones, are more effective in reducing CO_2 than rural trees. They can be up to 15 times as valuable in limiting CO_2 build-up due to locking up CO_2 in biomass and reducing the need for air conditioning and heating. Urban trees also help trap dust and pollutants in their leaves, improving air quality (Gustavo Cantuaria, 2019).

Table 2.2: Summary of vegetation impact on UHI mitigation. Source: author

Indicator	***Researcher***	***Study***	***Result***
Green roof	Al-Sanea et al, 2014	The potential for green roofs to reduce the cooling load of buildings in Riyadh, Saudi Arabia.	Green roofs with a coverage of 80% can reduce the cooling load of a building in Riyadh by up to 27% *Synthesis:* Vegetated rooftops mitigate the UHI island by boosting the thermal insulation of the structure.
Vegeta-tion	Zhang et al 2017	The developed multi-objective model is applied to evaluate the diurnal cooling trade-offs in Phoenix, Arizona.	Optimal positioning and adding only 1% of new green space could surface cool surfaces temperature by 1-2 C *Synthesis:* a small increase in green cover can make a significant difference in an arid zone.
	Akbari et al 1992	The simulations demonstrate the combined effect of vegetation shading and evapotranspiration on building energy demand in several cities in the United States.	Addition one tree\house, energy savings for air conditioning range from 12 to 24%, and the addition of three trees\ house can reduce the air conditioning load by 17 to 57%. *Synthesis:* significant impact of trees on reducing energy demand.
	Hamida bencheikh, Ameur Rachid, 2012	The study explores the cooling effect of green cover during summer in the city of Beni-Isguen, Algeria, a hot arid climate.	Vegetation can cool outdoor spaces by 2-3°C, creating an "oasis effect" and reducing heat stress. Palm groves cool by providing shade, evapotranspiration, and a rough surface. *Synthesis:* Green vegetation in hot arid regions can reduce heat stress and create an oasis effect
Urban park	Algretawee et al 2019	The study analyzed 27 urban parks in Melbourne, selected based on size and distance from the city center.	Melbourne's parks were found to reduce temperatures in the surrounding areas by 3-10°C, and the study also showed that the cooling effect of parks can extend up to 746 meters. *Synthesis:* The implementation of urban parks has been proposed as a potential strategy to mitigate the UHI effect in densely populated urban areas.
Green wall	Sherine et al, 2019	The study examined outdoor comfort in a city block in Egypt on the hottest day using PMV and air temperature calculations.	Reduction of 10°C throughout the day, and improved outdoor thermal comfort, as measured by a 2-point decrease in PMV values (from HOT to COOL) for the entire city block. *Synthesis:* Green walls impact thermal comfort through their ability to absorb, reflect, and transmit solar radiation.

3. Water bodies

Understanding the impact of water on the urban heat island (UHI) effect is increasingly important. The concept of a water-cooling island (WCI) is based on the fact that water evaporation consumes energy that would otherwise be transformed into sensible heat, thereby reducing UHI. The cooling effect of water bodies can increase human thermal comfort in the WCI zone (Mohajerani et al., 2017). Using water to cool roofs has also been proven as a means of reducing UHI, decreasing the temperature of the building and having an impact on the ambient temperature as well, particularly in areas where air conditioning is widely used (Huang et al., 2020). See Table 2.3.

Table 2.3: Summary of Water impact on UHI mitigation. Source: author

Indicator	***Researcher***	***Study***	***Result***
Water bodies	L. Li, D. Zhou, Y. Ouyan 2013	The study investigated the impact of urban green spaces, including water bodies, on the UHI in the arid city of Phoenix, Arizona.	Water bodies, such as lakes and ponds, had a significant cooling effect on the surrounding areas, with temperatures up to 2-3°C lower than the non-water areas. ***Synthesis:*** increasing the number and size of water bodies and green spaces could be an effective strategy for mitigating the UHI in arid cities like Phoenix.

4. Urban geometry: The thermal condition of cities in arid zones is influenced by various urban design parameters such as aspect ratio, street orientation, sky view factor, and urban form. High aspect ratio leads to lower daytime air temperature and lower PET values due to increased shading. Sky view factor affects exposure to the sun and wind speed, while urban form depends on the climatic conditions and geographical position of the city. However, there is no universal solution, and the best urban design parameters depend on the specific context (Mohajerani et al., 2017).

A. Building orientation: Choosing the right location, shape, and orientation of a building is crucial for optimal exposure to the sun path and prevailing winds, especially in hot climates where natural ventilation is important. See figure 2.8 for a recommended orientation according to climate zone after Kuppaswany Iyengar. The Phoenix Central Library (figure 2.9) is an example of a building designed with these principles in mind, using shading and glazing techniques to minimize solar gain while maximizing cooling and lighting effects (Kuppaswany Iyengar., 2015).

Figure 2.9: Phoenix central library by Will Bruder. Source: Kuppaswany Iyengar., 2015

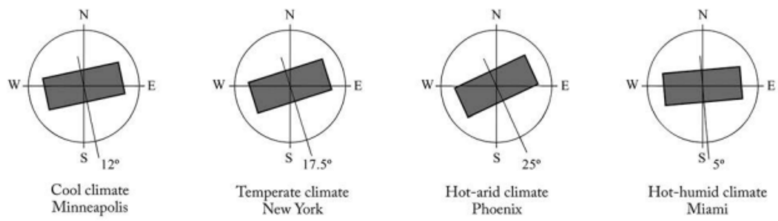


Figure 2.8: recommended orientation according to climate zone
Source: Kuppaswany Iyengar., 2015

B. Aspect ratio: the ratio between the height of canyon walls and its width, is a crucial factor in determining canyon geometry. A uniform canyon has an aspect ratio of around 1, while a shallow canyon has an aspect ratio below 0.5, and a deep canyon has an aspect ratio of 2 (K.Ahmed et al., 2005). Urban canyons, similar to natural canyons, channel wind and play an important role in enhancing wind speed and dissipating excess heat from urban areas(Elmira et al., 2016).

C. Street orientation: Street orientation is a crucial parameter in determining solar access and wind speed in urban canyons, which affects the thermal comfort level in sidewalks (Mohajerani et al., 2017). Urban canyon geometry can save up to 30% of energy used in commercial buildings and 19% in residential buildings (Elmira et al., 2016). We conducted a review of research focusing on how aspect ratio and street orientation affects the reduction of the urban heat island effect. See Table 2.4 for a summary of our findings.

Table 2.4: Summary of aspect ratio and street orientation impact on UHI mitigation. Source: author

Indicator	***Researcher***	***Study***	***Result***
Aspect ratio	F Bourbia, H.B Awbi, 2004	Simulated the shading level of street canyons with different aspect ratios in the hot-dry climate of El-Oued, Algeria	The air temperature in wide canyons with an aspect ratio of 0.5 is 4°C higher than that in narrow canyons with an aspect ratio of 2. ***Synthesis:*** Deeper canyons provide a more comfortable micro climate in urban environments..
Aspect ratio: *galleries and overhanging facade*	Ali-Toudert F, Mayer 2007	The study used ENVI-met model and PET index to evaluate the effects of galleries and overhanging facades on thermal comfort in summer in Ghardaia, Algeria.	Shading is crucial for summertime comfort, and increasing the aspect ratio from 1 to 2 could enhance PET values by up to 24 K. ***Synthesis:*** Urban canyon's vertical profile and orientation have a significant impact on human thermal sensation at street level.
Street orientation	Ali-Toudert F, Mayer 2007	The study examined various street orientations with different aspect ratios during a typical summer day in Ghardaia, Algeria. d. The study was conducted by means of the three-dimensional model ENVI-met to determine which one provides the best thermal comfort.	The N-S orientation and intermediate orientations NE-SW and NW-SE have similar PET patterns, while E-W orientation is more uncomfortable. Rotation to NE-SW or NW-SE orientation provides better thermal comfort, as the walls offer better shading. These orientations are a good compromise for winter solar access, allowing for greater sun exposure of facades compared to N-S orientation. ***Synthesis:*** Rotating the street orientation to NE-SW or NW-SE in arid regions can result in better thermal comfort as the shading provided by the walls is more effective in these orientations.

D. Sky view factor: The sky view factor (SVF) is the ratio of the visible sky to the potentially available sky in a given point on a surface. Buildings and vegetation obstruct the vision toward the sky, affecting the SVF, which is important in determining the geometry, density, and thermal balance of urban areas. It is also significant in generating and controlling the heat island effect and is expressed as a dimensionless number between 0 and 1 (Oke et al., 1991).

2.4.2.4. Synthesis

The impact of the urban heat island can be significantly reduced by implementing methods such as increasing the reflectivity of urban materials, urban greening, water bodies, and optimizing urban layout, as we have seen above. By increasing the reflectivity of surfaces, the amount of solar radiation absorbed by buildings and paved areas can be reduced, leading to lower temperatures. Urban greening and water features can provide shade, evaporative cooling, and heat absorption, which can further lower surface temperatures and improve air quality. Finally, improving urban layout can enhance airflow, mitigate the effects of heat islands, and improve thermal comfort. These techniques can be used to design and plan more sustainable and livable communities that are resilient to the effects of climate change.

2.4.3. Form

According to Golany, the configuration of cities plays a crucial role in determining human settlements. The urban form encompasses various variables that have a considerable influence on the local climate, including the dimensions, layout, and population density of regions, as well as the design of buildings, streets, and public spaces (Elkhazindar et al., 2022). Currently, building energy performance is understood to be dependent on several factors. Therefore, Baker and Steemers (2004) defined four factors that affect energy consumption in buildings (figure 2.10).

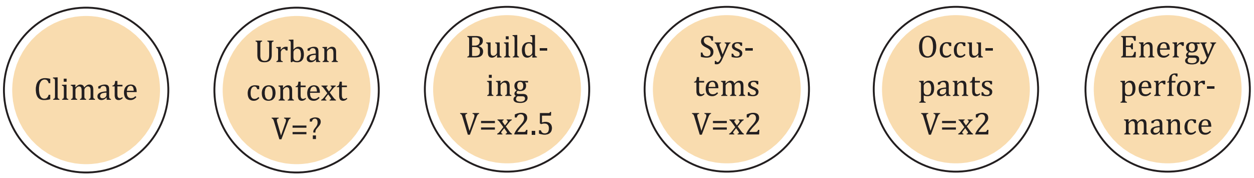


Figure 2.10: Factors that affect energy consumption in buildings. Source: Baker et al., 2004

2.4.3.1. Compactness: What shape should a building be to reduce heat losses?

A desirable geometric shape would ensure year-round comfort, keeping the interior cool during summers and warm during winters. Compactness would limit the surface area that is exposed to heat loss or intense solar radiation, making an optimal shape essential in achieving this goal.

The CF coefficient, which is the ratio of the heat loss surface area of the exterior envelope to the habitable volume (m2/m3), indicates how much the building is exposed to ambient weather conditions. A higher shape coefficient leads to greater energy efficiency. However, an excessively compact shape may not be suitable from an architectural or natural lighting perspective. Therefore, during the project's design phase, a balance must be struck to achieve the desired results without compromising on other factors (Baker et al., 2004). See table 2.5

Table 2.5: Summary of compactness impact on UHI mitigation. Source: author

Indicator	*Researcher*	*Study*	*Result*
Compactness	Alobaydi et al 2016	Investigated the impact of three different urban forms in the city center of Baghdad, Iraq on UHI,	High H/W ratio in compact urban forms had the lowest air temperatures. ***Synthesis:*** In an arid zone, it is recommended to adopt a compact form to achieve lower air temperatures and improve thermal comfort for occupants.
	Catholic University of Louvain 2012 / SAFE project	Study was conducted on three individual buildings of different types. The first building was a detached house with four facades and an area of 120 m2. The second building was a semi-detached house with the same area, and the third building was both isolated and semi-detached with the same area.	The detached house consumes 12.3% more energy for heating than a semi-detached house of the same size and 21.9% more than a terraced house. In addition, an isolated terraced house consumes 10.9% less energy than the same semi-detached house. ***Synthesis:*** energy consumption varies according to the type of building, its compactness, level of insulation, and other characteristics, and terraced housing reduces energy consumption.

2.4.3.2. Passive volume

The passive volume is the part of the building located within 6 meters of a window and which benefits from natural lighting and ventilation (figure 2.11). The LT method (Baker & Steemers, 1996) defines a passive zone as the part of a building located at a certain distance from a perimeter wall, which benefits from natural lighting, ventilation, and useful solar gains during the winter. Energy consumption associated with lighting and ventilation should be lower in these areas. However, these zones suffer from heat losses through the envelope and unwanted solar gains during the summer (Baker et al., 2004).

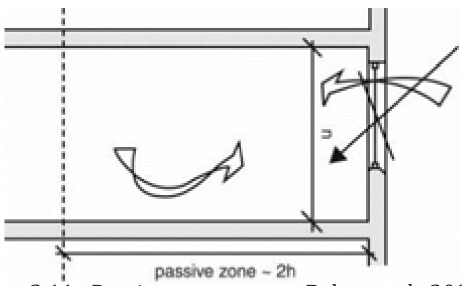


Figure 2.11: Passive zone source: Baker et al., 2004

2.4.3.3. Synthesis

The shape of a building can affects its energy consumption by influencing its exposure to solar radiation and airflow. Compact building forms with a high surface-to-volume ratio can reduce energy consumption by minimizing heat loss through the building envelope.

The shape of a building can affects its energy consumption by influencing its exposure to solar radiation and airflow. Compact building forms with a high surface-to-volume ratio can reduce energy consumption by minimizing heat loss through the building envelope.

2.4.4. Envelope

After determining the environmental impact and architectural form of the building, we zoom in to the building envelope. Building envelope means the wall, the ceiling, the floor, the ground and different openings (doors and windows) which defines the inner space, separates and filters the indoor space from the outdoor environment by controlling the amount of heat, cold, air and light intake per day. The physical (thermal inertia, thermal resistance, ...etc) and structural (type of materials, thickness, color, ...etc) characteristics of these components have a significant impact on the thermal performance of the building, therefore its energy consumption. (Izzet Yüksek, Tülay Tikansak Karadayi, 2017).

2.4.4.1. Materials

Understanding that building materials have multiple impacts helps green building professionals understand the broader implications of a particular material (Marian Keeler, Prasad Vaidya, 2016). The indoor conditions and the occupant thermal comfort are affected by the heat transfer in and out of a building caused by the material properties that vary in the degree and manner in which they transmit energy flow, which are: Thermal conductivity, thermal resistance (table 2.6), surface characteristics with respect to radiation, surface convective coefficients and heat capacity of the building material (Kuppaswamy Iyengar, 2015).

Table 2.6: Materials thermal conductivity and resistance Source: author based on ASTM

Material	***Thermal conductivity W/m.K***	***Thermal resistance K/W***
Concrete	1.4-2.5	0.04-0.09
Brick	0.6-1.2	0.07-0.13
Stone	1.2-2.5	0.04-0.09
Wood	0.05-0.15	0.05-0.15
Steel	50-60	0.0005-0.0006
Glass	0.7-1	0.025-0.035
Aluminum	200-230	0.00022-0.00025
Plaster	0.5-1	0.025-0.05
Insulation materials	0.03-0.05	0.4-2.5

Aside from the physical properties of the materials, other criteria (Figure 2.12) must be appreciated like aesthetics, performance, availability and cost. And environmentally focused, an additional criteria is added which is the amount of embodied energy required for producing these materials (Kuppaswamy Iyengar, 2015).

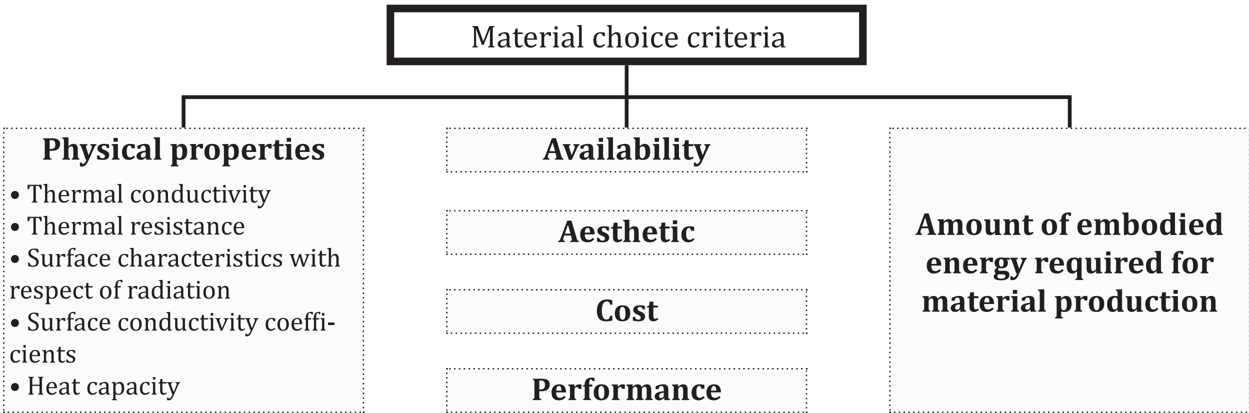


Figure 2.12: Material choice criteria. source: author

Energy efficiency shouldn't only be in the production phase of the building material (embodied energy) but also the use phase. Energy efficient materials are characterized by their properties (Figure 2.13) (Izzet Yüksek and Tülay Tikansak Karadayi, 2017):

Energy efficient materials properties

Local materials
They are local and don't need transportation, they have less embodied energy.

Recycled resources
Unlike materials that were produced from natural materials, recycled materials save up to 40 - 90% of energy on the manufacturing phase.

Durable materials
The more durable material is the more resistant and long lasting it is. It results a delay or elimination of need of renewing it or maintenance (aging).

High thermal insulation capacity material
The higher the thermal insulation is the lower the amount of energy used by the building to achieve human comfort on a daily basis.

Materials manufactured through low density industrial processes
Using less complicated and less heavy procedures during manufacturing phase results less embodied energy, such as in cement manufacturing using shaft furnaces instead of conventional rotary factory enhances energy saving up to 10 - 40%.

Natural materials obtained from renewable resources
Natural materials which are not only easily found, often locally, and have lower embodied energy, but also they usually come from renewable resources such as wood, bamboo, ...etc.

Labor intensive materials
Using highly qualified man power in manufacturing phase which is renewable energy resources such as solar, wind energy, ...etc instead of fossil fuels, for example dried earth bricks are considered labor intensive materials on the contrary burned earth bricks.

Materials consuming less energy during worksite process
Not only manufacturing phase consumes energy, but also worksite process because of its high need for electricity, machines in operation, heating and lightening.

Figure 2.13: Energy Efficient Materials properties. Source: author based on Izzet Yüksek and Tülay Tikansak Karadayi, 2017

2.4.4.2. Thermal inertia

The law of conservative energy says that energy can change its form or nature, but not created from nothing or destroyed to nothing and it applies for thermal energy (Figure 2.14) (José Ma P Sala Lizarraga & Ana Picallo-Perez, 2020).

It can be evaluated by 02 parameters (Figure 2.15) (Website Guide Bâtiment Durable Brussels):

- Diffusivity: $\alpha = \lambda / (\rho * c)$ [m^2/s] ability to conduct heat throught itself;
- Effusivity: $E = (\lambda * \rho * c)^{1/2}$ [J.K-1.m-2.s-1/2] ability to transfer heat to another surface.

With **λ**: Thermal conductivity (W/m·K), **ρ**: Density of the material in [kg.m-3] and **c**: Specific heat capacity of the material in [J.kg-1.K-1].

When a material has a high effusivity and low diffusivity, it is considered as a material with high thermal inertia (Figure 2.16 & table 2.7).

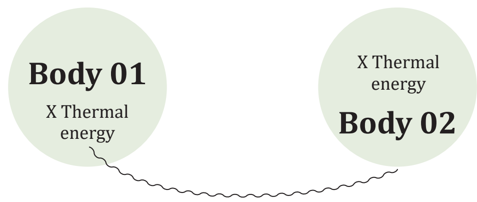


Figure 2.14: Thermal Energy law. Source: author

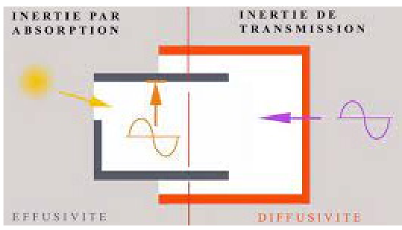


Figure 2.15: Effusivity and diffusivity Source: Website EnviroBoite

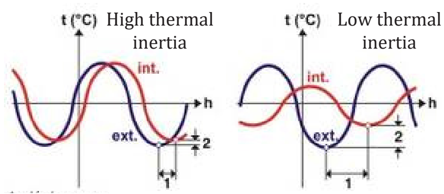


Figure 2.16: High And Low Thermal inertia. Source: Website EnergiePlus-lesite.be

Table 2.7: Thermal inertia of materials. Source: author based on ASTM

Materials	λ	ρ	c	Effusivity		Diffusivity x e-6		Thermal inertia
Concrete	1.4-2.5	2000-2600	0.8-1	47.3	H	0.875	L	H
Brick	0.6-1.2	1500-2000	0.8-1.2	26.8	H	0.5	L	H
Stone	1.2-2.5	2000-2700	0.8-1.2	43.8	H	7.5	L	H
Wood	0.05-0.15	300-900	1.4-2.4	4.5	M-H	0.119	M-H	L-M
Steel	50-60	7850	0.45-0.51	420.2	L	14.1	H	L-M
Glass	0.7-1	2500	0.75-0.85	36.2	L	0.37	H	L-M
Aluminum	200-230	2700	0.9-1.2	6971	L	82	H	L
Plaster	0.5-1	1200-1800	1-1.2	24.4	M	0.41	M	K
Insulation material	0.03-0.05	20-200	0.7-1.2	0.6	L	2.1	L	L

Local, green, durable and energy efficient materials are numerous, but certainly there is a best material for each scenario and case (Table 2.8). The best material answers most of the project's needs, in parallel to its environmental requirements.

Table 2.8: Summary of materials choice criteria. Source: author

Indicator	Researcher	Study	Result
Discom-fort and comfort loads	Mousa Ahmed Alhaddad and Zhou Tie Jun, 2012	A comparative study of the thermal comfort of different building materials (concrete block, rock, stone, mud brick and fired brick) in Sana'a Yemen, run on an actual existing 134m² concrete block building, to obtain monthly load discomfort in each case.	The indigenous material (fried brick) has the lowest load discomfort compared to contemporary materials, especially concrete which is the worst. We can see that fired brick and adobe (mud brick) are quite similar. The fired brick has the lowest load discomfort on the cold months but the highest on the hot months, the complete opposite of the stone, keep in mind that concrete blocks cost way more than locally made bricks while the stone is the most expensive. *Synthesis:* The fired brick is the best material for arid climate.
	R. Al-Mahaidi, S. Sriramulu, and M. Nehd,i, 2018	A comparative study between Compressed Stabilized Earth Blocks (CSEB) and fired earth brick (FEB)	The temperature change on the sample of CSEB is lower than the one of FEB. CSEB also showed low thermal conductivity and diffusivity. However, FEB showed higher specific heat capacity therefore it can store more heat. *Synthesis:* CSEB is a better solution for arid regions.
Additives	Umar Faruk Adamu and Abdul Hafiz Abubakar; 2018	A study investigate the different types of cement and lime additives on the properties of CSEB	The properties of CSEB were increasing as the percentage of additives increased. *Synthesis:* Cement and live additives significantly enhance CSEB's properties.

Table 2.8: Summary of materials choice criteria for thermal comfort. Source: author

Indicator	***Researcher***	***Study***	***Result***
Mechanical properties	M. S. Hossain et al, 2019	A comparative study on the mechanical properties between hollow and solid CSEB	The results showed that the solid CSEB had higher compressive and flexural strengths. However, hollow CSEB were lighter and had lower water absorption. *Synthesis:* Choice depends on the specific requirements of the project.
Thermal properties	B. K. Parbat, S. K. Patro, and S. K. Sekhar, 2016	A comparative study on the thermal properties of CSEB and FEB	The study showed CSEB had lower thermal conductivity and higher thermal resistance. Also CSEB properties were further more improved after adding stabilizers (rice husk ash and fly ash). *Synthesis:* CSEB is better option in arid regions for thermal comfort.

2.4.4.3. Thermal insulation

Thermal insulation is the process of reducing heat transfer between two rooms or environments that are at different temperatures and It takes place in 04 ways (Figure 2.17) : Radiation, conduction, convection and evaporation (Kuppaswamy Iyengar, 2015).

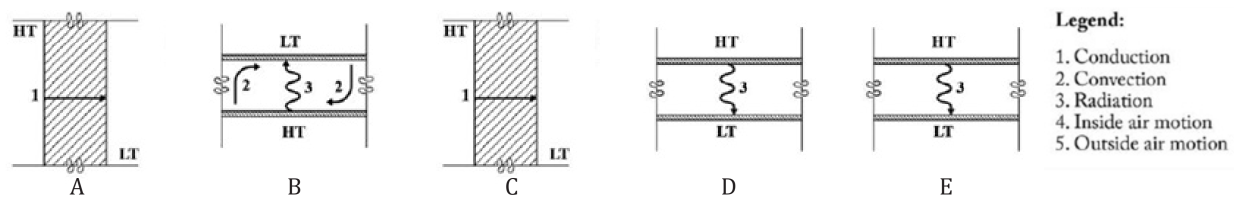


Figure 2.17: Heat Transfer Mechanism, A. Solid Material (conduction), B. Air Space In A Roof (Convection And radiation), C. Air Space In A Wall (convection And Radiation), D. Air Space In A Floor (radiation), E. Air Composite Assembly Of A Wall (conduction, Convection And radiation) . source: Kuppaswamy Iyengar, 2015

As insulation materials have a significant impact on energy efficiency (Table 2.9), their harm to the environment can seriously reduce the green credentials of a project (Alison G.Kwowk, AIA + Walter Grondzik, Pe, 2018). These materials are classified based on their materials or the climate they're best used in (Figure 2.19) (Gajanan Deshmukh and al, 2017) and can be installed in 03 ways: externally, internally or in a sandwich configuration (Figure 2.20) (Huakun Huang and al, 2020).

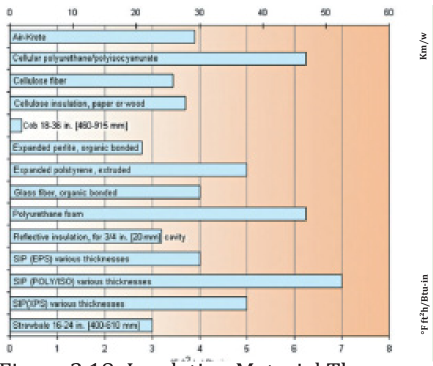


Figure 2.18: Insulation Material Thermal resistance. source: Kathleen.B

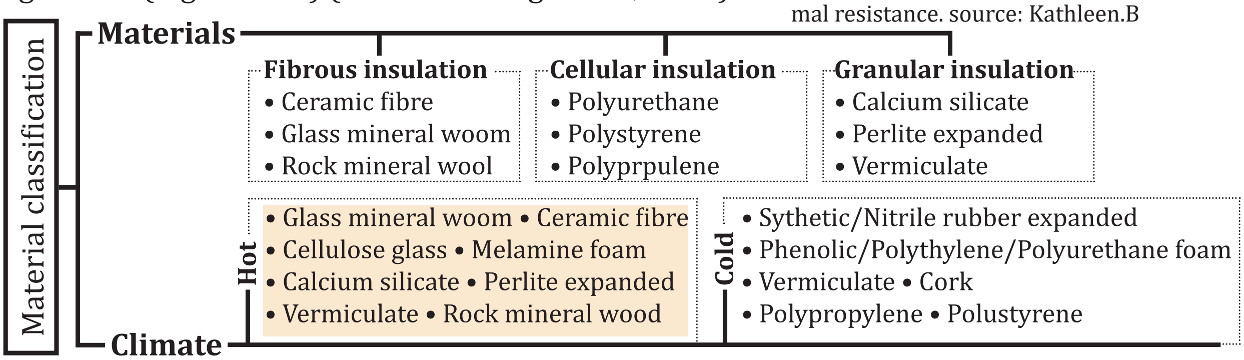


Figure 2.19: Insulation Material classification. source: Author based on Gajanan Deshmukh and al, 2017

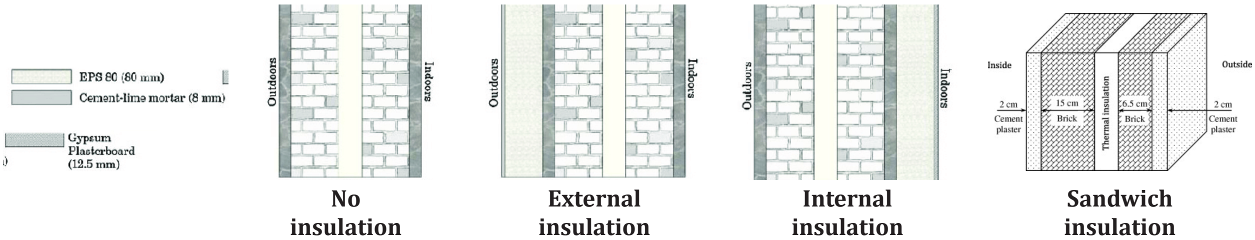


Figure 2.20: Thermal Insulation emplacement. source: Kolaitis et al, 2012 and Naouel Douas, 2011.

Table 2.9: Summary of thermal insulation on energy consumption. Source: author

Indicator	***Researcher***	***Study***	***Result***
Thermal comfort enhancement	Necib Hichem et al, 2013	Study aims to test thermal inertia changes on a residential building in Algeria, Ouargla after the integration of different types of Phase Change Materials (PCM) in different locations of external wall building into some of the 12 cavities of the 30x10x15cm brick's square holes.	When testing for different types (Paraffin wax, CaCl2 6H2O, n-eicosane, Paraffin 52-54 and P116) and emplacement (middle, near the inner wall, near the outer wall) of PCM in the brick, in a melting temperature that varies between 52 – 29.9°C, we can see the type CaCl2 6H2O is always showing low thermal flux compared to the other types. But also, compared to all the emplacements, the middle position gives best results of almost 4.6 W/m2 thermal flux through the whole test. *Synthesis:* Brick with CaCl2 6H2O type of PMC placed on the middle wall is a better option to improve thermal inertia
	Silvia Mariani et al, 2018	A comparative study of thermal energy performance of different innovative thermal insulated building solutions developed by contemporary architecture and traditional stone masonry walls, using Design Builder.	The innovative solutions ensured lower total annual energy consumption compared to the contemporary solutions, also energy savings. Also massive envelopes delay heat transmission and keep an indoor comfort. However, there is no improvement in thermal activity when wall thickness increased to 0.81m. In the other hand thermal activity was improved by using thermal insulation materials with reduced thickness (best case of 0.54m wall thickness). *Synthesis:* To prevent cost and surface loss by using thicker walls for thermal comfort, thermal insulation can ensure comfort with reduced thickness and cost.
Insulation emplacement	Lili Zhang et al, 2017	This study focuses on the wall energy conservation by using thermal insulation and specify its best emplacement.	We can see the smallest heat flow value when internal thermal insulation wall (35-54% and 53-86% less than other cases). *Synthesis:* The best insulation layer location on wall is internal configuration, and the closer to wall inner surface the lower inner surface temperature and higher wall thermal response rate.

2.4.4.4. Opening

Openings are classified based on 3 parameters (Figure 2.21) and the choice of the opening is based on the type and requirements of the project (Table 2.10): (Architect's Data, 2012)

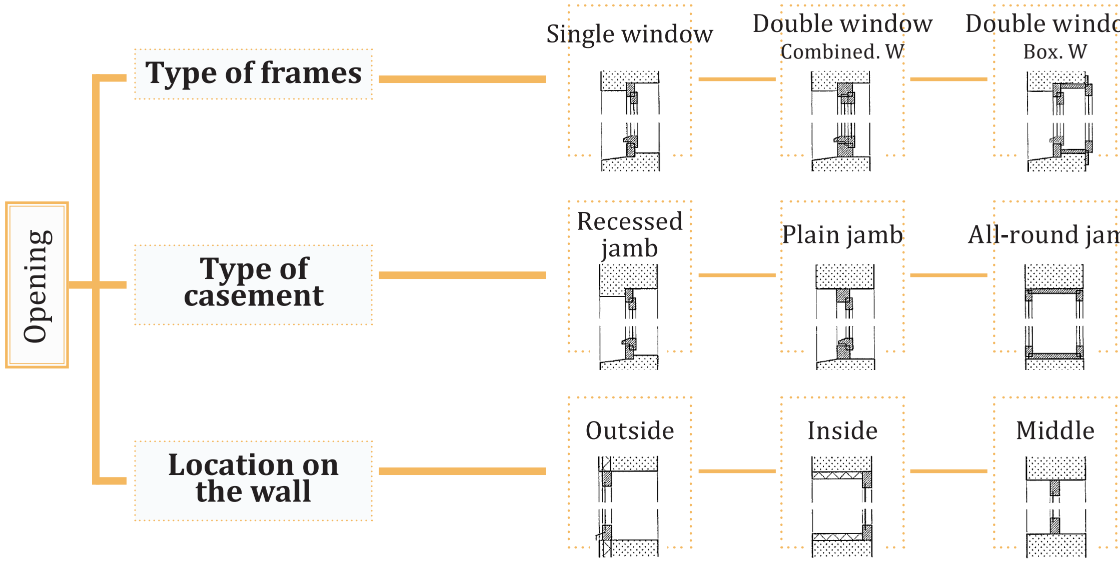


Figure 2.21: Opening classification. source: Author based on Architect's Data, 2012

Table 2.10: Summary of window impact on energy load. Source: author

Indicator	*Researcher*	*Study*	*Result*
Size, orientation and frame	Soojung Kimaa et al, 2016	This study highlights the impact of windows size, position and orientation on a family building energy load using BIM (Revit)	The smaller the size of the opening the less energy load. However, when window-to-wall ratio is 20%, the position of the window has the biggest influence on the energy loads. But with WWR more than 20%, window position merely effects the energy load. The lowest energy load is when the opening is positioned in the middle of the wall in 3 orientations (North, South and West) but highest when orientation is East. Each opening frame material has its thermal transmittance, the best one is the with the lowest TT: PVC and Wood. *Synthesis:* For a lower energy load, the best option is smaller the size the better, windows that are located in the middle in all orientation with PVC or wood window frame, but the highest load on every emplacement on the east orientation

2.4.4.5. Glazing

Glazing can be classified in 2 major classes (Figure 2.22) (Website The Constructor):

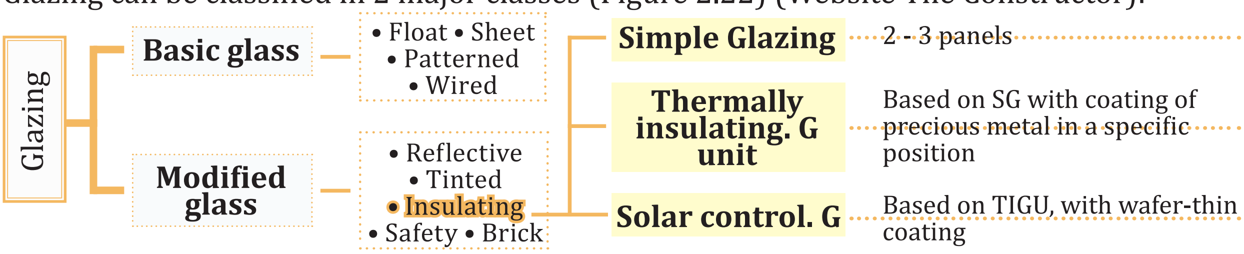


Figure 2.22: Glazing classification. source: Author based on Architect's Data, 2012

Insulating glazing classified depending on number of layering and type of coating, and each has an amount of impact on the indoor thermal comfort (Table 2.11).

Table 2.11: Summary of glazing impact on cooling and energy consumption. Source: authors

Indicator	***Researcher***	***Study***	***Result***
Glazing	Necib Hichem et al, 2013	A study using Design Builder that focused on the effect of different glazing types with various window orientations and WWR on energy consumption in a typical room in an office building located Aswan, Egypt	The higher the number of panels and coating, the best energy consumption and the less the worse. But since these hot regions require more energy for cooling than lighting, then the best option is G6 of low heat transfer coefficient and enough natural illumination. ***Synthesis:*** The best insulation glazing is with higher number of layering.

2.4.4.6. Shading options

Shading involves the reduction of solar radiation that is absorbed by a building's envelope (Table 2.13), therefore less amount of transferred heat to the interior (Mohammad Arif Kamal, 2010). Shading can be provided by (Table 2.12):

Table 2.12: Shading options. Source: authors based on Website Construction Specifier, Archdaily

Envelope	***Shading option***
Wall	Surrounding buildings, screens or vegetation.
	Orientation of the building on one or more of its external walls.
	Effect of recesses of the external envelope of the building.
	Static or moveable external shading devices: curtains, awnings, louvers, overhangs, porches or self-shading envelope.
	Internal shading devices.
	Reflective films
Roof	Rolling reflective coating and canvass, earthen pots, vegetation

Table 2.13: Summary of self shading on energy consumption. Source: authors

Indicator	***Researcher***	***Study***	***Result***
Static wall self-shading	Ahmed Fathy Abouelfadl and Mohamed Osama El-Gohary, 2019	This study focuses on the impact of 03 different (20x10x6cm) brick bond types for thermal performance in a hot arid climate zone, specifically on the southern façade.	The thermal mass was highly effected by the brick bond, the exposed surface of brick and mortar. Flemish and English bonds were the best, however Garden wall and Basket Weave were the worst ***Synthesis:*** The higher thermal mass is, the less direct sun contact, especially in case of unreinforced brick wall.

2.4.4.7. Synthesis

The envelope has a great impact on the energy consumption and the interior and exterior thermal comfort. A range of factors effect its thermal resistance, including: The choice criteria of construction and insulation materials, their physical, thermal and mechanical properties,the size, the emplacement, the shading. As well as the openings, the glazing and the insulation. In addition, the user's needs and preferences (aesthetics, cost, ...etc) must be considered in conjunction with the environment requirements.

2.5. Passive design in an Arid climate zone

2.5.1. Arid zone

Following climate classification of the German botanist and climatologist Wladimir Köppen which is based on temperature and precipitation patterns (further information see annexe), Algeria is characterized by five distinct climate zones (Figure: 2.19): Warm Mediterranean climate (Csa), Cold semi-arid climate (BSk), Hot semi-arid climate (BSh), Cold desert climate (BWk) and Hot desert climate (BWh) from North to south

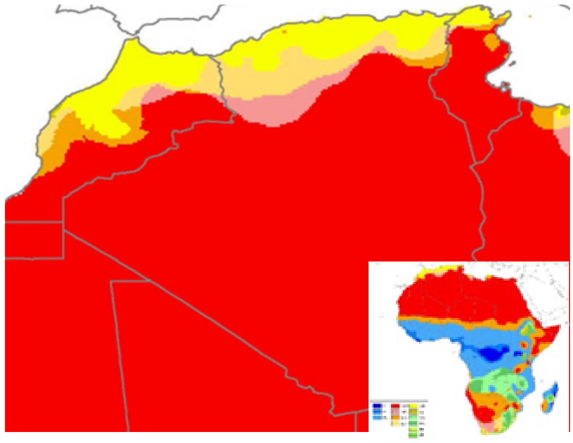


Figure 2.19: Köppen map of Algeria. Source: Peel and al, 2007

2.5.2. Adaptation in arid zone

Arid environments are highly sensitive to climate change, whereby the resultant warming effect tends to amplify pre-existing aridity conditions, leading to more frequent and severe conditions. Contemporary adaptation strategies, including irrigation systems, water conservation measures, and drought-resistant crop development, have further facilitated the successful settlement and habitation of arid regions.

For urban planning and design in general and the design of individual building in particular, architects strive to provide indoor and outdoor thermal comfort to counter high temperature, low humidity and high solar radiation using passive eco-friendly durable strategies starting from the material production phase, shedding light on energy efficient materials such as local and renewable materials on a life cycle basis of the building. But most importantly, they emphasize on the passive design which focuses on the environment integration, form and envelope aspects using passive cooling methods such as natural ventilation and renewable active cooling systems such as Canadian Well.

2.5.3. Materials in arid zone

Comfort in arid zones is a challenging target but can be achieved through the use of passive techniques. Materials are an important factor for durable building design to enhance indoor and outdoor thermal comfort (Table 2.14), for example concrete is a great thermal resistant material and it assures indoor comfort but it creates heat islands when used all over the city.

Table 2.14: Summary passive design materials in arid zone. Source: author

Indicator	*Researcher*	*Study*	*Result*
Earth based construction materials	Mohamed F. El-Kholy, Mahmoud A. A. Hassanain, and Hazem M. Hegazy, 2018	This study focuses on evaluating thermal and mechanical properties of earth based construction materials of an actual building in an arid climate zone: Adobe, CSEB and rammed earth	Results showed that these 03 materials provide good thermal performance, however, CSEB showed the lowest thermal conductivity and highest compressive and flexural strengths while adobe was quite the opposite. *Synthesis:* Earth based construction materials are the best for arid climate zone, and CSEB is the best option.

Table 2.14: Summary passive design materials in arid zone. Source: author

Indicator	***Researcher***	***Study***	***Result***
Block chemical property	Wael M. Issa and Ibrahim H. Alshamsi, 2019	This study evaluated thermal performance of different additives on CSEB in arid climate zone.	The study shows that Fly-ash and silica fume led to higher compressive strength and lower water absorption. In the other hand, lime improved durability. ***Synthesis:*** Fly-ash and silica fume improve strength and water resistance and lime improves durability in arid zone.
Block physical property	N.A. Soliman, M.K. Darwish, and S.M. El-Kholy, 2016	This study evaluates the thermal performance of CEB and compares them in the case of solid and hollow CEB in hot arid climate zone	The study shows that hollow CEB (λ = 0.35-0.41 W/m.K) are better than solid ones (λ = 0.52-0.72 W/m.K) due to the presence of air gap ***Synthesis:*** Hollow CEB are better option for hot-arid climate zone.
Brick mortar	A. Vianello, A. Romagnoli, and M. C. Bignozzi, 2012	This study tests thermal conductivity in hot arid climate zone of different types of mortar (cement-lime, clay and earth based mortars) on CSEB.	The study shows that cement-lime mortar has the highest thermal conductivity and heat transfer. Meanwhile, it shows the lowest with earth based mortars. ***Synthesis:*** Earth-based mortar is the best for hot-arid climate zone.
Brick bond	Ahmed Al-Hussaini and Farid Abed, 2017	This study evaluates the thermal performance of different brick bond patterns (stretcher, English, Flemish and combinations of these patterns) in masonry wall in hot-dry climate zone	The study shows that the patterns English and Flemish, as well as their combination English-Flemish bond is the most effective due to the air gaps that can be created between the bricks. On the other hand, the stretcher pattern was the worst due to the lack of air gaps. ***Synthesis:*** Flemish and English bonds, as well as their combinations are highly recommended for wall masonry in hot-dry climate zone.
Insulation material	Adel M.A. Sharif and Zahra R. Al-Douri, 2020	This study evaluates various types of thermal insulation materials in hot-dry and hot-humid climates.	Results showed that eco-friendly insulation materials (cellulose, sheep wool and recycled materials) had lower thermal conductivity compared to other insulation materials (fiberglass and polystyrene). In addition, the thicker the insulation, the better results. It has a higher cost but a better choice in the long run. ***Synthesis:*** Eco-friendly insulation is best option for hot-dry and hot-humid climates, especially for the long run. As well as, thicker insulation and proper installation technique maximize their thermal performance.

We find an endless number of great green and durable materials that can be used in Arid zone, but each has its own components and proportions, physical, thermal and mechanical characteristics, advantages and inconvenient, which will define the best option for our case (Table 2.15).

Table 2.15: Components and proportions, Physical, thermal and chemical characteristics, advantages and inconvenient of materials Source: author based on AMTM

Material	***Components & proportions***	***Characteristics***			***Advantages***	***Inconvenient***
		Physical	***Thermal***	***Mechanical***		
Stone	/	/	• Density 2300 – 2900 Kg/m3 • R = 0.1 – 1 W/m°C • λ = 0.7 – 3 W/m.K	• Density 1.5 – 3 t/m3 • WCS = 20 – 200 MPA • High durability	• High durability and resistance to weathering and erosion • Aesthetically pleasing and can increase property value • High thermal mass and low thermal conductivity, which can contribute to energy efficiency in buildings	• High cost and limited availability in some regions • Heavy weight, which can increase transportation and installation costs • Requires skilled labor for installation and maintenance.
Adobe (mud dried brick)	• 55-75% sand • 10-28% silt • 15-18% clay • 0-3% organic material	• Sandy clay soil with an important percentage of sand • Sized at 40x20x10cm	• Density 1200 – 1700 Kg/m3 • Thermal insulation R= 0-4 W/m°C • Thermal conductivity λ = 0.65 W/m.K	• Density 1.4 – 1.8 t/m3 • Wet compression strength 0 – 5 MPA • Low durability	• Raw material readily and locally available • Inexpensive production equipment	• High water consumption • Drying time dependent on climate • Low water resistance
Fired earth brick FEB			• Density 1200 – 2000 Kg/m3 • R = 0.2 – 0.8 W/m°C • λ = 0.6 – 1.2 W/m.K	• Density 1.6 – 1.9 t/m3 • WCS = 20MPA • High durability	• Low cost and raw material availability • High compressive strength and durability • Good resistance to weathering and erosion • Low thermal conductivity and high thermal mass, which can contribute to energy efficiency in buildings	• High embodied energy and carbon emissions in production • Longer production time and use of burning method
Compressed earth brick CEB	• 70-85% Soil: mixture of sand, silt and 5-25% clay • 0-10% Stabilizer: optional to improve strength and durability	• 25 x 12.5 x 7.5 cm	• Density 1600 – 1900 Kg/m3 • R = 0.4 – 0.8 W/m°C • λ = 0.5 – 1.2 W/m.K	• Density 1.8 – 2.2 t/m3 • WCS = 2 – 10 MPA • High durability	• Low cost and raw material availability • High thermal mass and low thermal conductivity, which can contribute to energy efficiency in buildings • Sustainable and environmentally friendly, with low embodied energy and carbon emissions in production	• Limited compressive strength compared to other materials such as concrete • Susceptibility to water damage without proper treatment and maintenance • Limited aesthetic appeal, which can affect marketability and public perception.
Stabilized earth brick SEB	• 60-70% soil • 0-10% sand • 5-10% cement • 2-5% lime • 10-12% water	• 25 x 12.5 x 7.5 cm	• Density 1700 – 1900 Kg/m3 • R = 0.4 – 0.8 W/m°C • λ = 0.5 – 1.2 W/m.K	• Density 1.8 – 2.2 t/m3 • WCS = 3 – 15 MPA • High durability	• Higher compressive strength than traditional earth bricks • Low cost and availability of raw materials • Low cost and availability of raw materials	• Requires stabilization agents, which can add to production costs and environmental impact • Susceptibility to water damage without proper treatment and maintenance • Limited aesthetic appeal, which can affect marketability and public perception.
Concrete	• 10-15% cement • 15-20% water • 25-30% fine aggregate (sand) • 35-40% coarse aggregate (gravel or crushed stone)	• 39 x 19 x 14 or 20 x 20 x 40 cm	• Density 2200 – 2500 Kg/m3 • R = 0.1 – 1.7 W/m°C • λ = 1 – 1.8 W/m.K	• Density 2.3 – 2.5 t/m3 • WCS = 20 – 40 MPA • High durability	• High compressive strength and durability • Availability of raw materials and widespread use in construction • Versatile and can be molded into different shapes and sizes	• High embodied energy and carbon emissions in production • Heavy weight, which can increase transportation and installation costs • Low thermal mass and high thermal conductivity, which can reduce energy efficiency in buildings.
Eco-crete	• 20-25% cement • 30-35% water • 20-25% fine aggregate (sand) • 20-25% coarse aggregate (recycled materials)	• 39 x 19 x 14 or 20 x 20 x 40 cm	• Density 1600 – 2200 Kg/m3 • R = 0.4 – 1.4 W/m°C • λ = 0.6 – 1.6 W/m.K	•Density 2 – 2.5 t/m3 • WCS = 20 MPA • High durability	• Sustainable and environmentally friendly, with low embodied energy and carbon emissions in production • High durability and resistance to weathering and erosion • High thermal mass and low thermal conductivity, which can contribute to energy efficiency in buildings	• Higher cost compared to traditional concrete • Limited availability and market acceptance • Requires specialized installation techniques and equipment.

2.5.4. Shading in arid zone

In arid zone, building's envelope should minimize heat contact therefore heat gain and maximize natural ventilation (Table 2.16). Not only choice of material should be considered, but also the way of building the outer wall. As well as having small and narrow openings. But for extra protection, they also often cover the wall with different shading options (figure 2.24), either integrated or fixed or mobile.

Table 2.16: Summary passive design materials in arid zone. Source: author

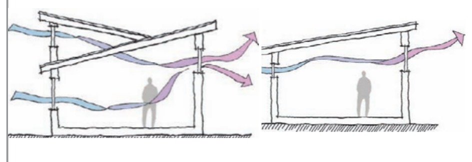
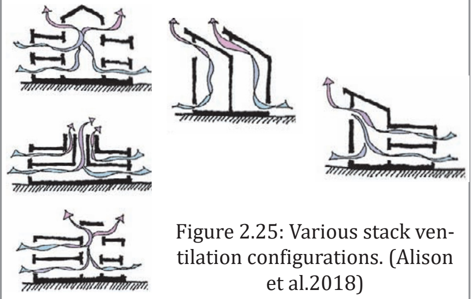
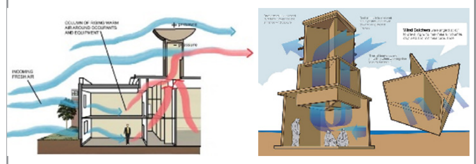
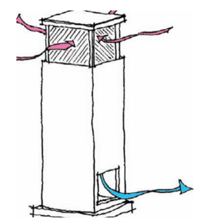
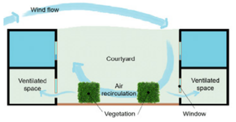
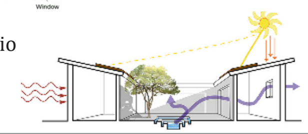
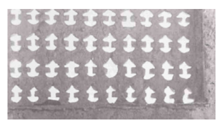
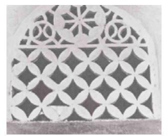
Indicator	***Researcher***	***Study***	***Result***
Shading option	H. M. Al-Homoud and K. F. Siren, 2010	This study reviews the different shading options and analyzes their effectiveness in indoor thermal comfort in arid zone.	Results showed that the most effective strategy includes external shading device (shading screens, louvers and pergola) and internal shading (curtains and blinds). In addition to building orientation, form and vegetation. ***Synthesis:*** overall shading strategies are important in reducing heat gain and improve indoor thermal comfort. It is recommended to use internal and external strategies, orientation, form and vegetation.

Figure 2.24: Köppen map of Algeria. Source: Peel and al, 2007

2.5.5. Cooling methods

2.5.5.1. Natural ventilation: Natural ventilation involves intentionally moving air in and out of buildings using air pressure differences created by wind, temperature, or humidity. Positive pressure on the windward side and negative pressure on the leeward side drive air through a building. It is dependent on three climatic conditions: wind velocity, wind direction, and temperature differential. Designers can manipulate these factors to create desired air movement, aided by location, orientation, and building form. (Kuppaswamy.I, 2015). Please refer to Table 2.18 for a summary of passive cooling methods that can be used to achieve natural ventilation in arid zones.

Table 2.18: Summary of cooling methods in arid zone. Source: author

Ventilation type	***Description***	***Prerequisites***	***Illustration***	***Architectural Issues***	***Studies***
Cross ventilation	It involves creating a flow of cooler outdoor air to carry heat out of a building. It requires outdoor air to be 3°F (1.7°C) cooler than indoor air, and wind pressure drives the process, with higher speeds leading to greater cooling.	Prevailing wind direction and design average wind speed (monthly), outdoor air temperatures (monthly, hourly), estimated design cooling load, desired indoor air temperature.	 Figure 2.24: High and low inlets and outlets provide structural cooling. (Alison et al., 2018)	Building form that maximizes exposure to the prevailing wind direction, provides for adequate inlet area, minimizes internal obstructions.	Cross ventilation reduced the energy consumption of air conditioning systems by up to 30% in Saudi Aabia. (Al-Homoud et al, 2009)
Stack ventilation	Stack ventilation uses natural convection by letting warm air rise and cooler air replace it. It creates its own air current by evacuating warm air at a high point and bringing in cooler air at a lower level. The height of the stack can be increased to achieve greater temperature difference, and it's often designed in sections.	Substantial height available for stack, potential for properly sized and located air inlets and outlets, solar access (for solar-assisted stacks only)	 Figure 2.25: Various stack ventilation configurations. (Alison et al.2018)	To work well, stack ventilation needs a large temperature difference achieved by increasing stack height. It's effective for areas within the lower half of its total height, so stacks should be double the building height or only serve a portion of the floor area.	Stack ventilation reduced indoor temperature by up to 4.4°C and relative humidity by up to 17.6% compared to non-ventilated conditions (Yong et al., 2013).
Wind towers	Known also as: *Malqaf, Badgir, Barajeel, Balanced stack ventilation.* Ventilation through the direct impact of breezes striking the exposed face of the diagonals, as well as through the principle of convection on the other three faces when the structure was warmed by the sun and ambient air.	Hot dry climate, available height for towers.	 Figure 2.26: Section of wind tower. (Jomehzadeh wt al., 2020)	Constructed on a square plan can be contained a cruciform device on the internal diagonals which allowed air to funnel down into a space at the bottom of the tower. The more it is rectangular the more it is efficient.	In Kuwait found that wind towers can reduce the cooling load of a building by up to 28% (Al-Sanea et al, 2012). Rectangular shape and larger size (2/3), being more effective (Ghadiri, Dehnavi, 2015).
Evaporative cool towers	Known also as: *passive downdraft evaporative cooling* Water evaporates into hot dry air at the top of a tower, cooling and moistening the air. The cooled air flows down and is used for cooling.	Hot dry climate, available height for towers, water source.	 Figure 2.27 Warm dry air enters the top of a cool tower, passes through moist pads, and exits the base of the tower as cooler and more humid air. (Alison et al 2018)	Evaporative cool towers work best with open floor plans that permit the cooled air to circulate throughout the interior without being impeded by walls or partitions.	Can reduce indoor temperatures by up to 6-8°C compared to the outdoor temperature in Kuwait (Al-Sanea et al, 2012).
Patios	Allowing air to flow freely and cool down through convection and radiation. This results in a reduction in the surrounding air temperature, making the outdoor space more comfortable. They can reduce outdoor air temperatures by up to 7°C and indoor temperatures by up to 4°C in hot dry climate zones.	Proper orientation for maximum shading, size and shape for natural ventilation and air movement, using materials low heat absorption, shading elements, Incorporating water features for evaporative cooling.	 Figure 2.28: Patio section. (Hao et al., 2021) Figure 2.39: Patio section. (studiofio.com) 	Proper drainage, structural design for weather conditions, regular maintenance, privacy concerns, and safety considerations.	A patio located in the center of a building can reduce the indoor temperature by 4-5°C in hot and dry regions (Mansouri et al, 2019)
Claustra	They generally are made in different decorative patterns of carved plaster plates, unlike the mashrabiya, which are wooden. They are mainly used to evacuate the hot air collected in the higher parts of the room, or in parapet walls, the low walls around roof edges, to produce drafts over people sleeping on the roofs in summer	Proper orientation and placement, sizing and spacing, structural design, appropriate material selection, and regular maintenance.	 Figure 2.30: Clausra above the door Oman Hassan Fathy 1977  Figure 2.31: Claustra in Dubai, Hassan fathy, 1977	Their impact on aesthetics, structural integrity, ventilation and airflow, energy efficiency, and maintenance requirements.	Claustra reduced solar heat gain by up to 70% compared to a solid wall, resulting in improved thermal comfort inside buildings (Al-Obaidi, Sabry, 2015).

2.5.5.2. Mechanical sustainable cooling methods

A. Earth tubes, also known as Canadian wells (figure 2.32), are a passive cooling system that utilizes the stable temperature of the earth to cool and dehumidify outdoor air before it enters a building (table 2.19). They consist of buried pipes that pre-cool the air, reducing cooling energy consumption by up to 30% in commercial buildings. The dimensions of earth tubes vary based on climate, soil type, and building loads, with recommended diameters of at least 200mm and lengths of 15-30m. The tubes should be placed below the frost line and at least 2m away from the building's foundation to prevent freezing and ensure proper ventilation (Ghaffarian Hoseini et al., 2017; Li et al., 2019).

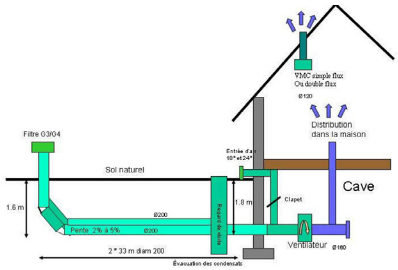


Figure 2.32: Earth tube. Source: baches-serre-direct.com

Table 2.19: Study about the effectiveness of earth tubes. Source: author

Indicator	*Researcher*	*Study*	*Result*
Earth tubes	Abdallah et al 2013	A study conducted in Egypt to investigate the performance of earth tubes	Earth tubes reduced the temperature of outdoor air by 7-11°C before it entered a building, resulting in a reduction of indoor temperatures by 1-3°C. The study also found that the use of earth tubes reduced the cooling load by 38%

B. Mixed mode ventilation: combines natural and mechanical ventilation. Mechanical ventilation supplements or replaces natural ventilation during peak cooling or heating periods. It is a sustainable alternative to traditional air conditioning systems in hot and dry climates (Boubakri.A, Zazzera.B, 2019). Studies have demonstrated the effectiveness of mixed mode ventilation in reducing energy consumption and peak cooling demand ep to 50% while maintaining acceptable indoor air quality (Websteret al,2013, Bauman et al., 2015).

C. Absorption chillers: offer an eco-friendly refrigeration alternative that utilizes heat instead of electricity and avoids harmful refrigerants. They operate through a chemical process and are commonly used in commercial and industrial settings. Studies indicate that absorption chillers can be highly energy-efficient, potentially reducing energy consumption by up to 60% and peak electricity demand by up to 80% compared to traditional compression refrigeration systems. (Chua et al, 2002 Gorjina et al., 2015).

2.5.6. Protection against sand encroachment: The study by Mestoul, Bensalem, and Adolphe (2015) explored the effectiveness of elevating obstacles to protect against sand encroachment in hot, dry climates. Elevating the obstacle to 3 meters proved most effective, dissipating positive pressure, eliminating wake zones, and increasing airflow. The study identified sand accumulation zones, confirming findings from Givoni's experiment on decreasing wind force. Overall, the study highlighted the efficacy of elevated obstacles, like "afregs," in mitigating sand encroachment.

2.5.7. Synthesis: principals of designing in an arid climate zone

The following table (2.20) presents the recommendations derived from our research on energy optimization in building design. These recommendations serve as a fundamental basis for the development of our project in Laghouat, aiming to create a resilient structure that harmonizes with its environment.

Table 2.20: Synthesis: principals of designing in an arid climate zone. Source: author

	Indicator	***Recommendation***
Environment	Increasing reflectivity	- Increase the reflectivity of urban materials through the use of cool pavements and lighter colors (higher albedo) can reduce the heat absorption and lower surface temperatures of buildings and roads.
	Urban greening	- Opt for denser and larger tree canopies to maximize the benefits of urban vegetation. - Choose trees with high foliage area (Leaf Area Index) promotes greater evapotranspiration, shading, resulting in a more significant cooling effect and energy saving.
	Water bodies	- Incorporate water elements such as fountains enhance evaporative cooling and improve human comfort.
	Urban Geometry	- Opt for narrow canyons with high aspect ratio (H\w) - Rotate street orientations to NE-SW or NW-SE (more effective shading) - Maximize the sky view factor by adopting compact design where building and vegetation in urban areas obstruct solar radiations.
Form	Compactness	- Adopt a compact urban form by minimizing the amount of exposed surfaces and maximizing shading effect. (m2/m3)
	Passive volume	- The higher the passive volume to total volume ratio increases, the lower the energy consumption decreases.
Envelope	Materials	- Utilize earth-based construction materials, which offer high thermal resistance and low thermal conductivity. Such as: Adobe, Stone, fired brick
	Thermal inertia	- Utilize materials with high thermal inertia, such as: fired bricks and compressed stabilized earth blocks (CSEB)
	Thermal insulation	- Use thermal insulation such as: PCM to reduce thickness of walls and achieve thermal comfort. - Place the insulation layer on the external configuration, and the closer to wall outer surface the lower heat transmission and higher wall thermal response rate.
	Opening	- Choose smaller-sized openings to reduce energy load, and opt for frame materials such as PVC or wood with lower thermal transmittance.
	Glazing	- Select window glazing with a higher number of insulation material layers for optimal thermal performance.
	Shading options	- Implement shading options, such as pergola screens, vegetation, claustra, moucharbieh and double skin facades, for facades exposed to prolonged sunlight.
Ventilation	Natural ventilation	- Opt for natural ventilation as it offers energy efficiency, improved indoor air quality, thermal comfort, connection with the outdoors, and sustainability benefits.

2.7. Thematic research

2.7.1. Mission: The three WHYs?

Why commercial	*Why Souk*	*Why Oasis*
Revive city's commercial exchange by creating a multi-functional center for entertainment, leisure, culinary experiences, and cultural events.	Revive the city's unique identity "Kser" through reflected history, originality, architecture and urban identity of the place on different experiences.	Revive the old nature state of the city: Palm grove land. Also, balancing the city's day & night life style thanks to the micro-climate effect of the oasis.

Figure 2.33: Illustrates the contribution of each theme we had chosen to the city. Source: Author

The combination of the three will create a sustainable vibrant center that balance modernity with authenticity in Laghouat.

2.7.2. Souk

Souqs hold cultural and historical significance in the Middle East and Islamic societies. They are vibrant hubs in ancient cities, characterized by unique architecture and communal activities that shape urban architecture and create a sense of place.

2.7.2.1. Definition

According to the Arabic dictionary Al-Mawrid, a souk is defined as a place where goods are bought and sold, and where people gather for commercial transactions. Heba Osama, 2020 further describes it as a traditional marketplace that includes pedestrian areas with shops, plazas, and arcades. Similarly, Ibn Battuta referred to souks as vibrant centers of trade and culture, noting the diverse range of goods available, such as exotic spices, perfumes, textiles, and livestock. Overall, souks play a significant role in Arab culture and commerce, renowned for their lively atmosphere, vibrant displays, and animated negotiations between buyers and sellers.

2.7.2.2. Historical Background

The history of souqs is tied to Arab civilization and the trade routes that connected Africa, Europe, and the Far East. Before the 10th century, souqs were caravanserais located on the outskirts of cities, where traveling merchants could rest, exchange goods, and meet others. With Islamic conquests and the expansion of the Muslim Empire, souqs moved inward and became the backbone of urban life, transforming cities into commercial capitals. Souqs were not only important economically but also culturally and socially for their societies (Heba Osama, 2020).

Initially, traditional markets had a casual arrangement where goods were placed on the ground and vendors operated in open-air shops with makeshift tents creating open lanes in between. This informal market layout was also observed in urban areas where vendors would take advantage of pedestrian traffic near gates, main roads, and the central mosque (Dilmi Djamel, 2006).

2.7.2.3. Types of traditional markets

The traditional markets in historic cities may be classified according to the nature of the trade activities that were carried out there, such as: retail trade, wholesale trade and production activities (Dilmi Djamel, 2006).

A. Retail Markets: in historic cities were often located along main streets and grouped together based on the type of goods they sold. They were arranged linearly or in cluster form, which may be open or covered (figure 2.34). The linear arrangement consisted of commercial buildings with the ground floor used for commercial purposes and the upper floor for residential purposes. Arched entrances led to khans, which included lodging, shops, storerooms, offices, and workshops. Cluster composition led to the formation of covered markets like bazaars and khans (Dilmi Djamel, 2006) .

Figure 2.34: Arial view of market in Mashhad, Iran. Source: Dilmi Djamel, 2006

B. Wholesale Markets: Wholesale markets were usually located outside the city walls or near the gates and had large-scale operations with substantial storage warehouses and lodgings. They were similar to retail markets in terms of the grouping of goods and activities and could be arranged linearly or in clusters (Dilmi Djamel, 2006).

C. Workshops: In historic cities, manufacturing activities were restricted to the market place and its surrounding areas. They were well connected to the streets where merchandise could be transported to retail or wholesale markets. The manufacturing activities were arranged based on similarity and the specialization principle. In some cities, places were named after the main activities, such as "sũq al-nahāsin" the copper work and carpenters' markets in Casbah city, Algiers (figure 2.35) (Dilmi Djamel, 2006).

Figure 2.35: Workshop of coppers-smith in Casbah, Algiers. . Source: Dilmi Djamel, 2006

2.7.2.4. The spatial and functional structure of Souk

A. Location: In Islamic cities, traditional souqs are located in the district of the Friday mosque to be easily accessible (figure 2.36). The Friday mosque serves not only as the center of religious activities but also as the assembly place for all inhabitants of the city (Heba Osama, 2020). Additionally, in other references market, mosque, school and public bath were interrelated and formed a complete whole (Dilmi Djamel, 2006).

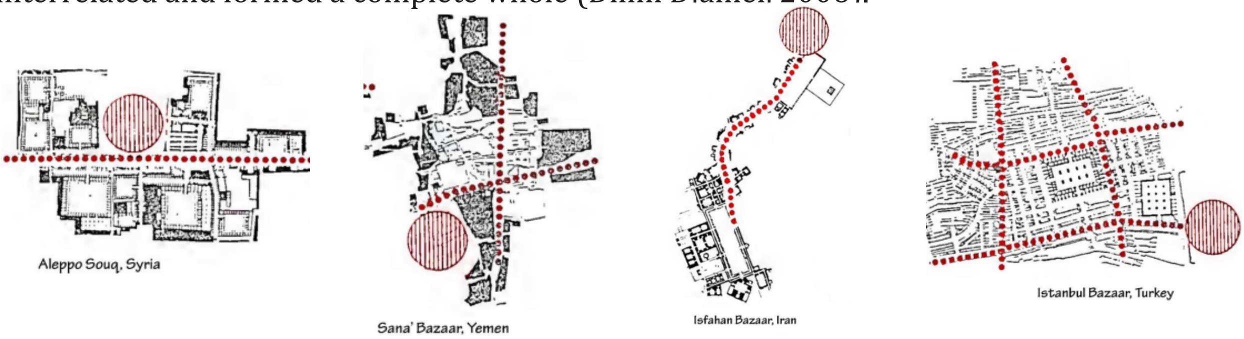


Figure 2.36: The different forms of the souq's main routes in relation to the Friday mosque. Source: Heba Osman, 2020

B. Functional organization: In traditional markets of historic cities, shops selling similar goods were grouped together, often named after these specialized activities (Heba Osama, 2020). The arrangement of these activities near the mosque followed a logical system, with clean activities closer and unclean activities further away (figure 2.37). This system allowed for easy inspection of goods and made it easier for the Muhtasib to control quality and collect taxes (Dilmi Djamel, 2006).

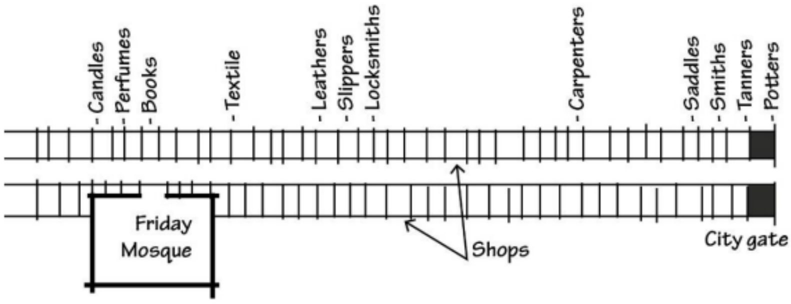


Figure 2.37: Typical arrangement of goods in the souqs.
Source: Heba Osman, 2020

C. Architectural characteristics: The two types of souq layouts are the linear souq and the network of souqs (figure 2.38). The linear souq has a major route with shops on both sides while the network souq has streets intersecting at right angles. Both layouts follow a distinct equation of Friday mosque, souq, and residential dwellings (Heba Osman, 2020).

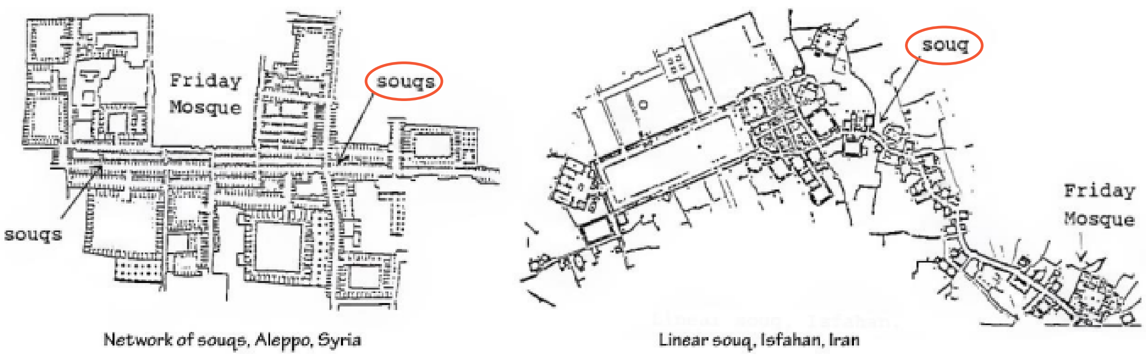


Figure 2.38: Souk layout, **Left:** Network of souks in Syria. **Right:** Linear souk in Iran. Source: Heba Osman, 2020

E. Complementary functions found in the souk: the souk area in historic cities also contains public buildings such as mosques, schools, coffee houses, restaurants, and fountains that are available for public use (figure 2.39)(Dilmi Djamel, 2006).

Commercial | Religious | Educational | Entertaining | Cultural

Figure 2.39: Complementary function found in the souk Source: Authors based on Dilmi Djamel work 2006

These buildings and elements are located within the market area, sometimes integrated with commercial buildings, and in other cases, existing as standalone structures (Dilmi Djamel, 2006). Thus, the souk is not only a place for buying and selling goods, but it also serves cultural and educational functions as well as providing spaces for social interaction and community activities such as artistic workshops and poetry meetings.

2.7.2.5. Souk in Algeria

Traditional souks in Algeria were not just commercial centers, but also played a critical role in urbanization during Ottoman rule by creating social and cultural opportunities for people from diverse backgrounds to exchange goods and ideas and help establish new urban centers while strengthening existing ones (Boudjenouia, Djilal, 2017). Additionally, they also served educational and cultural purposes, with many souks housing schools where students could learn about Islam, Arabic, and other subjects, as well as playing a central role in the intellectual and cultural life of cities such as Tlemcen, as noted in a study by Aghrout and Aït Saada (2015).

As mentioned earlier, our goal is to breathe new life into the historical site of Laghouat by constructing a culturally-rich souk that resonates with visitors. To achieve this mission, we undertook an exhaustive study of existing souks in Algeria, paying special attention to those located in desert regions. As our search progressed, we landed upon Biskra's souk - extensively examined by Amar Bennadji et al (2023) over its sensory experiences. Our plan is to use these findings for creating a dynamic and functional structure in Laghouat that embodies the vibrant spirit of the region.

A. Functional and spatial characteristics of Biskra souk: The market hall building was designed differently from the prevailing French enclosed steel-framed model of halles, and was largely open to the outside with heavy enclosure walls supporting a tiled roof. Successive extensions were made to the building, with the addition of stalls causing modifications to the exterior facades to provide cross-ventilation (figure 2.40). Initially, the market hall contained more vending stalls than shops separated by walls, but later an interior street was created separating two rows of shops (Amar Bennadji et al, 2023).

Figure 2.40: Main entrance of Souk Biskra, yellow to point out the shading options used to adapt to the hot dry climate. Source: Amar Bennadji et al, 2023, edited by author

B. A set of heritage ambiances: the study conducted by Amar Bennadji et al. encompasses individuals' experiences and interactions with environmental factors including sound, light, smell, and texture within architectural or urban settings (Figure 2.41). Four travel stories were considered for this study on the market's ambiances (Amar Bennadji et al, 2023).

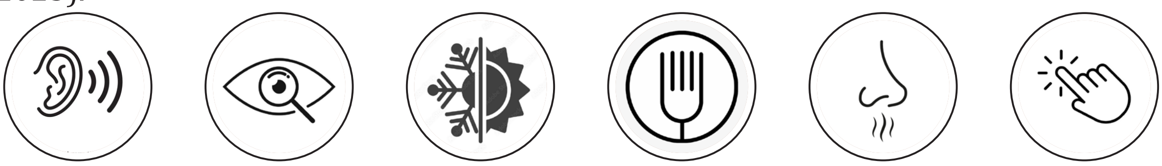


Figure 2.41: Sensory experience. Source: Authors

1. The auditory atmosphere: The diverse crowd, including locals and people from different ethnicities and regions, created the most significant auditory ambiance in the market. The local craft industry, animals like camels and flies, also contributed to the unique auditory atmosphere of the market.

2. The visual\ luminous atmosphere: the clear and sunny sky, the color of the buildings, and the appearance of the constructions. The arcades surrounding the market provided shaded areas and played a vital role in climate control. The square shape and inner courtyard of the market, inspired by local Saharian architecture, were also noted as important elements of its visual atmosphere (figure 2.42).

3. The thermal\aeraulic atmosphere: the hot and semi-arid climate of Biskra is associated with the clear, sunny sky and harsh thermal environment. The arcades around the market are seen as a necessary shelter from the unbearable heat, while the use of mud as a building material and deep walls help to exclude heat.

4. The atmosphere of taste: The market was a hub for gustative experiences with grilled beef and fried grasshoppers. The quality and taste of vegetables and fruits produced locally in the oasis were also noted (figure 2.42).

5. The olfactory atmosphere: was described as multi-faceted, with a mix of scents and smells from shops and eateries around the market. The travelers wrote about the fragrant merga soup, the breaths of saffron stews, and the meat that offers nothing attractive to the eye and smell of the gourmet. These odors varied throughout the day and were associated with specific locations in and around the market.

6. Tactility: The Biskra market had a variety of items for sale that appealed to the sense of touch, such as mutton, dates, sweets, and crafts with rough decorative patterns.

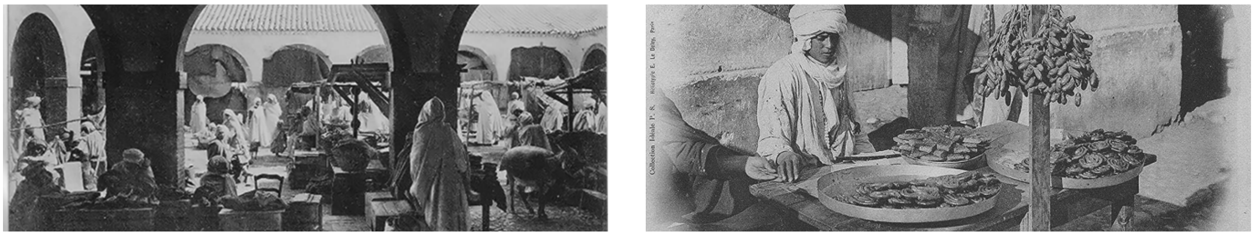


Figure 2.42: **Left:** luminous atmosphere specific to desert plazas. **Right**: traditional sweets illutrates the various tastes on offer, contributing to the atmosphere. Source: Amar Bennadji et al, 2023.

2.7.2.6. Conclusion

To sum up, it is clear that Souqs play a vital role within Middle Eastern, Arab and Islamic cultures as they hold significant cultural and historical importance. These traditional marketplaces offer more than just commercial services; they also have great social and cultural value too. Souqs are integral parts of creating urban architecture as well as establishing a sense of place within communities. Historically these markets were situated near crucial public buildings such as the Friday mosque. There exist two different types of layouts for souks: linear designs or networked structures.

During Ottoman rule in Algeria, they served an essential part in promoting education opportunities and contributed substantially towards numerous cultural aspects too. Incorporating spatial attributes observed within existing markets such as Biskra's into modernized versions would help encapsulate the vibrant aura visible throughout regions into new establishments today such as in Laghouat.

2.7.3. Commercial and entertainment center

2.7.3.1. Lenses: Definition of a commercial and entertainment center

For a better understanding of this complex *Commercial and Entertainment Center*, we shall decompose it. Based on Cambridge dictionary, Oxford dictionary and business dictionary, we define the following:

- Commerce: refers to all activities of buying, selling and trading of goods and services, involving all steps of production, distribution, marketing and sale.

- Entertainment: refers to all activities that ensure enjoyment, amusement and relaxation to a specific audience.

- Commercial and entertainment center: It's where commerce and entertainment come together in one place. It's a place where people shop, eat and engage in various leisure activities, including shops, restaurants, gym, cinema and other spaces depending on the costumer's needs and desires.

In the book of Architect's Data, a commercial and entertainment center was described as "*A shopping center / mall is a larger and more elaborate collection of retail outlets, eating places etc, it has fixed opening times, therefore no semi-public access routes; main external access normally from only one road, but additional side access from a car park or multi-storey car park is possible.*"

2.7.3.2. Development of commercial center:

A. History development

Commercial and entertainment centers have a long history and a great evolution over time. Originally, they were hubs for trade and commerce (example: Souk Okaz), but over time they evolved into centers for leisure and entertainment (Figure 2.43).

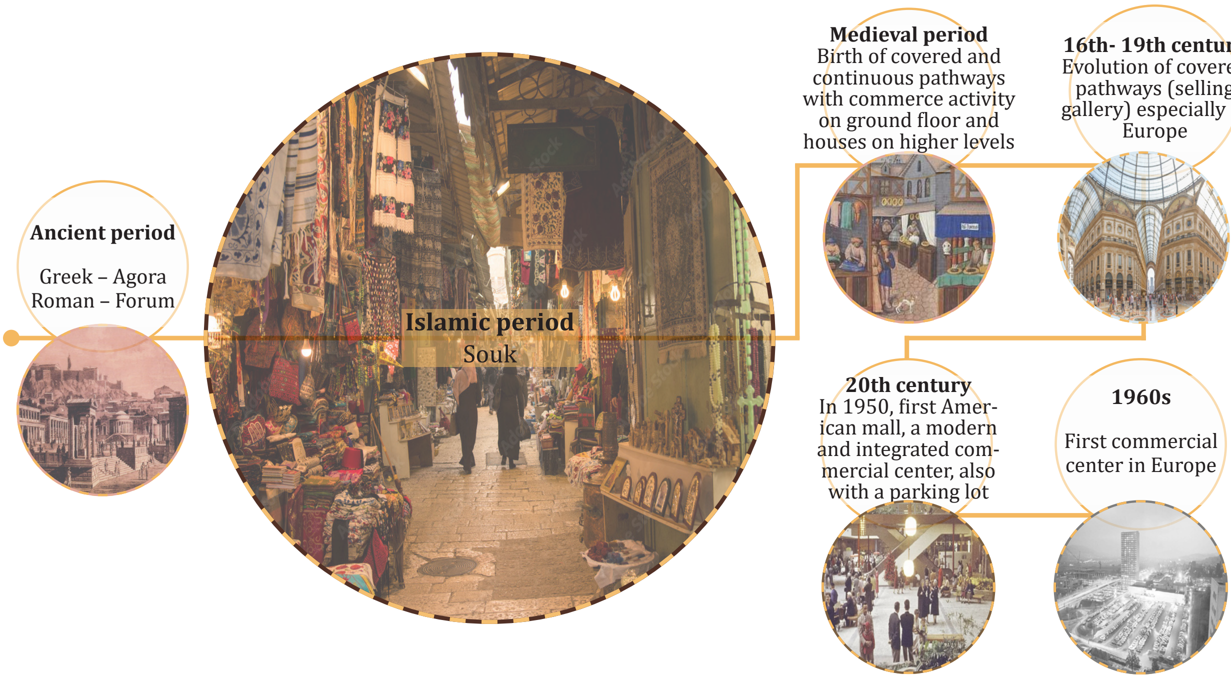


Figure 2.43: Commerce Through history. source: Author based on Gouadjelia Imane and Kouachi Amina, 2018

B. Changing identity

Ensam Lee's recent research on commercial centers reveals a transformation in their identity, as shown in Figure 2.44. Previously, these centers offered a monotonous buying and selling experience. However, they have now evolved into multifunctional buildings, incorporating cultural and educational elements to enhance visitor enjoyment. By examining the history and previous pages on Souks, we find that the integration of culture, entertainment, and education has long been present, demonstrating that lessons from the past are always valuable and necessary, even in the context of development.

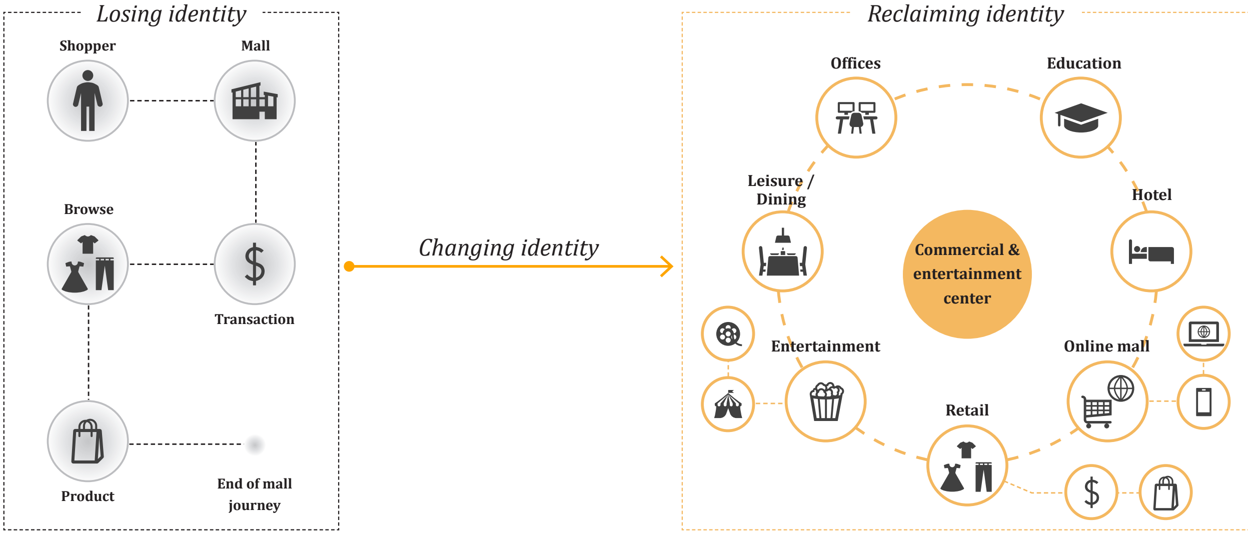


Figure 2.44: Commerce Changing identity. source: Author based on Ensam Lee, 2015

2.7.3.3. Importance of commercial and entertainment center in urban planing

Commercial and entertainment center, a vibrant city's nucleus that has a profound impact on the tapestry of the city as it is the city's identity contributor key and dynamic fusion (Figure 2.45) (Carmona,Tiesdell, 2007).

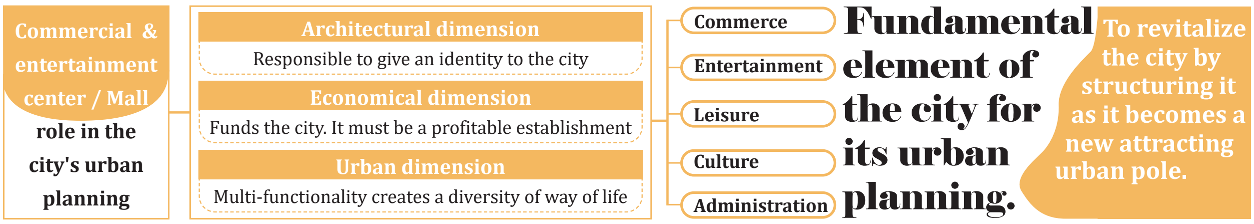


Figure 2.45: Importance of commercial & entertainment center in urban planning source: Author

2.7.3.4. Commerce in Algeria

The commerce in Algeria is the evolution of historical, traditional and contemporary commercial spaces along side with the customer's needs, classified in 3 categories depending on the surface (Figure 2.46): Small, medium and large surfaces (Gouadjelia,Kouachi, 2018).

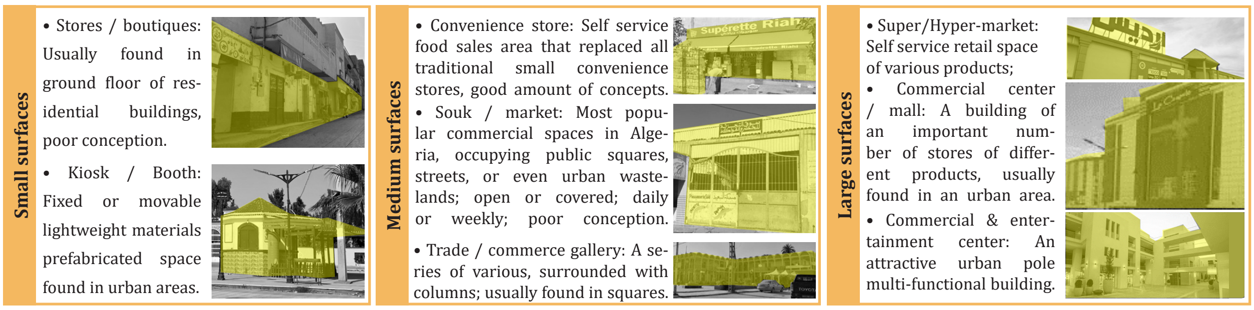


Figure 2.46: Commerce in Algeria source: Author based on Gouadjelia Imane and Kouachi Amina, 2018

2.7.4. Oasis effect: Urban parks

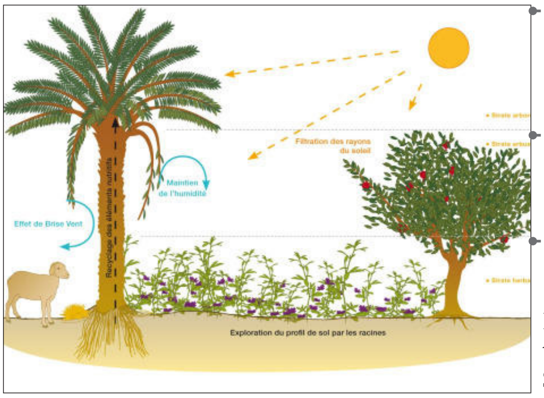
The aim is to restore Laghouat's historical image as an oasis and counter the loss of green spaces in the city. To achieve this, the establishment of an urban park with dense vegetation is deemed essential. This park will contribute to the city's cultural and environmental aspects, revitalizing its image in a socially and culturally suitable way, while simultaneously mitigating the urban heat island effect.

2.7.4.1. Oasis: desert paradise

A. What is an oasis: An oasis is a place in the desert where there is a source of freshwater that allows for the growth of vegetation, providing relief and shelter for animals. It is often identified by the isolated vegetation and may also be accompanied by human settlements. (Cambridge dictionary, National geographic, worldatlas)

B. How an oasis is formed? Oases come into existence when subterranean aquifers or rivers emerge on the land surface, which can happen naturally through pressure, or due to artificial wells (human)or occasional thunderstorms. The process of creating an oasis begins with a human planting a date palm seed. A hole is dug in the ground, which accumulates moisture, allowing the seed to germinate. The seed is then shielded by dried branches to protect it from the sand and water is used for irrigation (WorldAtlas).

C. Oasis effect: also known as the urban oasis effect or park cool island effect, refers to the localized cooling impact of green spaces such as parks and urban forests on the surrounding regions. This effect is caused by factors such as shading from vegetation, greater evapotranspiration, and the decrease of heat-absorbing surfaces (Bou-zeid, 2014). It can help to reduce urban heat islands and improve city microclimates. Additionally, worldAtlas suggests that the oasis effect is also due to the different levels of vegetation and their density, which further enhance the microclimate (figure 2.47).



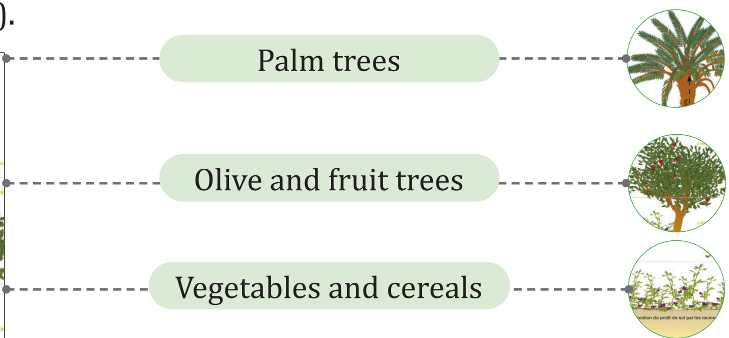


Figure 2.47: This is the origin of the unexpected green barrier against the invasive sands, cultivated by making the most of its microclimate. Source: WorldAtlas

Therefore, we conclude that the oasis effect can be achieved through an urban park. As a result, we conducted research on different styles of urban parks and the multisensory experiences they offer.

2.7.4.2. Urban Parks: definition: An urban park refers to a park situated within an urban environment that provides a range of amenities such as relaxation, recreation, education, physical activity, inspiration, and enjoyment to both local residents and visitors of the urban area (Law insider).

A. Plants and green spaces

1. <u>The choice of plants for landscaping a space depends on the following three parameters (Atik, 2022):</u>

Functional and spatial characteristics — Visual and sensory characteristics. — Adaptation of plants to site conditions.

<u>B. Plant size and spatial context:</u> The selection of plants based on their size plays a crucial role in determining the spatial framework of a landscape. This parameter offers control over the field of vision, movement, and physical experience within a given space. The plants are categorized according to their height into five distinct categories (figure 2.48) (Jakobsen, 1977, cited in Atik, 2022):

Figure 2.48: **from left:** Ground level: "ground-cover plants", Below knee level: "low plantings", nee level to eye level: "medium-height plantings", Above eye level: "tall shrubs and small trees", Trees vary from 5 to more than 20. Source: Atik, 2022

C. <u>Shape of the green space:</u> Different plant arrangements offer varying perceptions of space. The shape of a green space, such as circular or elongated, affects its dynamics and conveys different meanings. The height-to-width ratio of a space also impacts its dynamics, with a balance needed to avoid feelings of confinement or claustrophobia (figure 2.49) (Atik, 2022).

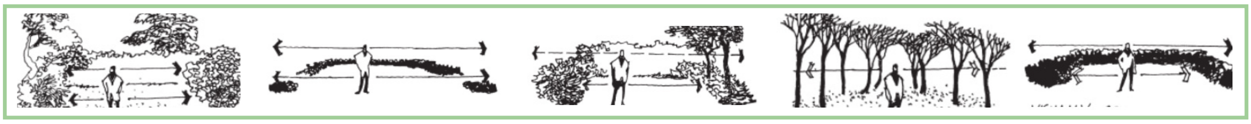
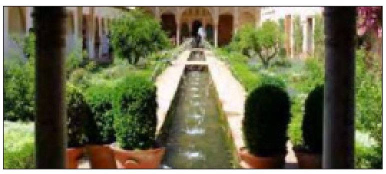


Figure 2.49: **from left:** Visually and physically enclosed. Visually and physically open. Visually partially enclosed, physically enclosed. Visually partially enclosed, physically open. Visually open, physically enclosed. Source: Atik, 2022

2.7.4.3. Urban park design styles

Regular (formal)

Symmetrical and balanced designs, seen in different architectural styles like French and Islamic. Geometric shapes, right-angled intersections, level terrain, trimmed hedges, and individually chosen trees and plants (Turner.T, 2005).



2.50. Alhambra: courtyards revealed gradually, flowing water, interconnected basins, symmetrical parterres, tiled pathways, and a variety of plants for color and fragrance. Source: Atik, 2022

Irregular (informal)

Asymmetrical design like English, Chinese, and Japanese that embrace natural landscapes, with designs adapted to the terrain and without geometric principles. Hedges and borders are left in a natural state (Atik, 2022).

2.51. Ye He Yuan garden: Chinese gardens adopt the technique of imitation and symbolism to recreate natural landscapes within limited spaces. Source: Atik, 2022

Mixed styles

Composite style merge regular and irregular design styles. They are seen in Parisian parks like the Luxembourg, which have various sections, including an Italian garden, combining different design approaches (Atik, 2022).

2.52. Luxembourg park: combine regular and irregular styles. Source: paris1900.lartnouveau.com

2.7.4.4. Green Spaces: Sensory Perceptions:

Sensory experiences in green spaces contribute to the development of the multi-sensory theory, which is employed in the creation of sensory parks that stimulate the senses and improve perception, particularly for people with specific educational needs, such as children. Sensory parks are particularly created to encourage good emotional reactions and to aid in treatment and mental recovery. According to research, natural surroundings provide several advantages, including stress reduction and the elicitation of happy feelings, which leads to improved moods. This is due to the fact that alliesthesis, or the integration of sensory information, affects subjective well-being. Positive emotions strengthen cognitive connections while also encouraging cooperative conduct and social interactions (Atik, 2022).

2.7.4.5. Irrigation system

Best irrigation system for arid zone is Drip irrigation (Figure 2.53-a), thanks to its pipes and emitters networks installed next to the plant, that delivers the water to the plant's roots without any loss (evaporation or runoff). Drip system had 4 types: Soaker hoses, Emitter system, Drip tape and Micro misting system (For further details, check annexe). Best system for an urban park is Micro Misting system (Figure 2.53-b), due to it ability to water boarder areas. In addition, it is the best option for larger plants and areas with a more extensive coverage required. In addition, a Rainwater Harvesting system can be used for capturing, storing and reusing rainwater (Figure 2.54)(Website TrustBusket and DIG Corporation).

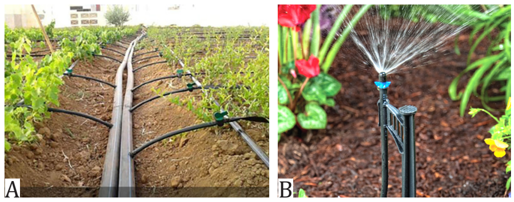


Figure 2.53: a. Drip irrigation system. B. Micro Misting system. source: Website TrustBusket and DIG Corporation

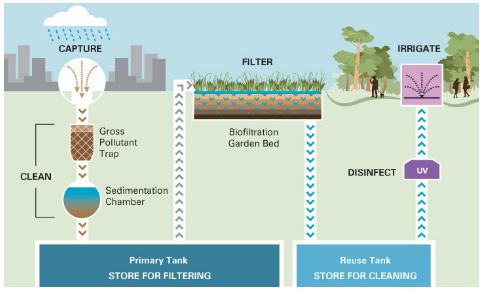


Figure 2.54: Rain Water Harvesting system. source: Website City f Melbourne Urban Water

2.7.4.6. Chemicals

• Mulching: A layer of organic materials will be placed on top of the soil to prevent evaporation, suppress weed and improve water infiltration and overall conserve soil moisture in arid zones (Figure 2.55-a).

• Super-absorbent Polymers/Hydrogels: Absorbs an amount of water and gradually releases it to the plant as the soil dries out with no water loss (Figure 2.55-b).

• Anti-transpirants: Reduces loss of water through leaves by forming a thin layer on the leaf surface (Figure 2.55-c)

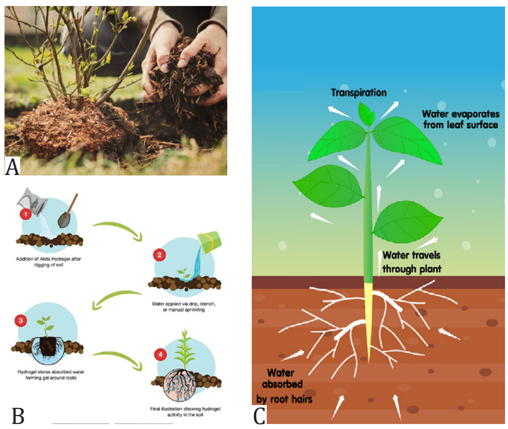


Figure 2.55: A. Mulching B. Hydrogel C. Transpiration . source: Website AllThatGrows, Nabteh, Toppr

2.7.4.7. Pavement

• Green concrete
• Wood
• Stone (natural, gravel, ...etc)
• Rubber tiles

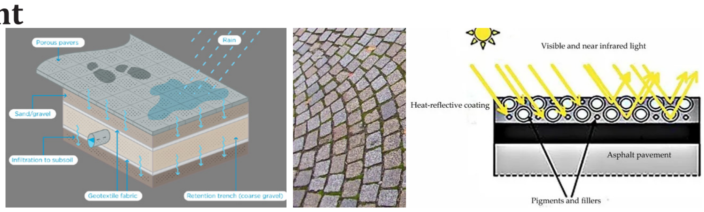


Figure 2.56: A. Porous pavement B. Xeriscape Pavements C. Reflective and cooling pavement C. . source: Website City f Melbourne Urban Water, Architecture Student Chronicle, The Constructor

2.7.5. Case study synthesis: The following case studies were analyzed following 4 main titles: Environment, Form, Envelope and climate responses (Table2.21)

Table 2.21: Case studies synthesis. Source: author

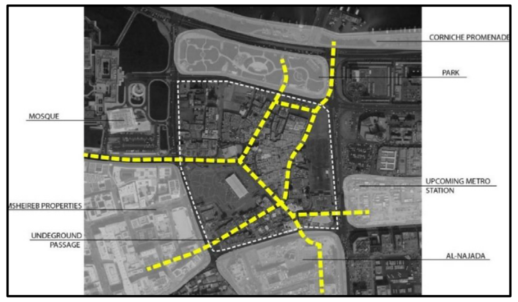
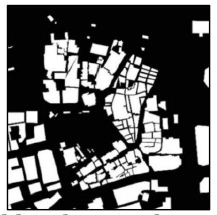
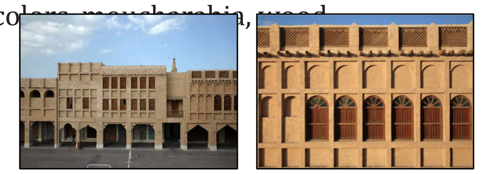
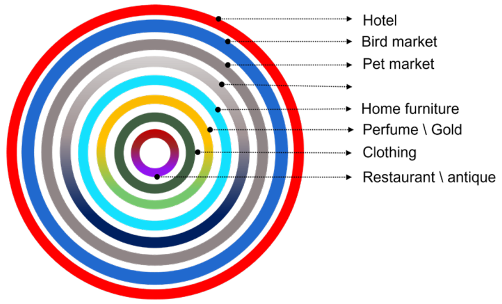
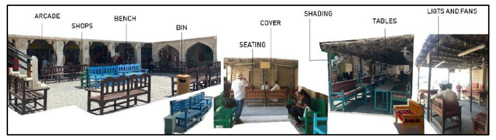
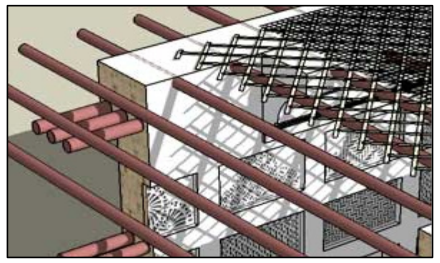
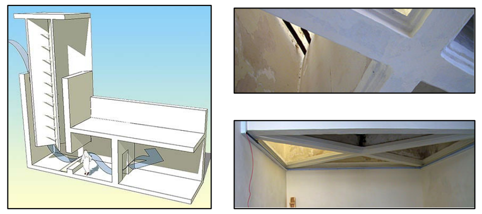
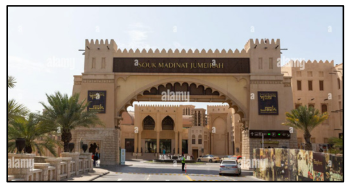
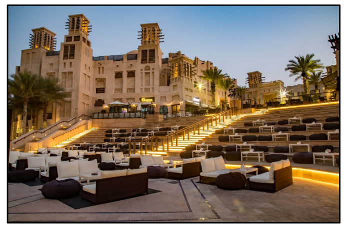
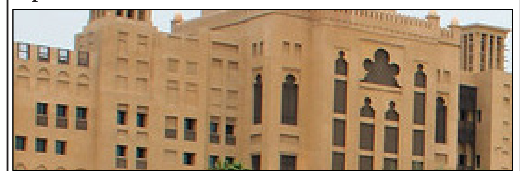
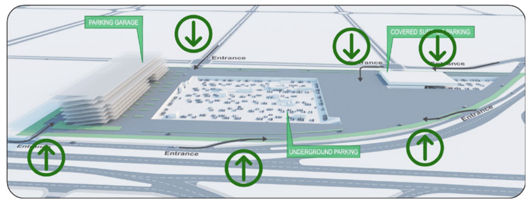
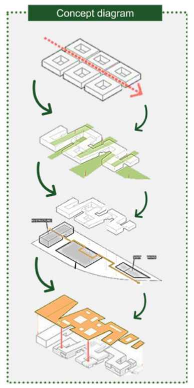
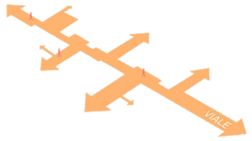
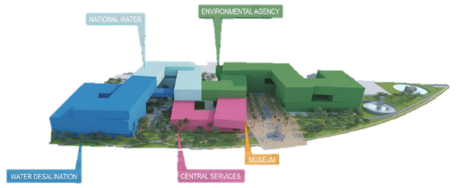
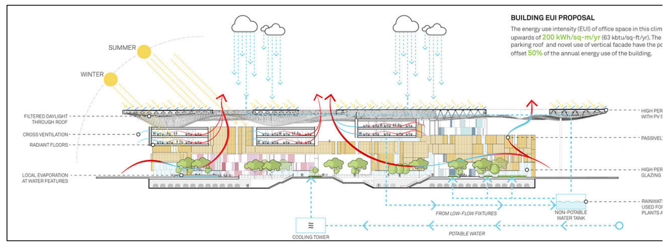
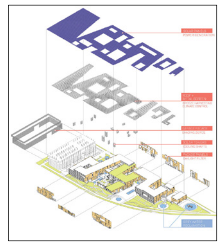
Case study synthesis						
	Project's name	*Environmental*	*Form*		*Envelope*	*Climate response*
		Urban concept	*Architectural concept*	*Program concept*	*Structural aspect*	
Souk	Souq Waqif	• Urban connectivity: establish a strong connection between the coast and the land by major route "Main spine".  • Site integration  • Walkability: with every location being easily accessible within a radius of 300 m from the geometric center.	 • Form and volume development: Compacted tissue with narrow walkways ''sikakks'' for shadow and wind, Sikkaks are directed to the North \ northeast to benefit of the coastal breeze. + discovery and exploring concept  • Influenced by the southern architecture of Iran: Arched plastered latticed, simple forms, different levels of façade, symmetrical and rhythmic layout, soft colors, moucharabia, wood 	• Conserve the activities of the souk and distribution of its specialized areas  • Activate the social memories by introducing art galleries and different cultural activities. Such as: Local restaurants, exhibitions, chess play, learn about pearls, horse stables, boutique hotels, festivals and performances.  • Augment the human dimension and users' experience: by a diversity of public spaces, urban furniture and active ftontages 	• Wall construction: formed with series of bearing incorporated columns in sun-backed bricks with a span of 90cm and beams of dangeel wood. The main joint used was a mortar obtained from mixing mud and gypsum. • Roof construction: The roofs were often flat composed of mangrove poles and covered with woven bamboo fixed with ropes.  	• Resilient architecture: the ability to adapt to changing conditions, and to maintain or recover functionality after a disruption. • Narrow walkways in the direction of the coastal breeze. • Facade with light colors and closed opening facing the west side and shadowing options in public spaces • Utilizing local materials for structure: Sun-backed bricks- seashore stones, Danjeel wood which to adapt more to climate change • Wind towers: constructed on a square plan and contained a cruciform device on the internal diagonals. The distribution room about 1.5 m height. 
	Souk Madinat Jumeirah	• Integrated within its environment •Traditional architecture of narrow walkways and courtyards  	• Form and volume: mimic the traditional architecture of the country and convey the characteristic features of traditional architecture in the modern world. 1- Use of barajeel ''wind towers'' 2- Effect of natural materials 3- Windows have been designed in the shape of traditional windows 	• Hierarchization of function consists of various shops ranging from jewelry to clothing and garments, mostly belonging to international brands.  • Activate the social memory: by different performances and an outdoor theatre	• The materials used are concrete for the main structure and aluminum. However, both plaster work and aluminums has been rendered to give the effect of traditional natural materials of mud plaster and wood 	• Wind tower: as a strategy for cooling • Introduction of water canels for refreshments • Moucharabai 1- Regulating the amount of indoor light 2- Regulating air movement 3- Cooling down the indoor spaces 4- Help in decreasing the humidity levels in indoor spaces 

Table 2.20: Case studies synthesis. Source: author

Case study synthesis

	Project's name	***Environmental*** / ***Urban concept***	***Form*** / ***Architectural concept***	***Form*** / ***Program concept***	***Envelope*** / ***Structural aspect***	***Climate response***
Souk	Riadh Sustainable complexe	• Site access and circulation: The site has multiple points of egress to accommodate the nearly 5000 people that will arrive and depart daily. There are a total of six vehicular access points on the site 	 • The Viale (Main Street)  • Diversity of courtyards 	• Islamic street : the heart and soul of life, the main axis of the city's economic zones where its souqs (markets) were concentrated. 	• Super roof: Shaded roof and a solar system on top that generates 75% of the entire energy use of the project. And overhangs from the south side. • Facade panels: Daylight filter and operable windows for natural ventilation. • Roof metal screen: Lightweight composite metal panels layered in patterns that recall traditional Arabic patterns for breeze harvesting climate control. • Solar towers: have 2 functions one as a captor of solar energy and secondly as a cooling shafts by ventilation and convection.  	• Cross ventilation, • Stack ventilation, • Night ventilation of thermal mass, • Earth cooling tubes, • Night-flush cooling, • Passively cooled courtyards, • Evaporative cooling, • Cool towers, • Cool roof, • Rainwater and gray water recuperation, • plug load control management.

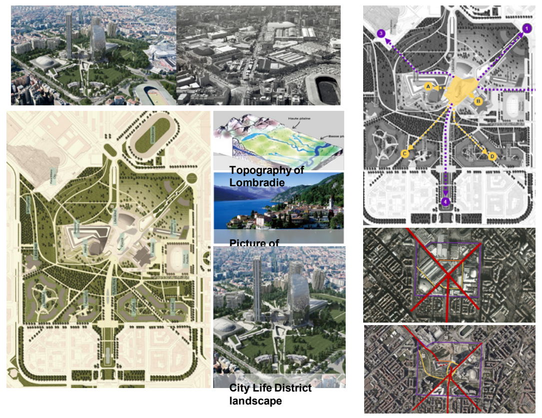
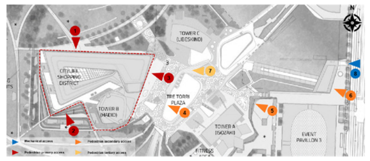
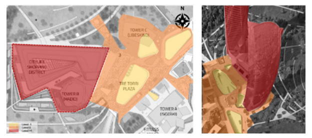
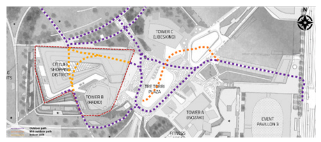
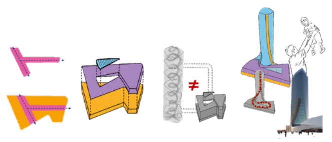
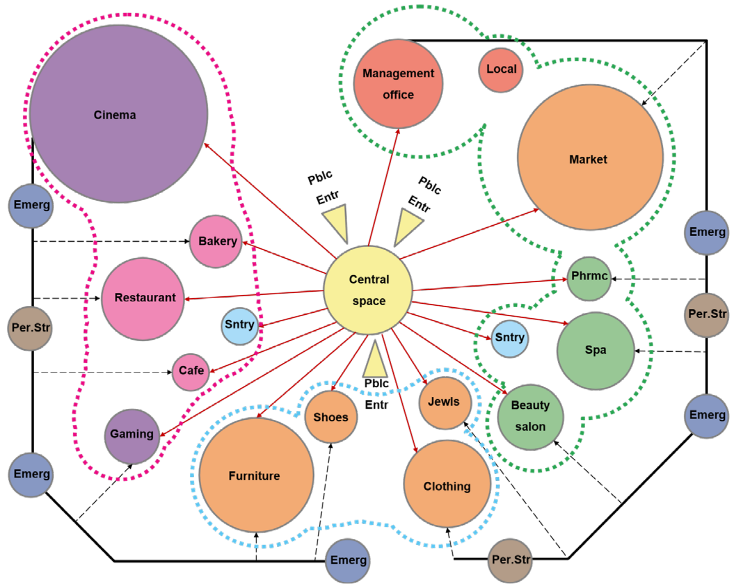
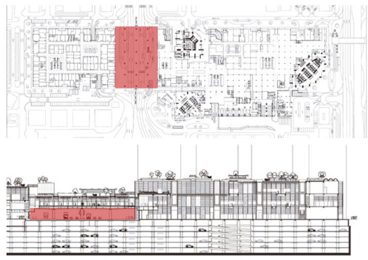
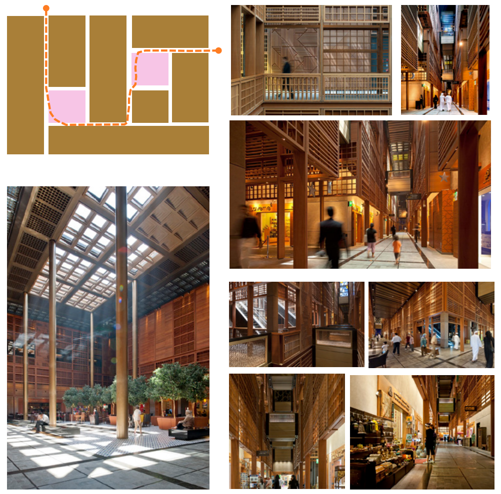
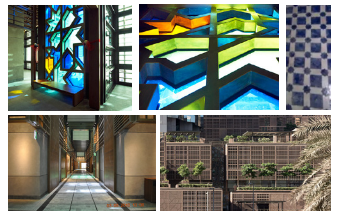
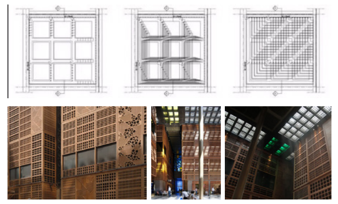
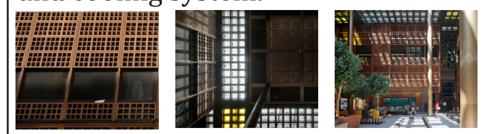
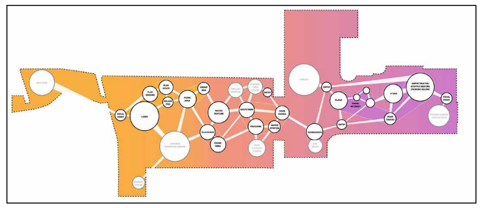
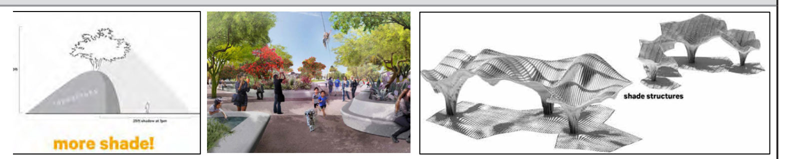
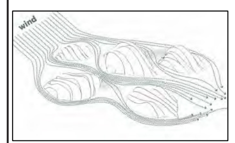
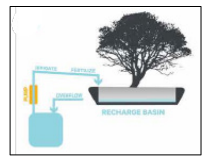
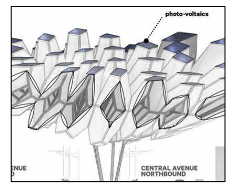
	Project's name	**Environmental** / **Urban concept**	**Form** / **Architectural concept**	**Form** / **Program concept**	**Envelope** / **Structural aspect**	**Climate response**
Commercial and entertainment center	***City life***	• Histori-functional urban integration: The 36Ha City life district was previously an exposition park back in 2013, before it was developed into a well connected urban plan. • Axis urban integration: urban planning of the district was based on the axis of the city which enhanced the relation between the project, its environment and the city. • Nature urban integration: landscaping reflects the diversity of Lombardy nature (difference in levels in the plaza = the different levels in the nature) 	• Access: The choice of position was built on 2 goals: Internal-commercial and environmental-connected  • Levels: multi-leveling design, the organically shaped paths will converge in the center exploding into a patchwork of activities.  • Commercial path: The pedestrian path is animated with the ups and downs, the lows and highs, the walk and the green, the built and the unbuilt  • Form follows function: the design was based on the city's axis that created circulation 1st and the built around it. 	• Multifunctionality: the project holds a number of functions, primary (retail, culinary and leisure) and secondary (well being, hygiene and management). • Function hierarchy: Hierarchy of levels: Welcoming and a pointed-target functions in the ground floor, long-time-consuming function in 2nd level away from the main entrance to prevent high flow and lastly an entertainment floor (cinema, gaming and chatting in restaurants). • Function relation: Association of certain function with each other, ex. Cinema with culinary spaces • Public and service: Each has his own path, ways of circulation and own spaces (public: stores, public sanitary & staff: staff room, delivery, staff sanitary). 	/	/

Table 2.20: Case studies synthesis. Source: author

Case study synthesis

	Project's name	*Environmental*	*Form*		*Envelope*	*Climate response*
		Urban concept	*Architectural concept*	*Program concept*	*Structural aspect*	
Commercial and entertainment center	Central market	• Historical and functional integration: the project is located in a historical area with a strong histori-commercial value. • Project's value follows its environment's value: Project located close to a number of important projects such as airport, hotel, ... etc. • Functional-urban integration: project's activity follows its surrounding environment (commerce & business). • Accessibility-urban integration: a bus stop integrated within the project. 	• Site integration: building rectangle form follows the site, and alignment. • Modular units and rythm: the project follows a 22.4x22.4m² square unit in plan and 2.8x7m² in façade. • Easy access: the project has an important number of accesses (1 mechanical and 6 pedestrian) • History arabo-Islamic integration: Modular units are distributed around a central space (atrium) following a dim-lighted narrow pathways like an old souk with a vertically continuous façade where the use of Arabic geometry in the mousharabeah. As well as natural lighting from the façade and the ceiling with a color tinted windows (blue, yellow and green) for an Arab souk vibe. Also different wall colors, shades and textures.  • Nature integration: a green roof with relaxation area.	• Multifunctionality is anti-shopping-banality: a rich multifunctional program in primary (bus station 22.4%, retail and recreation 21%, history and heritage 14%) and secondary functions (hygiene facilities 2.8%, clinic 2.1%, administration 2.1%). • Souk layout: the units are distributed around a central space with narrowed pathways that lead to the stores. 	• Structure follows function: steel structure in spacious areas (atrium) and reinforced concrete for smaller areas. • Interior ambiances: color and textures contrast (finishing plaster layers) and using different materials (concrete, plaster, wood, clear and tinted glass, hand made tiles).  • The more the merrier: different types of openings in façade (manually opened windows, no-opening windows) and ceiling (automatic opened windows) 	• Structure: choice of structure allowed the creation of atriums with important height that helps in the ventilation. • Materials: use of insulated concrete pallets, GRC panels, 2 internal glass layers and high tempered aluminum external layer and natural stones for thermal insulation. • Wall: Double envelope with protective layer as solar skis, as well as thick wall for thermal insulation. • Green roof with solar panels • Directed ventilation (openable windows), oriented ventilation (season adaptive sliding room unities), and an artificial ventilation system. • Heating and cooling: passive cooling and heating via atriums, as well as the thermal mass, and an artificial heating and cooling system. 

	Project's name	*Environmental*	*Form*		*Climate response*
		Urban concept	*Architectural concept*	*Program concept*	
Urban park	Hance park	• Connectivity: Major entry points should be clearly identified and improve connections to streets, light-rail, bicycle & pedestrian routes, and adjacent neighborhoods. • Lighting: Enhance lighting to extend use and increase perceptions of safety. • Visibility: Design should enhance visibility and awareness from surrounding streets and from Central Avenue Bridge. Entry points should be clearly visible.	• Inspiration from the local geographic and geologic features within the Valley of the Sun (Valley: spacious and shady neighborhood park, canyon: central avenue, plateau: events area). 	• Metaphor: clouds & oasis 	• Shade  • Wind tunnels • Closed loop irrigation • Solar panels   
	Al Ain park	• Identity strength: reinforcing the oasis activity with additional cultural secondary ones. 	• Oasis master planning: the pedestrian paths are biomimetic, divide the whole oasis into zones of date palms and fruits. • Traditional architecture: preserving areas of archeological interests and following the same architecture for the newly added buildings. 	• Rich built and unbuilt: rich biodiversity of the plants in the oasis, preserving and improving areas of archeological interests and additional cultural building. 	• Microclimate impact: Thanks to the oasis, by comparison with the other cities, it's relaxing, and the humidity is low. • Sustainability: the oasis promotes a sustainable method of irrigation "falaj". 

2.7.6. Recommendation:

After analyzing the case studies, we came to the recommendations that shall be considered when designing our project (Table 2.22).

Table 2.22: Thematic research recommendation. Source: author

Environmental	*Form*		*Envelope*	*Climate response*
Urban concept	*Architectural concept*	*Program concept*	*Structural aspect*	
1- The buildings contribute positively to the overall character of the city and the neighborhood in which it is located; 2- Entrances: All building entrances shall be clearly articulated to indicate a transition from the exterior to the interior of the building. Every main entrance shall have a special emphasis when compared to the other portions of the building. 3- Maintain the same skyline of the surroundings 4- Separated entrances and exists of public and private 5- The internal site vehicular circulation system shall be designed to minimize conflicts between inbound and outbound traffic and incorporate safe pedestrian paths of travel.(adjacent roads)	1- Building design should closely copy or mirror surrounding development, the buildings vary colors, materials, or architectural elements. 2- Entrance with a prominent architectural feature that is unique to the overall building design.	1- Assure a visual and spatial continuity. 2-Ensure to plan different sequences through the walk to keep visitors more time as possible 3- Horizontal hierarchization (souk specialization) and vertical hierarchization. 4- Integrate vegetation and water features inside the building as a spatial continuity of an oasis 5- Kiosks or directories could be provided near the pedestrian entrances of commercial center to assist visitors in wayfinding. 6- Augment human dimension by different public spaces and seatings.	1- Adequate materials for thermal comfort 2- Adequate lighting for a better visual comfort 3- Storefronts shall include large window and door openings to provide a more inviting and engaging pedestrian environment. Commercial storefronts shall exhibit a minimum of 45% void (openings) to 55% solid (wall) ratio.	1- Integrate patios and courtyards with vegetations and water basins 2- Use double glazing and sufficient insulation 3- Compacted form with engaging more common walls 4- The use of light colors on roofs and walls, and the use of reflective materials on the roof to reduce the thermal transfer and solar absorption 5- Green roofs, can be flat or inclined less than 30 degrees. They help cut down on noise, solar radiation and thermal transfer 6- Take advantage of naturel ventilation and air movement by adapting cross and stack ventilation to augment the movement of air between indoors and outdoors 7- Keep the sunshine out by propre vegetation and prevent sandy winds by persistent trees. 8- Use of solar panels to generate energy, and should be located on the roof to protect the building from direct solar radiations and capture the maximum of solar energy 9- Integrate earth cooling tubes 10- Night-flush uses night ventilation to cool the mass of the building 11- Parking underground to eliminate any pollution outdoor and ensure a better air quality 12- Massive walls and slabs with high thermal inertia 13-Evaporative cooling by spraying water in the air 14-In case of heating, the use of passive heating by the storage of thermal mass 15- Intelligent building façade: it can change its behavior to respond to the environmental conditions by altering its color, adding shade or orienting itself 16- recuperation of rain and reuse of grey water

2.7.7. Project's program:

With the combination of the souk's spatial ambiances and the modern commercial and entertainment center, we have created a program that addresses the daily needs of the citizens, providing contemporary activities and spaces while preserving culture and tradition (Table 2.20). A qualitative programming was developed, taking into consideration the formal and functional characteristics, furnishings, comfort, and technical requirements of each activity, listing its principal and secondary spaces for each function. Subsequently, a quantitative programming table was developed. Please refer to the annex for the detailed programming table.

Table 2.20: Main and secondary functions of our project. Source: author

Main Function	*Sub-Main Function*
Retail	Clothes, Shoes, Accessories (bag, watches, ...etc), Perfume, ...etc
Culinary	Restaurant, Fast food, Coffee shop, Ice cream shop, Bakery, ...etc
Entertainment - Leisure	Cinema, Gym, Gaming room, ...etc
Culture	Souk experience, Different art galleries and exhibition, workshops, ...etc

Secondary Function	*Sub-Secodary Function*
Well being	Beauty center, spa, hair salon, ...etc
Education	Bookstore, Library, Clubs, Hubs, ...etc
Relaxation	Park, Indoor patios and outdoor green and public spaces, terraces, ...etc
Administration	Management, business, ...etc
Services	Technical room, Security Room, ...etc

2.7.8. Conclusion:

The case study analysis of souks, commercial and entertainment centers, and urban parks in the arid zone, similar to our project, has provided a valuable foundation and a source of inspiration. It offers recommendations for the future design and development of our project by understanding key considerations, challenges, and design strategies related to the climate requirements. This analysis serves as a guiding framework to ensure the project's success in creating a sustainable and climate-responsive design that aligns with the unique needs of the arid zone, while also providing a modernized souk experience. It aims to fulfill the customers' daily needs and offer enjoyable, entertaining, and leisure activities.

2.8. Conclusion

This chapter has provided a comprehensive examination of the concept of energy optimization through an extensive review of relevant research studies. Its primary objective has been to identify the key factors that significantly impact energy consumption and explore the potential for achieving thermal comfort in challenging climatic conditions. By synthesizing the findings from various scholarly sources, this chapter has shed light on the effectiveness of simple yet impactful measures in reducing energy consumption while ensuring occupant comfort.

The research conducted in this chapter has revealed that several strategies can be employed to achieve thermal comfort with minimal energy consumption in harsh climates. These strategies include:

A. Utilization of reflective materials with high albedo: that reflect heat can potentially reduce energy storage and lower urban temperatures in summer.

B. Integration of greenery and water features: the strategic placement of vegetation and water elements can enhance evaporative cooling and create a more comfortable microclimate, thereby reducing the energy demand for cooling.

C. Adopting a compact form: has proven effective in arid zones, utilizing narrow canyons to maximize the sky view factor, enhance natural ventilation, and provide effective shading.

D. Utilizing earth-based construction materials: like adobe, stone, and fired brick, which offer high thermal resistance, low thermal conductivity and high thermal inertia.

F. implementing thermal insulation techniques: like phase change materials (PCM) can reduce wall thickness while maintaining desired comfort levels.

G. Implementation of shading devices: such as pergolas or external blinds, helps to mitigate solar heat gain and maintain lower indoor temperatures, reducing the need for mechanical cooling.

H. Selection of glazing materials: Opting for glazing materials with lower thermal transmittance (U-value) can minimize heat transfer through windows and reduce the energy required for heating and cooling.

I. Incorporation of natural ventilation: Designing buildings with appropriate openings and ventilation systems facilitates the natural flow of air, promoting cooling and reducing the need for mechanical ventilation.

Moving on to the thematic research, a comprehensive analysis was conducted on the Souk, commercial and entertainment center, and urban parks, utilizing research and case studies from arid zones. The objective was to deeply understand the urban, architectural, and programmatic concepts of these components and their adaptability to the prevailing climatic conditions. This analysis facilitated the development of a qualitative and quantitative program that aligned with the specific project requirements and objectives. By carefully examining the interrelationships among these elements, a well-informed and integrated approach to the project's design and implementation was achieved.

In summary, the key points of the thematic research can be summarized as follows:

1. Souk:
A. Urban recommendation: Place the Souk in close proximity to the city's historical site and significant public buildings, to preserve cultural heritage and ensure accessibility for residents from all areas of the city. This strategic positioning promotes connectivity, community engagement, and a sense of belonging within the urban fabric.
B. Architectural recommendation: choose organization and shape that reflects the city's architectural and cultural heritage. Embrace local elements to create an authentic and vibrant souk, enhancing the experience for visitors and residents alike.
C. Program recommendations: specialized walkways within the souk design to enhance the sensory experience for visitors.

2. Commercial and entertainment center:
D. Urban recommendation: Creating a pedestrian-friendly environment by including plenty of walkways, open spaces, and green spaces to improve the entire shopping experience. Providing convenient parking and integrate public transit choices to prioritize accessibility.
E. Architectural recommendations: It is advised that the center be harmoniously integrated into its surroundings. This may be accomplished by taking into account the architectural style, materials, and color palette that match the local surroundings. Incorporating green areas, gardening, and natural components also helps to develop a connection with nature and improves the entire mood.
F. Program recommendation: Incorporation of diverse amenities such as movie theaters, restaurants, cafés, retail stores, and performance spaces. Furthermore, having a combination of indoor and outdoor places may provide visitors with a range of settings and enrich the entire experience.

3. Urban parks:
G. Urban recommendations: Optimize park location and accessibility. Also, Foster connectivity and walkability, through well-designed pathways, pedestrian-friendly streets, and convenient access points to encourage walking and cycling.
H. Architectural recommendations: Harmonize with the surrounding context by ensuring that the architectural design of the park blends harmoniously with the existing built environment and reflects the local architectural style. This creates a sense of continuity and reinforces the park's connection to its surroundings.
I. Program recommendations: Create inviting gathering spaces within urban parks by incorporating architectural elements that encourage social interaction, such as seating areas, picnic spots, and plazas. Additionally, enhance the sensory experience by integrating elements that reflect the local culture, history, and identity, such as public art and cultural exhibitions.

The combination of the three structures will culminate in a unique and immersive experience that captures the essence of Laghouat. This synthesis will be further explored and illustrated in Chapter 3, showcasing the harmonious blend of cultural heritage, urban vitality, and natural beauty.

CASE STUDY

CHAPTER 03

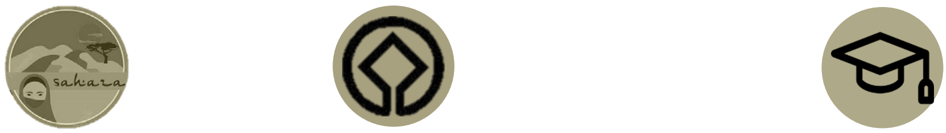
3.1. Introduction

Laghouat is a naturally rich city, multi-layered history to be discovered and an intresting urban structure to be analyzed. Therefore a project in Laghouat can be successful and rich if only was strongly related to the city and integrated within its environmental context.
For an optimal project integration, we are analyzing the site, seperating, decomposing and breaking it down into a set of essential elements to give a clear overview of their interrelationships. This city and site analysis of external references research encompass 03 primary dimensions: 1. Climate analysis, 2. Diachronic (historical) analysis and 3. Application typo-morpho-sensorial analysis, resulting strategies recommended for the project.

3.2. City presentation: Laghouat الأغواط

3.2.1. City choice criteria:

The city was chosen based on city characteristics and workshop objective (Fig 3.1)



Strategic situation
Sahara gate

Cultural heritage richness
Local architecture

Workshop objective
Adress environment climate related problems, comprehend them and solve them.

Figure 3.1. City choice criteria. Source: Author

3.2.2. Name origin

The name origin of Laghouat has a number of hypothesis:

• Arabic origin: Laghouat is the plural form of Ghaout [غوط] or Ghouta [غوطة], meaning a space where water and trees are found, or a house surounded by garden (website almaany) (Fig 3.2).

• Berber origin: meaning jagged mountains or like Ibn Khaldoun described it in his book "Book Histoire des Berbères et des Dynasties Musulmanes de l'Afrique Septentrionale" saw-tooth mountains (Ibn Khaldoun, 1852)(Fig 3.3).

• Spanish origin: Derived from the word Aguadas meaning a place rich in groundwater, connected to the underground water wells that abound in the lower part of the city, which were used to sprout meadows and gardens.

Figure 3.2. Arabic origin. Source: Author

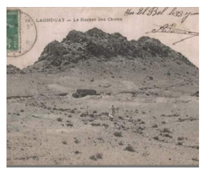


Figure 3.3. Berber origin. Source: Website Delcampe

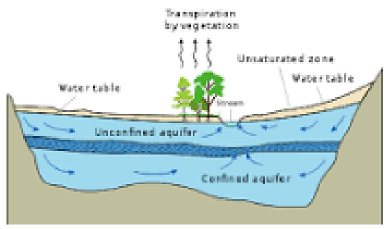


Figure 3.4. Spanish origin. Source: Website National Geographic Society

3.2.3. Geographical situation

3.2.3.1. Territorial scale

The Wilaya of Laghouat is situated in the Sahara's northern region, nestled at the base of the Saharan Atlas, bordered by Tiaret (North), Djelfa (East), El-Bayadh (West) and Ghardaïa (South), and 400km south of Algiers. It spans 25052km^2 with a population of 661700 inhabitants in 2017, yielding a density of 26.41 Inhab/Km^2 (RGPH, 2008).

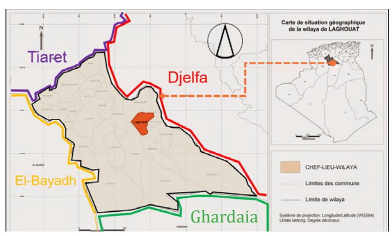


Figure 3.5. Territorial situation of Wilaya Laghouat Source: Website carte Algérie, edited by the author

3.2.3.2. Regional scale

The Wilaya of Laghouat comprises 10 Daïras and 24 Municipalities as a result of the administrative division of 1974 and then 1984. The Municipality of Laghouat is limited by Tadjmout (Northern West), El-Khneg (Southern West), El-Assafia (East) and Ben Naceur and Ben Chohra (Southern East).

Figure 3.6. Regional situation of the Municipality of Laghouat Source: Website Okbob, edited by the author

3.2.4. Accessibility

The Municipality can be accessed from outside the Wilaya (Fig 3.7 & 3.8):

• By land: National roads (Highway): RN1 (North-South), RN47 (North) and RN23 (West),

• By air: An airport is situated 14Km south of the center of the municipality of Laghouat

Figure 3.7. Accessibility of Municipality of Laghouat Source: Website Découpage Administratif de l'Algérie et Monigraphie & Google Earth, edited by the author

Figure 3.8. a. RN1, b. RN 47, c. Airport. Source: Website EuroNews, VitamineDZ and DreamsTime

3.2.5. Tapestry of Laghouat

The word "Tapestry" highlights the richness, complexity, cultural diversity of the Wilaya of Laghouat, with their heavy impact making Laghouat stand as an alluring tourism destination to be explored (Fig 3.9).

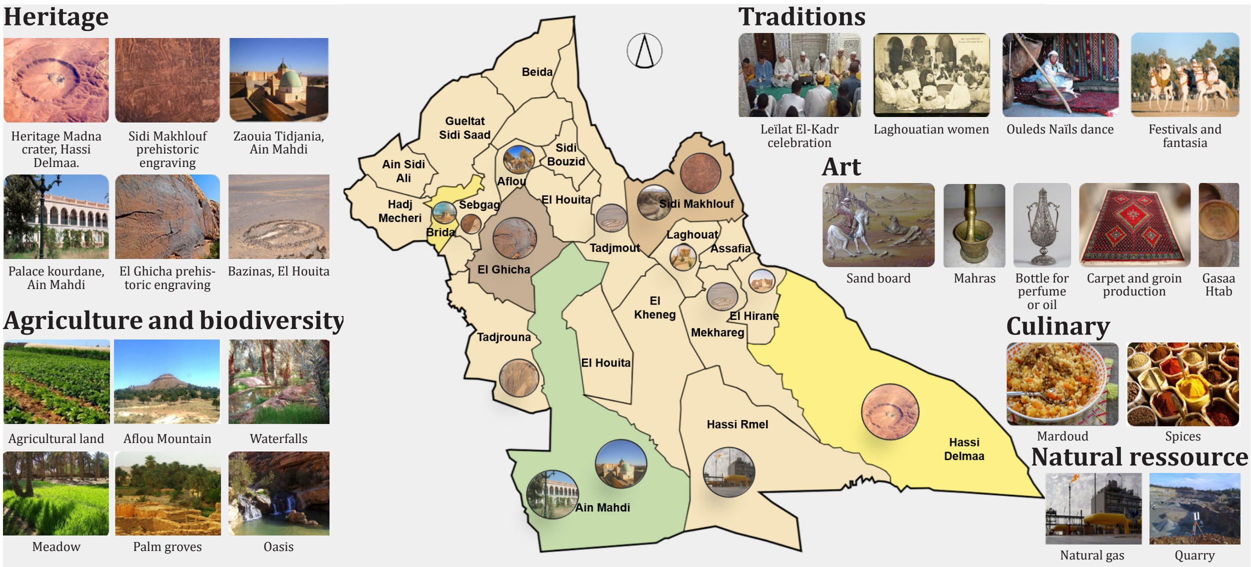


Figure 3.9. Tapestry of Laghouat. Source: Website CNRA dz, APS dz, Laghouat dz, VitamineDZ, elaborated by the author

3.2.6. Population

Laghouat's population has seen major shifts. It decreased in 1852 due to a genocide during French colonization, but later rebounded as a form of resistance. After gaining independence, the population grew rapidly, driven by the discovery of gas and more job opportunities (Odette, 1976) (Fig 3.10).

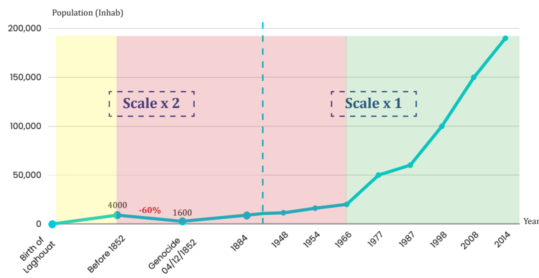


Figure 3.10. Population of Laghouat. Source: Website Canvas, elaborated and edited by the author

3.3. Climate analysis

The climatic data used for the simulations cover the period from 2007 to 2021 for the city of Laghouat-Medaghri, obtained from the website climate.onebuilding.org. The bioclimatic analysis is conducted using the psychrometric chart of Climate Consultant V6 developed by the University of California. See Figure 3.11 below. By applying the adaptive thermal comfort model, the comfort thresholds are limited between 18.4°C for heating and 30.7°C for cooling (90% acceptability).

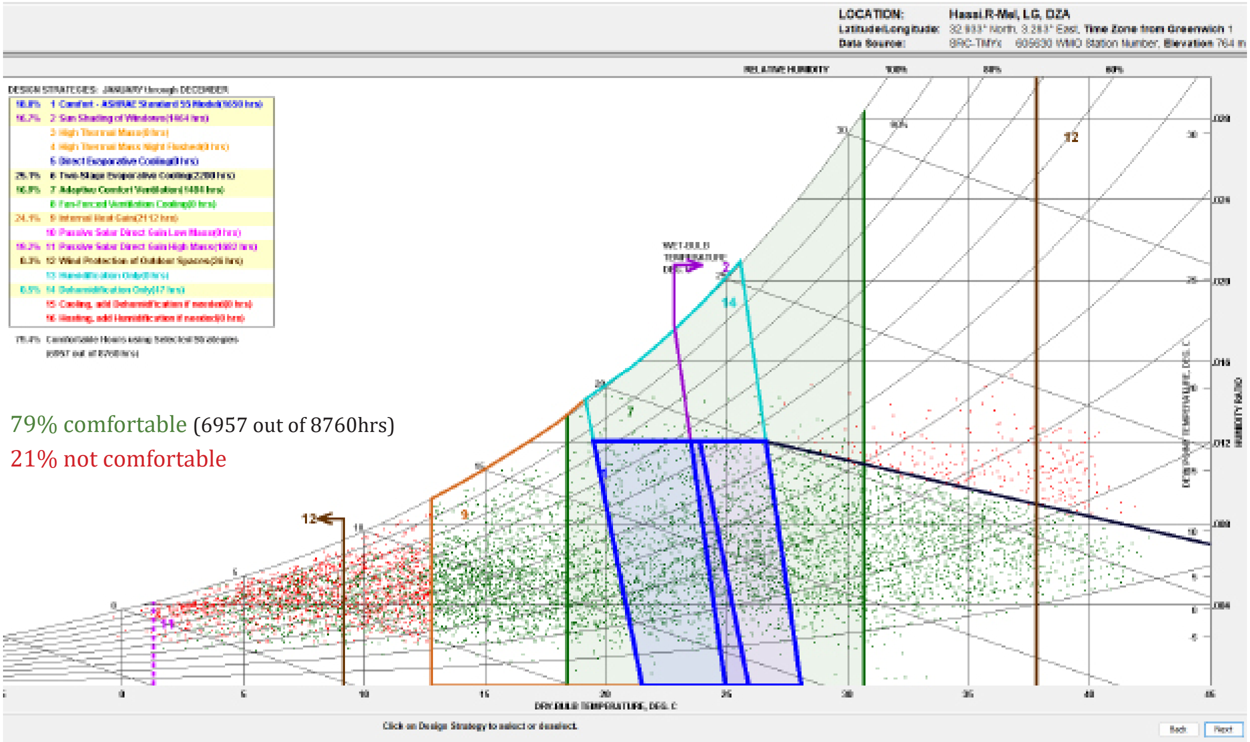


Figure 3.11. Psychrometric chart for Laghouat. Source: Climate consultant

The psychometric diagram indicates that the climate of Laghouat is thermally comfortable for 79% of the year. The most significant factor in reducing cooling demand is the two-stage evaporative cooling, accounting for 25.1% (2200 hours). Passive solar gains through high-mass elements could further improve comfort by up to 19.2% (1061 hours). Sun shading of windows and adaptive comfort ventilation contribute to reducing cooling demand by up to 16.7% (1464 hours) and 16.9% (1484 hours) respectively.

All the passive design strategies mentioned above could provide thermal comfort for up to 79% of the year. Additionally, all the strategies proposed by the model revolve around natural ventilation, such as cross ventilation, and solar protection through overhangs or the use of double-pane high-performance glazing.

3.3.2. Recommendations of climate analysis

Daily temperature

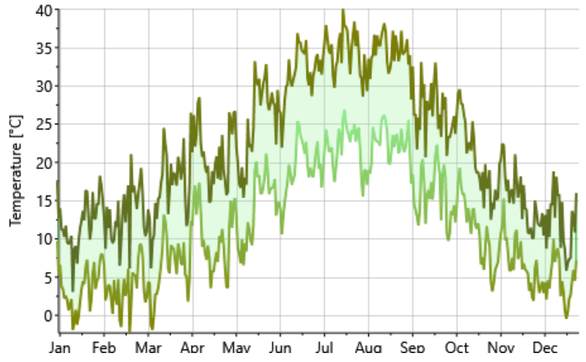


Figure 3.12: Daily temperature at Laghouat. Source: Meteonorme 7

Radiation

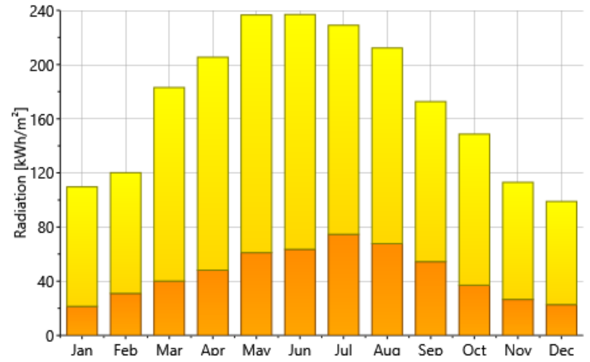


Figure 3.13: Radiation range at Laghouat. Source: Meteonorme 7

Sunshine duration

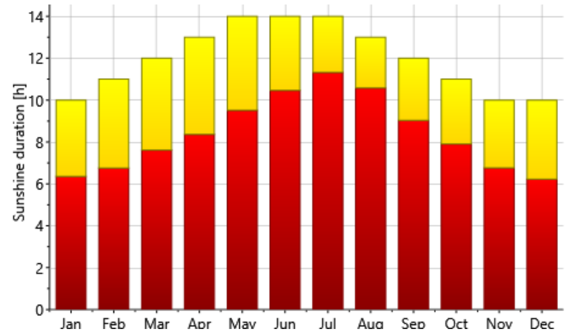


Figure 3.14: Sunshine duration. Source: Meteonorme 7

Recommendations

1- Increase the presence of vegetation, water features and green roofs help to provide shade, reduce heat absorption, and increase evapotranspiration.

2- Reflective surfaces and solar reflective windows films helps to reflect solar radiation rather than absorbing it.

3- Construction materials with high thermal inertia and low thermal conductivity

4- Protection against overheating and visual discomfort through minimizing sun radiation contact by using of sunshades, roofs, moucharabieh, etc.

Precipitation

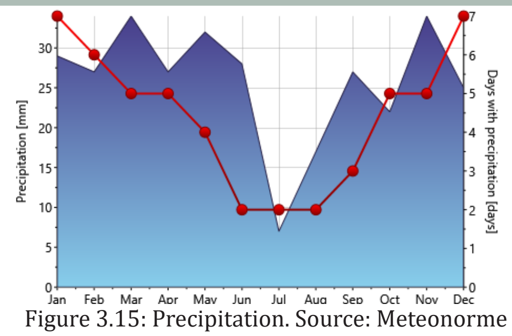


Figure 3.15: Precipitation. Source: Meteonorme 7

Recommendations

The precipitation is low and irregular, therefore creating green spaces to cool down and selecting vegetation that is adapted to the climate is recommended.The use of external wall protection for local materials(ex. brick: low water resistance) in case of a sudden rainfall (Annual: 30 mm)

Humidity

Recommendations

The humidity level varies between a maximum of 73% in December and a minimum of 26% in July. It is recommended to use vegetation and water to provide evaporation and humidity in dry weather.

Wind

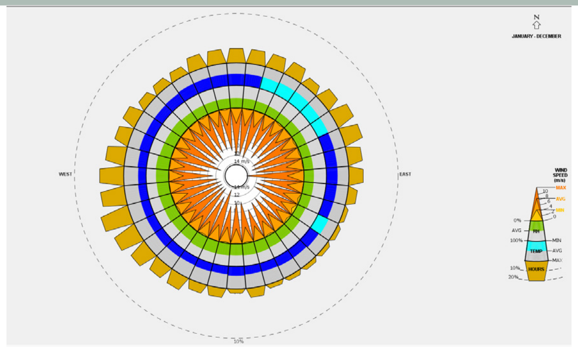


Figure 3.16: Wind wheel. Source: Climate consultant 6

Recommendations

Implant vegetation and water features on the southwest and northwest sides (dominant winds) to freshen up the area. Protection from the Sirocco wind (blows for 65-70 days from May), common on the north and west sides, and the strong CHEHILI wind from the south has speeds of 15-30 m/s, with a southwest direction frequency of 687 hours/month by creating vegetation barriers in the landscape to prevent sand accumulation. Taking advantage from the prevailing cold wind to create natural ventilation.

Szokolay diagram

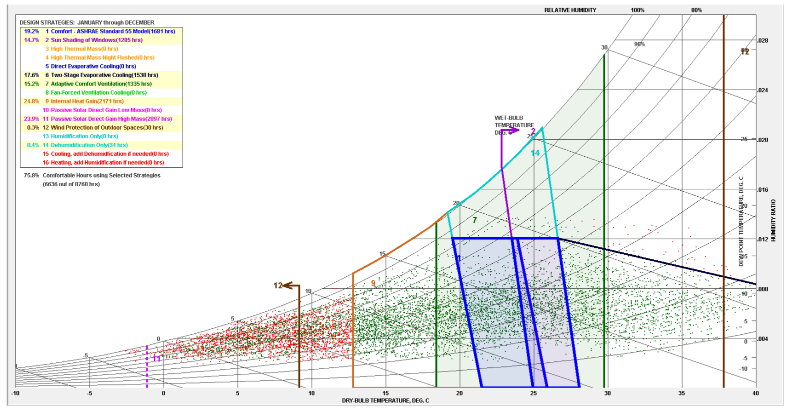


Figure 3.11: Szokolay diagram. Source: Climate Consultant 6

Recommendations

75.8% of the hours will be comfortable

1- Good natural ventilation oriented to prevailing breezes

2- Shade to prevent overheating with flat roofs (light colored)

3- Use light colored building materials and cool roofs

4- screened occupancy areas and patios can provide passive cooling

5- Provide double pane high performance glazing (Low-E) on west, north, and east but clear on the south

6-Evaporative cooler and humidifying hot dry air before it enters the building from enclosed outdoor spaces.

Mahoney tables

Figure 3.1: Table of Mahoney. Source: Author

Table	Recommendations
1	- Building oriented north and south along the longitudinal east-west axis to minimize sun exposure. - Compact plan with an interior courtyard.
2	- Compact design.
3	- Unnecessary ventilation. - Building with dual orientation allowing intermittent ventilation.
4	- Average, 25% to 40% of the wall surface with openings.
5	- Openings in the north and south walls at human height, facing the wind, and with practical openings in the interior walls.
7	- Massive construction, offset exceeding 8 hours.
8	- Offset exceeding 8 hours.
9	- Space for sleeping outdoors required.
11	- Location for sleeping in the open air.

3.4. Diachronic analysis

3.4.1. Historical overview

The city of Laghouat went through shaping and transformation process untill this day, with-four main periods (Fig 3.17): Pre-islamic periode, Arab-Islamic period, French Colonization period and Post independance period. Each of these periods has left its architectural mark.

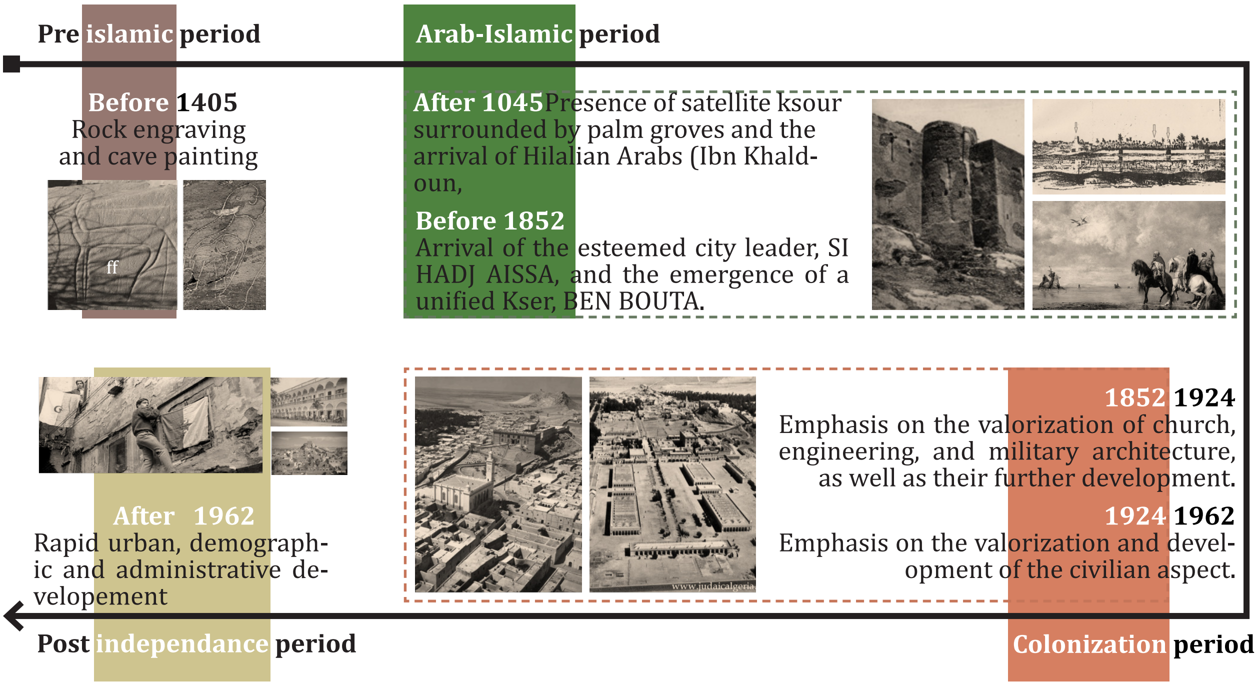


Figure 3.17 Historical overview of they city of Laghouat. Source: PPSMVSS, UNICEF, Musée moujahid, APS Dz elaborated and edited by the author

3.4.2. City evolution

3.4.2.1. Preislamic period

Laghouat has a deeper history line way before the arrival of arab muslims. During the Roman period, Laghouat was part of the Nomadic Gétulie in North Africa where they found a dam on the Oued Djedi. As well as Berber remnants such as the Maghraouas ruins, epigraphic discoveries were made in Messaad, while tombs were found in Kheneg, 50 km away and surrounding ruins of Berber villages (Fig 3.18).

Figure 3.18. El Ghicha, a mother elephant protecting its calf, used as the logo for UNICEF in 1986. Source: PPSMVSS, Laghouat

3.4.2.2. Arab-Islamic period

Laghouat's history includes the arrival of the Arab Hilaliennes in 1045 where there were already a number of agglomerations surrounded by palm groves (Fig 3.19). In 1368, the Zianid Sultan Abou Hammou rallied his followers in Laghouat before seeking refuge in M'Zab region after being ousted by the Sultan of Fez. The establishment of two tribes with their own ksers (Oulad Serghine - East and Oulad Ahlaf - West), and the unification of the ksars under

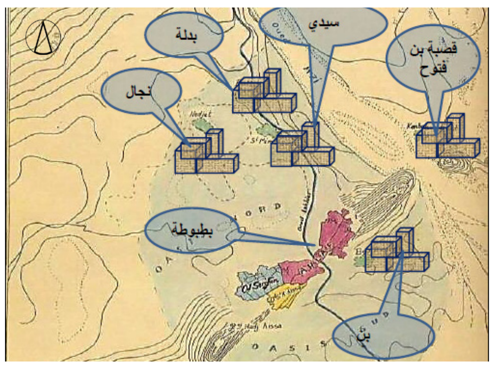


Figure 3.19. Laghouar or El Arouat in 17 century based on George Hirtz- L'Algérie nomade et ksourienne. Source: PPSMVSS, Laghouat

Sidi El Hadj Aissa (Fig 3.20) resulting the birth of Ksar of Laghouat in 1698. The city came under the rule of the dey of Médéa, who was under Ottoman rules, in 1727 but resisted taxes in 1784 yielding a punishement from the Bey of Oran in 1785. Cheikh Ben Nacer organized the Larbaa tribe from 1834 to 1854, ensuring the city's defense against invaders.

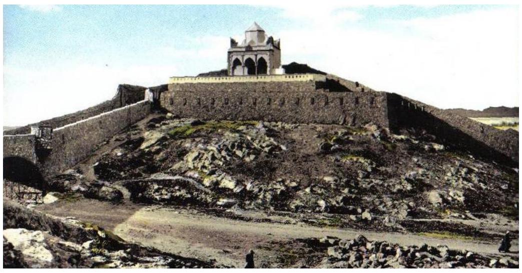


Figure 3.20. The Gouba of Sidi Hadj Aissa. Source: VitamineDz

This period can only be divided into 03 phases

1

Figure 3.21. First phase. Source: PPSMVSS edited by the author

The kser comprised 03 small isolated residential clusters arranged in an agricultural layout along the waterway. Each cluster was self-contained, consisting of residential areas, a souk, mosque, central square, and a cemetery. These clusters were protected by fortification walls and defensive towers (PPSMVSS) (Fig 3.21).

2

The spatial expansion of the 03 clusters beyond their massive walls, facilitated by a significant road network connecting them to the main axis, synergistically reinforces the city's commercial vocation, contributing to its economic vitality and prominence in trade-related activities (PPSMVSS) (Fig 3.22).

Figure 3.22. Second phase. Source: PPSMVSS edited by the author

3

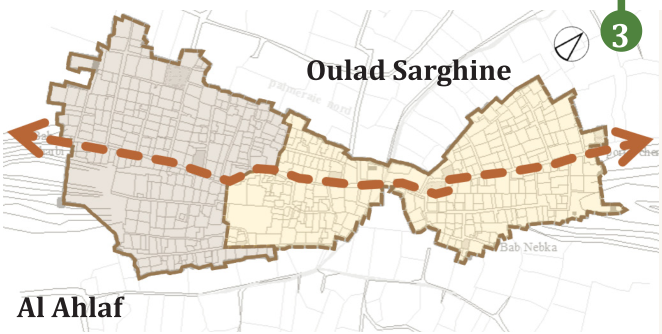


Figure 3.23. Third phase. Source: PPSMVSS edited by the author

The merging of the 03 clusters resulted in the consolidation of a 02 cohesive compact and irregular urban fabric entities reflecting the characteristics of the surrounding environment (Birth of the Kser). The fortified Kser, encompassed by substantial 4m brick ramparts strengthened by 04 defense towers (PPSMVSS) (Fig 3.23).

Synthesis: A Kserian compact texture characterized by composite forms, where the proximity of constructions emerges as a result of their integration with the site's topographic, climatic factors and their social cohesion (Fig 3.24).

A strategic, protected, and multifonctional site thanks to its location as the gate of the sahara, at the end of 2 hills, surrounded by palm trees and water sources (Oued), serving as a residence, refuge, social and commercial hub, and a transitional pole between the North and the South.

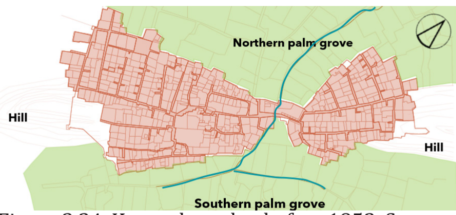


Figure 3.24. Kser urban plan before 1852. Source: PPSMVSS edited by the author

3.4.2.3. Colonization period

This period can only be divided into 02 phases

• **Road demolition, expansion & fortification (1825-1924)**: After the bombardment of the old Kser, the city underwent a strategic revival. Embracing principles of regularity, a new encircling wall framed orderly streets with gates aligned to major axes with the reconstruction of Fort "Morand" in 1856 on the eastern side and Fort Bouscaren on the western side atop Tizgarin mount fortified the city's presence, preserving the Zgag El Hdjaj neighborhood as a pre-colonial testament with minimal intervention while a new barracks marked the city's enduring transformation (PPSMVSS) (Fig 3.25).

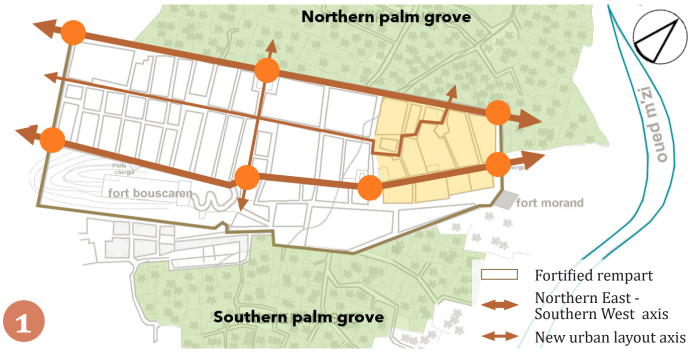


Figure 3.25. Kser plan after 1852 - 1924. Source: PPSMVSS edited by the author

The transition from the original arboreal fabric of the ksar to a checkerboard pattern was driven by the military imperative of colonial settlers, aiming to establish control and transform the city into a military base as a precursor to further expansion into the Algerian Sahara.

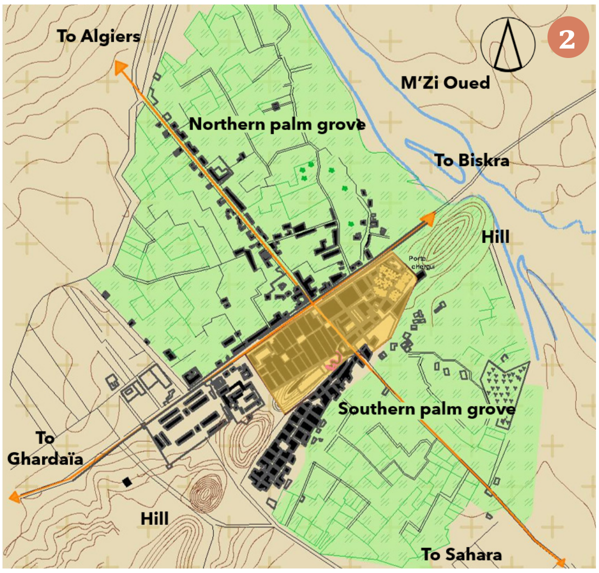


Figure 3.26. Kser plan 1924-1962. Source: PPSMVSS edited by the author

• **Civil urban area developement (1924-1962)**: The city witnessed extensive construction efforts both within and beyond its enclosure. Internally, streets were widened in Zgag El Hadjaj, while El Gharbia district was established. Externally, the creation of the El Mgatae thoroughfare led to the dispersion of houses in the northern and southern oases along the NorthWest-SouthEast axis. Simultaneously, the development of the 5th of July district and Shetit neighborhood along the NorthEast-SouthWest axis gave rise to vibrant commercial, civil, and administrative spaces (PPSMVSS) (Fig 3.26).

Nurturing growth, the city confronted forces. Nature's constraint impacted the NorthEast (Oued), while military guarded the SouthWest. Undeterred, an ambitious Northward path beckoned, lured by abundant agricultural treasures in the oasis (Fig 3.27 & 3.28) (table 3.2).

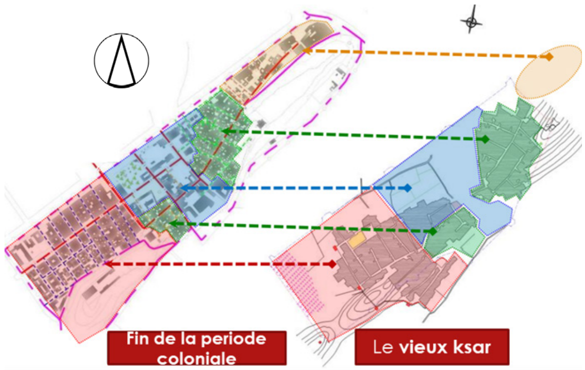


Figure 3.27. Kser plan before and after colonization period. Source: PPSMVSS

The city's focus shifted significantly from military to civilian functions through the establishment of plazas, shops, and other related amenities, signifying a notable transition in its civic orientation (check annexe).

3.4.2.4. Post-independance period

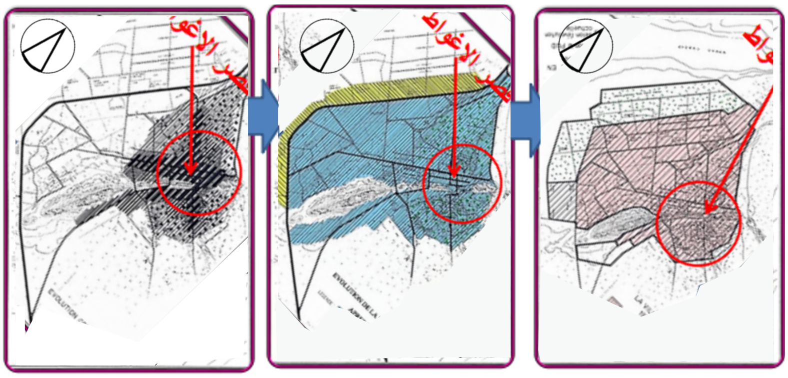


Figure 3.28. Laghouat 1962-1990. Source: PPSMVSS edited by the author

1962-1975: Significant population growth driving Northern and Southern oasis developement.
1975-1990: Status of provincial capital resulting urban developement on large scale (road expansion and infrastructure projects)
After 1990: 1st PDAU was made (PPSMVSS) (Fig 3.28)

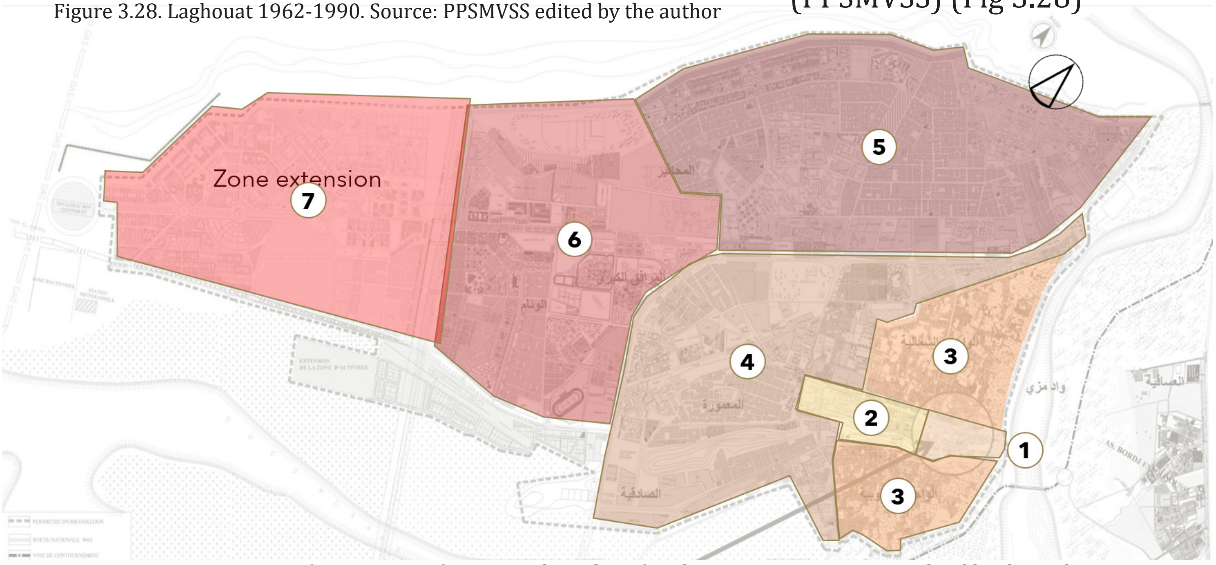


Figure 3.29. Stratification map of current urban plan of Laghouat. Source: PPSMVSS edited by the author

Overall, untill this day, the city is developped in the following order (PPSMVSS) (Fig 3.29):
1. Historical core: The ancient city, consisting of 02 distinct areas (Arab-islamic 01 and colonial 02);
2. Palm groves: Spontaneous extensions in 2 areas, Northern and Southern (3)
3. First expansion: Subdivisions and ZHUN (Residential Zones for Priority National Housing) after the city's expansion through a structuring axis RN01 (4)
4. New extension: Northern palm grove expansion to the West side, incorporating design concepts from ancient city to establish a new neighbrorhood (5 & 6)
5. Expansion zone: Allocated for housing development projects guided by the Urban Development Master Plan (PDAU) (7)

3.4.3. Major structures

Nestled within the captivating tapestry of the city's vibrant past, a multitude of grandiose major structures proudly proclaim their presence, serving as tangible testaments to the bygone eras that have shaped its narrative (Fig. 3.30).

Figure 3.30. a. History core map, b. Fortress Bouscaren, c. Church Saint Hélarion, d. Mosque Essafah, e. Mosque Atik, f. Fortress Morand . Source: PPSMVSS, VitamineDZ, edited or taken by the author

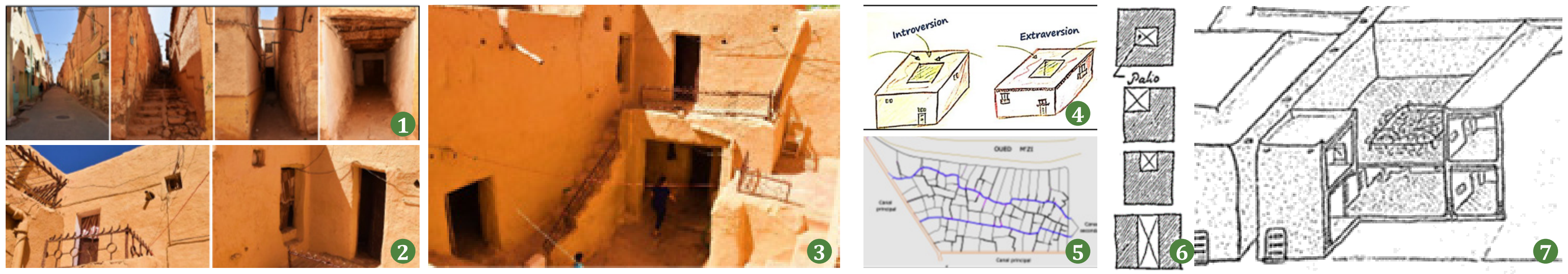
3.4.3.Synthesis and climate responses

After analyzing the city's transformation across three distinct periods, it is crucial to further investigate the city's characteristics at three different scales: environment, form, and envelope (Table 3.2, 3.3, 3.4), within each respective period. This comprehensive analysis endeavors to enhance our understanding of each city and its corresponding responses to climate conditions.

3.4.3.1. Arab-islamic period: Zgag El Hadjaj

Table 3.2: Synthesis and climate response and synthesis of Arab-islamic period Source: author

Environmental	*Form*	*Envelope*
1. Palm groves surrounding the city: Thermal regulator, creating a microclimate during summer and providing protection against climatic uncertainties. **2. Natural environment:** Steep moderately terrain surrounded with 02 palm groves areas, integrated near the Oued Lkheir, facilitating agricultural and construction activities due to the clayey soil, sloping gently from north to south, allowing for improved irrigation through seguias. **3. Agricultural layout:** The agricultural grid follows a pattern of 120x140m, aligning with the watercourse. This organized system optimizes water management by establishing canals along this grid. **4. Kser layout:** Compact perforated and irregular urban fabric, built at different elevations and adopting an irregular trapezoidal shape dictated by the topography and constrained by physical features such as Oued M'zi, the northern limit, Tizegranine Hill, and the two Northern and Southern palm groves. **5. Road System:** Hierarchically organized accessibility of public spaces extending to impasse, ensuring privacy and integrating with the site. It follows an arboreal system with winding roads, aiming to provide protection against intense solar radiation and prevailing winds. **6. Offset and Narrowing of Alleys:** The deliberate design of offset and narrowing of alleys enhances natural ventilation by creating windbreaks and shaded spaces. It also serves to prevent the intrusion of sandstorms. 9. **Mizabs**: or rainwater spouts, are constructed using palm tree wood and juniper. They serve as gargoyles through which rainwater flows.	**1. Compactness:** Dense construction occupying the entire footprint of the block utilizing shared walls to occupy the entire surface, reducing exposed surfaces to climatic conditions. **2. Kser typology:** Square or rectangular introverted individual housing units, with street-level commerce. **3. Access:** Marked by a sinuous entrance, the shape of which varies depending on the position of the house within the block, often incorporating a staggered entrance design to ensure privacy. **4. Spatial Organization:** The houses are inward-facing, surrounding an open central space called "Haouch," "Rahba," or patio promoting communication among residents and its location varies from one house to another. This central space serves as a thermal regulator, benefiting from the presence of water and vegetation, especially evergreen plants. It also functions as a solar space, illuminating the surrounding rooms. The spatial arrangement promotes air circulation by allowing fresh air to enter through the patio and main entrance, while expelling hot air from various rooms. Service spaces (ex. storage and bathrooms), usually placed before living areas as a protection from sun radiation contact, include thermal insulation measures. **5. Ceiling Height:** The room heights range from 2.5 to 2.8 meters, enhancing ventilation speed (Venturi effect). **6. S'Tah (terrace):** The terrace serves as a drying area during the day and a cooling space at night. It is surrounded by 3-meter-high walls to ensure privacy and protect lower floors from solar radiation. **7. El-Ateba (threshold):** A small step of 20 cm height acts as a barrier against sand winds, pests, and the penetration of rainwater. **8. Taka (slit openings):** Small openings located above doors, facilitating floor ventilation. They can also be found at the terrace level. **9. Mizabs:** Gargoyles designed to channel rainwater, constructed using palm tree wood and juniper. **10. Pergola:** Used in the patio or skifa to support plants (karma), providing shade and decorative elements to the space.	**1. Building dimensions:** Develops over two levels with a prospect (building height) ranging from 1.4 to 4.6. **2. Local construction materials:** Toub (mud bricks), lime, limestone, palm tree trunks, reeds for a higher thermal resistance and lower thermal conductivity. **3. Construction module:** Rectangular prisms made of clayey-sandy soil mixed with water and dried in the sun giving it a high thermal resistance thanks to the high temperature of this arid zone (30x16x-11cm). **4. Structure:** Load-bearing walls with thicknesses of 40 to 50 cm, providing high thermal inertia. Foundations made of thick limestone (80 cm) and beams constructed with palm tree trunks. **5. Foundation:** 1-meter height to protect against rainwater runoff. If there is a rocky base, the wall starts directly without a foundation. When a foundation is used, limestone stones bonded with lime mortar are buried and wider than the wall, ensuring stability. **6. Flooring:** Palm tree trunks, palm frond branches, or reeds, coated with lime plaster or earthen mortar, and topped with a layer of earth. **8. Floor Covering:** Terracotta brick pavement laid on a 5cm layer of earthen mortar, which is applied on a layer of sand. **7. Facade:** Smooth and textured (as an external thermal insulation to minimize solar radiation contact with the actual wall), blind facade that follows the street's alignment, with small and limited openings. Composed of three parts: - Soubassement: Made of limestone rubble stones to protect the wall from rising dampness. - Body: Constructed with adobe blocks using clay as a binder. - Crown: Stone coping to protect the wall from rainwater and connect its facades. **9. Decoration:** Extension of palm tree trunks from the flooring, solid brick screens (claustras), and light colors chosen to minimize the absorption and storage of solar radiation.



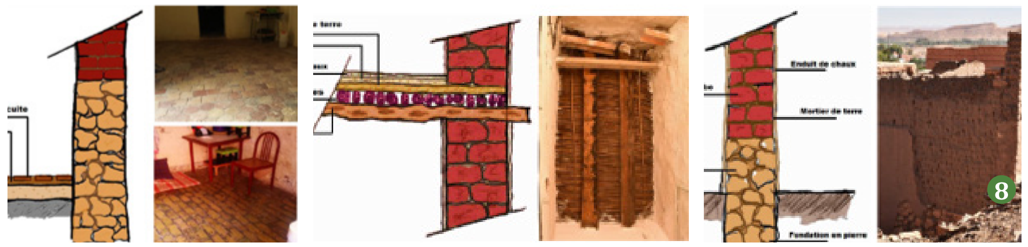


Figure 3.31. 1. Zgag, 2. Facade, 3. Patio, 4.Kser typology 5. Irrigation system 6. Patio type, 7. Kser home, 8. Construction detail. Source: Bencheikh Darda, 2021 - Takhi. B - Benarfa Kamel, 2018

3.4.3.2. Colonial period: El Gharbia

Table 3.3: Synthesis and climate response of colonial period. Source: author

Environmental	Form	Envelope
1. Urban layout: A hybrid fabric 35x65m combining colonial typology (centralization of public squares) and pre-colonial typology (shared walls). Centralized public squares provide microclimate benefits. **2. Road system:** Wide streets designed for commercial activities, with arcades to provide protection against solar radiation because of the intense solar exposition, with a width of 14 meters and a prospect of 0.6 for primary roads, while secondary roads have a more favorable exposure with a width of 8 meters and a prospect of 1.2. **3. Covered passages:** Existing covered passages are preserved and adapted to the climate to provide shade. **4. Street orientation:** Streets have a straight layout oriented towards the North-West to South-East, which is not ideal in terms of solar exposure. **5. Building heights:** Very low, reaching up to R+1 in main streets and RDC (ground floor) in secondary streets.	**1. Residential and administrative zone:** Individual housing with commerce activity in the ground floor. **2. Access:** Absence of the old hierarchy road system, houses directly accessed from the main street. **3. Urban typology:** Two types of spatial organization, European-style with an outward orientation, characterized by commercial arcades facing the street and the absence of a patio which does not correspond well to the climatic conditions. In the other hand, hybrid style mix of ksour and colonial typologies, featuring an outward orientation with the presence of a patio that adapts better to the city's climate. **4. From:** square or rectangular plots. **5. Volume:** Buildings have cubic and parallelepiped shapes, which help limit thermal loss. **6. Architectural typology:** Houses have an extraverted design with arcades on the exterior. Most houses lack interior courtyards, and there are large openings to the outside. The main facade is often used for commercial purposes. **7. Ventilation:** Ventilation is achieved through large windows on the exterior facades.	**1. Building height:** Develops over two levels with a prospect ranging from 0.6 to 1.2. **2. Materials:** • Local materials for their thermal inertia, retaining heat for longer periods and releasing it later in the day, like sun-dried mud bricks "Toub" used in arcades and infill walls (earth bricks) as well as variously shaped bricks fired in kilns, rammed earth (pisé), cut stone in load-bearing walls to reinforce adobe houses, as well as wood, palm trunks, branches, leaves, reeds. • Cement: It has the drawback of being impermeable to water vapor transfer, which can lead to moisture problems in walls. • Binders: Earth-based plaster with excellent thermal, acoustic, and moisture regulation properties. Lime and sand mortar for wall coatings, which have similar characteristics to earth-based plaster. gain. **3. Facade:** Light-colored facades with windows and false balconies on the facade contribute to thermal gains, unlike pre-colonial exterior facades that lacked windows. Ornamentation with brick cornices and openings, as well as the use of tiles, helps reduce solar heat gain **4. Decoration:** Decorative elements are often present on the arches.

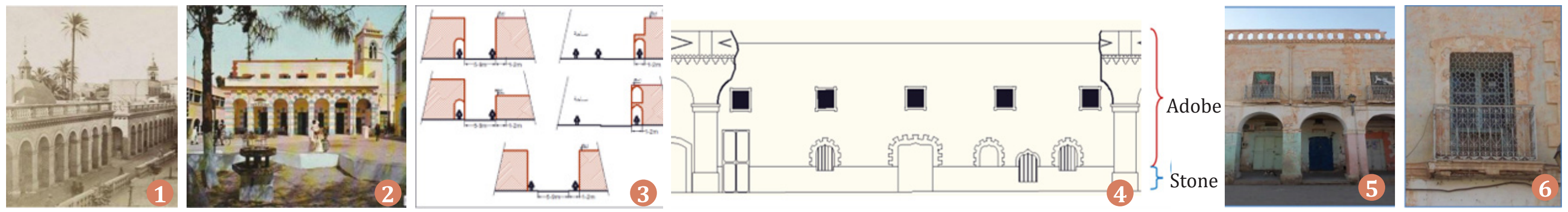


Figure 3.32. 1. Randon square, 2. Arcade, 3. Prospect, 4. Colonial facade 5. Arced facade 6. Colonial window. Source: Archive Laghouat, Abdelhfidhi Meriem- 2016

3.4.3.3. Post-independance period: El Gharbia

Table 3.4: Synthesis and climate response post-independance periodSource: author

Environmental	Form	Envelope
1. Urban layout: Dysfunctioned, irregular and heterogeneous fabric. **2. Compactness:** mostly seen in collective housing where they use block and slab construction, Affected by two factors in this case: • Lack of building continuity and dispersion. • Absence of a courtyard and presence of large windows (increased heat gain). **3. Orientation and occupancy of blocks:** Optimal orientation along the south-west development axis with central occupation. **4. Prospect:** 0.4/0.7, which does not adapt well to the region's climate, leading to thermal and visual discomfort. **5. Building height:** 2-5 storey buildings. **6. Urban furniture:** Lack of vegetation and urban furniture that adapts with the climate.	**1. Residential area:** individual and collective housing, as well as various amenities. **2. Form and volume:** Cubic-shaped buildings with recesses to create shading effects. **3. Architectural style:** a variation in architectural styles that do not reflect the local style, with a combination of traditional and modern architectural elements with the incorporation of imported traditional architectural prototypes. The use of balconies is also observed. **4. Architectural typology:** in site plan of housing complexes, no man's land is transformed into a side courtyard, often used as a relaxation space or for parking cars or storage with the loss of a central courtyard that serves as a distributor of light and ventilation, replaced by a corridor.	**1. Building heights:** range from 2-5 storey. **2. Prospect:** ranges from 0.4 to 0.7. **3. Materials:** For construction, mostly concrete, also brick. For facade, brick, glass, metal, wood, as well as PVC is used to enclose the "haouch" in traditional houses to control ventilation and protect against prevailing winds. **4. Facades:** Colorful (not always suitable for the climate) smooth surfaces with large openings set back to take advantage of the shading effect created and utilize shutters, incorporating curtain walls which is not suitable for the climate of the city. Used of Mousharabeah and pergola for decoration perposes only, but not their function

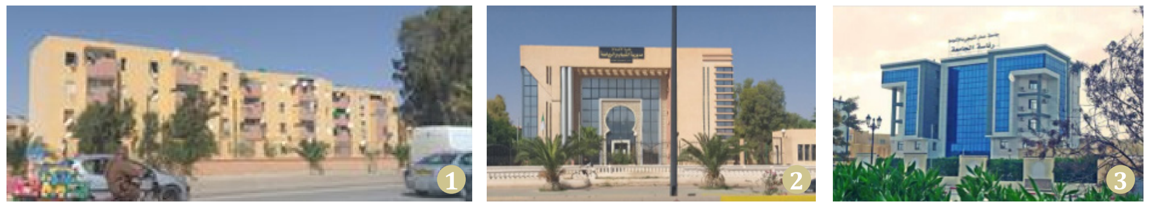


Figure 3.33. 1. Bar construction 2. Modernized facade, 3. Excessive use of glass in modernized facade. Source: Google maps and author

3.4.4. Conclusion:

Passive strategies since begining of time: The appropriate passive strategies employed in the Arab-Islamic period, in terms of the utilized construction materials and adopted architectural typologies, are most suitable for the prevailing climatic conditions. However, as the colonial era unfolded, despite the colonizers desire to appropriate the city and dissociate it from its architectural heritage, the climatic conditions of the city necessitated the subsequent adoption of the ksourienne typology to achieve better integration within an arid environment.

False modernism: In contemporary times, we witness a departure from the ancient passive strategies and a closer embrace of what is commonly referred to as modern architecture and materials. Concurrently, the demographic factor has significantly contributed to the degradation of architectural quality in exchange for quantity, as there is now a prevailing emphasis on rapid and cost-effective construction practices. Regrettably, the consideration of climatic comfort has receded in importance within the prevailing architectural discourse.

3.5. Urban analysis

3.5.1. Introdction

Building on historical insights, the following chapter conducts a meticulous typo-morpho-sensorial analysis. It encompasses boundary delineation , district interrelations, road, plot and built system analysis, and public space identification. This analysis reveals the city's nuances and informs strategic interventions for the project at hand.

3.5.2. Delimitations of the study peremeter

3.5.2.1. Situation

The case study is situated NorthEast municipality of Laghouat. It is limited by an artifical belt: RN01 (North), 1st November Ave (east), secondary road (west), and a natural wall Hill Tizegirine (South). It encompasses diverse components and activities (leisure, culture, and consumption), serving as a linkage between two significant sites within the city (Fig 3.34 & 3.35).

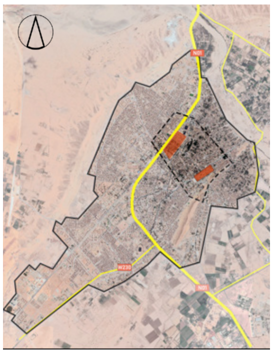


Figure 3.34. Case study location - City scale. Source: Google earth, edited by author

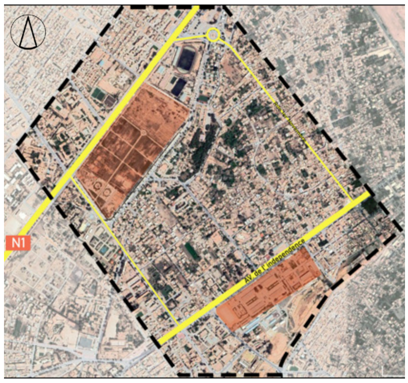


Figure 3.35. Case study plan Source: Google earth, edited by author

3.5.2.2. Site choice criteria

Although the sites are in close proximity to each other, each possesses distinct characteristics. Our project's site exhibits a constellation of factors that cohesively align with its geographical, cultural, and environmental aspects, facilitating a contextually architectural solution.

Site 01

- Strategic location on RN1 connecting Northern and Southern parts of Algeria.
- Situated between 02 extensions: Northern oasis and new extension.
- Historical significance as part of the former palm grove.
- The botanical garden.

Figure 3.34. Site 01. Source: Google earth, edited by author

Site 02: Our project

Focal position: Its central position to most of the city's neighberhood, holds paramount importance, drawing visitors and embodying rich historical heritage.

Main axis: It lies alongside historic and structural main axis (Independance Ave)

Revitalization: A historically significant terrain housing a dormant caserne, which, despite its alive vibrant strategic location, suffers from limited activity and a need for revitalization.

Preservation: PDAU's proposition is the integration of a public multi-functional project within this significant terrain, considering its profound implications for the preservation and promotion of cultural heritage.

Figure 3.35. Site 02 Our project. Source: Google earth, edited by author

Site
Case study limits
Road system

3.5.3.Limits

The city of Laghouat, centrally positioned in the Wilaya, serves as the grand-Sud region's capital and gateway (Fig 3.36). With its influential stature, it attracts neighboring agglomerations, experiencing remarkable and dynamic linear development towards the south (Fig 3.37). The study area is delimited by the formidable natural barrier of Tizegrarine to the south, the national road 1 to the north, and secondary roads to the east and west, defining its spatial boundaries (Fig 3.38).

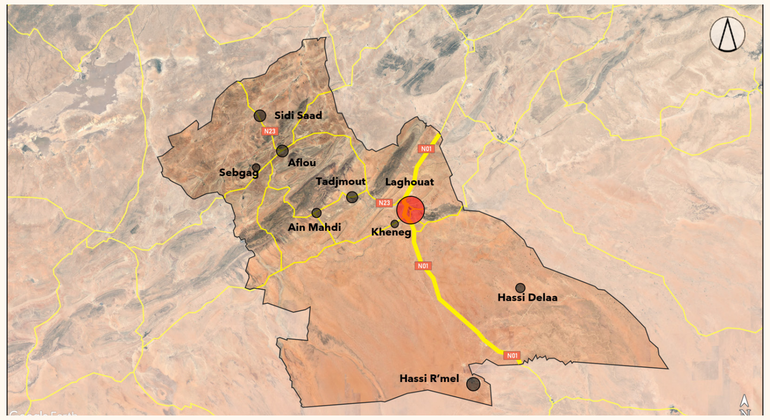


Figure 3.36: Limits, Wilaya scale. Source: Google earth, edited by author


Figure 3.37: a. Limits, Municipality scale, b. Oued M'Zi, c. Lahmar Mount, d. Daya . Source: Google earth, edited by author

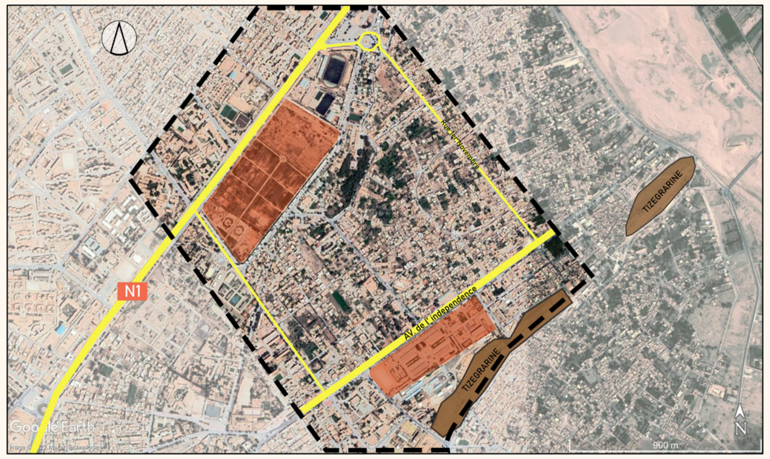


Figure 3.38: Limits, case study scale. Source: Google earth, edited by author

3.5.4.Districts

3.5.4.1. Role

City districts are perceptually and functionally homogeneous, providing distinct spatial experiences that shape urban identity and organization [Kevin Lynch] (Fig 3.39 & 40) (table 3.5).

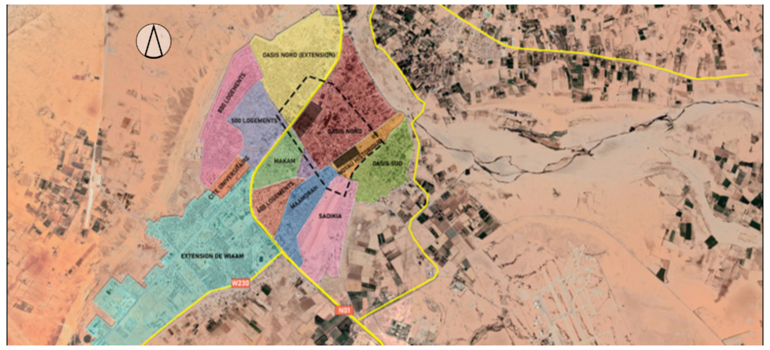


Figure 3.39: Case study role, Municipality scale. Source: Google earth, edited by author


Figure 3.40: a. Case study role, district scale, b. Old tapisery, c. View to Zgag of the old Kser, d. Northern oasis, e. Southern Oasis, f. Lastest extension . Source: Google earth, edited by author

Table 3.5 : Case study role, Municipality scale. Source: Author

Districts	Form	Topography	Function	Typology	Texture	Symbol	Character
The Historical core	Rectangular	Slope	Residential & commercial	Traditional architecture	Regular and irregular compactness	Historical, the core	Kser with colonial intervention
The 02 historical oasis	Trapezoid & irregular	Light slope	Residential & commercial	Mixed between old and new construction	Regular and irregular compactness	History inspired	Oasis style

3.5.4.2. Landscape qualities

The historic nucleus, including the Vieux Ksar and colonial fabric, embodies the city's heritage value. However, it suffers neglect, degradation, and the risk of flooding, endangering its historical identity (Fig 3.41).

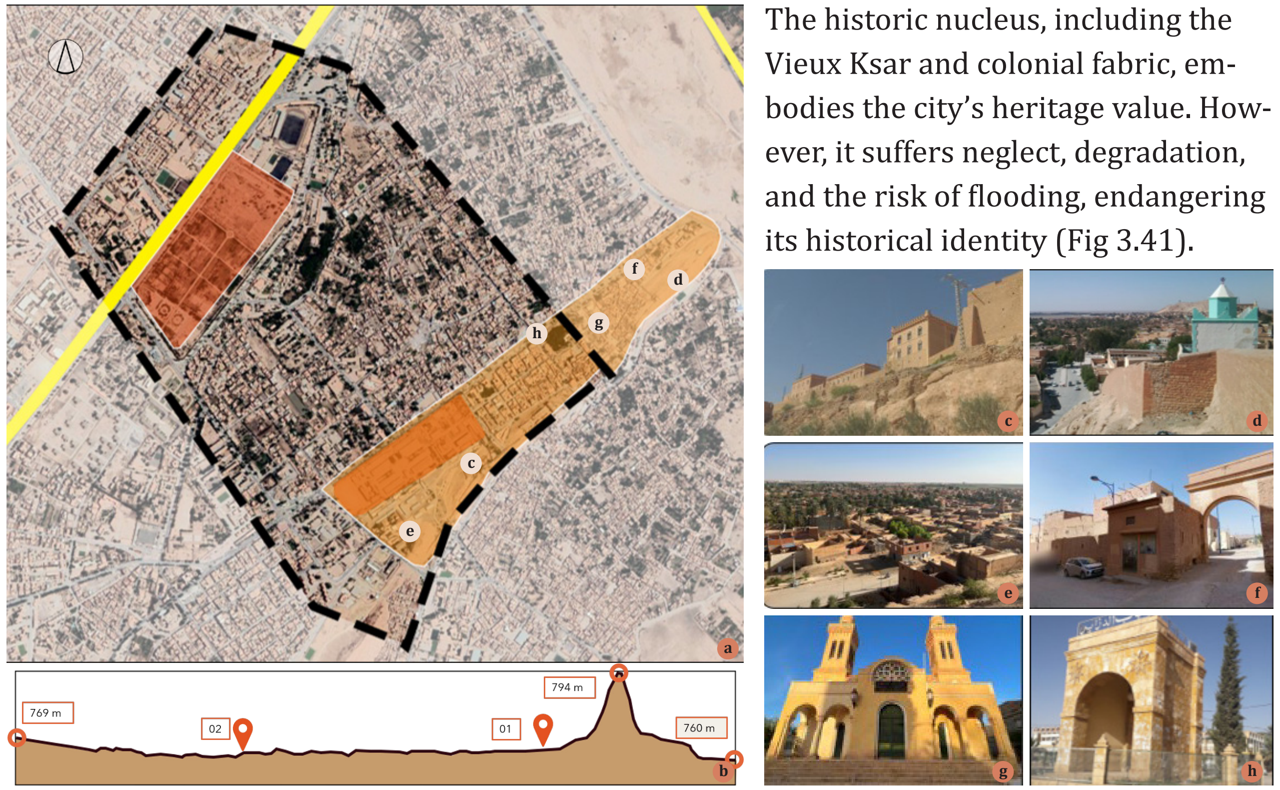


Figure 3.41: a. Landscape qualities of case study, b. Section. c. View to Tizigirine Hill, d. Tomb, e. View to the Southern oasis, f. Archway in Zgag El Hadjaj, g. Church Saint Herlion, h. Algiers archway. Source: Google earth edited by author

3.5.4.3. Challenges and constraints

Natural (Oued M'Zi, Tizigirine hill) and artifical constraints (RN01, barracks, Botanic park) prevent connected and continuied city developement (Fig 3.42).


Figure 3.42: a. Challenges - Municipality scale, b. Challenges - case study scale, c. Tizigarine hill, d. RN01, e. Barracks, f. Oued. Source: Google earth, edited by author

3.5.5. Road system

3.5.5.1. Road hierarchy: Physical and sensorial

The physical analysis highlights key factors in enhancing road system (Fig 3.38):

- Dimensions of road: Spatial configuration, width, prospect;
- Historical urban value: Cultural significance, architectural heritage, and contextual integration;
- Activities: Functionality, programmatic diversity, and accessibility;
- Type and direction: Road classification, traffic flow, and pedestrian movement.

But according to Kevin Lynch's sensory analysis, a misalignment in the hierarchical organization of roadways is observed. The Avenue 1er Novembre is characterized by its historical value but experiences a lesser flow of traffic, while the Boulevard Sellis is associated with a significant perceived traffic volume during the visit. (Fig 3.43, 44, 45 & 46) (Table 3.6).

Figure 3.43: a. Physical hierarchy of road system, b. Sensorial hierarchy of road system. Source: PDAU, edited by author

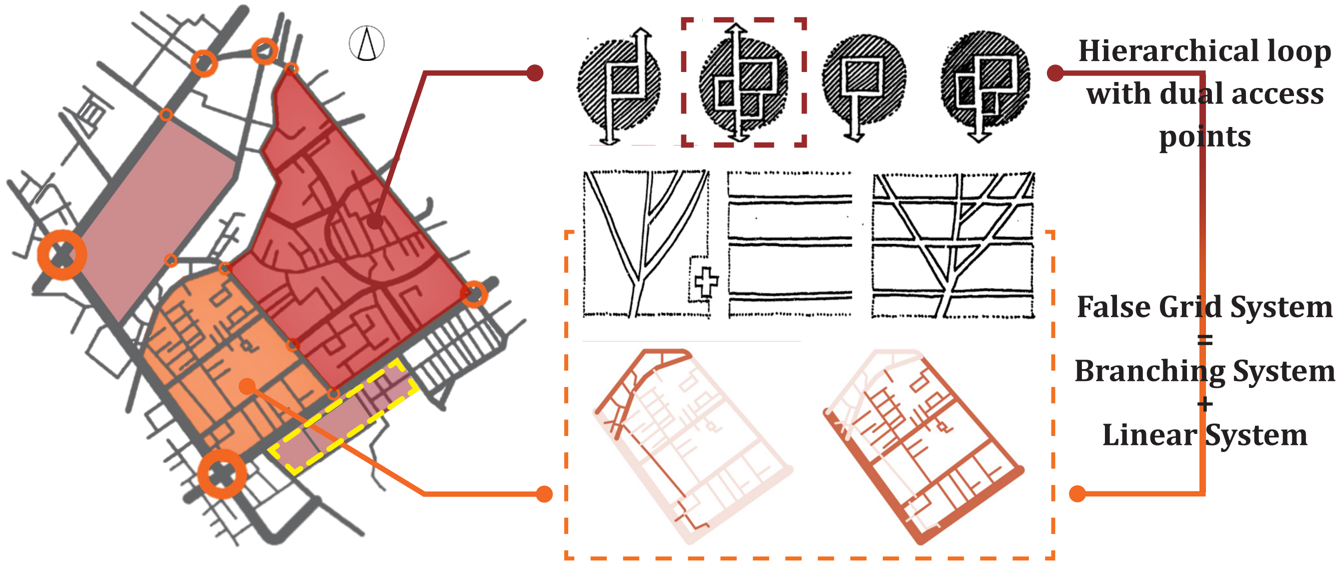


Figure 3.44: a. Type of road systems. Source: Pr. KAMMOU Lhoussaine, 2019 &PDAU, edited by author

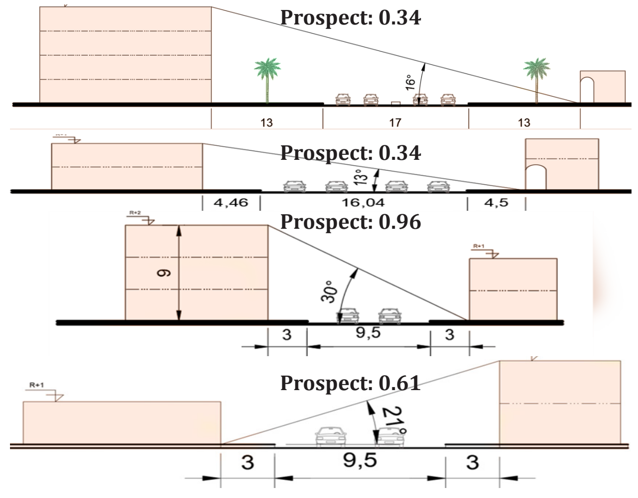


Figure 3.45: a. Section RN1, b. Section Independence Ave, c. Section November 1st, d. Section Sellis Bd Source: Author

Table 3.6: Road technical information. Source: Author

Road	Dimension	Layout	Direction	Activity	Height
RN1	17	Curved	Double	Multi functional	2-3 storey
Independence Ave	18	Straight	Double	Retail, residential, and other	1-2 storey
November 1st Ave	11	Straight	Double	Retail & residential	2-3 storey
Sellis Bd	10	Straight	Double	Retail & residential	3-4 storey


Figure 3.46: a. RN1, b. Independence Ave, c. November 1st, d. Sellis Bd Source: Author

3.5.5.2. Node hierarchy: Physical and sensorial

The hierarchy of the node takes into account the hierarchy of the roads that intersect it and the proximity of significant nodes within the site plays a role in attracting attention and interest at the city-wide scale.

Figure 3.47: a. Sensorial nodes hierarchy map, b. Botanic park, c. Resistance square, d. Bus and taxi station, e. Stadium, f. Algiers archway, g. Imam Malik Mosque Source: Google earth, edited by author

Synthesis:

The city is hierarchized based on historical and urban importance, geometry, and the flow of each road. The idea of modernizing the city by expanding the roads, especially the primary ones, does not work in the city of Laghouat due to its hot climate (Prospect ↑ comfort ↓), at least during the daytime. The hierarchization of roads leading to the two sites, both primary and secondary, bestows functional value to future projects.

3.5.5.3. Accessibility: Transport & mobility

The transportation system covers all city extensions and includes bus and taxi services. The main bus and taxi station, located in the city's central area (RN1), serves both intra-city and inter-community transportation needs. However, the new bus station in the southern region is not operational due to its distant location from the city center (Fig 3.48).

Bus stops are concentrated in 300-meter circles, representing Laghouat's different extensions (Maamoura, Oasis Nord, El Wia'am). This arrangement ensures efficient and accessible public transportation connections.

Figure 3.48: a. Bus stop, b. Bus station. Source: Author

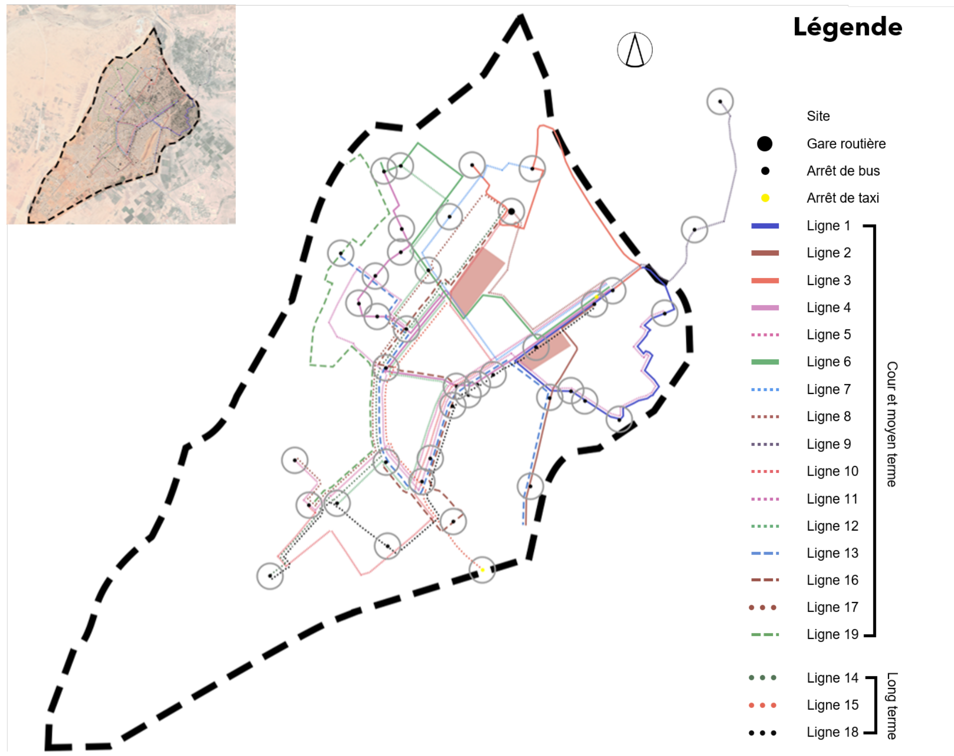


Figure 3.49: Mobility and transport line map. Source: Google earth, edited by author

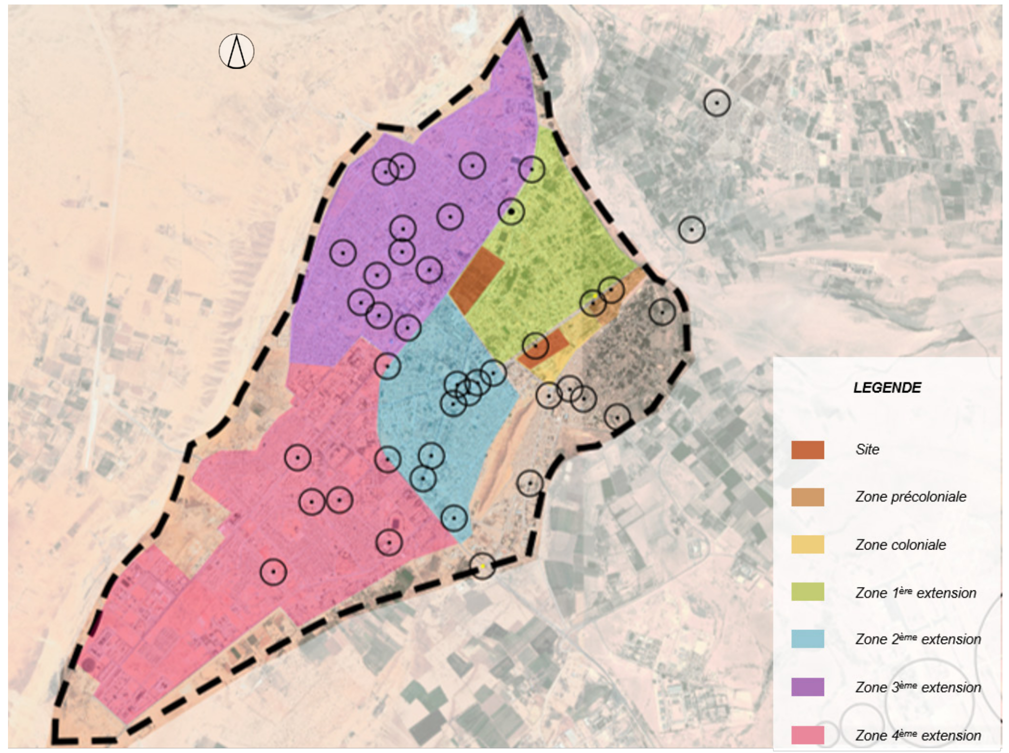


Figure 3.50: Mobility with zones map. Source: Google earth, edited by author

3.5.5.4. Security

3.5.5.4.1. Accessibility, visibility & surveillance

The integration of mechanical lanes and associated sidewalks establishes a spatial hierarchy, complemented by unobstructed sightlines on major routes for clear views. Street signage boards facilitate navigation, while the utilization of Google Maps enhanced our city exploration. The exclusive deployment of security cameras on the national urban road N1 ensures enhanced safety measures throughout our journey (Fig 3.51).

Figure 3.51: a. Security in accessibility, b. Mechanical and pedestrian accessibility, c. Road visibility- Independence Ave, d. Communication by display panel in Zgag Sidi Yanes, e. Communication by display pannel in Independence Ave, f. Surveillance by artifical lighting, g. Surveillance by "Eyes on the road" effect - Barracks. Source: Google earth, edited by author

3.5.5.4.2. Territoriality

The site exhibits a discernible zoning pattern, albeit with varying degrees of clarity. The private zone encompasses collective housing in the new extension of Oasis Nord and individual housing as well as ground-level commercial activities (limited to houses facing the secondary street) in the old extension of Oasis Nord. The public zone comprises diverse facilities catering to commerce, service, education, religious, recreational, and sanitary functions (Fig 3.52)

Figure 3.52: a. Security in territoriality, b. Institute of Sports Activity Techniques, c. ENS School, d. Youth and Sports Directorate, e. Essafah Mosque, f. Community museum - Church Saint Hérilion, g. Bousskaren fortress. Source: Google earth, edited by author

3.5.5.4.2. Urban fabric continuty

Unurbanized and undeveloped spaces facing major roads become susceptible to malicious activities, significantly compromising urban safety, and undermining architectural integrity (Fig 3.53). Implementing revitalizing interventions is imperative to effectively secure and activate these neglected areas for long-term sustainability and community well-being.

Figure 3.53: a. Security in urban fabric continuty, b.Unplanned area, c. Built area. Source: Google earth, edited by author

3.5.5.4.3. Density

It can be posited that density is balanced through the presence of varying levels of density in different zones, neither too sparse nor excessively crowded, thereby facilitating effective surveillance (Fig 3.54).

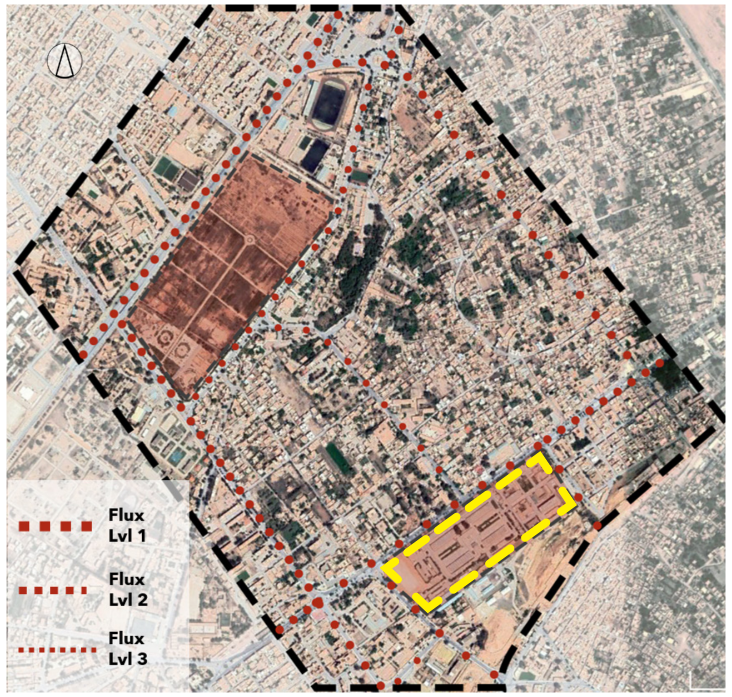


Figure 3.54: Security in density. Source: Google earth, edited by author

3.5.5.4.4. Flux

A significant flux implies a substantial number of eyes on the street, thereby indicating heightened levels of observation and surveillance (Fig 3.55).

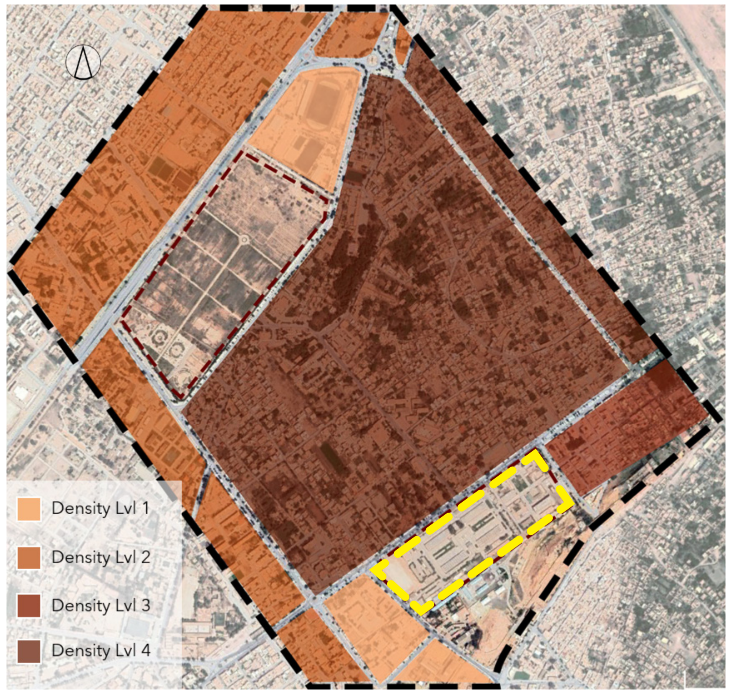


Figure 3.55: Security in flux. Source: Google earth, edited by author

3.5.5.4.5. Parking

The inadequacy of public parking areas and their substitution with linearly designed parking facilities along roadways has resulted in the emergence of haphazard parking. Certain public amenities, such as healthcare facilities, incorporate designated parking areas as an integral part of their project design. The deficiency of parking areas necessitates their inclusion and enhancement within the proposed project program (Fig 3.56).

Figure 3.56: a. central linear parking , b. lateral linear parking, c. Haphazard parking. Source: Author

3.5.5.5. Urban furniture

Used urban furniture isn't adaptive to the region's climate (Fig 3.57 & 3.58).

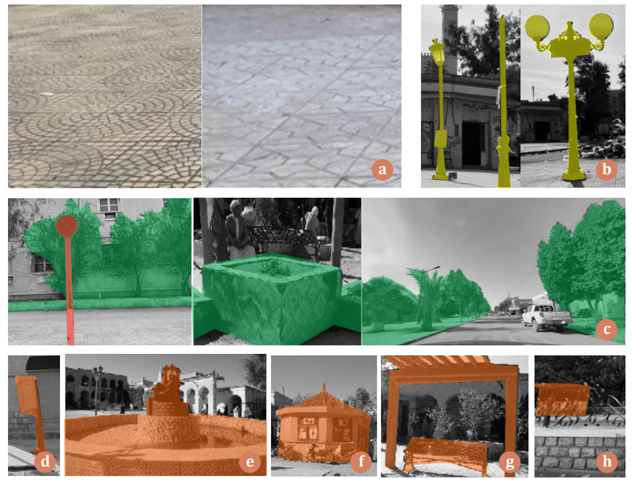


Figure 3.57: Urban furniture in the Independence Ave a. Ground treatment, b. Lamppost, c. Green space and display panel, d. Telephone, e. Fountain, f. Kiosk, g. Bench, h. Bus stop. Source: Author

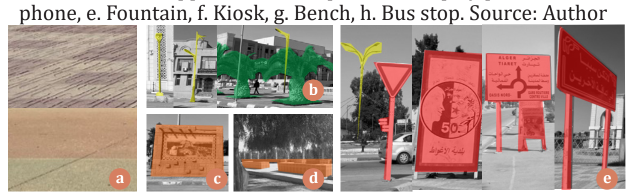


Figure 3.58: Other urban furniture in the city a. Ground treatment, b. Lamppost and green space, d. Mosaic panel, d. Bench, e. Display panel. Source: Author

3.5.6. Parcel system

The parcellary system emerges from the territorial subdivision, typically through the process of subdivision. The parcels, also referred to as "land properties," "land units," or "plots," are notably distinguished by their dimensions, proportions, and orientation. Our study perimeter comprises three distinct fabrics, each characterized by its own system (Fig 3.59).

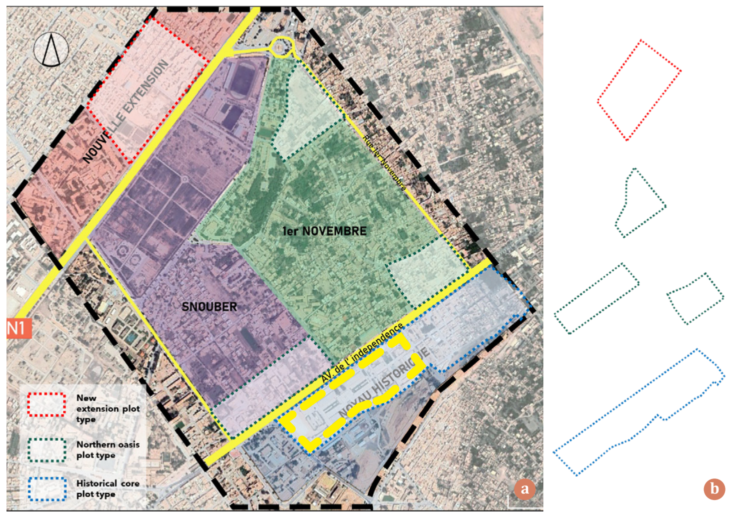


Figure 3.59: a. Parcel system, b. Different plots in case study parameter. Source: Google earth, edited by author

The historical core was analyzed by (Fig 3.60):

3.5.6.1. Dimensional criteria

It assumes a rectangular form parallel to the main Independence Avenue with a 271,104 m2, 27.11 hectares surface.

3.5.6.2. Formal criteria

The presence of 03 parcel shapes is observed:

- Rectangular Shape: Resulting from a grid structure (colonization).
- Trapezoidal Shape: Arising from the adaptation of the rectangular form to curves, also through the intersection of the two non-orthogonal roads.
- Composite Shape: Parcel densification and the outcome of inherited influences on form.

Furthermore, a dominance is noticed in the following parcel types:

- Strip or L-shaped Parcels: They are elongated rectangular shapes in depth. High density is achieved to increase the number of street fronts.
- Deformed Stout Parcels: Rectangular shape tending towards a square.

Figure 3.60: Historical core parcel analysis. Source: PDAU, edited by author

3.5.7. Built system
3.5.7.1. Visual reference point
3.5.7.1.1. City scale
The points of reference encompass large-scale facilities that exhibit two distinct architectural typologies: local and modern (Fig 3.61).

Figure 3.61: a. Reference point on Municipality scale, b. Directorate of Mujahideen, c. Trésor, d. University Rectorate, e. Grand Mosque . Source: Google earth edited by Author

3.5.7.1.2. Case study scale
The variation and concentration of landmarks signify the significance of these areas. These landmarks share the same local architectural style (Fig 3.62).

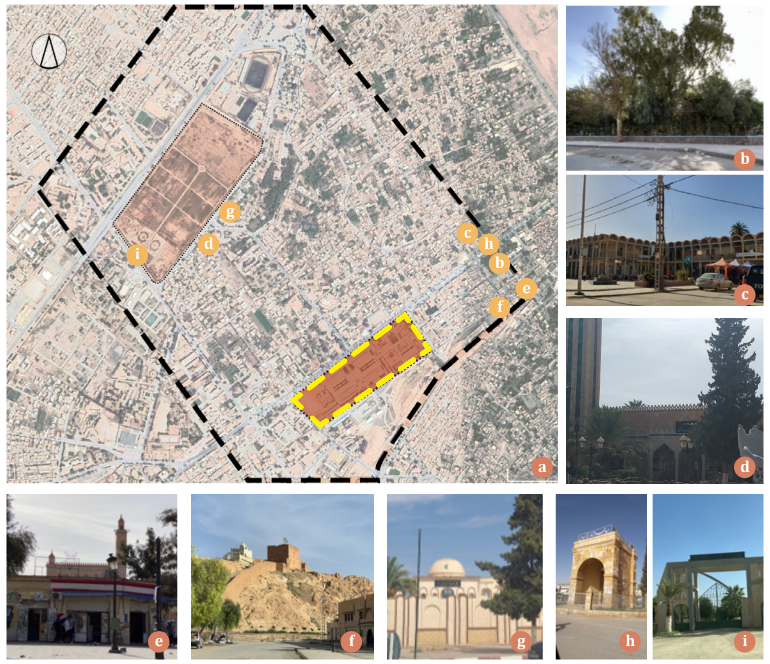


Figure 3.62: a. Reference point on case stydt paremeter scale, b. Bailek garden, c. 2 storey store galery, d. Bilal Ben Rabah Mosque minaret, e. Safah Mosque, f. Bouskaren fortress, g. Governorate Residence Dome, h. Algiers archway, i, Botanic park. Source: Google earth edited by Author

3.5.7.2. Facility
3.5.7.2.1. City scale
The city of Laghouat exhibits two significant poles: An academic and educational pole located along the RN1 highway, and a neglected heritage pole situated within the historical core (PDAU) (Fig 3.63).

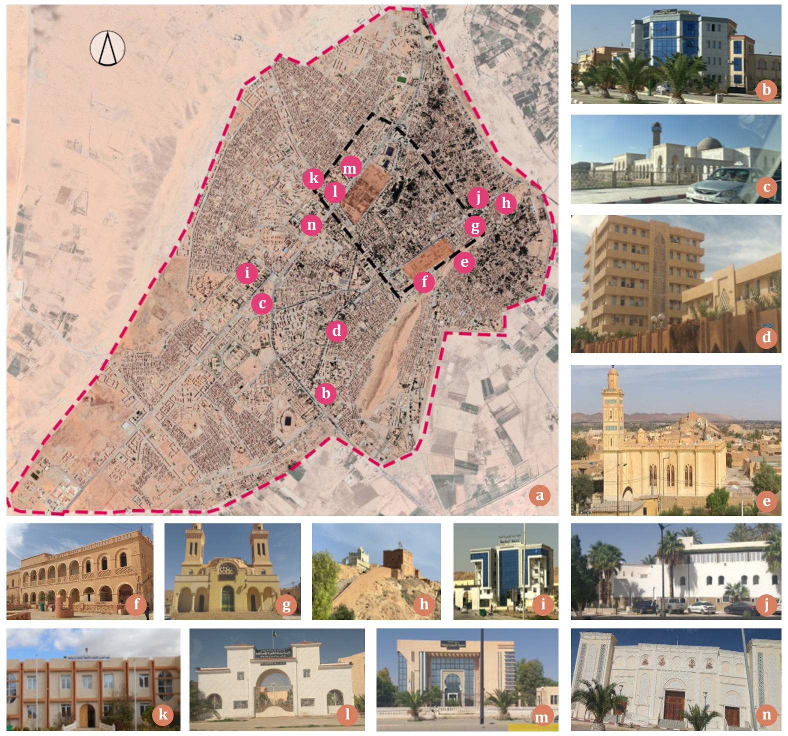


Figure 3.63: a. Facility map city scale, b. Directorate of Mujahideen, c. Grand Mosque, d. Trésor, e. Safah Mosque, f. Bouskaren fortress, g. Municipality museum, h. Morand fortess, i, University, j. Marhaba hotel, k. Institute of Sports Activities Techniques, l. ENS college, m. Department of Youth and Sports, n. New theater . Source: Google earth edited by Author

3.5.7.2.2. Case study scale
The case study is a residential area where habitat is dominant. Our site is situated more on the histori-commercial side of the case study peremeter and the city (Fig 3.64).

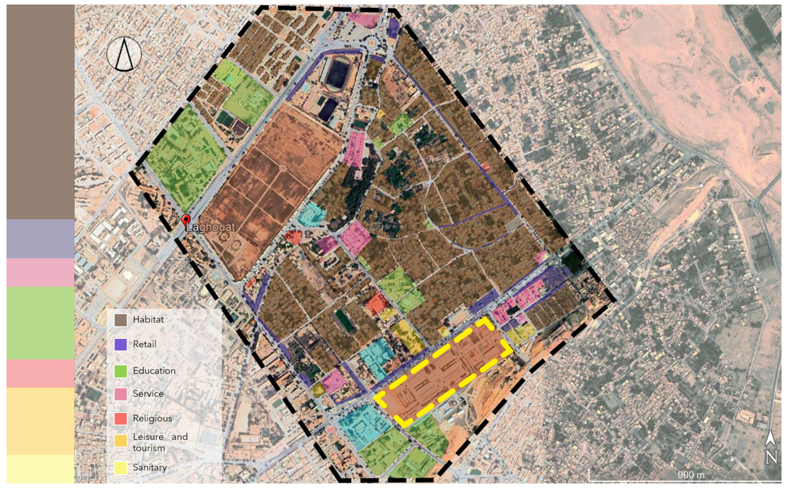
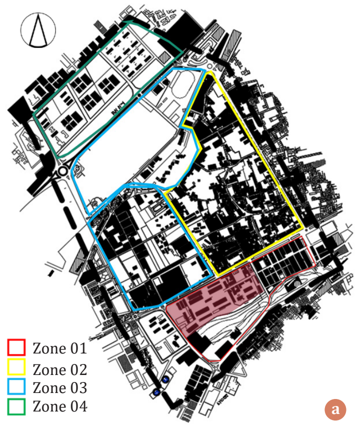


Figure 3.64: Facility map case study scale. Source: Google earth edited by Author

3.5.7.3. Density
3.5.7.3.1. Solid and void
An imbalance is observed in the distribution of density between the northwestern and southeastern parts of our study area, accompanied by a concentration of open space in the form of a large garden (Fig 3.65).

Figure 3.65: a. Occupancy pattern case study scale, b. Built, c. Private space, d. Public garden, e. Void, f. Road, g. Public space. Source: Based on PDAU edited by Author

3.5.7.3.2. Occupation type
• A decline in the type of ground coverage is observed between the old extension and the new extension, where this difference varies according to the function being occupied.
• The adaptation of houses with courtyards and the use of party walls reduce compactness coefficients and limit the surfaces exposed to climatic conditions. (Fig 3.66).



• **Density:** High; • **CES:** 0.8; •**COS:** 2.4
• **Form:** 02 predominant building forms: courtyard houses and cube shaped or vertically elongated plot based buildings.

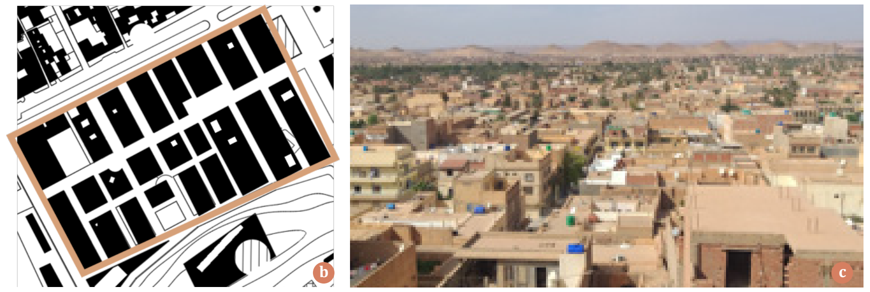


Figure 3.66: a. Type of zones in cas study parameter, b. Historical core zone, c. Kser. Source: Based on PDAU edited by Author

3.5.7.4. Building's condition

The classification of building conditions is based on cleanliness, maintenance, and safety. Three states of buildings are identified according to their construction period: moderately degraded condition for colonial fabric buildings, good condition for the existing extension, and very good condition for the new extension. Our site is situated in an area of moderately degraded and good condition (Fig 3.67).

Figure 3.67: a. Building's conditon of cas study, b. Good condition built, c. Moderately degraded built, d. moderately degraded space. Source: Based on PDAU edited by Author

3.5.7.6. Road alignment

In Independence Avenue, alignment is ensured by the buildings themselves or boundary walls. However, the alignment is interrupted by secondary roads (perpendicular to the avenue) and nodes characterized by a setback (Fig 3.69).

Figure 3.69 a. Independance Ave alignment, b. Boundary wall, c. Setback. Source: Google earth, edited by Author

3.5.7.5. Building heights

A hierarchy is observed in the distribution of building heights with the dominance of 2 and 3 storey buildings near our site (Fig 3.68).

From the PDAU report, in prinipal road, the maximum height can building reach is 4 levels with authorized retail activity on the ground floor.

Figure 3.68: a. Building height case study scale. Source: Google earth, edited by Author

3.5.7.7. Facade, colors and texture

The dominance of solid over void is evident in traditional introverted dwellings with small openings for ventilation. Vertical elements provide height, while rhythm and repetition are present. Arcades are used near shops for warmth in winter and protection from vertical solar rays in summer. Central arches, claustra, and moucharabieh elements are also utilized.(Fig 3.69).

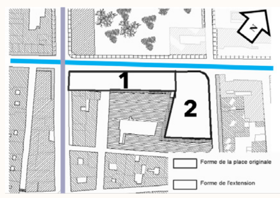
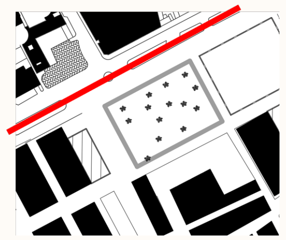
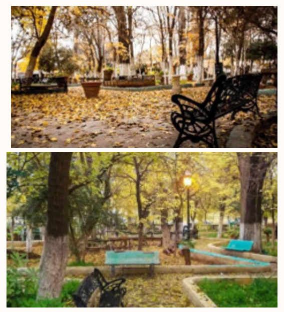
Figure 3.69 a.b.e.f. Zgag El Hadjaj aesthetics, c. Rahbat Zitoun, d. Independence Ave, g. Barracks - our terrain. Source: Google earth, edited by Author

3.5.8. Open public space

The city's limited green spaces, including the "public garden" and "botanical garden," fail to compensate for the historical absence of abundant green areas and watercourses that regulated temperature and provided humidity in the former palm grove. This impacts the overall urban quality of life. While public squares dominate the southeastern historic core (Zgag El Hadjadj, El Saffah, Elgharbiya), they suffer from neglect. These green spaces also serve as vital playgrounds, supplementing limited recreational options provided by stadiums (Fig 3.70) (Table 3.7).

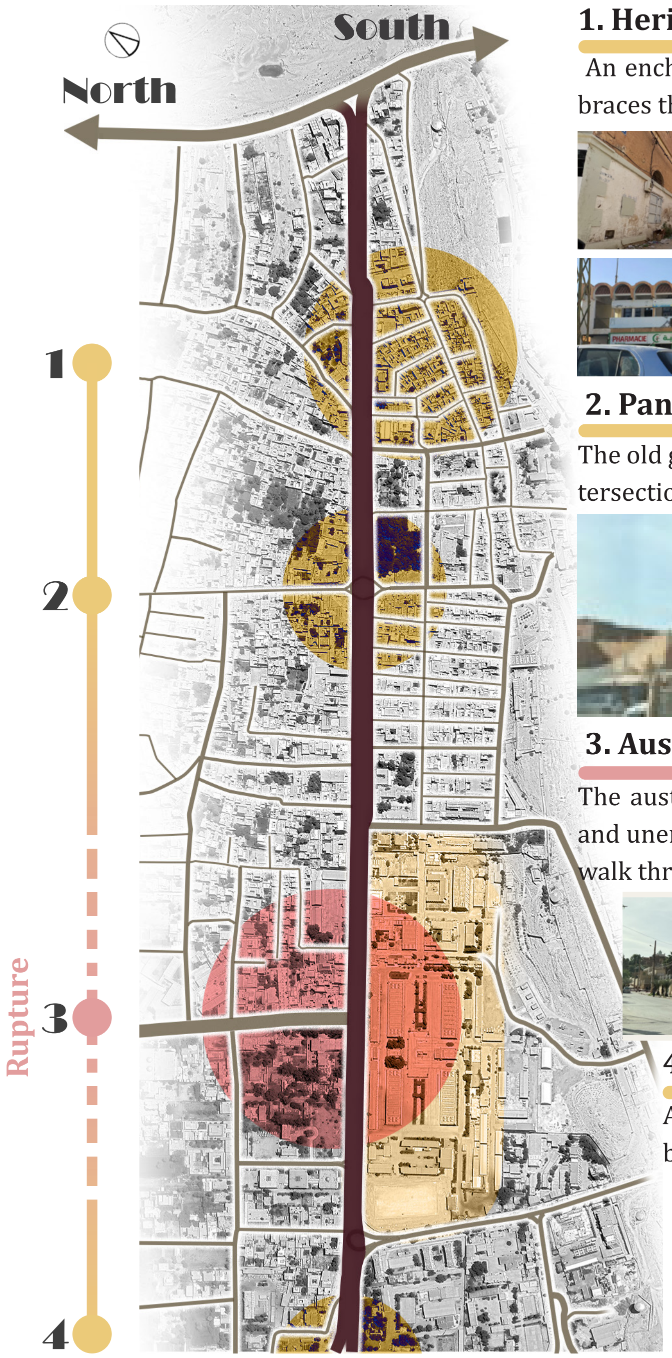
Figure 3.70: a. Public space map case study scale, b. Staduim, c. Jnan Bailek, d. Rahbat Zaitoun, e.f.g.h. Open public space. Source: Google earth, edited by Author

Table 3.7: Open space example. Source: Google earth, edited by Author

Space	Characteristics	Scheme	Pictures
Rahbat Zaitoun	This public square, functioning as an open market, consists of two attached plazas forming an "L" shape. The rectangular main plaza (1784.68m^2) serves as a public market for fruits and vegetables, while the trapezoidal secondary plaza (1208.81m^2) functions as a meeting space. Unfortunately, the square currently suffers from poor cleanliness and hygiene.	 Aimirouche road; Larbi Ben Mhidi road	
Jnan El Bailek	This public garden or park, known as "Baylak," which translates to "free garden" in the local dialect, holds historical significance. Situated in the old city center, the historic core of Laghouat, it spans an area of 7753m^2. The garden attracts retirees and children, who enjoy its leisure and recreational offerings.	 Independance Ave	

3.5.9. Sequential analysis

Considering the location of the site within the historic core, a significant dominance of cultural heritage and commercial activities is observed, albeit lacking proper maintenance. Furthermore, the presence of a sequential disruption caused by the barracks creates an urban and social barrier. In this context, our project aims to establish a focal point that maintains the rhythm and introduces a sequence to the alignment along Independence Avenue. Leveraging its strategic position, the project will enhance the cultural and heritage aspects of the city, resulting in a new regional hub for commercial and touristic attraction. (Fig 3.70).

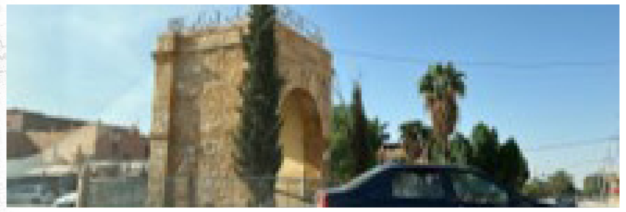


1. Heritage sequence

An enchanting aura and a vibrant tapestry that embraces the authentic essence of the region's heritage.

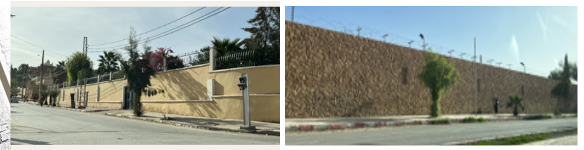
2. Panoramic sequence

The old gateway to North marking the node on the intersection of the two historical strcutural axis.



3. Austere sequence

The austere surroundings of the area create a plain and unembellished atmosphere, prompting people to walk through it quickly.



4. Lively sequence

After a long quiet walk, the Resistance square breathes back dynamic air into the road.

Figure 3.70: Sequenctial analysis. Source: Google earth, edited by Author

3.5.10. Conclusion: Strategies

In conclusion, the meticulous typo-morpho-sensorial analysis conducted in this chapter has provided valuable insights into the urban fabric and dynamics of the city, resulting comprehension and understanding of the city's nuances. These findings serve as a solid foundation for informing strategic interventions and decision-making in the context of the project at hand. By leveraging the knowledge gained from this analysis, we can effectively address the challenges and capitalize on the opportunities presented by the urban environment, ultimately contributing to the enhancement and sustainable development of the city. The presented strategies (Table 3.8), illustrated in the strategies map (Fig 3.71) are the result of the intersection of SWOT rows and columns presented in the next page (Table 3.9).

Table 3.8: Strategies. Source: Author

	Opportunity	Threat
Strength	***Maximize opportunities*** ***SO1:*** Exploiting the site's strategic location to enhance the neighborhood and city. ***SO2:*** Enhancing visibility and attraction through an engaging project. ***SO3:*** Providing accessible amenities that prioritize pedestrian experience. ***SO4:*** Integrating open spaces for social interactions and diverse experiences. ***SO6:*** Adding sequence and coherence to the urban alignment.	***Minimize threats*** ***ST1:*** Encouraging pedestrianization through the installation of urban furniture that adapts to climatic conditions. ***ST2:*** Promoting the city's heritage through a project inspired by local architecture. ***ST3:*** Valuing oasis ecosystems for sustainable development. ***ST4***: Enhancing public space (botanical garden) through redesign to: - Recreate the oasis vocation (northern palm grove). - Reinforce the microclimate. - Ensure optimal visitor orientation.
Weakness	***Correcting weaknesses by taking advantage of opportunities.*** ***WO1***: Leveraging opportunities to address weaknesses and promote local architecture to enhance its architectural richness. ***WO2:*** Integrating vegetation into the project to: - Minimize noise pollution caused by vehicular traffic. - Create a microclimate. ***WO2:*** Utilizing architectural elements for better adaptation to climatic conditions.	***Minimize weaknesses and threats*** ***WT1:*** Resolving the parcel issue by valorizing them with appropriate functions. ***WT2:*** Utilizing architectural elements according to their original function. ***WT3:*** Creating interconnected open spaces. ***WT4:*** Considering the microclimatic aspect in open spaces. ***WT5:*** Densification and diversification of neighborhoods (Urban Development Plan - UDP). ***WT6:*** Proposing a multifunctional project. ***WT7:*** Avoiding sequential disruption through the introduction of multifunctional activities.

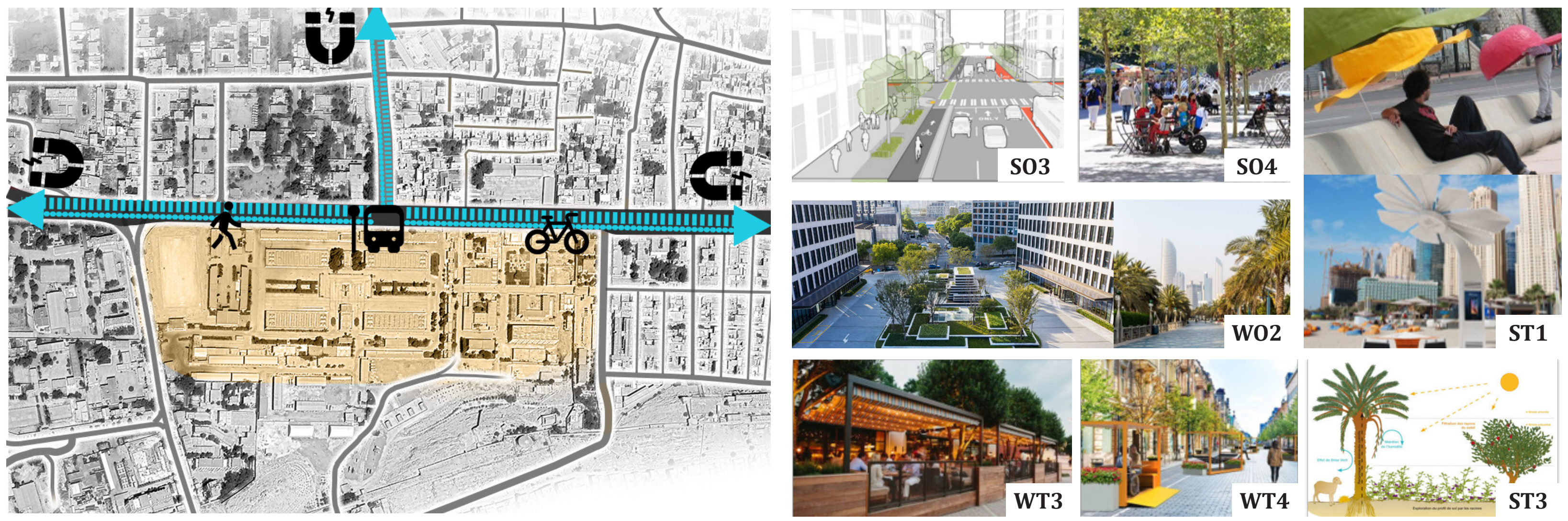


Figure 3.71: Strategies map Source: Google earth, edited by Author

3.5.11. SWOT

Table 3.9: SWOT. Source: Author

Strength	***District***	1• Architectural and urban heritage wealth, 2• Proximity to the historic center with cultural and touristic value, 3• Proximity to the national road RN1, 4• Intersection of multiple neighborhoods.	1• Strategic location of the city as the gateway to the Algerian desert. 2• The landscape quality of Tizigeranine. 3• The establishment of a vibrant center within the city.	***District***	**Opportunity**
	Road system	1 • Limited land boundaries by major roads that attract a large public due to their significance and high level of safety (RN1, Independence Avenue, and Sellis Boulevard). 2 • High visibility and easy accessibility to intervention site. 3 • Concentration of bus stops near the intervention site, facilitating public attraction from different parts of the city. 4 • Presence of urban furniture.	1• Possibility to integrate a project that targets a large number of the public. 2• The potential to utilize and enhance urban furniture.	***Road system***	
	Plot system	1 • Regular rectangular shape. 2 • The advantage of having four facades. 3 • Presence of two types of urban fabric within the historic core.	1 • Large parcels of land.	***Plot system***	
	Built system	1 • Concentration of commerce activities in the cultural heritage pole on Indépendance Ave. 2 • Richness of local architecture and local architectural elements. 3 • Building alignment complies with urban regulations. 4 • Promising prospects in the historic center.	1 • Balance of skyline in Independence Ave. 2 • Projects for modernization, overall upgrading, and major cultural events in the city of Laghouat.	***Built system***	
	Open public space	1 • Presence of a botanical garden and a public garden as green spaces.	1 • Possibility of redeveloping public spaces and establishing a network between them.	***Open public space***	
	Sequential analysis	1 • Strong historical and cultural sense of belonging in the southern part of the study area. 2 • Sense of security ensured through high visibility.	1 • Functional dominance.	***Sequential analysis***	
Weakness	***District***	1 • Historical core in need of maintenance.	1 • Densification of certain neighborhoods that may contribute to noise pollution and vehicular traffic.	***District***	**Threats**
	Road system	1 • Sources of noise pollution. 2 • Excessive prospecting exceeding limits, affecting pedestrian flow and underutilization of urban furniture. 3 • Lack of parking areas and utilization of central and lateral linear parking along the roads.	1 • The risk of having deserted pathways and missing out on proper development opportunities. 2 • Emergence of parking occupation zones on sidewalks.	***Road system***	
	Plot system	1 • Lack of legal considerations . 2 • Unregulated construction in the northern oasis area.	1 • Risk of functional diversion of unoccupied parcels leading to insecurity. Densification of parcels.	***Plot system***	
	Built system	1 • Lack of maintenance in the historic part. 2 • Absence of local character in the new extension (extraverted). 3 • High solar accessibility in the new extension. 4 • Eclectic use of architectural elements in the new facades.	1 • Risk of loss of the city's heritage monuments. 2 • Unplanned urbanization in the northern palm grove. 3 • Risk of non-adaptation to climatic conditions. 4 • Risk of zoning. 5 • Forgetting of memory and loss of its purpose due to the absence of tourist and cultural facilities.	***Built system***	
	Open public space	1 • Lack of open space network. 2 • Mineralization of open spaces. 3 • Absence of microclimate elements such as cool water, greenery, and shade.	1 • Lack of orientation for visitors due to the absence of public spaces. 2 • Risk of flooding in the city.	***Open public space***	
	Sequential analysis	1 • Noise pollution caused Independence Ave. 2 • Lack of exchange spaces and inter-generalization. 3 • Sequential disruption. 4• Inadequate waste and water management.	1 • Risk of Seguia becoming a waste site, attracting mosquitoes.	***Sequential analysis***	

3.6. Conclusion and recommendation

Table 3.10: Recommendation table of thematic, diachronic and urban analysis. Source: Author

	Environment Urban aspect	Form		Envelope	Climate responses
		Architectural aspect	*Program aspect*	*Structural*	
Diachronic analysis	• Fractal architecture: is a geometric shape containing detailed structure at arbitrarily small scales • Adapting narrow walkways and pathways to increase wind velocity and a protection from solar radiation • Plant more vegetation and plant to create a microclimate, they should be located wisely taking into consideration site analysis. • Seguia, a water canal to ensure irrigation and at the same time it refresh the weather by humidifying the weather	• Compacted form with integrated patios and narrow walkways as a metaphor of ksour. • Integrating patios as a thermal regulator and as well as a solar space that ensure lighting to other spaces. • Terrasses that can be exploited during winter and summer seasons. • Pergola to support plants and is used as a shadow option.	• Patio has a social dimension as it enhances human relationships. • Services spaces their location should be chosen wisely as they play a thermal isolation for other important spaces. • Integrate public spaces as they have an important role in the lifestyle of a laghouati.	• Use local materials as they are more adaptable to climate zone and more resistant. Such as: Taub, lime, palm tree trunks, reeds. • Adapt soft colors. • Small openings. • Use moucharabia to ensure natural and ventilation and a protection against sun exposure.	• Integrate different courtyards and water basins. • Narrow walkways according to the ratio h/w. • Integrate more vegetation and different type of plants as they regulate the weather and absorb CO2 in the air. • Compacted form as it ensures a more passive zone which increase the optimization of energy. • Soft colors with high albedo percentage. • shadow options such as moucharabia. • Use of local materials which make the building more resilient.
Urban analysis	• Take advantage of the strategic location of the site for a project that will accentuate the neighborhood and the city. • Encourage walkability by installing a diversity of urban furniture that adapts to climatic conditions. • A project that adds sequence to the alignment. • Assure connectivity of the city by adding more activities. • Integrate a bus stop to reduce the use of a car. • Narrow walkways with high ratios of h/w.	• Promote local architecture to revive the importance of this architectural. • Use fractal architecture in two dimensions for a more metaphoric form of the ksour.	• Integrate in the project a network of public and entertainment spaces for the development of social relations and the creation of different atmospheres. • Valuing oasis ecosystems for sustainable development.	• Use of architectural elements for better adaptation to climatic conditions. • Use architectural elements according to their original function. • Integrate the project with its environment using light colors. • The use of local or adequate material to.	• A resilient architecture by adapting ksour concepts and principals. • Increase the surface of green spaces to reduce the heat island effect. • The use of adequate materials that reduce the absorption of heat. • A diversity of urban furniture that are adapted to climate conditions. • Keep the summer sun out by engaging common walls to reduce exposed exterior walls and use sunshades. • Augment the velocity of the wind by reducing rugosity. • Encourage walkability for a more sustainable development. • cool pavement by planting vegetation and water canals.

3.7. Site analysis

3.7.1. Site choice - urban planning

Our site holds barracks, that were built back in the colonial era, of a 600m long facade, 200m wide and approximately 12Ha, creating a rupture in the historic-commercial Independance Ave.

01 The PDAU recommends integrating public, commercial, cultural, and residential projects in this specific area due to its pivotal historical importance and architectural legacy. By harmoniously blending these elements, it creates a dynamic urban landscape that fosters a vibrant community and enhances quality of life.

Figure 3.72. Sub-site choice - urban division step 01. Source: Google earth, edited by author

Figure 3.73. Sub-site choice - urban division step 02. Source: Google earth, edited by author

02 Extending the historical and structural axis from the kser and the urban axis of the Northern Oasis, and a division following a historically inspired grid (explained in Chapter 03, page 61).

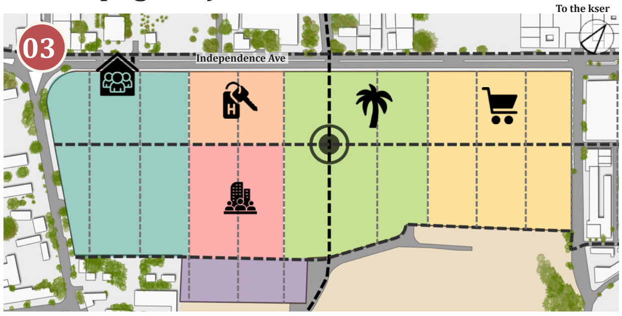
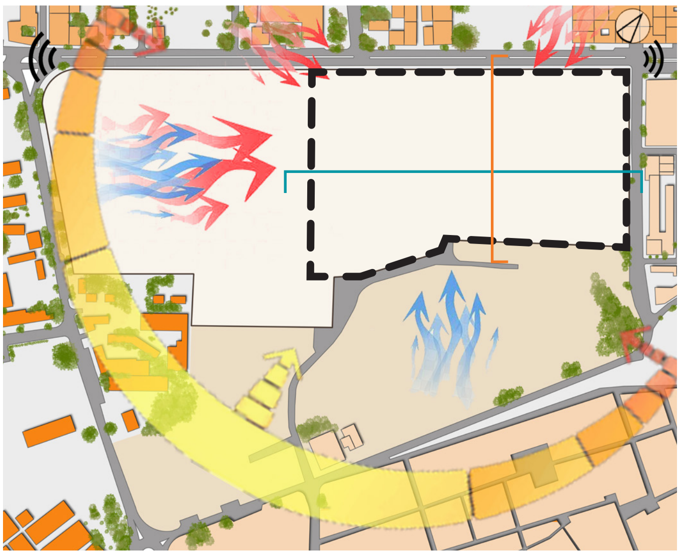


Figure 3.77. Sub-site choice - urban division step 03. Source: Google earth, edited by author

03 Following the PDAU's recommendation by integrating a Commercial and Entertainment center with a cultural souk esperience the closest to the kser, an urban oasis park on the intersection of the 2 axis, a boutique hotel, a startup company and a residential city "القصر الجديد".

3.7.2. Site synthesis



Dimensions: 356 x 200

Surface: 71200 m^2

COS %: 40 - 70%

COS m^2***:*** 28480 - 49840 m^2

Slope 01: 5.5%

Slope 02: 1%

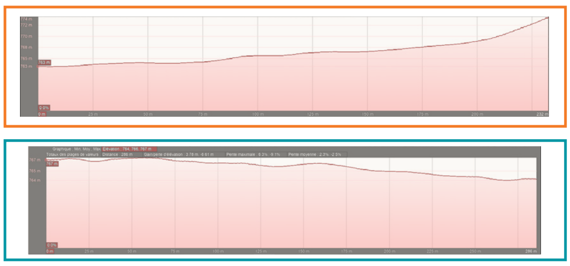


Figure 3.78. a. Site analysis synthesis, b. Site section. Source: Google earth, edited by author

3.8. Fundamental concepts of the project

To easily identify the fundamental concepts, it is necessary to define our project's vision and mission. Refer to Figure 3.50.

What's our VISION and MISSION

VISION
Sustainable vibrant city center that balance modernity and authenticity

MISSION
Achieve a continuity of the urban activity with multifunction spaces such as commercial (souq) and leisure, with sustainability in design and heritage

Figure3.79: Vision and mission of our project. Source: Author

Concepts are classified into three main categories, and within each category, we generate sketches of ideas as a preliminary brainstorming process before starting the design.

1- Urban concepts 2- Program concepts 3-Architectural concepts

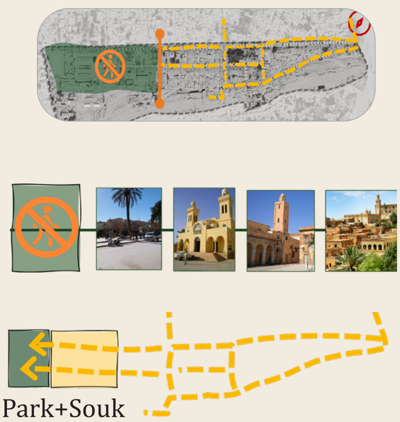
3.8.1. Urban concepts

Figure 3.80. Urban concepts

1- Sense of place

1.1. The transformation of barracks into a multi functional project revitalizes the historical core and integrates it within the surrounding environment, embracing the distinct physical, cultural, and social attributes.

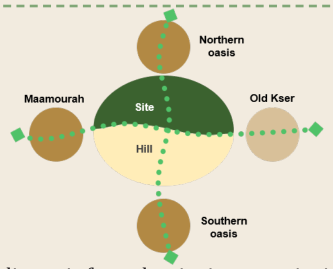
1.2. Cultural walk along the main axis connects the historic "kser," significant monuments, and through our project ''Souk'', culminating in an urban park symbolizing Laghouat's rich heritage, historic and natural status. This immersive pathway fosters a profound connection between the built environment and its cultural legacy, inviting visitors to engage with the city's hidden stories.



Transform barrack to Multifunction project with souk experience beside it an urban park to breath a new life into the city.

2- Visual and spatial continuity

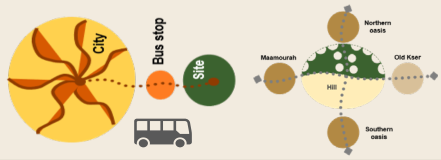
2.1. By extending the axis from the kser and incorporating a network of Rahbat into our site, our objective is to enhance permeability and facilitate ease of movement. This integration will ensure a seamless flow throughout the space, while also establishing a visual continuity of the axis.



Extending axis from the city into our site in order to make it more accessible

3- Sustainable urban connectivity

4.1. Bus stop and bicycle lane: environmentally friendly modes of transportation are added to promote efficient mobility, and enhance connectivity within urban areas.



3.8.1. Urban concepts

4- Human dimension experience

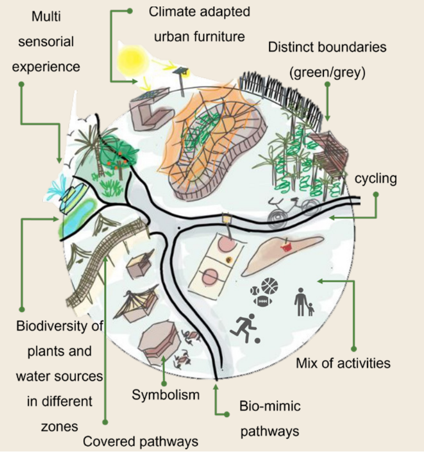
4.1. Pedestrian-friendly spaces with wide sidewalks and safe crossings.
4.2. Mixed-use development to create a vibrant urban environment.
4.3. Pedestrian streets, cycled pathways and public transportation.
4.4. Prioritization a human-scale design approach to create cities that are more livable, walkable, and enjoyable for everyone
4.5. Creation of attractive public spaces.

5- Biophilic design

5.1. Integrating an urban park with an oasis metaphor aims to reintroduce greenery through biophilic design principles. Our site can enhance biodiversity, improve air quality, mitigate the urban heat island effect, provide opportunities for recreation and relaxation, and promote a sense of harmony and tranquility within the urban fabric.

Figures 3.80: Urban concepts

Happy street starting from Ksar and the historical monuments till our site



3.8.2. Program concepts

1- Multi-sensorial experience

The multi-sensorial experience is of utmost importance for a souq, as it plays a pivotal role in creating a captivating and memorable environment for visitors. By engaging multiple senses such as sight, sound, touch, smell, and even taste, the souq becomes a rich and immersive space that goes beyond mere visual aesthetics. The incorporation of various sensory stimuli through thoughtful spatial organization enhances the overall atmosphere, encourages exploration, fosters a deeper connection to the products and culture, and leaves a lasting impression on visitors. It adds a layer of authenticity, excitement, and engagement that elevates the souq experience to a truly sensory journey. Figure 3.81

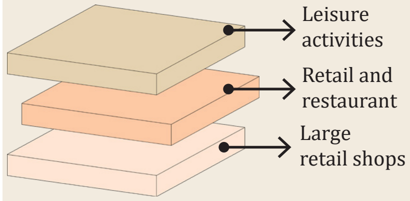
Figures 3.81: Program concepts

3.8.2. Program concepts

Figures 3.81: program concepts

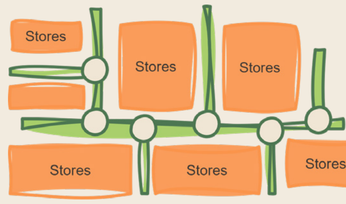
2- Functional hierarchization

Vertical hierarchization and horizontal specialization as a reference to a typical souk organization. (Each alley specializes in certain goods.)



3- Culture and society

3.1. Activate social memory through spatial organization, reminiscent of the traditional souk's main spine line.
3.2. Activate social memory by different art galleries with integrated workshops.



A spin line organization with Sikkas and at each intersection we find a new sequence or art gallery

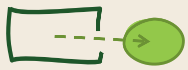
4- Sense of discovery

4.1. By creating sequences of patios with different perspectives and various activities to enhance the sense of discovery for visitors in order to draw more consumers.


Creating different perspectives to enhance the sense of discovery in visitors.

5- Flexibility

5.1. Spaces that are adaptable to different user needs and activities. Movable partitions, modular furniture, and flexible layouts.

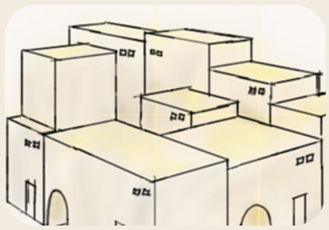


Flexible terrasses

3.8.3. Architectural concepts

3.82: Architectural concepts

1- Kser organization metaphor

1.1. The compact form and narrow alleys in the souk replicate the bustling atmosphere of traditional markets, where visitors can explore vibrant stalls along labyrinthine streets. This design choice aims to create a sense of intrigue and encourage immersion in the souk's unique character. Furthermore, this form enables a seamless integration of the project with its environment, aligning with architectural typology and climate conditions. The narrow pathways provide ample shade and minimize exposure to direct sunlight, enhancing the resilience of the souk design.


The compact form help us to integrate the project within its environment (Historic core)


Narrow pathways that intrigue the sense of exploration and discovery.

3.8.4. Architectural concepts

1- Kser organization metaphor

1.2. A network of pathways, lined with palm trees and vegetation, merges progressively as we make our way towards the park.

2- Harmonious form

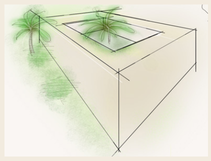
2.1. Fractal geometry as it was employed in old traditional textures by incorporating repetitive patterns with self-similarity at different scales. This technique resulted in intricate and visually captivating designs that achieved a harmonious balance between order and complexity. One notable type of fractal geometry is the Minkowski curve. This application of fractal geometry in old textures helps to evoke a sense of timelessness, organic beauty, and a connection to the natural world within architectural design.

3- Dialogue project with its environment

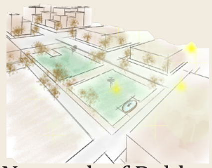
3.1. Historical integration is achieved through the functional and aesthetic incorporation of architectural elements in the facade, as well as the use of locally sourced materials.

3.2. The design includes the creation of various viewpoints and terraces, offering diverse perspectives and outdoor spaces for visitors to enjoy.

3.82: Architectural concepts

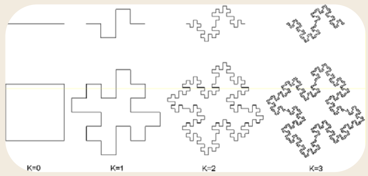


Palmerian merge



Network of Rahbat

Ksar of Laghouat



D=log(N)\log(S) D=1.5

D: fractal dimension\ N: number of pieces \ S: Reduction factor

Integrating arches and terraces creates diverse viewpoints, blending historical elements with captivating views for an engaging architectural design.

The accumulation of the environmental, architectural, and programmatic concepts helped us to generate an image of our project.

A sketch of the image of the Ksar of Laghouat

Inspiration

A sketch of our mental image

3.83: Conceptual image: Source: Author

3.9. Form developement

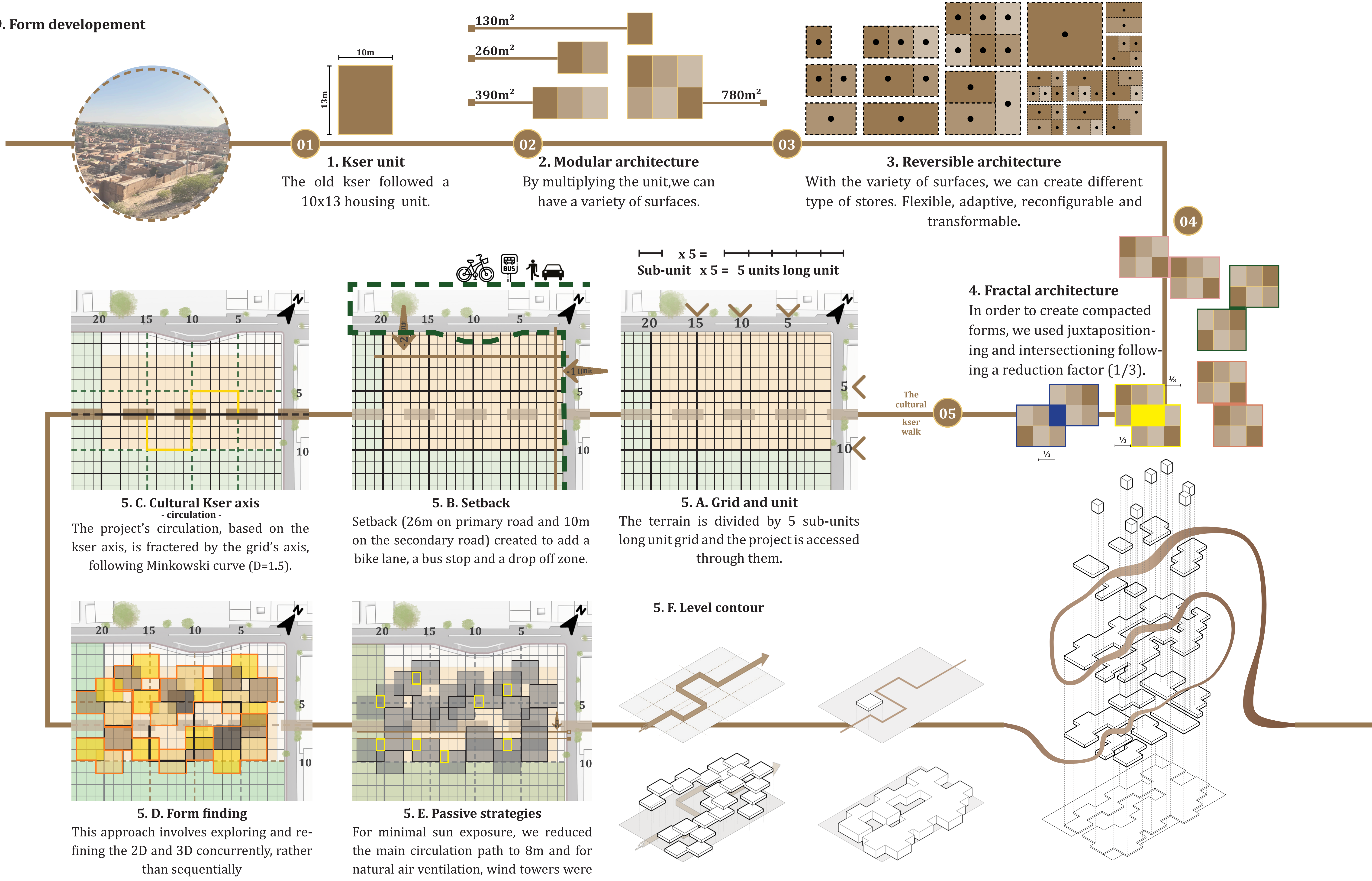
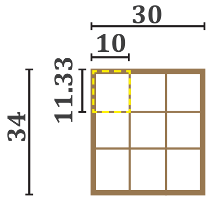
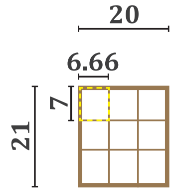


Figure 3.84. Souk process. Source: Author



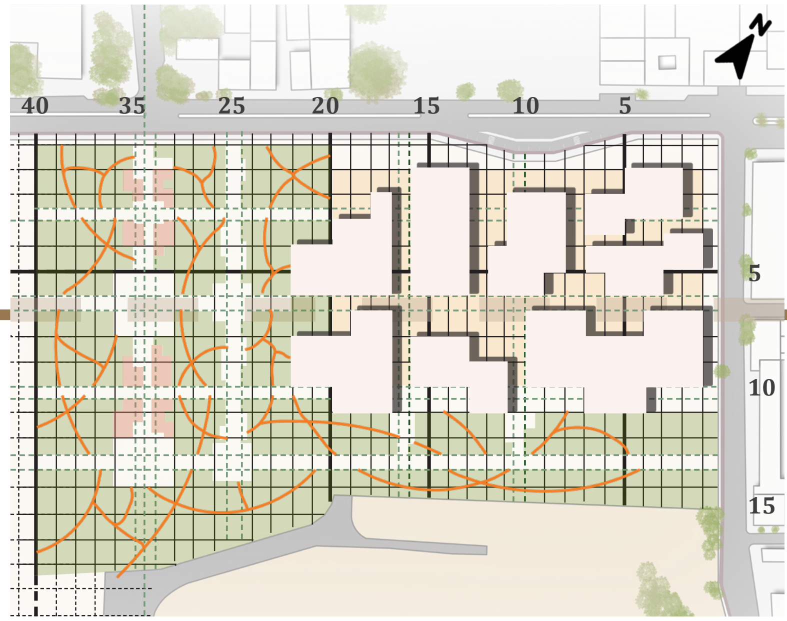


6. B. Back to fractal

Using Minkowski curve also, from the 2 open spaces of the intersections, resulting 2 sub units; creating the main park welcoming pathways with site setting and gathering areas

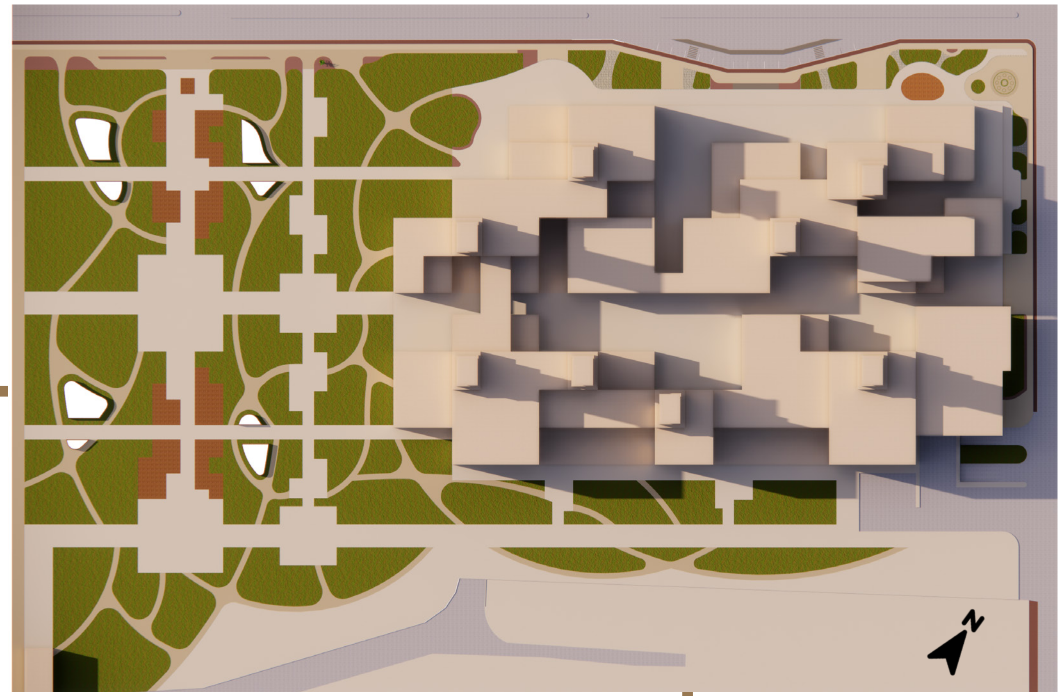
6. C. Mixed garden

With the geometry used in the park, a nature integration was added by the flowy wavy pathways to give the sense of the leisurely free walk.



6. D. Site plan

The integration of the nature and the continuity of the greenery to the heart of the project and its urban and side facade.



6. A. Axis & intersections

The circulation was created from the axis resulting the green areas, and their intersection is an open space.

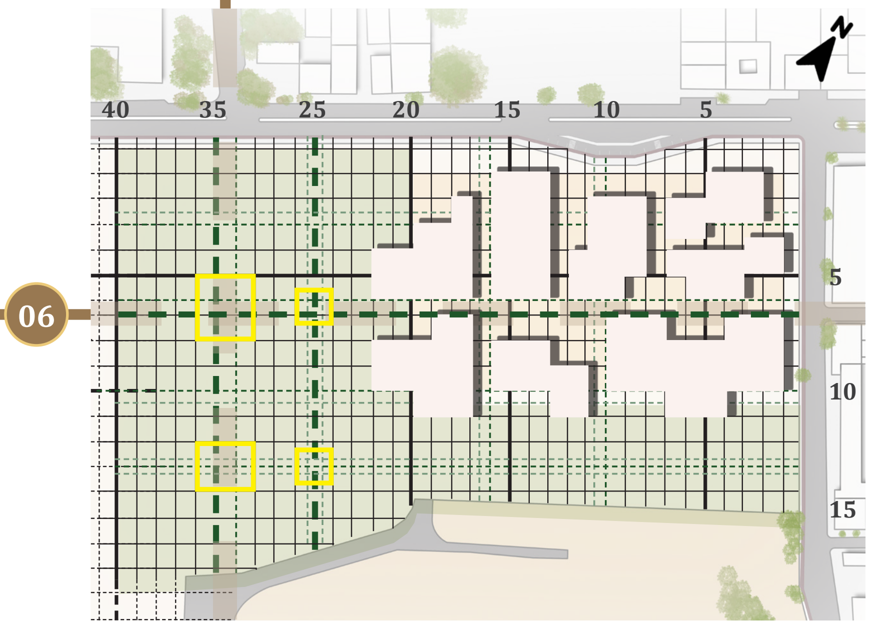


Figure 3.85. Park process. Source: Author

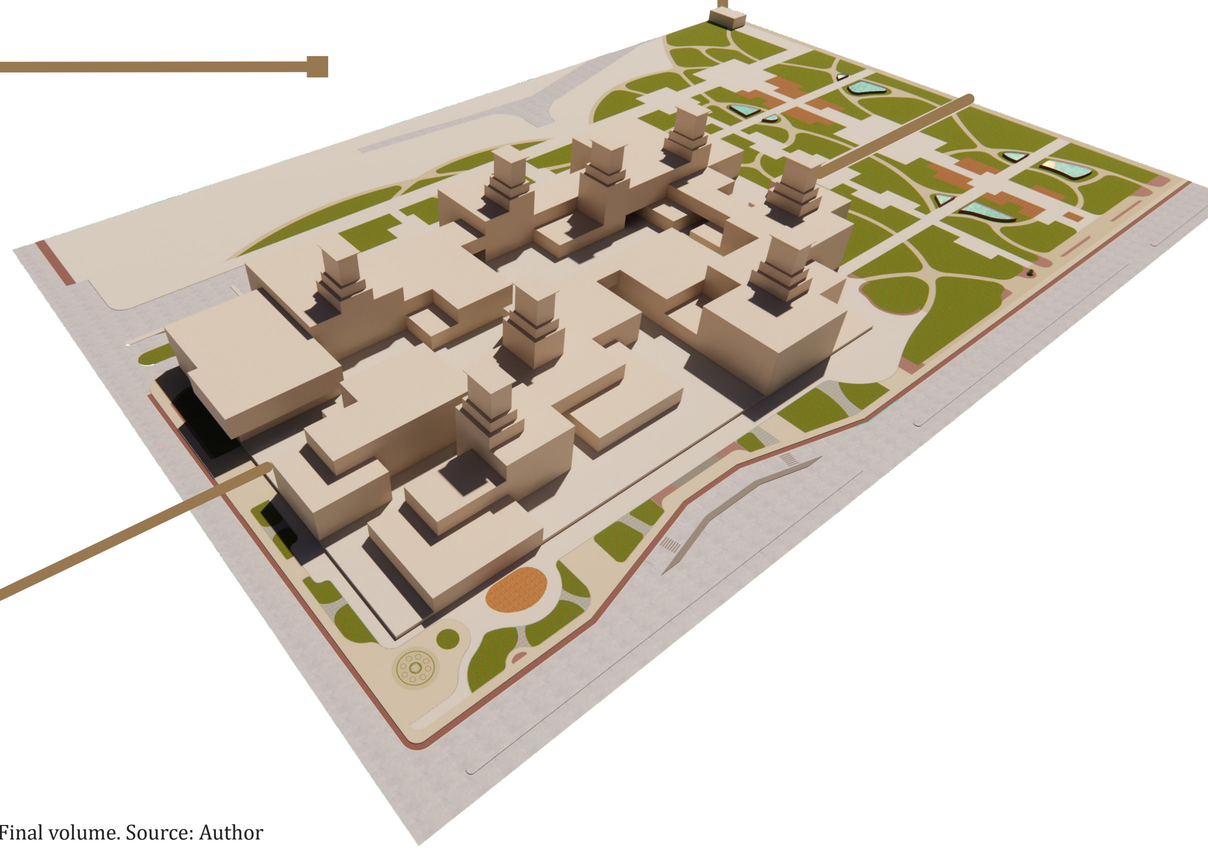


Figure 3.86. Final volume. Source: Author

3.10. Spatial organization

After formulating a design inspired by the aforementioned concepts and principles, characterized by a compacted layout with narrow pathways that evoke a sense of exploration and nostalgia for the traditional kser architecture, while simultaneously ensuring adaptability to the challenging arid climate, our next objective is to imbue it with vitality through the integration of functions that consist of five fundamental dimensions(fig.3.87). These dimensions encompass commerce, culture, entertainment, education, and relaxation. They collectively serve as the driving forces behind the project, with each dimension harmoniously contributing to the the overall aesthetic and functionality of the project.

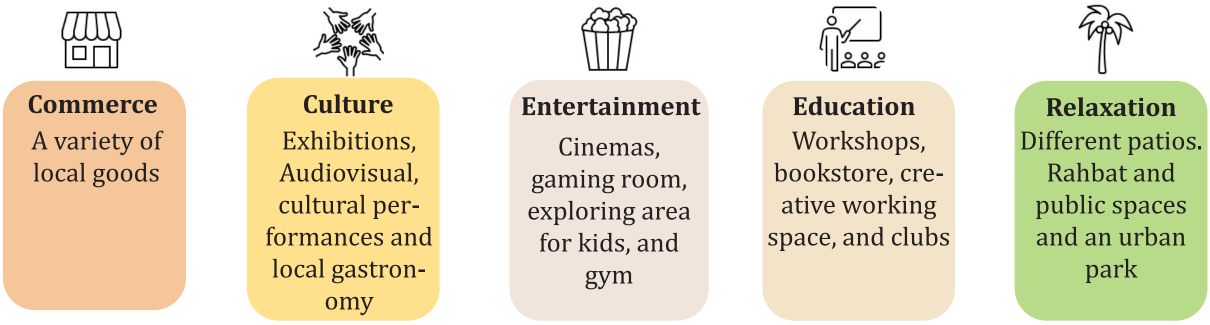


Figure 3.87: Axes of our program development

3.10.1. Logic of organization

Based on the logic of a traditional linear souk our project is structured throughout a spine that structure the whole project. This spine is the main circulation towards various multi-functional spaces. Out of this spine the visitor continue its promenade through secondary shaded alleys by the compactness of the forms and volumes of the project making the canyon effect to cool the streets (figure 3.88).

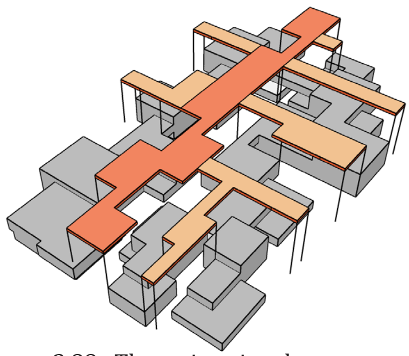


Figure 3.88: The main spine that structure the whole project. Source: Author

The spaces in our project are organized according to their corresponding functions and grouped based on similar activities such as clothing, fabrics, home decor, and more. Within each specialized group, there are spaces dedicated to culture, education, and training such as exhibitions and workshops. This organizational approach encourages visitors to return and contributes to the resilience of the space (figure3.89).

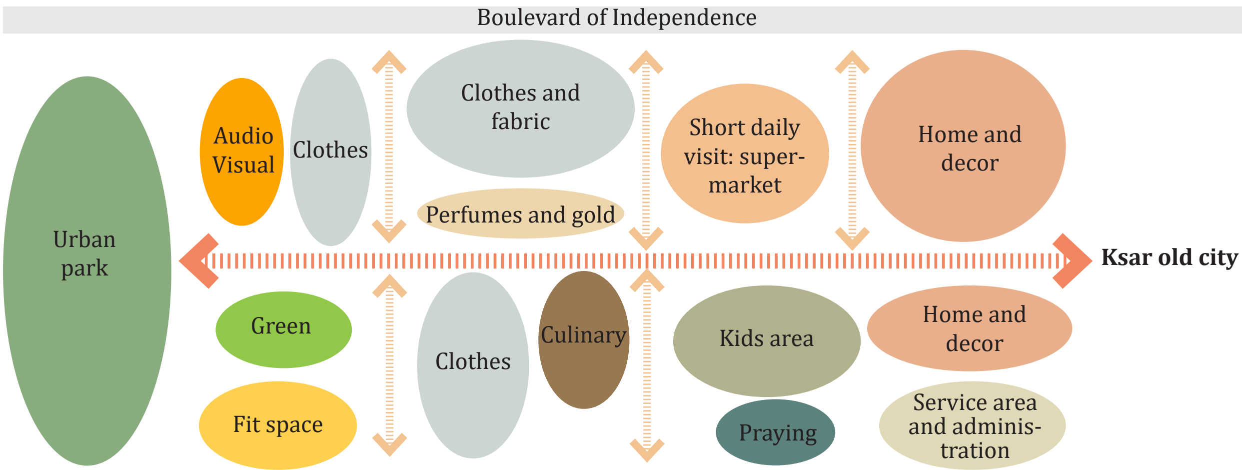


Figure 3.89: Spatial organization of Ground floor. Source: Author

3.10.2. Logic of organization: Multi-sensorial experience

Furthermore, the spaces and functions have been organized using a sensorial approach that helps visitors discover the place through the six senses (hearing, vision, smell, taste, thermoception). The sensations associated with these senses are linked to the history of the place, reminding visitors of their previous souk experiences in the city of Laghouat (figure 3.90). From our perspective, this sensorial approach remains the best way to connect visitors with the glorious past of the location.

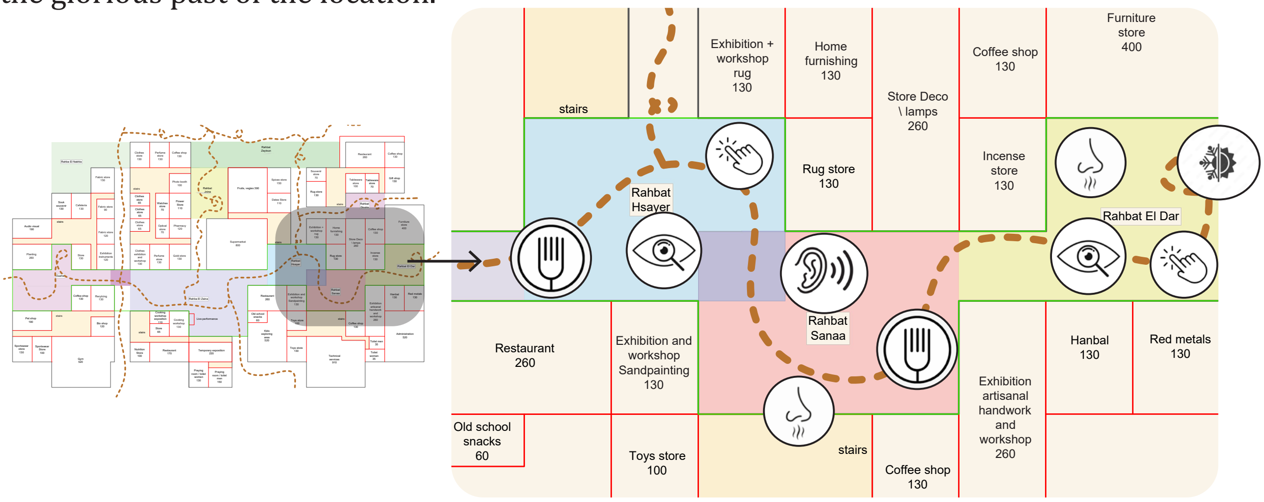


Figure 3.90: Exemple of sensorial experience Source: Author

On the upper example shows how the spaces are organized to provide a sensory experience. As we enter, we are greeted by a rahba and the smell of incense and the sight of various handicrafts. Moving forward, we encounter Rahba that offer thermosensation, along with a coffee shop where we can indulge in the aroma and taste. Continuing our exploration, we come across a rug store with vibrant carpets on display, inviting us to experience their textures through touch. Additionally, there is another rahba and a restaurant available as well (figure 3.91).


Figure 3.91: Illustrations from our project demonstrate the sensorial experience

3.10.3. Space distribution harmony

We have strived to harmonize the functions found on the lower levels with those on the upper levels, according to the visitors' needs. As a matter of fact, shopping and food and beverage facilities are located on the ground level, while entertainment functions are situated on the upper level. Additionally, the larger functions and spaces have been distributed in a way that balances the number of visitors (figure 3.92).

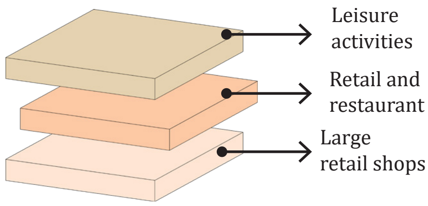


Figure 3.92: Illustrations of space distribution Hierarchization

3.10.4. Horizontal circulation

As mentioned earlier, our circulation is primarily based on a main spine line with secondary shaded alleys. However, during extreme weather conditions, circulation is facilitated inside the buildings to provide comfortable experience. Our approach to circulation inside the building also emphasizes on discovery and exploration. As we journey along the path, the illumination at the end of the pathway sparks our curiosity, compelling us to unveil what lies ahead (see Figure 3.93).

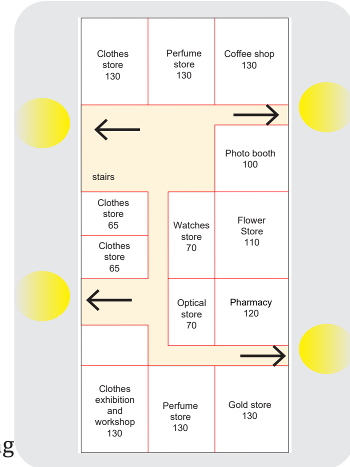


Figure 3.93 Discovery approach based on light inside the building

3.10.5. Vertical circulation

Each cluster has vertical circulation using stairs and elevators distributed smoothly according to safety rules and regulations. It is worthed to notice that the stairs are provided at the top with wind catchers to reinforce the natural ventilation. There are two types of stairs : public ones and for emergency exit along the exterior walls (figure 3.94). The public ones are located in a way to facilitate the vertical circulation ending on open vertical space (mezzanine) offering views to the lower spaces.

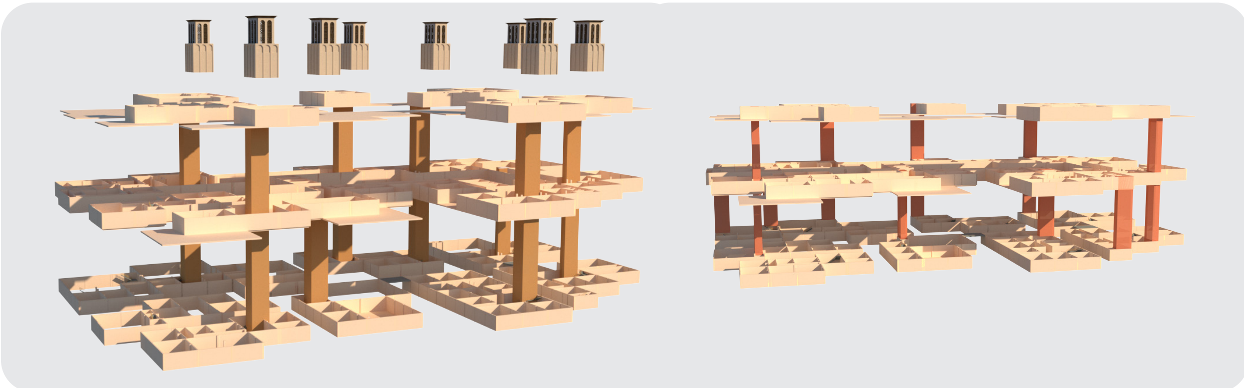


Figure 3.94: Vertical circulation. Left: public circulation, Right: Emergency circulation

3.10.6. Network of Rahbat

Various *rahbat* were integrated along the spine. With their vegetation they create a micro climate effects. Rahbat are connected by a water line that represents Seguia or "Salsabil". These rahbat were named either based on their functions or on their historical significance. At the end of the last rahba, an urban park is added to symbolizes the fulfillment of an oasis in Laghouat, as well as a metaphore of paradise in Islam (figure 3.95).

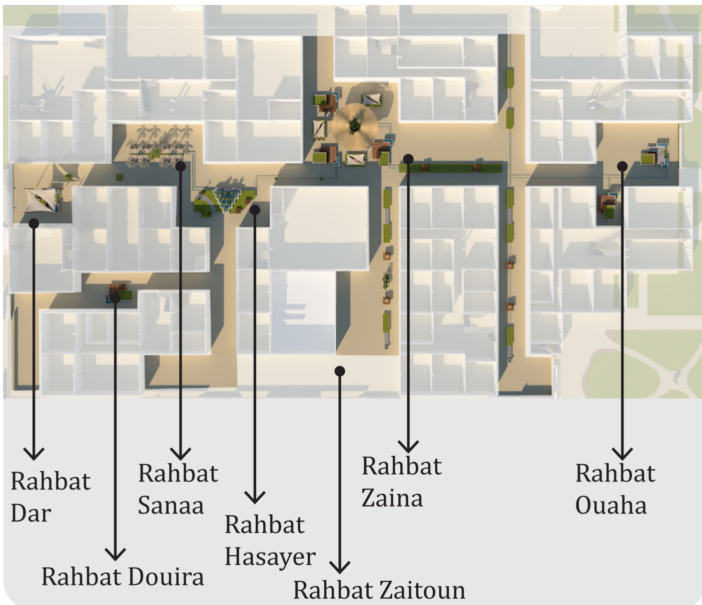


Figure 3.95: Network of Rahbat Source: Author

Exploded axonometric

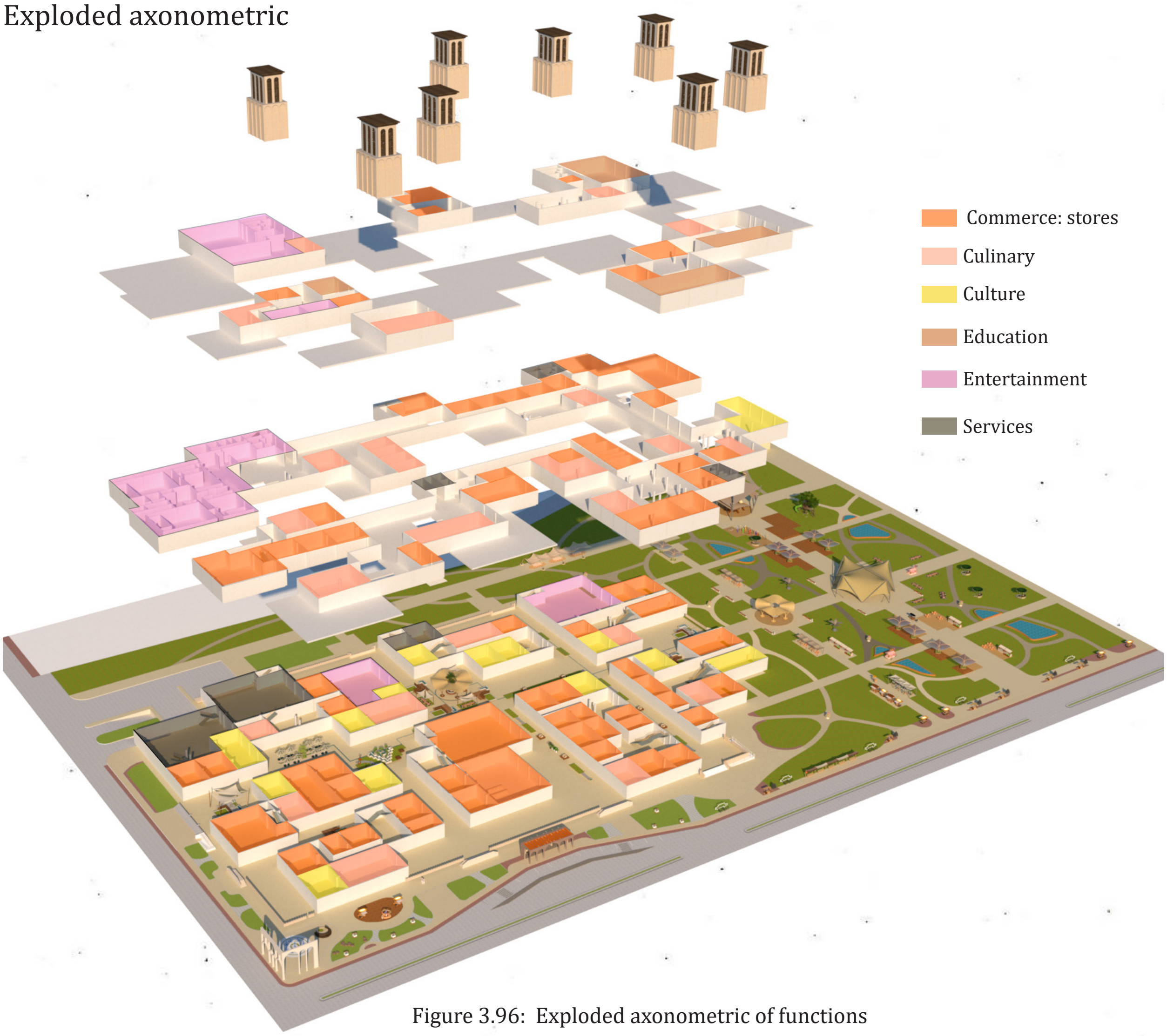


Figure 3.96: Exploded axonometric of functions

3.10.7. Urban park

The urban park has been designed to symbolize an oasis, featuring dense vegetation and integrated water elements. Various public activities have been incorporated as micro events within the park. Two types of pathways have been carefully considered: the linear geometric path and the fluid path, both aimed at providing diverse promenade experiences while showcasing the significance of trees and ensuring optimal air quality for visitors. Notably, the intersection between the city road and the road from Kser has been symbolized by a tent, representing the heritage of Laghouat and hosting cultural events (figure 3.97).

Figure 3.97 Different views from the park. Source Author

• ***Plant types:*** The plants play an important role in the multi-sensory experience. They were chosen based on the application “Picture This AI” that shows the type of trees and flowers in Laghouat, as well as taking in consideration the use of different heights, different colors and smells for rich experience (Fig 3.98), check annexe for further details.

A. Trees

1. Date palm (Phoenix dactylifera) Flower, Leaf, Care, Uses - PictureThis (picturethisai.com)
2. Saharan cypress: The Saharan cypress is a drought-tolerant tree that can grow in very dry conditions. They can grow up to 30 meters tall and have a distinctive, twisted trunk.
3. Acacia trees are drought-tolerant and can grow in poor soil conditions. The trees produce small, white flowers that are a source of nectar for bees.
4. Olive (Olea europaea) Flower, Leaf, Care, Uses - PictureThis (picturethisai.com)
5. Juniper trees are evergreen trees that can grow in very dry conditions. The trees produce small, blue berries that are edible. They are drought-tolerant and can survive with little water.
6. Arar tree (Tetraclinis articulata) Flower, Leaf, Care, Uses - PictureThis (picturethisai.com)
7. River red gum (Eucalyptus camaldulensis) Flower, Leaf, Care, Uses - PictureThis (picturethisai.com)
8. Oriental plane (Platanus orientalis) Flower, Leaf, Care, Uses - PictureThis (picturethisai.com)

B. Flowers

1. Acacia flowers are common in Laghouat, and they produce small, white flowers that are a source of nectar for bees. The flowers are also edible and can be used to make tea.
2. Desert roses are a type of succulent plant that grows in arid regions. The flowers are made up of tiny, overlapping petals that form a star-shaped pattern. Desert roses are often used as decorations or in traditional medicine.
3. Hyacinths are a type of bulb flower They are known for their sweet scent and colorful blooms. Hyacinths can be grown in pots or in the ground, and they are a popular choice for springtime gardens.
4. Field Marigold is a species of flowering plant in the daisy family known by the common name field marigold.
5. Common Poppy is an annual herbaceous species of flowering plant in the poppy family Papaveraceae.
6. Thymelaea virgata is a genus of about 30 species of evergreen shrubs and herbaceous plants in the family Thymelaeaceae, bearing small flowers ranging from yellow to green
7. Centaurea oranensis
8. Starflower Pincushions is a species of flowering plant in the honeysuckle family, Caprifoliaceae. It is known by the common name starflower pincushions or starflower scabious. It is native to southwestern Europe and North Africa

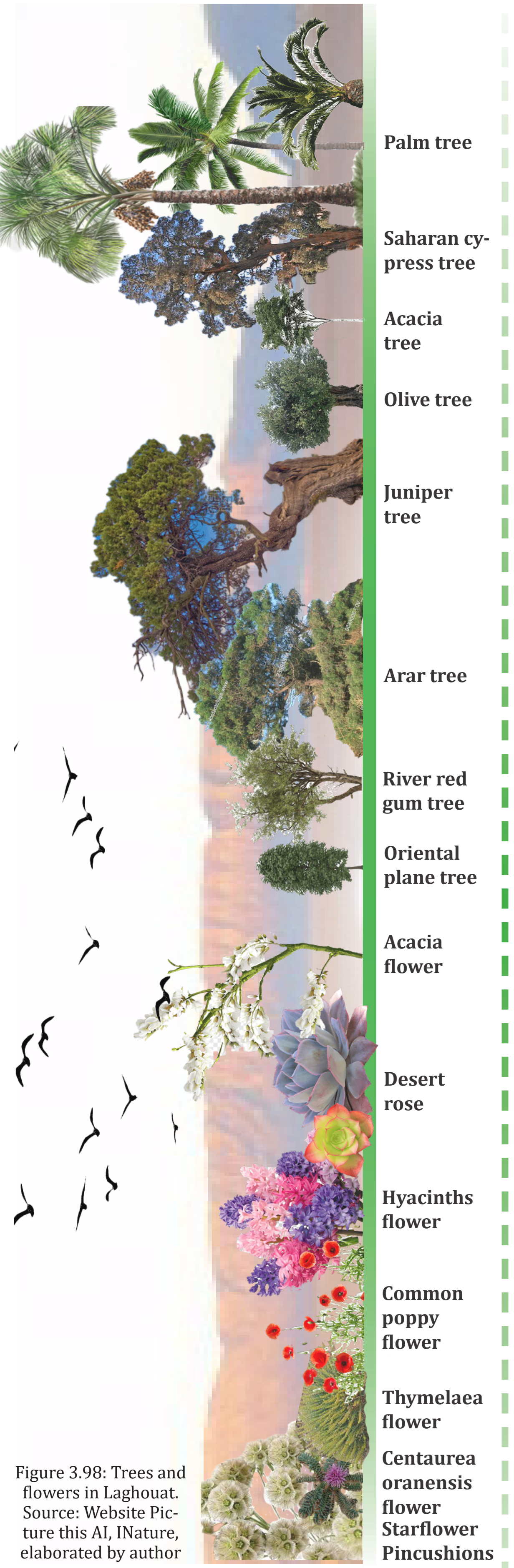


Figure 3.98: Trees and flowers in Laghouat. Source: Website Picture this AI, INature, elaborated by author

• ***Activities:*** Additional to the micro climate effect of the urban park, but it’s also a destination for different activities, for different events, daily and occasionally, for all different ages, in order to balance their nocturne night life style (Fig 3.99).

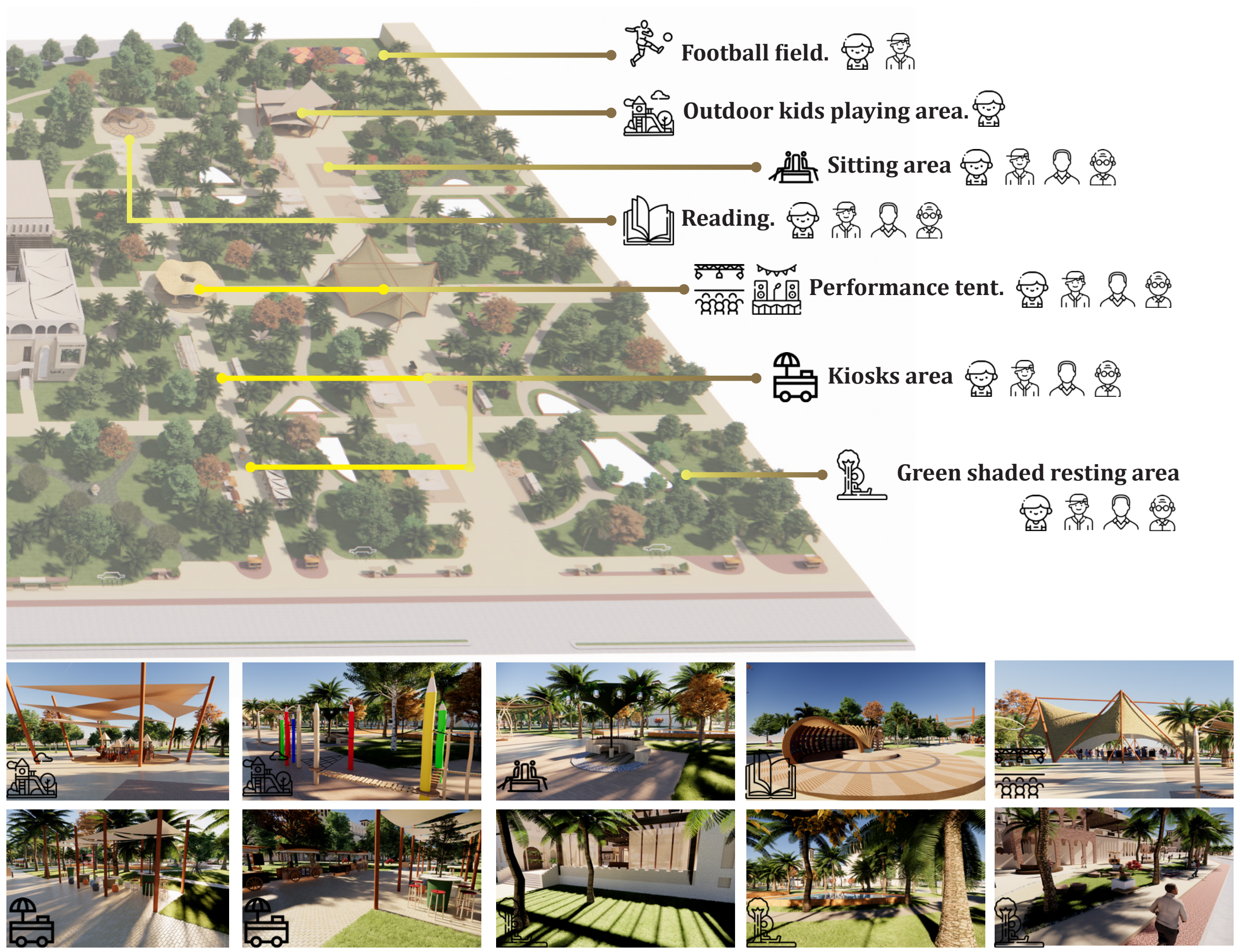


Figure 3.99: Activities of the urban park. Source: Author

3.10.8. Urban furniture:

Each was designed adapted to the region’s climate and to fit the project’s aesthetics (Fig 3.100), considering color (Albedo effect), shape & form (shading), materials (green house gas), ..etc.

Figure 3.100: The project’s urban furniture. Source: Author

3.11. Envelope analysis

3.11.1. Facade

The facade expresses the integration of the project within its environment, both historically and climatically. The following concepts and principles are used:

• ***History preservation (kser)***: It ensures that the external appearance of a building reflects its historical significance, contributes to the preservation of cultural heritage, and maintains the continuity of the built environment, as well as for better climate adapting.

Figure 3.101. The preservation of history through facades. Source: Author

• ***Contemporary minimalism:*** Since our main concept is the heritage preservation, the contemporary architecture should be minimalist to meet the local architecture simplicity.

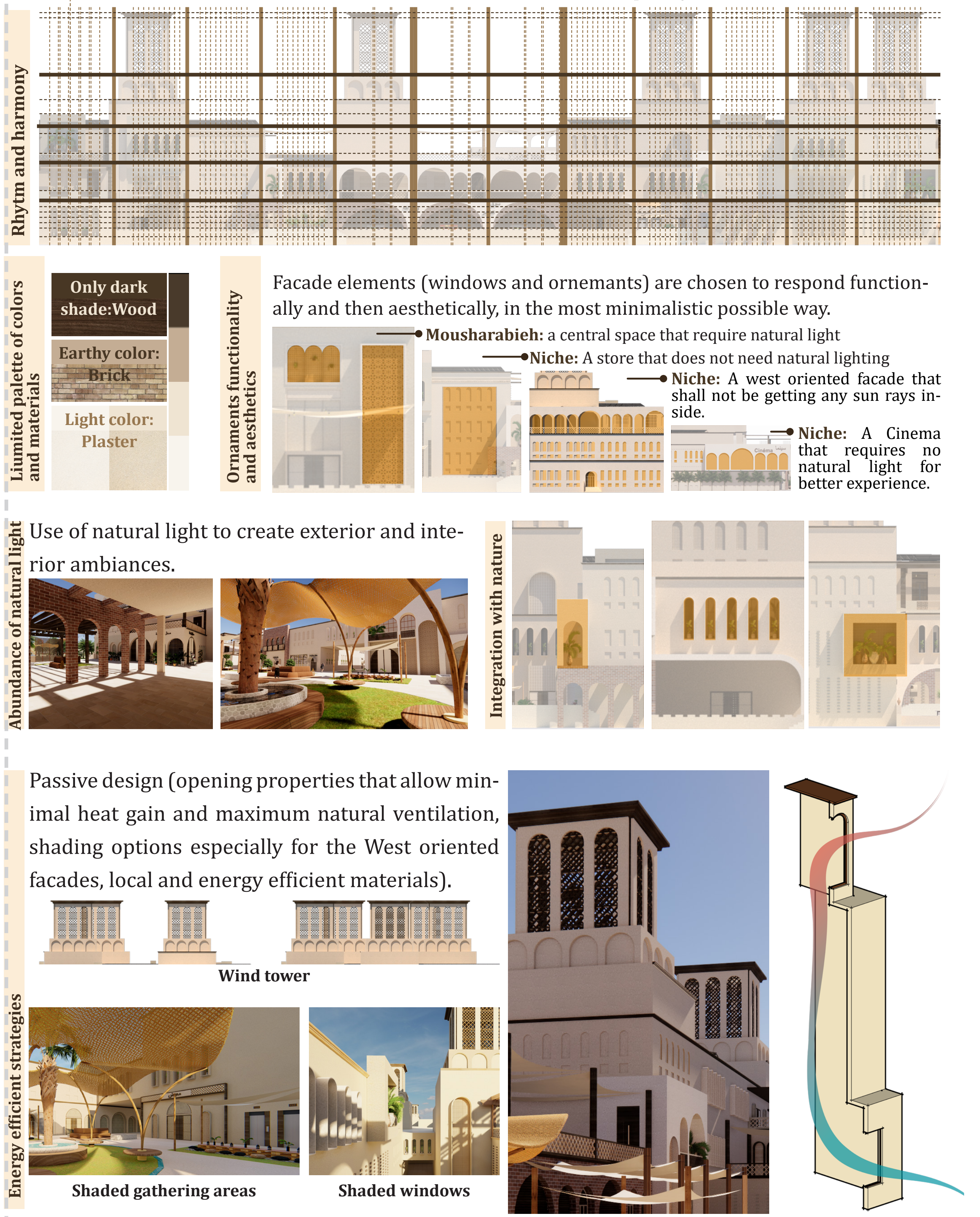


Figure 3.102. The contomporary minimalism through facades. Source: Author

3.11. Envelope analysis

3.11.2. Structure

3.11.2.1. Materials

In order to balance heritage preservation, climate adaptation and functionality, we chose local and modernized materials.

Figure 3.103. Construction materials. Source: author

3.11.2.2. Construction system

Since Laghouat is famous for its stone quarry, stone was our first choice for the construction system. However, it was unfortunately not chosen because of the load requirement (6.5x10m span and 5.1 m height for each level of the 3-storey building) and the level of compactness we were working with. Therefore, we chose reinforced Geopolymer concrete (for its lower greenhouse gas mission, waste utilization, durability and strength) for columns and beams. And for the slab, we chose the concrete and timber composite slab (used in Hotel Marhaba by Pouillon.F in Laghouat).

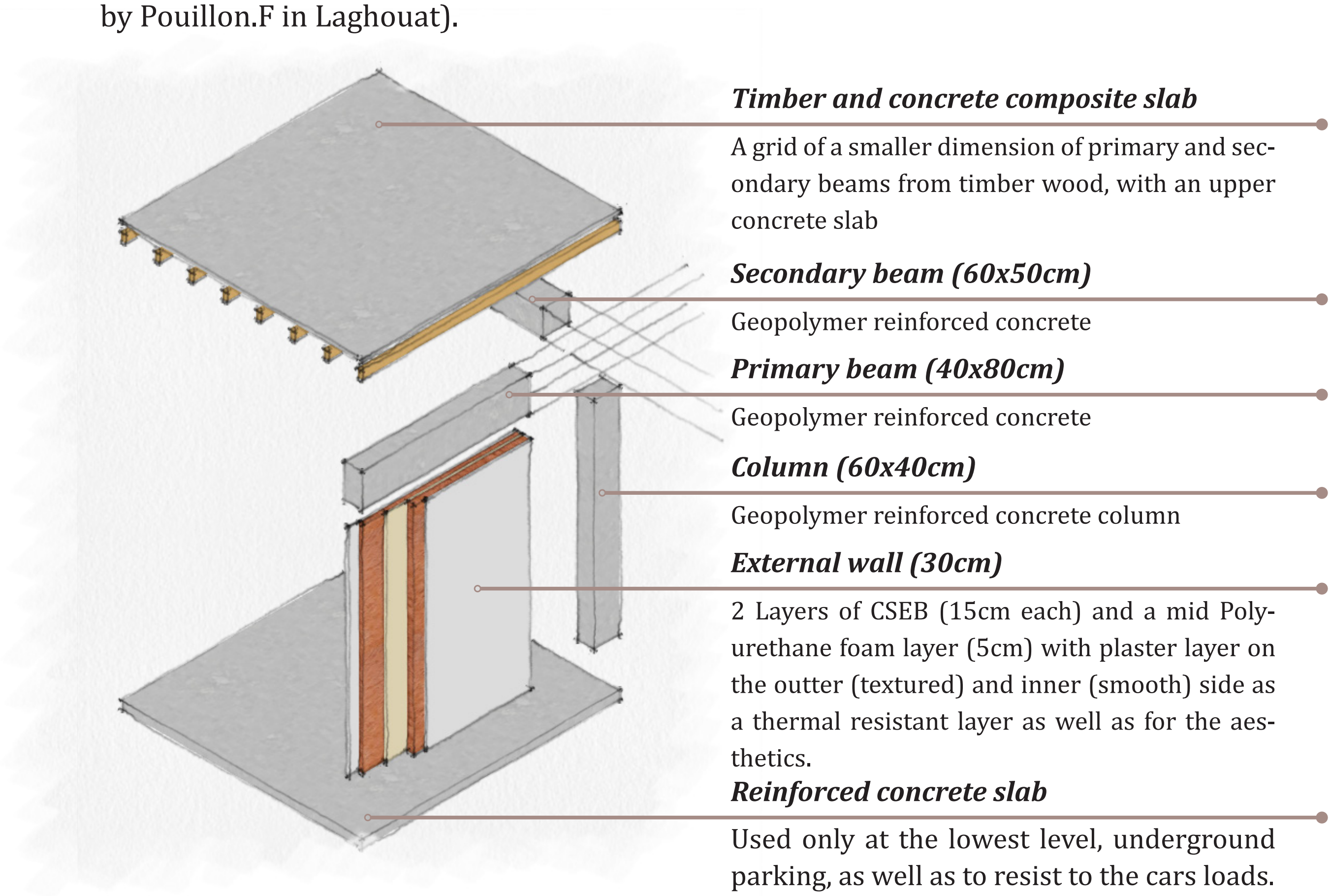


Figure 3.104. Construction system. Source: author

3.12. Spatial qualities: ambiances

3.13.1. Compacted spatial configuration: The project's layout features a labyrinthine design with narrow, winding alleyways and interconnected passages. This encourages exploration and fosters a dynamic and engaging environment, creating a sense of serendipity.

Figure 3.105: Plan view of the project Source: Au-

3.12.2. Cultural identity and sense of place: Our souq embodies cultural symbolism and a profound sense of place, mirroring the distinctive identity of the city and its inhabitants. From its color palette, reminiscent of the historical hues of the kser, to its architectural elements derived from the kser's design, every aspect reflects a

Figure 3.106: Historical symbolism Source: Author

3.12.3. Varied scales and heights: Our souq showcases a diverse range of scales and heights within its spatial composition. This deliberate manipulation of verticality contributes to a multi-layered experience. Tall structures, such as wind towers, act as landmarks, guiding visitors through the maze-like layout.

Figure 3.107: Different heights Source: Author

3.12.4. Multi-Sensory Engagement: integration multiple sensory elements to craft a rich and immersive experience. The interplay of light and shadow, as sunlight filters through narrow openings, creates a visually captivating atmosphere. Additionally, the enticing aromas of spices and local delicacies, coupled with the comforting sensation of Rahbat, along with the vibrant sounds of vendors' calls and bustling crowds, collectively immerse visitors in a sensorial journey, stimulating both their physical and emotional senses.

Figure 3.108: Sensorial experience Source: Author

3.12.5. Courtyards and Gathering Spaces: The souq features courtyards and open gathering spaces as communal focal points. Adorned with decorative elements and shaded options, they offer respite from the bustling market, allowing rest, socializing, and community engagement. These vibrant nodes promote a sense of belonging and cultural exchange.

Figure 3.109: Rahbat Dar. Source: Author

3.12.6. Enclosed and Shaded Spaces: The souq's architecture embraces enclosure, providing shelter from the sun and creating an intimate atmosphere within the bustling marketplace. Shaded areas like covered walkways and arcades offer protection from the climate and help maintain a cooler microclimate within the souq's interior.

Figure 3.110: Shaded spaces Source: Author

3.13. Environmental strategies used in the project

Figure 3.111. 3D view of passive strategies Source: Author

Environment

1- The use of increased reflectivity of urban materials such as yellow brick and stone, can help to mitigate heat absorption.

2- The introduction of vegetation and water within the project for a greater evapotranspiration, shading, and improved air quality

3- Integrating an urban park in order to help to mitigate the urban heat island effect (UHI) by creating a cool urban park.

4- Evaporative cooling fans were distributed along the paths.

5- Shaded urban furniture adaptable to climate conditions

6- Integrating a bicycle lane and a bus stop in order to encourage the use of public transport instead of private cars

Figure 3.112. Environment related strategies. Source: Author

Form

1- The compact form with narrow alleys minimizes the exposed surfaces to the sun.

2- Prospect varies between : 2 - 3, in order to enhance wind speed while offering shadows

3- Employing wind towers and Canadian tubes for natural lamentation. Also, underground parking helps to cool the building

4- Galleries, colonnades, overhangs, and side fins are used to increase shading and minimizing the ingress of heat.

5- Introduction of Rahbat, furnished with vegetation and water, and shaded with pergolas to offer a comfortable area to relax, while also enhancing natural ventilation around the project.

Figure 3.113. Form related strategies. Source: Author

Envelope

1- The use of compressed stabilized earth brick (CSEB) with a layer of polyurethane foam insulation in between two layers of brick.

2- The employment of light-colored materials for a higher albedo and lower heat absorption.

3- The use of different textures, such as adding bricks to the wall as an outer shell , can help to reduce the transmission of heat.

4- The use of a low window-to-wall ratio and double-glazed windows with small sizes.

5- Double skin facade with the use of moucharbieh inspired from Laghouat

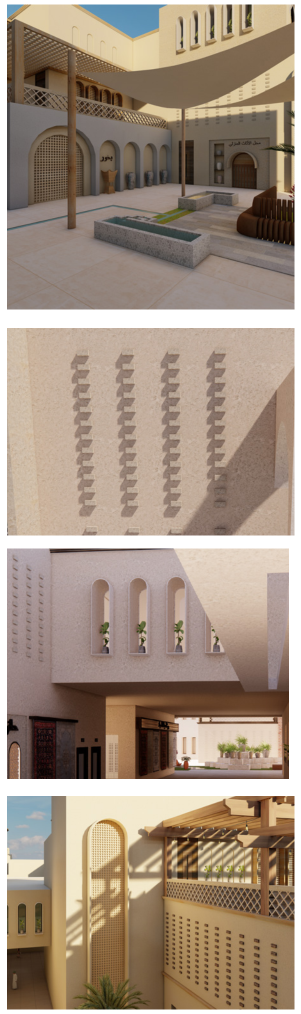


Figure 3.114. Envelope related strategies. Source: Author

3.14. Finding the most influential indicators through simulations

3.14.1. Simulation procedure

The Design of Experiment (DOE) was used as a systematic approach in our research. After defining objectives and hypotheses, we identified variables affecting energy optimization, both outdoors and indoors within the building envelope. These findings were summarized in a table (pg. 34) and then applied in our design process. Our focus was on testing our hypothesis of reducing energy consumption in our Souk.

We aimed to identify optimal microclimatic conditions for outdoor thermal comfort and their impact on achieving optimal indoor thermal comfort. To achieve this, we utilized thee software ENVI-met (3.1) and DesignBuilder (7.0.2.006) for analyzing selected scenarios, incorporating uncertainty and sensitivity analysis. This analysis aimed to identify influential factors for energy optimization and achieve the desired levels of indoor and outdoor thermal comfort.

3.14.2. The input parameters for the simulations

1- The total area used for ENVI-met analysis (240x175m)
2- A rectangular model representing a store was selected for DesignBuilder analysis due to its central location within the project where most gatherings occur.
3- External walls: 30cm of burned bricks with cavity (15cm, 5cm, 10cm).
4- Facade: 10% glazing, double glazing with a U-value of 1.5 W/m2·K.

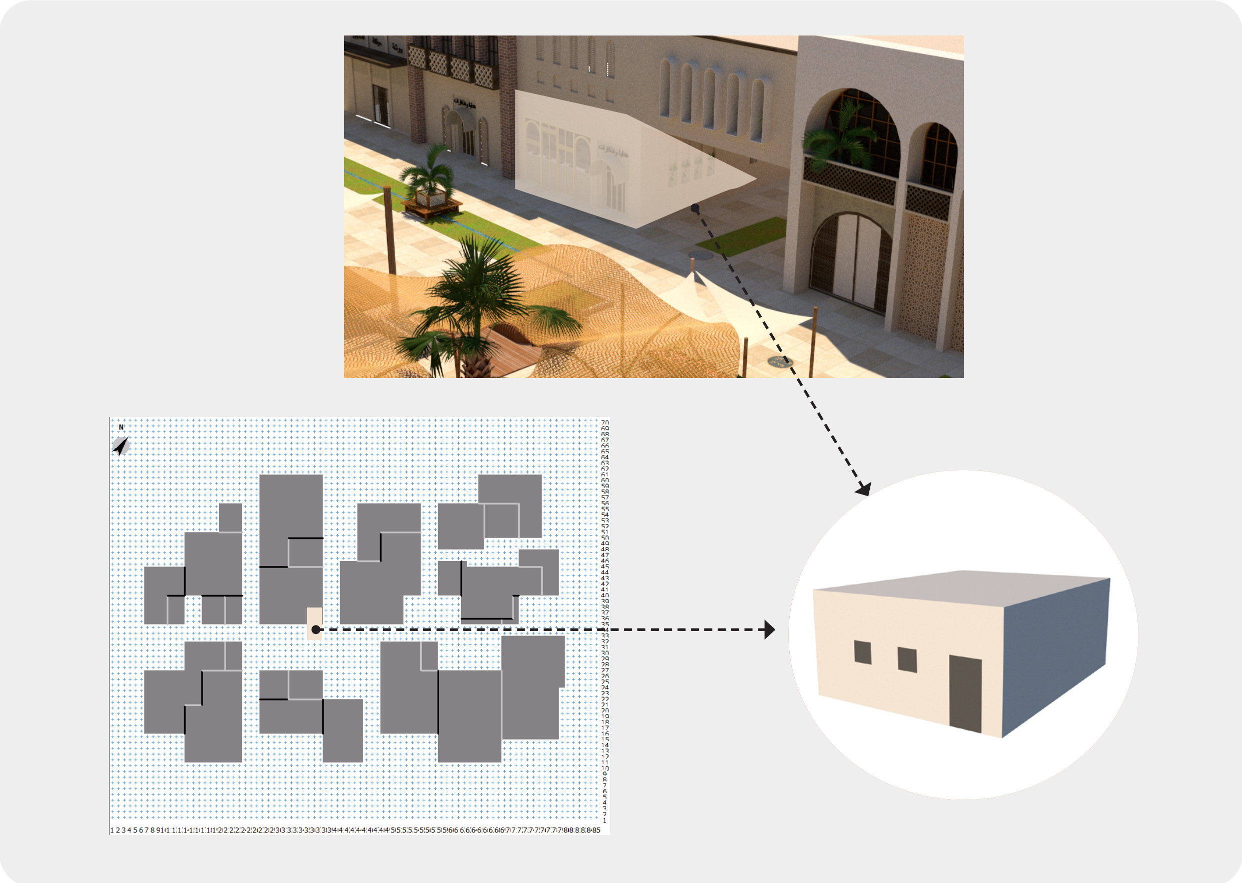


Figure 3.115: Simulation models. **Up:** Situation of the store in the project **Left**: ENVI-met model, **Right**: Design Builder model. Source: Author

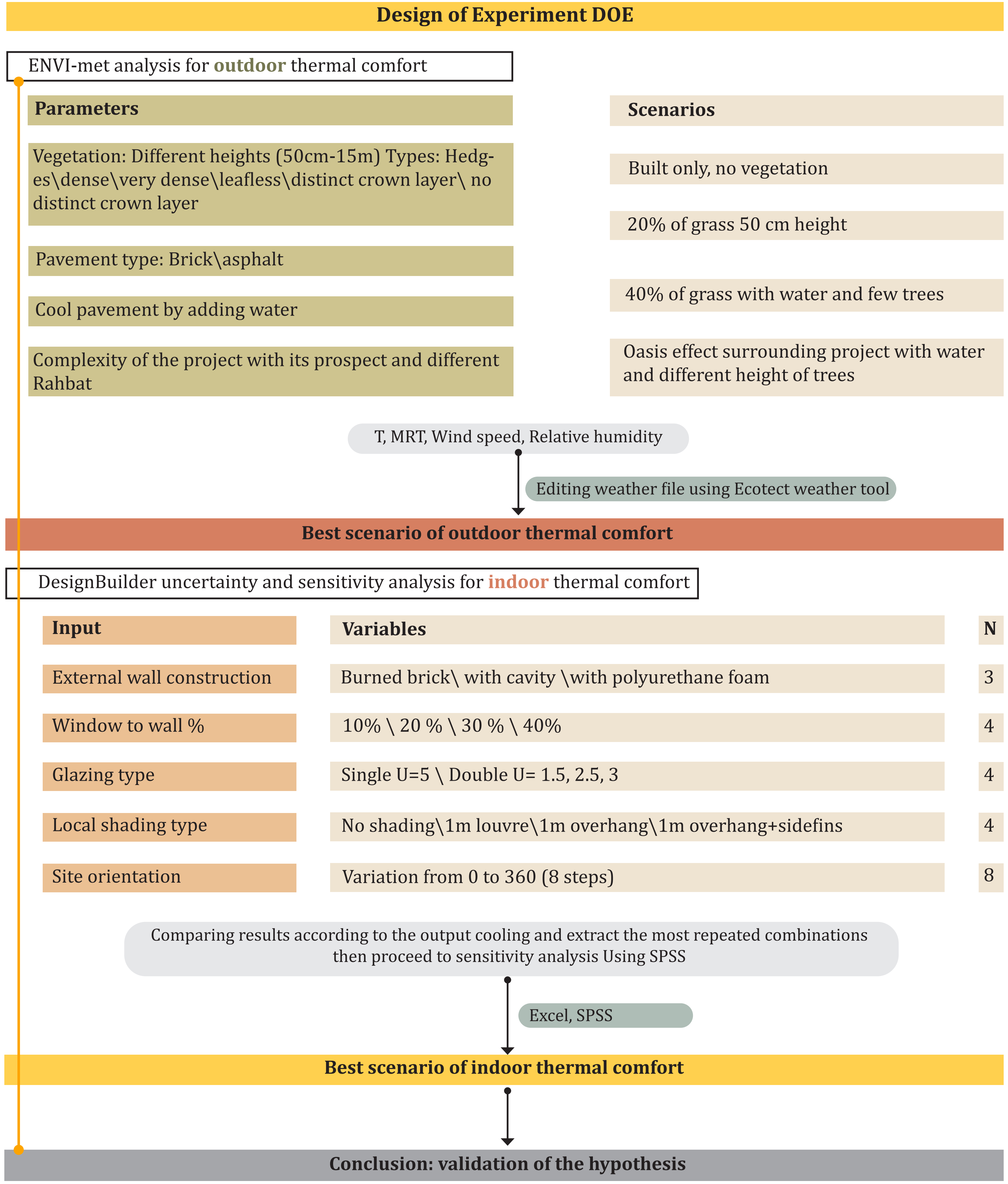


Figure 3.116: Simulation protocol. Source: Author

3.14.3. ENVI-met analysis for outdoor thermal comfort

According to Meteonorm, the hottest day of the year is July 21st, so we proceeded with the simulations on this day.

Table 3.11: Simulation results. Source: Author

Scenario	1 - Built only, no vegetation Asphalt pavement			2- 20% of grass 50 cm height Brick pavement			3- 40% of grass with water and few trees			4- Oasis effect surrounding project with water and different height of trees		
Hours	**6h**	**15h**	**18h**	**6h**	**15h**	**18h**	**6h**	**15h**	**18h**	**6h**	**15h**	**18h**
Potential air temperature °C	32.45 °C	35.14 °C	34.8 °C	32.15 °C	34.95 °C	34.63 °C	30.1 °C	32.19 °C	31.95 °C	26.19 °C	29.75 °C	28.82°C
Mean radiant temperature °C	50.15 °C	Above 72.96 °C	65.23 °C	49.83 °C	70.04 °C	65.19 °C	40.3 °C	67.47 °C	45.33 °C	19.3 °C	65.64 °C	31.38 °C
Relative humidity %	34 %	15 %	17%	34%	15%	17%	37%	25%	23%	40%	28%	29%
Wind speed m\s	1.76 m\s	1.95m\s	2.32 m\s	1.76 m\s	1.95m\s	2.32 m\s	2.3 m\s	2.73 m\s	2.90 m\s	2.91 m\s	3.16m\s	3.28 m\s
Comment	- Based on the data presented in the table, our initial analysis reveals a noteworthy decline in scenario 1 of 2°C in potential air temperature at 15:00, coinciding with the peak time on July 21st, despite the absence of vegetation. - The inclusion of trees and water in scenario 3 yielded a discernible reduction in both radiant and potential temperature. Furthermore, there was a significant elevation in relative humidity from 15% to 25%. - In scenario 4, which represents the optimal and implemented approach in our project, entailing the incorporation of vegetation and water surrounding the building, a reduction in potential temperature from 35°C in scenario 1 to 29.75°C in scenario 4 was observed, indicating a difference of 6 degrees.											

3.14.4.Design Builder analysis for indoor thermal comfort

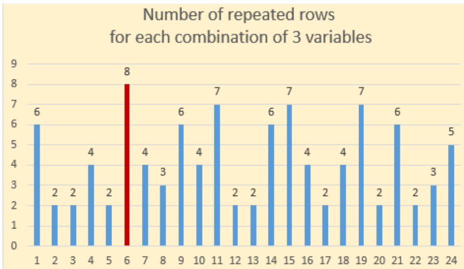
We exported the data from scenario 4 (24 hours) into Design Builder to examine the impact of outdoor thermal comfort on indoor thermal conditions, with the aim of optimizing cooling energy consumption. In order to do so, we ran simulations for 300 iteration using Latin hypercube sampling(LHS). The results were classified into class A class B, for better interpretation we divided class A (A1, A2).

The Best Scenario (Cooling 4.398 kwh) is composed of: ***Brick burned \ window to wall: 20% \ Sgl Blue 6mm \ Overhang + sidefins (1m projection) \ 315***

Table 3.12: Simulation results Design builder class A1with microclimate conditions. Source: Author

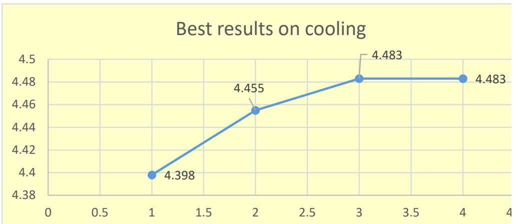
Class A1 (4.389-6.189 Kwh) (100 iteration)

Number of repeated combinations

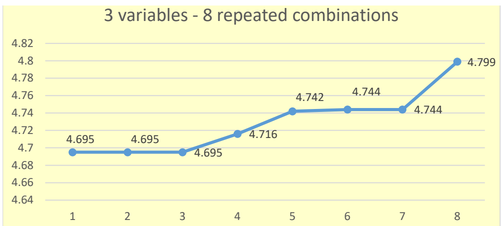


24 unique combinations of 3 variables (External wall, type of glazing, shading options)

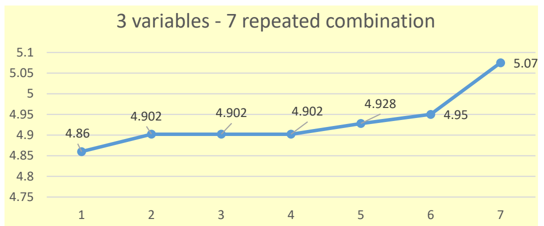
Best combinations (Excel)



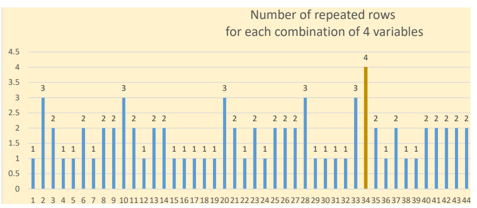
Best four combinations in terms of cooling with 3 repeated variables: Brick burned / Sgl Blue 6mm / Overhang + sidefins (1m projection)



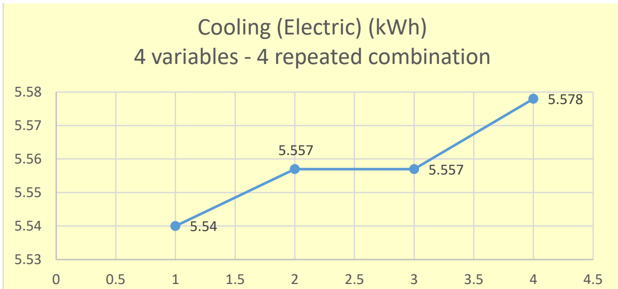
8 repeated combinations of 3 variables: Brick burned / Dbl Clr 3mm/13mm Arg / 1.0m Overhang



7 repeated combinations of 3 variables: Brick burned / Dbl Clr 3mm/13mm Arg / No shading



60 unique combinations of 4 variables (External wall, type of glazing, shading options, ratio window to wall)



4 repeated combinations of 4 variables: Burned brick with cavity / window to wall: 20 / Sgl Blue 6mm / 1.0m Overhang

Sensitivity analysis (SPSS)

Brick burned	Burned brick with cavity
50%	50%

10	20	30	40
29%	27%	23%	21%

Dbl Clr 3mm/13mm Arg	Dbl Elec Abs Bleached 6mm/13mm Arg	Sgl Blue 6mm
37%	30%	33%

1.0m Overhang	1.0m projection Louvre	No shading	Overhang + sidefins (1m projection)
24%	29%	27%	20%

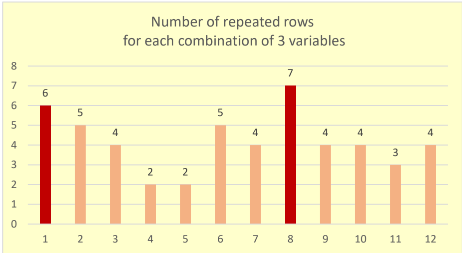
0	45	90	135	180	225	270	315
12%	10%	15%	13%	12%	12%	13%	13%

Comment: Firstly, the above graphs present the optimal combinations that can be utilized to achieve effective cooling in this class. It is evident from the extracted repeated combinations that brick burning was more prevalent, with the sensitivity analysis revealing its significant impact, accounting for 50% of the results. Moreover, the type of glazing, specifically Dbl Clr 3mm/13mm, exhibited a substantial influence on the cooling outcomes, contributing to 37% of the observed variation. Additionally, both the window-to-wall ratio of 10 and the shading option of 1m projection louvre demonstrated comparable effects, constituting 29% each. In contrast, the orientation variable had the least pronounced impact, contributing only 15% to the overall variability.

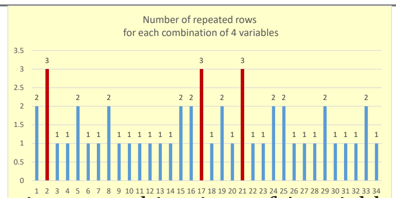
Table 3.13: Simulation results Design builder class A1 with microclimate conditions. Source: Author

Class A2 (10.154-11.213 Kwh) (50 iteration)

Number of repeated combinations

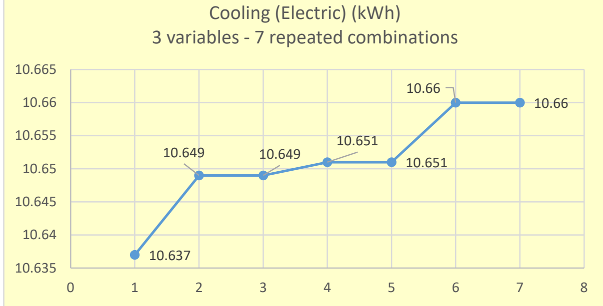


12 uniques combinations of 3 variables (External wall, type of glazing, shading options)

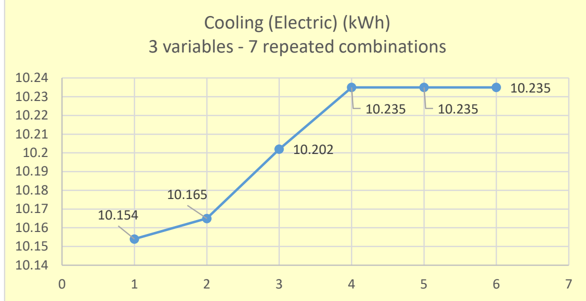


34 uniques combinations of 4 variables (External wall, type of glazing, shading options, ratio window to wall)

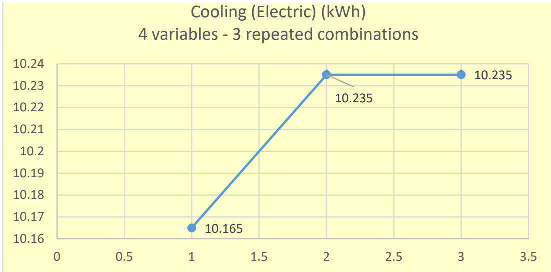
Best combinations (Excel)



7 repeated combination of 3 variables: Burned brick with polyurethane / Dbl Clr 3mm/13mm Arg / 1.0m Overhang



The best: 6 repeated combination of 3 variables: Burned brick with polyurethane / Sgl Blue 6mm / Overhang + sidefins (1m projection)



3 repeated combinations of 4 variables: Burned brick with polyurethane / Window to wall: 40% / Sgl Blue 6mm / Overhang + sidefins (1m projection)

Sensitivity analysis (SPSS)

Burned brick with polyurethane
100 %

10	20	30	40
15%	11%	11%	13%

Dbl Clr 3mm/13mm Arg	Dbl Elec Abs Bleached 6mm/13mm Arg	Sgl Blue 6mm
17%	16%	17%

1.0m Overhang	1.0m projection Louvre	No shading	Overhang + sidefins (1m projection)
16%	11%	10%	13%

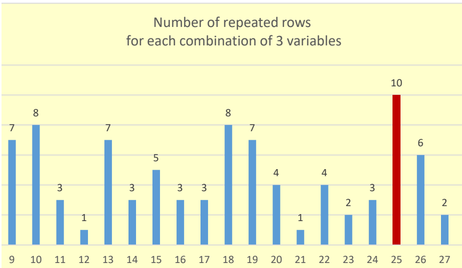
0	45°	90°	135°	180°	225°	270°	315°
16%	14%	14%	14%	10%	12%	8%	12%

The above graphs provide insights into the optimal combinations that can be employed to achieve effective cooling in this particular class. It is evident from the extracted repeated combinations that the utilization of Burned brick with polyurethane was the sole variable observed in the construction of the external wall for this class, with the sensitivity analysis revealing its profound impact, accounting for 100% of the results. Moreover, two types of glazing, namely Dbl Clr 3mm/13mm and sgl Blue 6mm, significantly influenced the cooling output, contributing to 17% of the observed variation. Furthermore, the shading option of a 1m overhang demonstrated an effect of 16%, which was equivalent to the impact of orientation (0°) on cooling output. In contrast, the window-to-wall ratio of 10% exhibited a relatively lower influence, affecting cooling output by 15%. Based on these findings, it can be concluded that in this class, the external wall emerged as the most influential variable, while the remaining factors displayed relatively similar effects in terms of percentage.

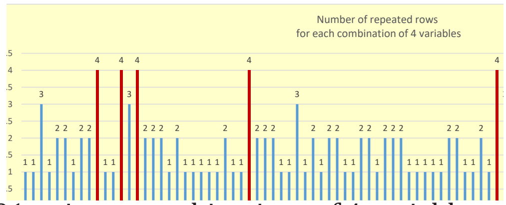
Table 3.14: Simulation results Design builder class B with climate conditions before adding scenario envi-met. Source: Author

Class B (74.032-88.889 Kwh) (150 iteration)

Number of repeated combinations

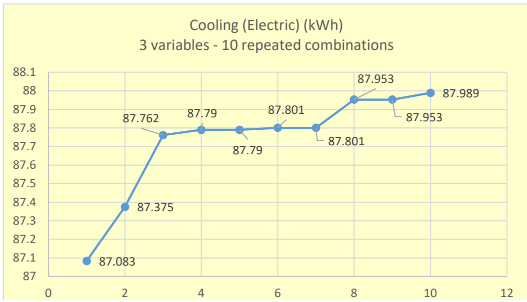


36 uniques combinations of 3 variables (External wall, type of glazing, shading options)

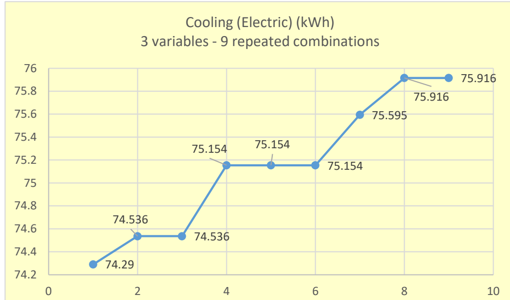


91 uniques combinations of 4 variables (External wall, type of glazing, shading options, ratio window to wall)

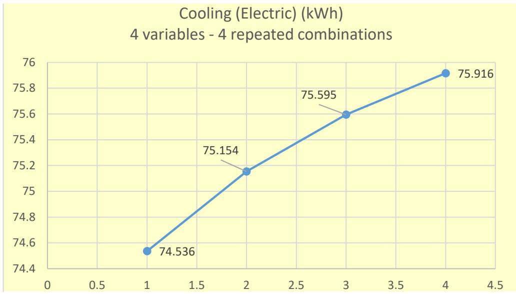
Best combinations (Excel)



10 repeated combination of 3 variables: Brick burned / Dbl Elec Abs Bleached 6mm/13mm Arg / Overhang + sidefins (1m projection)



7 repeated combination of 3 variables: Burned brick with polyurethane / Dbl Elec Abs Bleached 6mm/13mm Arg / 1.0m projection Louvre



The best: 4 repeated combinations of 4 variables: Burned brick with polyurethane10Dbl Elec Abs Bleached 6mm/13mm Arg1.0m projection Louvre

Sensitivity analysis (SPSS)

Brick burned	With cavity	with polyurethane
33.3%	33.3%	33.3%

10	20	30	40
20.7%	24.7%	27.3%	27.3%

Dbl Clr 3mm/13mm Arg	Dbl Elec Abs Bleached 6mm/13mm Arg	Sgl Blue 6mm
30.7%	36%	33.3%

1.0m Overhang	1.0m projection Louvre	No shading	Overhang + sidefins (1m projection)
23.3%	23.3%	25.3%	28%

0	45	90	135	180	225	270	315
12%	13%	10%	12%	15%	12%	14%	12%

The graphs above depict repeated combinations, where a set of four variables yields optimal results for cooling energy. It is apparent that different types of burned brick have comparable effects on the cooling output. However, burned brick with polyurethane demonstrates the most favorable impact on optimizing cooling energy, as indicated by the graphs. The sensitivity analysis reveals its significant influence, accounting for 33.3% of the results. Dbl Elec Abs Bleached 6mm/13mm Arg glazing contributes to 36% of the observed variation. Overhang + sidefins (1m projection) shading option and a window-to-wall ratio of (30) each demonstrate effects of 28% and 27.3%, respectively. Orientation has the least impact, with a contribution of 15% (180).

3.14.5. Interpretation of Findings

Table 3.16: Best scenarios. Source: Author

Best scenario of ENVI-met			
Oasis effect surrounding project with water and different height of trees			
Hours	**6h**	**15h**	**18h**
Potential air temperature °C	26.19 °C	29.75 °C	28.82°C
Mean radiant temperature °C	19.3 °C	65.64 °C	31.38 °C
Relative humidity %	40%	28%	29%
Wind speed m\s	2.91 m\s	3.16m\s	3.28 m\s

Best scenario of each class in Design Builder							
A1							
Cooling kwh	**CO2 kg**	**Weather file data**	**External wall**	**Glazing type**	**Window to wall**	**Local shading type**	**Site orientation**
4.398	25.453	Envi-met microclimate	Brick burned	Sgl Blue 6mm	20	Overhang + sidefins (1m projection)	315
A2							
10.154	28.274	Envi-met microclimate	With polyurethane	Sgl Blue 6mm	10	Overhang + sidefins (1m projection)	45
B							
74.032	66.984	Unedited weather file	With polyurethane	Dbl Elec Abs Bleached 6mm/13mm Arg	20	Overhang + sidefins (1m projection)	135

The simulations conducted in Envimet and Design Builder yielded significant results (table 3.16). In Envimet, the incorporation of vegetation, water, and compact urban forms with high prospect and interior open spaces led to a notable 6-degree Celsius reduction in potential air temperature, effectively mitigating urban heat island effects.

The graphs generated in Design Builder demonstrated a clear relationship between cooling energy demand and prevailing climate conditions. The utilization of microclimate data resulted in a substantial decrease in cooling energy demand, reducing it from 74 to 4 kWh in Class A. Conversely, under harsh weather conditions, the demand reached 74 kWh on July 21st.

The insulation requirements varied based on microclimate conditions. In favorable conditions, insulation was not necessary as the external conditions provided adequate thermal insulation. However, in harsh weather conditions, insulation became crucial to prevent heat transfer into the building.

The type of glazing material emerged as the third most influential variable, following construction materials. Its optimal configuration depended on the prevailing weather conditions. In microclimate scenarios, a single-panel glazing sufficed, while in harsh weather conditions, double glazing with a reduced window-to-wall ratio and additional local shading mechanisms were required.

Interestingly, certain combinations within the microclimate scenario demonstrated the potential for optimal cooling energy performance even without the utilization of shading devices.
In conclusion, our hypothesis was confirmed: the mitigation of urban heat island effects through the implementation of vegetation, water, and compact urban forms optimizes cooling energy and enhances indoor thermal comfort. This is achieved through the careful selection of suitable materials, shading options, glazing types, and window-to-wall ratios.

3.15. Conclusion

The deliberate selection of Laghouat as the project's location was motivated by its role as an entry point to the Sahara, its arid climate, and its remarkable architectural heritage that harmonizes with the surroundings. The project aimed to create a sustainable commercial and entertainment center that offers an authentic souk experience, with a focus on preserving the city's unique identity, particularly the "Kser."

To ensure a comprehensive and well-informed approach, the project employed a combination of typo-morphological and sensorial methodologies, supplemented by thorough surveys, interviews, and a SWOT analysis. These research methods were instrumental in shaping the project's theme, which aimed to revive the city's unique identity, with a particular focus on the revered "Kser" - an architectural marvel with historical significance. By meticulously preserving the authenticity of the "Kser" and skillfully integrating its distinctive architectural elements and urban characteristics, the project sought to create an array of sensorial encounters that authentically represent the heritage of Laghouat.

A key emphasis throughout the design process was on sustainability, with a deliberate intention to mitigate the urban heat island effect. We sought to develop an environment that not only respected and celebrated the historical and cultural significance of the city but also prioritized the implementation of sustainable practices. In this regard, the integration of suitable green spaces and an urban park played a vital role, leveraging the micro-climate effects of the oasis and further enhancing the project's objectives.

To substantiate the project's sustainability goals, various software tools were employed to analyze and validate the proposed design options. The results confirmed the initial hypothesis, showcasing the effectiveness of incorporating elements such as vegetation, water features, and compact urban forms to reduce the urban heat island effect, optimize cooling energy consumption, and significantly improve indoor thermal comfort.

GENERAL CONCLUSION

CHAPTER 04

4. General Conclusion

Within the context of the specialization "Architecture, Environment, and Technology," our research endeavors were devoted to tackling the challenges confronting Laghouat, an arid city situated in Algeria. Our primary focus centered on presenting pioneering eco-conscious measures that are in accordance with its socio-cultural and environmental requirements.

Conducting an extensive investigation, we delved into a wide array of factors that impact energy optimization in building design. These factors encompassed the macro-level surroundings as well as the intricate elements of the building envelope. Our overarching aim was to devise fresh and appropriate solutions specifically tailored to the unique circumstances of Laghouat, all the while promoting sustainable environmentally responsive design that exhibits resilience in the arid climate.

The choice of Laghouat was intentional. It is a gateway city to the Sahara, an arid city with harsh weather and a fabulous architectural heritage that is in harmony with the environment. It also has a lot of tourism potentialities due to its rich history dating back to the prehistoric period. We undertook a typo-morphological and sensorial approach enhanced with questionnaires and interviews along with a SWOT analysis to come up with the theme of our project: a sustainable commercial and entertainment center with souk experience. The thematic research was therefore concentrated on the souk, commercial and entertainment center, and urban park.

The project was designed on the linear spatial organization of the traditional souk experience. This embodies local culture and practices by creating a heritage ambiance that seeks to rejuvenate the city's unique identity, particularly the "Kser." The project honors the history of the Kser by preserving its authenticity and incorporating its distinct architecture and urban characteristics into various sensorial experiences within a sustainable environment that avoids the urban heat island effect. An urban park was added to strengthen this approach and leverage the oasis's micro-climate effects.

In order to verify our options in terms of sustainability, we used several softwares. Our hypothesis was confirmed: the mitigation of urban heat island effects through the implementation of vegetation, water, and compact urban forms optimizes cooling energy and enhances indoor thermal comfort. This is achieved through the careful selection of suitable materials, shading options, glazing types, and window-to-wall ratios.

The obtained results are promising and therefore encourage further research on architecture in arid zones and similar cities to create a balance between socio-cultural needs and environmental requirements. This balance will allow people to live in harmony with nature while also preserving the heritage of the place.

BIBLIOGRAPHIC REFERENCES

Bibliographic references

Articles, reviews, and magazines

• Abbas Mohajerani, Jason Bakaric, Tristan, Jeffrey-Bailey, 2017, Journal of Environmental Management 197 (2017) 522-538.

• ABDOU M., SEMCHA A. and KAZI-AOUAL F., 2021, Physico-mechanical characterization and durability of stabilized compressed earth bricks in the region of Timimoun in southwestern Algeria, Journal of Materials and Engineering Structure, Vol 8(2021), P 287-300(e-ISSN: 2170-127X)

• AFKHAMIAGHDA M., 2015, A Case Study of Masdar City: Feasibility of adapting Masdar city to Yazd Iran, P 1-32.

• AHMAD I., MOHAMAD N., 2012, Structural Behavior of Precast Lightweight Concrete Sandwich Panel Under Eccentric Load: An Overview, International Journal Of Sustainable Development, Vol 5(3), p 49-58.

• Akbari H, Rose LS, Taha H. (1999). " Characterizing the fabric of the urban environment: A case study of Sacramento, California". Technical Report LBNL-44688, Lawrence Berkeley National Laboratory, Berkeley, CA. http://dx.doi.org/10.2172/764362.

• Akbari H, Rose, LS. (2008). "Urban surfaces and heat island mitigation potentials". Journal of the Human Environmental System 11(2), 85-101

• Akbari, H., Rose, L.S., 2008. Urban surfaces and heat island mitigation potentials. J. Hum. Environ. Syst. 11 (2), 85e101.

• AL-HAFITHA O., KB S.B., BRADBURYC S. et DE WILDED P., 2017, The Impact of Courtyard parameters on its shading level An experimental study in Baghdad Iraq, Energy Procedia, Vol 134, P 99-109.

• ALCHAPAR N. et al, 2020, Energy-efficient urban buildings. Thermo-physical characteristics of traditional and recycled roofing technologies, Revista Ingeniería de Construcción (English version), Vol 35 Nº1, Page 73-83.

• Algretawee, H., Rayburg, S., & Neave, M. (2019). Estimating the effect of park proximity to the central of Melbourne city on Urban Heat Island (UHI) relative to Land Surface Temperature (LST). Ecological Engineering, 138, 374-390. do: 10.1016/jecoleng. 2019.07.034

• ALHADDAD M.A. and JUN Z.T., 2013, A Comparative Study of the Thermal Comfort of Different Building Materials in Sana'a, American Journal of Engineering and Applied Sciences, Vol 6(1), P20-24.

• Ali-Toudert F, Mayer H. Effects of asymmetry, galleries, overhanging façades and vegetation on thermal comfort in urban street canyons. Sol Energy 2007;81:742–54

• Alobaydi, D.; Bakarman, M.A.; Obeidat, B. The Impact of Urban Form Configuration on the Urban Heat Island: The Case Study of Baghdad, Iraq. Procedia Eng. 2016, 145, 820–827. Available online: https://www.sciencedirect.com/science/article/pii/S18777 05816301126

• ALONSO C., Design strategies in facades for the reduction of housing energy consumption, CSIC [Spanish Council for Scientific Research].

Bibliographic references

Articles, reviews, and magazines

- Ayat Elkhazindar , Sahar N. Kharrufa and Mohammad S. Ara., 2022, The Effect of Urban Form on the Heat Island Phenomenon and Human Thermal Comfort: A Comparative Study of UAE Residential Sites, Environment and Urban Systems: Simulation, Modeling and Analysis, 15, 5471
- Bourbia F, Boucheriba F. Impact of street design on urban microclimate for semi arid climate (Constantine). Renew Energy 2010;35:343–7
- BRAULIO M., GALLEGO T., LECHA A., 2014, Analysis of timber as sustainable material for
- BRUNO A.W., SCOTT B., D'OFFAY-MANCIENNE Y. and PERLOT C., 2020, Recyclability, durability and water vapor adsorption of unsterilized and stabilized compressed earth bricks, Materials and Structures, Vol 53, P 149- 164.
- Carlo Rattia, Nick Bakerb , Koen Steemersb., 2004, Energy consumption and urban texture, Energy and Buildings, vol 288,
- Chapman, S., Thatcher, M., Salazar, A., Watson, J. E. M., & Mcalpine, C. A. (2018). The Effect of Urban Density and Vegetation Cover on the Heat Island of a Subtropical City. Journal of Applied Meteorology and Climatology, 57(11), 2531-2550. doi: 10.1175/jamc-d-17- 0316.1
- CIANFRINI M. et al, 2015, THERMAL INERTIA OF HOLLOW WALL BLOCKS: ACTUAL BEHAVIOR AND MYTHS, CISBAT 2015, Vol 1, P149-154.
- Clare Heaviside, 2020, Urban Heat Islands and Their Associated Impacts on Health, Oxford Research Encyclopedia of Environmental Science,
- Cui, Y. Y., & Foy, B. D. (2012). Seasonal Variations of the Urban Heat Island at the Surface and the Near-Surface and Reductions due to Urban Vegetation in Mexico City. Journal of Applied Meteorology and Climatology, 51(5), 855-868. doi: 10.1175/jamc-d-11-0104.1
- CUITIÑO G. et ESTEVES A., 2018, Wattle and Daub Experimental Workshop: Durability Testing after 14 y ears of Uninterrupted Use, EJERS European Journal of Engineering Research and Science, Vol 3(12), P78-83.
- Du, H., Song, X., Jiang, H., Kan, Z., Wang, Z., Cai, Y., 2016. Research on the cooling island effects of water body: a case study of Shanghai, China. Ecol. Indic. 67, 31-38.
- Elena Morinia, , Ali Gholizade Touchaeib , Federico Rossia , Franco Cotanaa , Hashem Akbaric., 2018, Evaluation of albedo enhancement to mitigate impacts of urban heat island in Rome (Italy) using WRF meteorological mode, Urban climate, 24, 551-566
- Elmira Jamei, Priyadarsini Rajagopalan , Mohammadmehdi Seyedmahmoudian , Yashar Jamei., 2015, Review on the impact of urban geometry and pedestrian level greening on outdoor thermal comfort, Renewable and Sustainable Energy Reviews, 54, 1002-1017, http://dx.doi.org/10.1016/j.rser.2015.10.104 1364-0321/& 2015
- ESTEVES A., et al, 2018, Building Shape that Promotes Sustainable Architecture. Evaluation of the Indicative Factors and Its Relation with the Construction Costs, Architecture Research, 8, p 111-122.

Bibliographic references

Articles, reviews, and magazines

- ESTEVES A., MERCADO M.V., GANEM C. et GELARDI D., 2017, Positioning and Design Recommendations for Materials of Efficient Thermal Storage Mass in Passive Buildings, Architecture Research, Vol 7(2), p29-40.
- ESTEVES M.J. et CUITIÑO G., 2020, The construction system of wattle and daub in
- F Bourbia; H.B Awbi (2004). Building cluster and shading in urban canyon for hot dry climate: Part 2: Shading simulations. , 29(2), 291–301. doi:10.1016/s0960-1481(03)00171-x
- Feyisa, Gudina Legese; Dons, Klaus; Meilby, Henrik (2014). Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. Landscape and Urban Planning, 123(), 87–95. doi:10.1016/j.landurbplan.2013.12.008
- Gavin_Gui Jooseng, Phelan Patrick E, Kaloush Kamil E, Golden Jay S. Impact of Pavement thermophysical properties on surface temperatures. Journal of Materials in Civil Engineering 2007;19:8.
- Georgakis Ch, Santamouris M. Experimental investigation of air flow and temperature distribution in deep urban canyons for natural ventilation purposes. Energy and Buildings 2006;38(4):367–76.
- Giannopoulou K, Santamouris M, Livada I, Georgakis C, Caouris Y. The impact of canyon geometry on intra urban and urban: suburban night temperature differences under warm weather conditions. Pure Appl Geophys 2010;167:1433–49
- Golany, G.S. Urban design morphology and thermal performance. Atmos. Environ. 1996, 30, 455–465. Available online: https://www.sciencedirect.com/science/article/abs/pii/1352231095002669
- GUPTA R. and GREGG M., 2017, Assessing energy use and overheating risk in net zero energy dwellings in UK.
- IMPERADORI M., MASERA G. et IANNACCONE G., 2006, High Energy Efficient Buildings: Sustainable Strategies Based On Structure/Envelope Techniques With Artificial Thermal Inertia, XXXIV IAHS World Congress on Housing Sustainable Housing Design.
- ing Xiea , Hui Lia, Ahmed Abdelhadya, John Harveyb., 2019, Laboratorial Investigation on Optical and Thermal Properties of Cool Pavement Nano-Coatings for Urban Heat Island Mitigation, Building and environment, 147, 231-240
- IZARD J.L., 2006, L'INERTIE THERMIQUE DANS LE BATIMENT, ENVIROBAT-Méditerranée.
- IZARD J.L., 2006, Le coefficient de forme, EnviroBat-Méditérranée.
- Johansson E. Influence of urban geometry on outdoor thermal comfort in a hot dry climate: a study in Fez, Morocco. Build Environ 2006;41:1326–38.
- K. Ahmad; M. Khare; K.K. Chaudhry (2005). Wind tunnel simulation studies on dispersion at urban street canyons and intersections—a review. , 93(9), 697 717. doi:10.1016/j.jweia.2005.04.002

Bibliographic references

Articles, reviews, and magazines

- Karasawa, A.; Toriiminami, K.; Ezumi, N.; Kamaya, K. Evaluation of performance of water-retentive concrete block pavements. In Proceedings of the 8th International Conference on Concrete Block Paving, San Francisco, CA, USA, 6–8 November 2006.
- KIM S et al, 2016, Assessment of the Impact of Window Size, Position and Orientation
- LAVAFPOUR Y., 2011, Passive Low Energy Architecture in Hot and Dry Climate, Australian Journal of Basic and Applied Sciences, Vol 5(8), P 757-765(ISSN 1991-8178).
- MARIANI S., ROSSO F. and FERRERO M., 2018, Building in Historical Areas: Identity Values and
- Martínez Molina, A.; Tort Ausina, I.; Cho, S.; Vivancos, J., 2016, Energy efficiency and
- McKinley Deery, 2021, The influence of vegetation and green spaces on air quality and outdoor air temperature Mitigation on multiple scales, Undergraduate honors thesis, The university of Vermont, USA, 57, URL:
- Megan Rupard, 2019, Urban Heat Islands: Causes, impacts and mitigation, California Polytechnic State University San Luis Obisp, USA, URL:
- MOHAMMADI H. and VALIBEIG N., 2018, THE ANALYSIS OF ELEMENTS GEOMETRY POSITION IN THE IRANIAN GARDEN STRUCTURE, Journal of Architecture and Urbanism, Vol 42(2), P 112-119(ISSN 2029-7955).
- Mohd. F. Shahidan; Mustafa K.M. Shariff; Phillip Jones; Elias Salleh; Ahmad M. Abdullah (2010). A comparison of Mesua ferrea L. and Hura crepitans L. for shade creation and radiation modification in improving thermal comfort. , 97(3), 0–181. doi:10.1016/j.landurbplan.2010.05.008
- Neveen Hamza, 2023, Architecture and Urban Transformation of Historical Markets Cases from the Middle East and North Africa, New York: Routledge
- Nunez M, Oke TR. Energy balance of an urban Canyon. 1977.
- Oke TR, Johnson GT, Steyn DG, Watson ID. Simulation of surface urban heat islands under ‘ideal’ conditions at night part 2: diagnosis of causation. Bound-Layer Meteorol 1991;56:339–58.
- OLIVEIRA D.V. at al, 2016, Mechanical performance of compressed earth block masonry using granitic residual soils, 16th International Brick and Block Masonry Conference.
- RAGAB A., 2023, Investigating the Impact of Different Glazing Types on the Energy Performance in Hot Arid Climate, Journal of Advanced Engineering Trends, Vol 42(1), P 69-84.
- RAIMUNDO A.M, AFONSO M.S and OLIVEIRA A.V.M, 2023, Assessment of Energy, Environmental and Economic Costs of Buildings’ Thermal Insulation–Influence of Type of Use and Climate, Buildings, Vol 13, p 279-305(I S S N: 2075-5309)
- RIDHA S., GINESTET S. and LORENTEL S., 2023, Adopting A Sustainable Urban Design To Improve Thermal Comfort In An Arid Climate, Journal of Engineering and Sustainable Development, Vol 27(2), P 171-179.

Bibliographic references

Articles, reviews, and magazines

• Rinner, C., & Hussain, M. (2011). Toronto's Urban Heat Island--Exploring the Relationship between Land Use and Surface Temperature. Remote Sensing, 3(6), 1251-1265.

• ROBERTO R.F et al, 2019, Analysis of the Influence Subjective Human Parameters in the Calculation of Thermal Comfort and Energy Consumption of Buildings, Energies, Vol 12(8), P316-338.

• SAADON E.I.S., ABDULLAH J. and ISMAIL N., 2013, Evaluating The IEEE 802.15.4a UWB Physical Layer

• SAARI S., BAKAR B.H.A. and SURIP N.A., 2017, Flexural Strength of Interlocking Compressed Earth Brick (ICEB) Unit, IPTEK Journal of Proceedings Series, Vol 3(6), P56-61 (ISSN: 2354-6026).

• Santamouris, M., 2013b. Using cool pavements as a mitigation strategy to fight urban heat island - a review of the actual developments. Renew. Sust. Energy Rev. 26, 224-240.

• SANTANA B.O., TORRES-QUEZADA J., COCH H. et ISALGUE A., 2022, Monitoring and Calculation Study in Mediterranean Residential Spaces: Thermal Performance Comparison for the Winter Season, Buildings, Vol 12(3), 325.

• Santiago, J.-L., Martilli, A., & Martin, F. (2016). On Dry Deposition Modelling of Atmospheric Pollutants on Vegetation at the Microscale: Application to the Impact of Street Vegetation on Air Quality. Boundary-Layer Meteorology, 162(3), 451- 474. do: 10.1007/s10546-016-0210-5

• Sawka, Michelle; Millward, Andrew A.; Mckay, Janet; Sarkovich, Misha (2013). Growing summer energy conservation through residential tree planting. Landscape and Urban Planning, 113(), 1–9. doi:10.1016/j.landurbplan.2013.01.006

• Sherine Wahba, Basil Kamil , Khaled Nassar , Ahmed Abdelsalam., 2019, Green Envelop Impact on Reducing Air Temperature and Enhancing Outdoor Thermal Comfort in Arid Climates, Civil Engineering Journal, Vol.5,1124-1135 http://dx.doi.org/10.28991/cej-2019-03091317

• SUE GRIMMOND, 2007, Urbanization and global environmental change:

• SULAIMAN H., SIPOWICZ E., FILIPPÍN C. et OGA L., 2019, Energy Performance of Dwellings in a Temperate Climate Area of Argentina. An Architectural Proposal, The Open Construction and Building Technology Journal, Vol 14, P1-16.

• Synnefa A, Santamouris M, Livada I. A study of the thermal performance of reflective coatings for the urban environment. Solar Energy 2006;80(8): 968–81

• Takebayashi, H., Moriyama, M., 2012. Study on surface heat budget of various pavements for urban heat island mitigation. Adv. Mater. Sci. Eng, 2012, Article ID 523051

• Thermal comfort in historic buildings: A review. Renewable and Sustainable Energy Reviews, p70-85.

Bibliographic references

Articles, reviews, and magazines

• Vu Thanh Ca; Takashi Asaeda; Eusuf Mohamad Abu (1998). Reductions in air conditioning energy caused by a nearby park. , 29(1), 83–92. doi:10.1016/s0378-7788(98)00032-2

• YALLEY P.P.K. and MANU D., 2013, Strength and Durability Properties of Cow Dung Stabilized Earth Brick, Civil and Environmental Research, Vol 3(13), P117-125 (ISSN: 2224-5790 “Paper”, ISSN: 2225-0514 “Online”).

• Yang, Feng; Lau, Stephen S.Y.; Qian, Feng (2011). Thermal comfort effects of urban design strategies in high-rise urban environments in a sub-tropical climate. Architectural Science Review, 54(4), 285–304. doi:10.1080/00038628.2011.613646

• YÜKSEK I., KARADAYI T.T., 2017, Energy-Efficient Building Design in the Context of Building Life Cycle, Energy Efficient Building, Chapiter 5, P 94-123.

• Yupeng Wang, Hashem Akbari, 2016, Analysis of urban heat island phenomenon and mitigation solutions evaluation for Montreal, Sustainable Cities and Society, Volume 26, 438-446.

• ZAMBELLI E., IMPERADORI M., MASERA G. et LEMMA M., 2003, High Energy-Efficiency Buildings.

• Zhang, Y., Murray. A. T., & Turner. B. L. (2017). Optimizing green space locations to reduce daytime and nighttime urban heat island effects in Phoenix, Arizona. Landscape and Urban

Books

• FATHY H., 1986, Natural Energy and Vernacular Architecture: Principles and Examples with Reference to. Hot Arid Climates, Chicago, the University of Chicago Press (ISBN: 0-226-23917-9)

• KALAISELVAM S. and PARAMESHWARAN R., 2014, Thermal Energy Storage Technologies For Sustainability. Systems Design, Assessment and Applications, USA: Elsevier (ISBN: 978-0-12-417291-3)

• Kuppaswany Iyengar., 2015, Sustainable Architectural Design An Overview, New York: Routledge, ISBN: 978-0-415-70234-8 (hbk)

•MEYERS R.A., 2012, Encyclopedia of Sustainability Science and Technology, CA.USA: Springer (ISBN 978-0-387-89469-0)

• SALA LIZARRAGE J.M.P and PICALLO-PEREZ A., 2020, Exergy Analysis and Thermoeconomics of Buildings Design and Analysis for Sustainable Energy Systems, Oxford UK ; Cambridge USA: Butterworth-Heinemann “Elsevier” (ISBN: 978-0-12-817611-5).

• The Clay Brick Association., 2015, 05 - Clay Brick Technical Guide, South Africa: The Clay Brick Association of South Africa (ISBN: 978-0-620-69221-2). [Original source: https://studycrumb.com/alphabetizer]

Bibliographic references

Thesis and dissertation

- AMRAR N. and ADJTOUTAH R., 2016, Habitat et équipement commercial en milieu littoral, AZUL, Mémoire de Master en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 66 Pages, https://di.univ-blida.dz/jspui/handle/123456789/142.
- ATIK T, 2022, Apport de l'expérience multi-sensorielle de l'Architecture des jardins en Psychologie positive, Cas du Jardin d'Essai du Hamma en période estivale, thèse de Doctorat en sciences "Architecture et environnement", EPAU, Algérie, 347, document non publié en ligne.
- BENAISSA M., 2021, Le processus de métropolisation : La mixite urbaine comme facteur de rayonnement international (PFE : conception d'un Mall a El Mohammedia), Architecture Urbaine, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Insti-tut d'Architecture et d'Urbanisme, Algérie, 113 Pages, https://di.univblida.dz/jspui/han-dle/123456789/142.
- BENCHEIKH D., 2021, Efficience énergétique des matériaux de l'architecture vernaculaire Cas de Ksar Zgag El-Hadjaj à Laghouat, Architecture ; Patrimoine bâti et Environnement, Thèse en vue de l'obtention du diplôme de doctorat D/LMD, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 308 Pages, https://di.univblida.dz/jspui/handle/123456789/142.
- BOUBEKEUR B. and SAIDJI I., 2020, Medina entre la mixité fonctionnelle urbaine et archi-tecturale dans le cardre de développement durable (P.F.E : création d'une médina, Projet : Médina Mall « méga Mall »), Architecture et habitat, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 78 Pages, https://di.univblida.dz/jspui/handle/123456789/142.
- BOUZIDA N. and HAMADOUCHE B.K., 2019, Valorisation touristique et amélioration du confort thermique dans les zones arides : conception d'un centre international de jeune à Béni Abbes, Architecture et Habitat, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 116 Pages, https://di.uni-vblida.dz/jspui/handle/123456789/142.
- CHERIF LARBI C.M., 2016, Etalement urbain durable Conception d'un éco quartier à la périphérie (Mouzaia ville) Et Conception d'un équipement culturel, Architecture et efficience énergétique, Mémoire de Master en Architecture, Université de Blida I, Institut d'architecture et d'urbanisme, Algérie, 77 Pages, https://di.univ-blida.dz/jspui/handle/123456789/142.
- ESCHOUF A. and MOHAMMEDI C., 2018, La vitalité urbaine du centre-ville de Tipaza Par la conception d'une centre multifonctionnel, Architecture et Habitat, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 86 Pages, https://di.univblida.dz/jspui/handle/123456789/142.

Bibliographic references

Thesis and dissertation

• HAMRAOUI S. and SAADAOUI A., 2019, Le paysage culturel concept d'un projet territorial face à l'étalement urbain Cas de la côte ouest de Bejaia « Immeuble mixte de l'esplanade », Projet urbain et paysage culturel, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 86 Pages, https://di.univblida.dz/jspui/handle/123456789/142.

• MECHEGAG A.M and NAIT-OUABBAS N., 2019, Réadaptation de l'habitat traditionnelle « Conception d'un éco-quartier à Ain Sefra », Architecture et habitat, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 92 Pages, https://di.univblida.dz/jspui/handle/123456789/142.

• MERABET-FILALI S. and RICHA A., 2020, Aménagement d'une nouvelle centralité commerciale à l'image du life style center : Projet d'aménagement du boulevard principal de la ville nouvelle de Hassi Messaoud et réalisation d'un centre commercial, Architecture et Habitat, Mémoire de Master 2 en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 105 Pages, https://di.univblida.dz/jspui/handle/123456789/142.

• MIHOUBI M.S., 2012, Equipement commerciaux et méthodologie de conception par recours à un système constructif tridimensionnel, Constructions Civiles et Industrielles Rationalisation et développement des systèmes constructifs industrialisés, Mémoire de Magister, UNIVERSITE MOHAMED- CHERIF MESSADIA Souk-Ahras, Institut des Sciences et Sciences de l'ingénieur (Génie civil), Algérie, 106 Pages, https://theses-algerie.com/?size=n_10_n.

• MOLINAR-RUIZ A., 2017, Cold-Arid Deserts: Global Vernacular Framework for Passive Architectural Design, Architectural design, Doctorate of Architecture, UNIVERSITY OF HAWAI'I AT MĀNOA, School of Architecture, USA, 125 Pages, https://scholarspace.manoa.hawaii.edu/items/b0ada9d3-4a02-4954-826a-3364d3c5091a.

• NADRI A., 2018, L'Architecture commerciale en Algérie entre conception et réalisation « cen-tre commercial ELQODS », Architecture ville et territoire (Arviter), Mémoire de fin d'études pour l'obtention du diplôme Master 2 en Architecture, , Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 80 Pages, https://di.univblida.dz/jspui/han-dle/123456789/142.

• PETIT A., 2015, Effets chromatiques et méthodes d'approche de la couleur dans la démarche de projet architectural et urbain, SCIENCES POUR L'INGÉNIEUR ; GÉOSCIENCES ; ARCHITECTURE, Thèse de DOCTORAT en Architecture, L'Université Nantes Angers Le Mans, l'École Nationale Supérieure d'Architecture de Nantes (ÉCOLE DOCTOALE), France, 383 Pages, https://hal.science/tel-01248894.

Bibliographic references

Thesis and dissertation

• ZIREGUE M.,2018, Démarche Congnitive pour la Revitalisation du Quartier Zgag El-Hedjadj du Ksar de Laghouat, Architecture ville et territoire, Mémoire de Master en Architecture, Université SAAD DAHLEB de Blida I, Institut d'Architecture et d'Urbanisme, Algérie, 88 Pages, https://di.univblida.dz/jspui/handle/123456789/142. [Original source: https://studycrumb.com/alphabetizer]

Softwares

- Climat consultant 6.0
- Métronome 7
- DesignBuilder 7.0.2.006
- IBM SPSS 24
- Excel 2022
- Envi-met 3.1
- Sketchup 2022
- Autocad 2023.
- Revit 2022
- Enscape 3.0.
- Photoshop 2022
- Illustrator 2022
- InDesign 2022

APPENDICES

- **Survey and interviews**

Visited 146

Started: 70

Completed: 70

Avr. Time: 4min

Completion rate: 100%

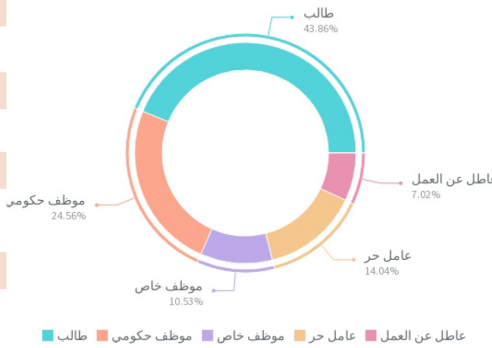


Figure A.113. What's your current statue? Source: Sparrowsurvey

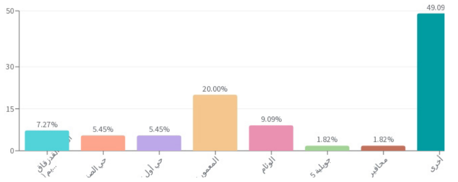


Figure A.114. Which city you live in? Source: Sparrowsurvey

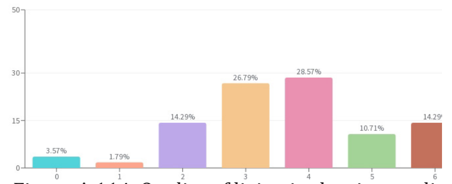


Figure A.114. Quality of living in the city you live in on scale from 0 to 6? Source: Sparrowsurvey

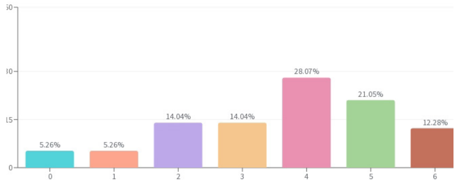


Figure A.115. Quality of services in the city you live in on scale from 0 to 6? Source: Sparrowsur-

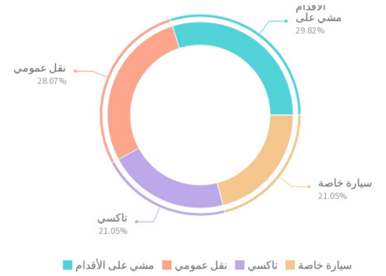


Figure A.116 Which transportation method is used the most? Source: Sparrowsurvey

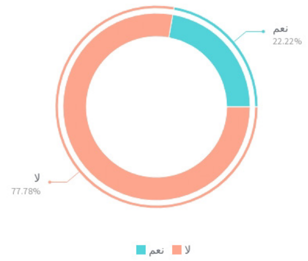


Figure A.117. Which transportation method is used the most? Source: Sparrowsurvey

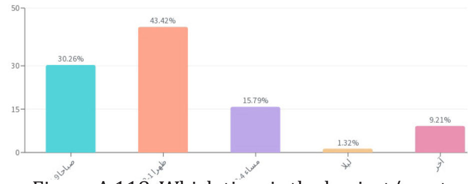


Figure A.118. Which time is the busiest/most crowding? Source: Sparrowsurvey

Figure A.119. What is the cause of the traffic jam? Source: Sparrowsurvey

Figure A.120. What is the busiest place in the city? And Why? Source: Sparrowsurvey

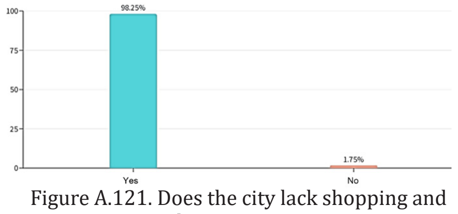


Figure A.121. Does the city lack shopping and entertainment places? Source: Sparrowsurvey

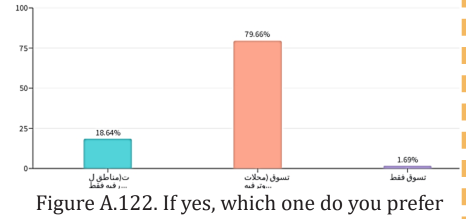


Figure A.122. If yes, which one do you prefer more? Source: Sparrowsurvey

- **Köppen climate classification:** Following climate classification of Köppen, the German botanist and climatologist Wladimir Köppen, based on temperature and precipitation patterns (Table 2.X), we find:

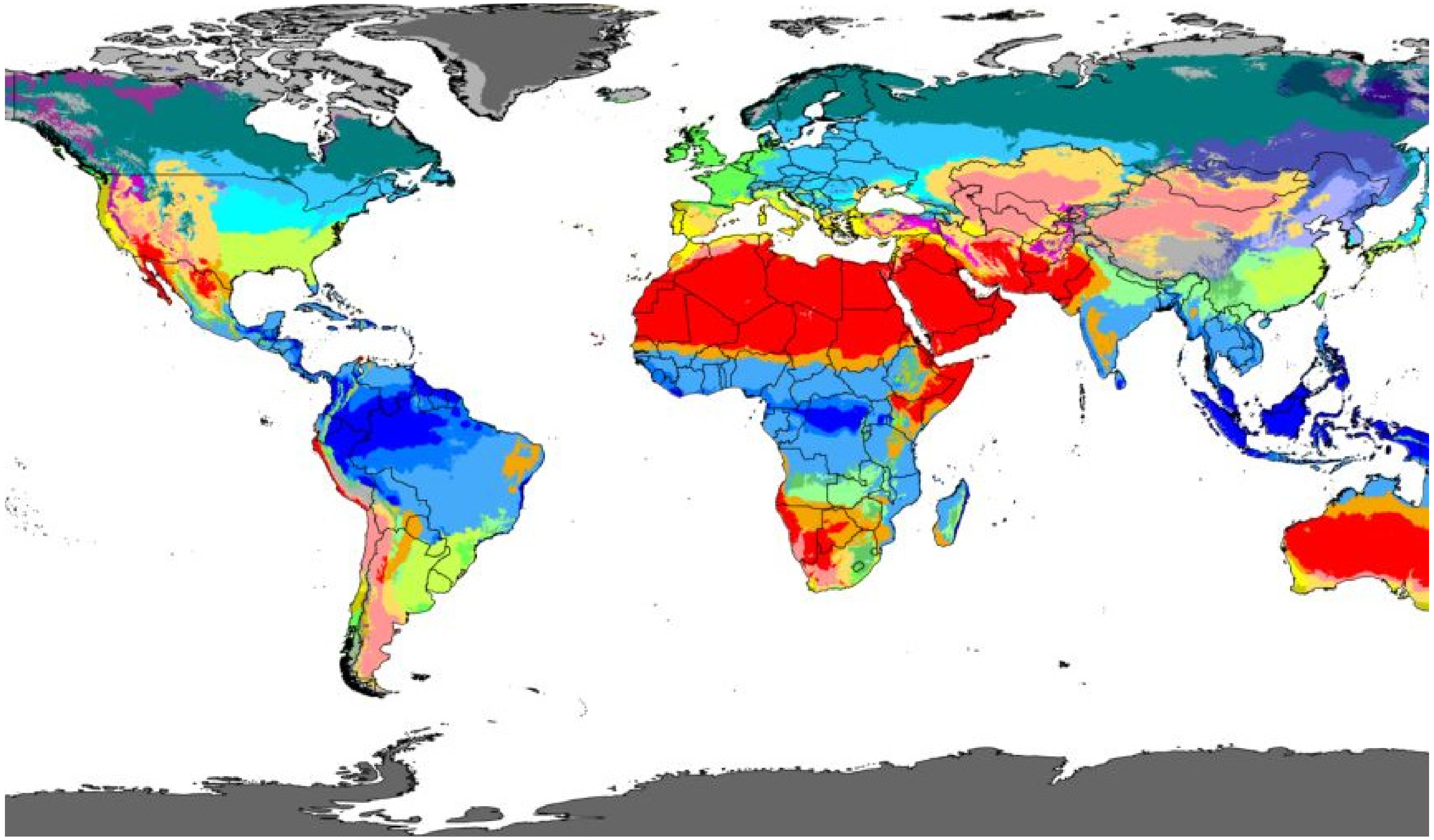


Figure B.1. Köppen climate classification map. Source: Beck et al, 2018

Table 3.16. Köppen climate classification. Source: Koeppen-geiger.vu-wien.ac.at

(A) Tropical	(B) Dry	(C) Temperate	(D) Continental	(E) Polar
High temperature throughout the year and abundant rainfall, further subdivided into wet tropical (AF) and monsoon tropical (AM).	Low precipitation and high evaporation rates, further subdivided into desert (BW) and steppe (BS).	Mild to warm summers and cool to cold winters with moderate precipitation throughout the year, further subdivided into subtypes bases on temp and precipitation pattern.	Large seasonal temperature variation with hot summers and cold winters, further subdivided into subtypes bases on temp and precipitation pattern.	Extremly cold temperature and little precipitation, further subdivided into tundra (ET) and ice cap (EF)

Table 3.X. Algeria's different types of climate zones. Source: Plantmap

Csa - Warm Mediterranean climate	"Csa Mediterranean Climates mostly occur on the western sides of continents between the latitudes of 30° and 45°.[6] These climates are in the polar front region in winter, and thus have moderate temperatures and changeable, rainy weather. Summers are hot and dry, due to the domination of the subtropical high pressure systems, except in the immediate coastal areas, where summers are milder due to the nearby presence of cold ocean currents that may bring fog but prevent rain."
BSk - Cold Semi Arid climate	" At least one month's averages below 0 °C (32 °F)"
BSh - Hot Semi Arid climate	" At least one month's averages below 0 °C (32 °F)"
BWk - Cold desert climate	" Cold desert climates (BWk) sometimes feature hot and dry summers, though summers typically are not quite as hot as summers in hot desert climates. Unlike hot desert climates, cold desert climates sometimes feature cold winters with marginal snow. Cold desert climates are typically found at higher altitudes than hot desert climates, and are usually drier than hot desert climates."
BWh - Hot Desert climate	" Hot desert climates usually feature hot, sometimes exceptionally hot, periods of the year. In many locations featuring a hot desert climate, maximum temperatures of over 40 °C (104 °F) are not uncommon in summer and can soar to over 45 °C (113 °F) in the hottest regions "

2. Programming:

2.1. Quality programming

Table B.3. Qualitative programming, part 1. Source: Author

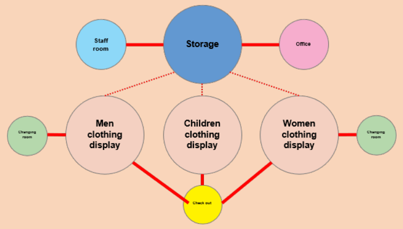
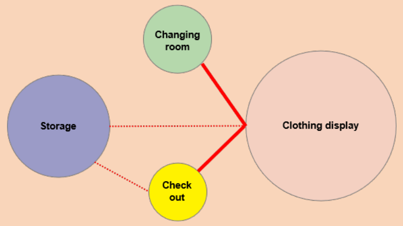
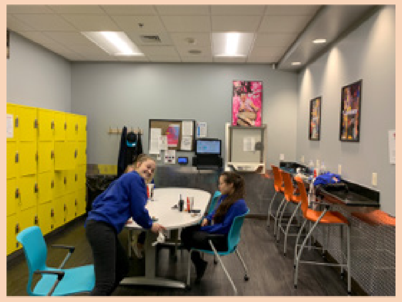
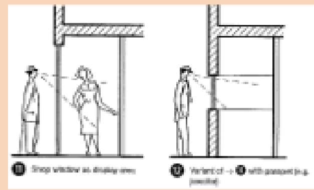
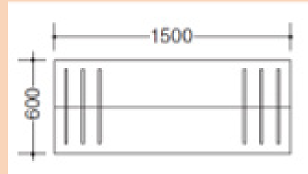
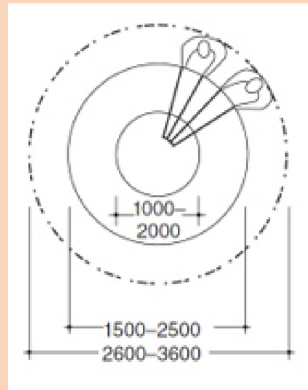
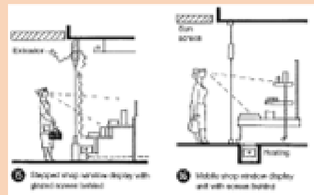
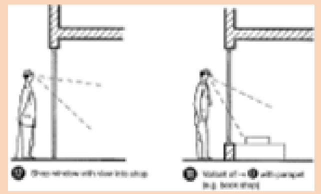
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Retail	Shopping (Clothes)	Display	• Check-out desk • Changing room • Sanitary • Storage • Staff room	• Presence of store front. • Check-out desk on the middle of the store. • Display area is open. • Important events displayed close to the entrance. • Changing room has multiple cabinets. • Men and women changing room separated. • Storage and staff room are in the back of the store hidden.	• Public circulate around all the displayed items. • Changing room has direct access to the display area but still hidden. • Men and women changing rooms don't have any contact with each other. • Public and staff sanitary are separated. • Public sanitary has direct access from the display area. However, the staff sanitary is only accessed from the staff area. • Staff room contain sitting area, changing room and sanitary, accessible only by the staff.  Clothing boutique functional diagram Source: Author  Clothing store functional diagram Source: Author	    	• Public circulation paths is at least 2 adults width. • Women and men changing rooms are separated. • Each changing cabinet has a door or a curtain.     	• Security system at the entrance to announce when a customer has entered and if a customer has stolen an item. • Security tags on the clothes. • Artificial lighting that marks new, popular or on sale items.

Table B.3. Qualitative programming, part 2. Source: Author

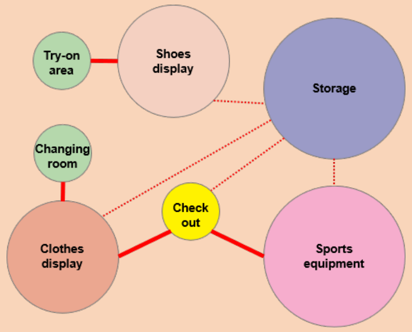
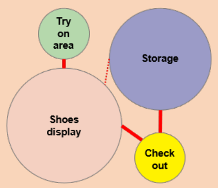
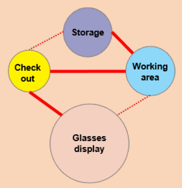
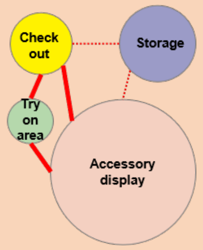
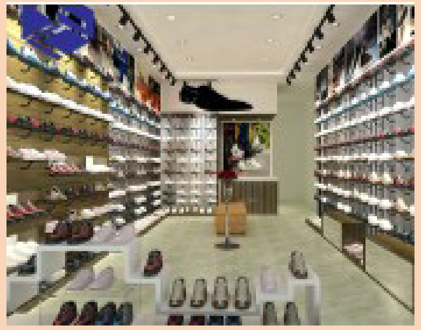
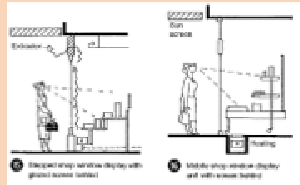
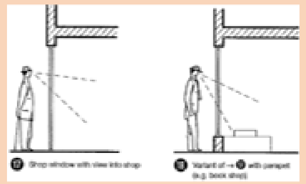
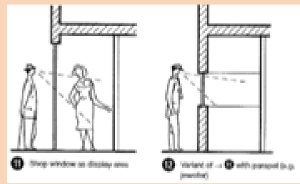
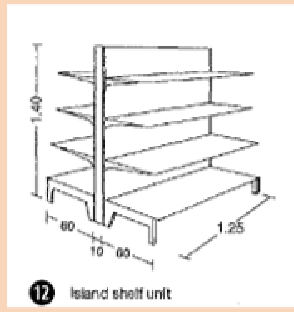
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Retail	Shopping (Sportswear, shoes, accessory, optical, jewellery)	Display	• Check-out desk • Try-on area • Sanitary • Storage • Staff room	• Presence of store front. • Check-out desk on the middle of the store. • Display area is open. • Important events displayed close to the entrance. • Multiple try on areas around the store. • Storage and staff room are in the back of the store hidden.	• Public circulate around all the displayed items. • Try on area doesn't come in the way of the circulation. • Public and staff sanitary are separated. • Public sanitary has direct access from the display area. However, the staff public is only accessed from the staff area. • Staff room contain sitting area, changing room and sanitary, accessible only by the staff.  Sportswear store functional diagram Source: Author  Shoes store functional diagram Source: Author  Accessory store functional diagram Source: Author  Optical store functional diagram Source: Author	   	• Public circulation paths is at least 2 adults width.     	• Security system at the entrance to announce when a customer has entered and if a customer has stolen an item. • Security tags on the items. • Artificial lighting that marks new, popular or on sale items • Expensive accessory and jewellery is usually kept in storage area, while displaying cheap copies.

Table B.3. Qualitative programming, part 3. Source: Author

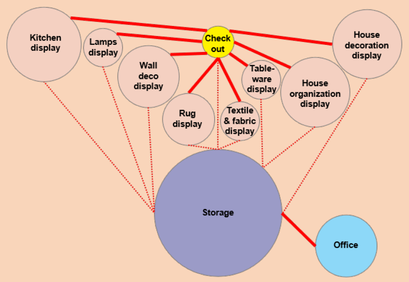
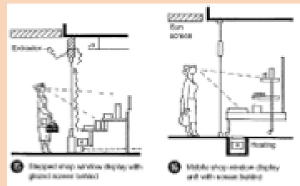
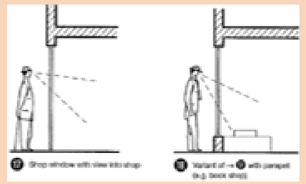
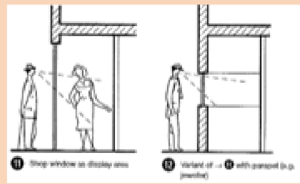
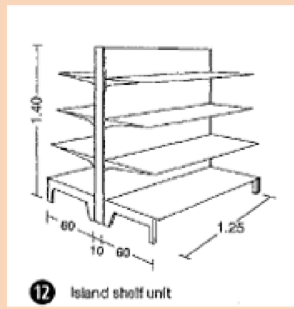
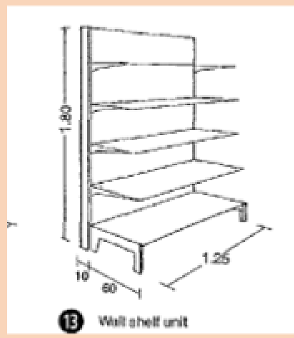
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Retail	Shopping (Furniture, table-ware)	Display	• Check-out desk • Sanitary • Storage • Staff room	• Presence of store front. • Display area is divided to zones, each has a type of furniture or tableware. • Furniture or table-ware are displayed in a close-to-reality-use way. • Storage and staff room are in the back of the store hidden.	• Public circulate around all the displayed items. • Display has a try-expo side. Public and staff sanitary are separated. • Public sanitary has direct access from the display area. However, the staff public is only accessed from the staff area. • Staff room contain sitting area, changing room and sanitary, accessible only by the staff.  Sportswear store functional diagram Source: Author	  	• The store is provided with a map with a clean path around the different zones of the store (ex. IKEA layout). Public circulation paths is at least 2 adults width.     	•Lighting: use natural lighting but mostly focus on artificial lighting.

Table B.3. Qualitative programming, part 4. Source: Author

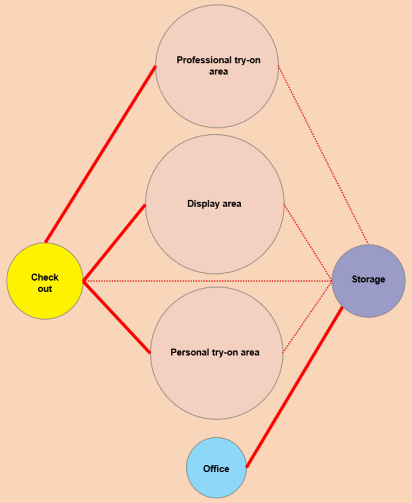
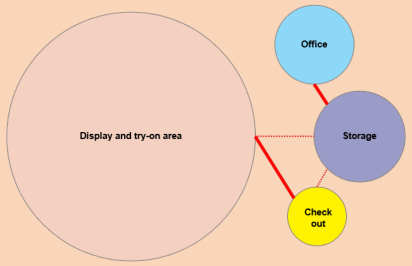
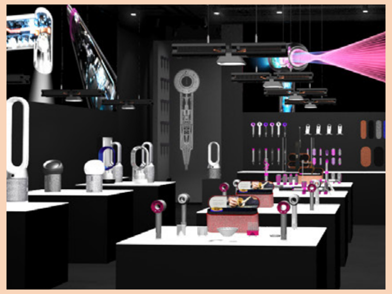
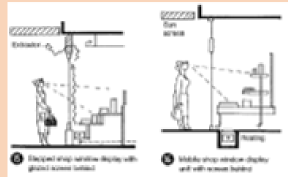
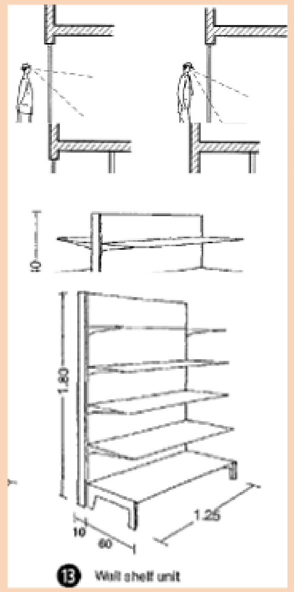
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Retail	Shopping (Home appliance, electronics)	Display	• Check-out desk • Check-in desk • Try-expo area • Sanitary • Storage • Staff room	• Presence of store front. • Check-out desk on the middle of the store. • Display area is open. • Important events displayed close to the entrance. • Each item's try-exp-o area is beside its displayed area. • Storage and staff room are in the back of the store hidden.	• Public circulate around all the displayed items. • Display has a try-exp-o side. • Public and staff sanitary are separated. • Public sanitary has direct access from the display area. However, the • staff public is only accessed from the staff area. • Staff room contain sitting area, changing room and sanitary, accessible only by the staff.  Home appliance store functional diagram Source: Author  Electronics store functional diagram Source: Author	    	• Public circulation paths is at least 2 adults width.  	• Lighting: Use of natural lighting but mostly focus on artificial. • Acoustic absorbing materials to minimize the noise and echo for when trying the product. • Security at the entrance to prevent stealing.

Table B.3. Qualitative programming, part 5. Source: Author

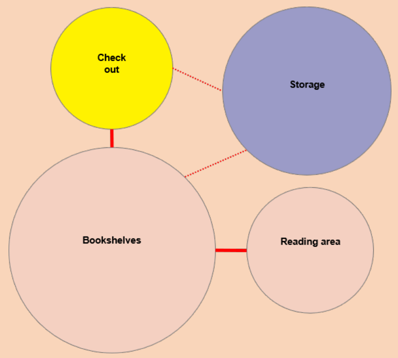
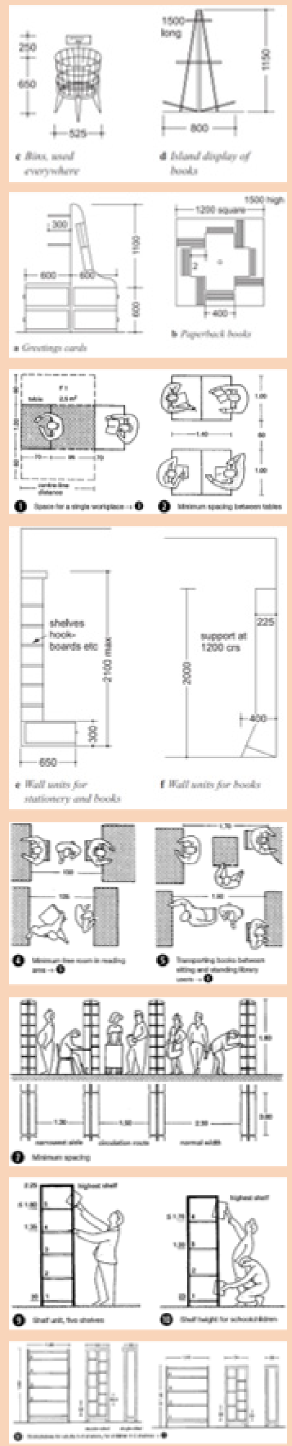
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Retail	Trade, buy and sell (books)	Display	• Checkout desk • Check-in desk • Sanitary • Storage • Staff room	• Presence of store front, that keeps a direct visual connection (in/out). • Reception found at the entrance where returning and trading operations happen, with a sitting area. • Bookshelves are found in zones (depends on the book genre), each zone has a reading area. • Reading area is divided to kids and adult sections. • Storage and staff room are in the back of the store hidden.	 Bookstore store functional diagram Source: Author	 	• The store is provided with a map with a clean path around the different zones of the store (ex. IKEA layout). Public circulation paths is at least 2 adults width. 	• Acoustic insulation for reading area • Lighting: Generally approx. 250-300 lx reading and working places, card index, information, lending counter 500 lx. • Climate in the user area: 20° ± 2°C, -50 ± 5% relative humidity, air changes (flow of outside air) 20 m3/h x no. • Avoid direct sunshine as UV and heat radiation destroy paper and bindings. • Air-conditioning systems should be used sparingly because of the high energy consumption and thus high operation costs. • Window ventilation is possible for low building depth . • Fire detectors and moose fire distinguish to prevent burning and/or wetting the books. • Burglary prevention through motion detectors and • Burglary-resistant glazing and theft protection through book security systems, optimally securing unsupervised emergency doors through electronically controlled automatic locking on alarm. • Mechanical securing of emergency doors, also with acoustic and/or optical signals, is not very effective.

Table B.3. Qualitative programming, part 6. Source: Author

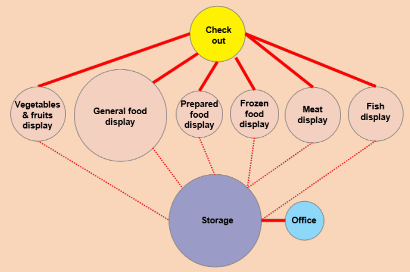
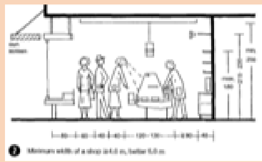
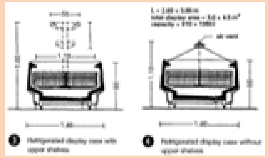
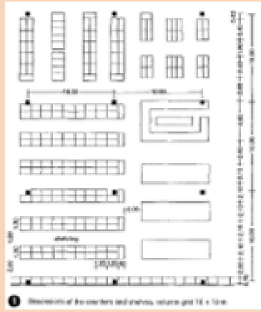
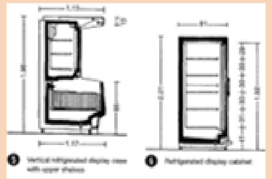
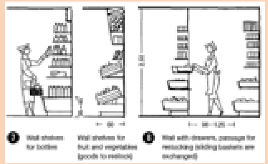
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Retail	Supermarket-ing (Supermarket)	Display	• Checkout desk • Sanitary • Storage • Staff room	• Baskets are found at the entrance of the supermarket. • Lined up check-out desks. • Display area is divided into zones, each a type (vegetables, fruits, fishery,...). • Important events displayed close to the entrance (sold, new items, ...).	• Public circulates around all the displayed items. • Public can't access the storage area. • Display zones are complementary (ex. all cold products found in one area)  Supermarket functional diagram Source: Author	   	        	• Natural lighting but mostly artificial Natural and artificial ventilation • Acoustic absorbing materials to minimize noise reflection • Multiple checkout stands

Table B.3. Qualitative programming, part 7. Source: Author

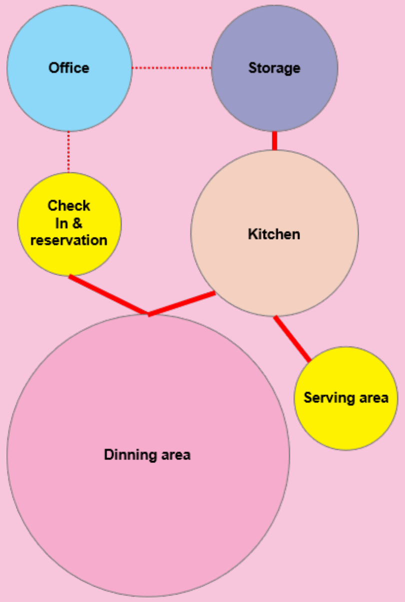
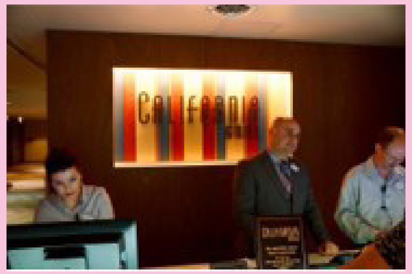
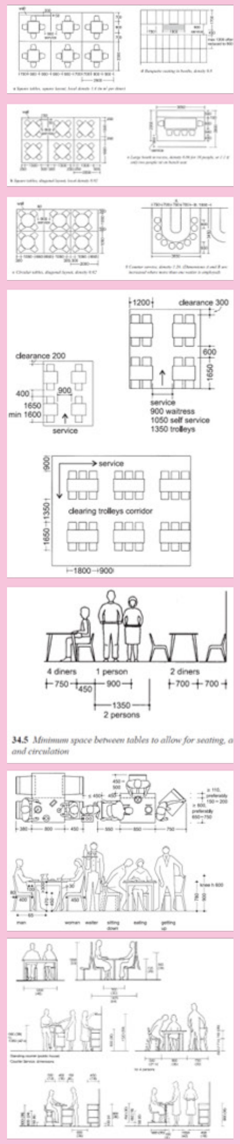
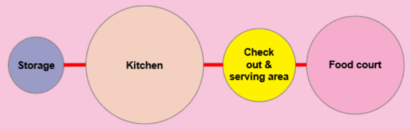
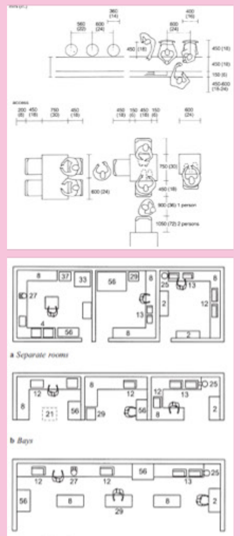
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Culinary	Reserve & eat (Restaurant)	Dinning area	• Check-in & out • Kitchen • Serving area • Sanitary • Storage • Staff room	• Reservation desk at the entrance. • Dinning area has different types of tables (number of chairs). • The kitchen is not visible • The kitchen has: preparing area, cooking area, warm and cold storage room and dishes washing area. • Serving area is a transition area between the • kitchen and the dinning area. • Public and staff sanitary are separated.	• Public pass through the reservation desk to either confirm or make reservation. • Serving and kitchen area are inaccessible to the public. • Public sanitary has direct access from the food court area. However, the staff sanitary is only accessed from the staff area.  Restaurant functional diagram Source: Author	   		• Natural and artificial lighting • Continuous natural and/or artificial ventilation • Acoustic absorbing material • Roger collector • Non slippery floor • Higher fire protection
	Quick meal (Fast food, cafeteria)	Food court or sitting area	• Check-out • Kitchen • Serving area • Sanitary • Storage • Staff room	• Check-out desk and serving area are at the same place. • Sitting area right at the entrance. • Kitchen is open to the sitting area • Kitchen is separated from the sitting area with a serving area.	• There is a visual connection between the kitchen, serving area and food court. • There is no connection, whatsoever, between the public and the storage. • Public sanitary has direct access from the food court area. However, the staff sanitary is only accessed from the staff area.  Fast food functional diagram Source: Author	 		

Table B.3. Qualitative programming, part 8. Source: Author

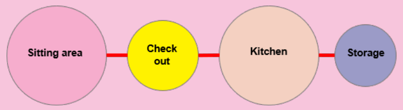
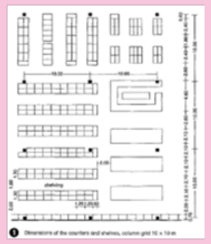
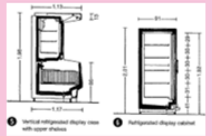
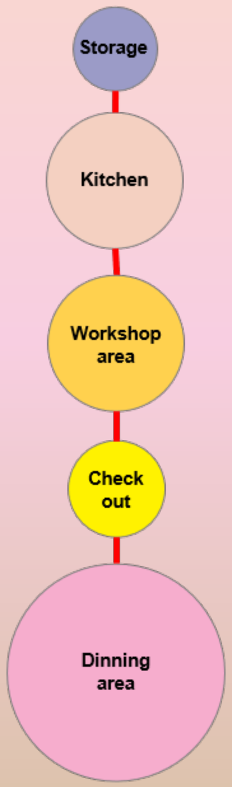
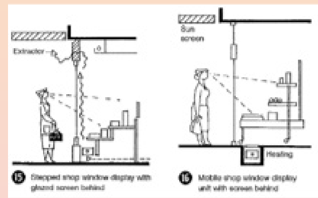
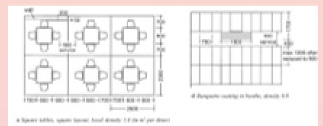
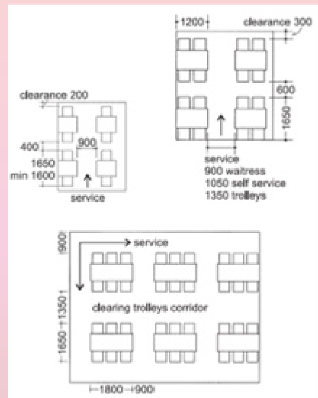
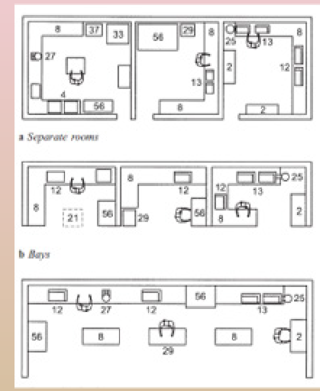
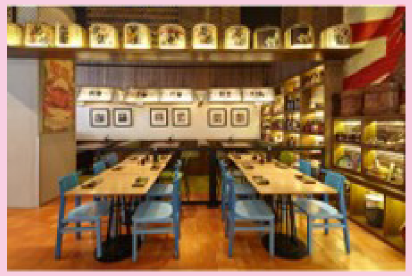
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Culinary	Try & buy (Bakery, spices)	Display	• Check-out desk • Waiting area • Kitchen • Storage • Staff room	• Display counter where also is a checkout. • Kitchen separated, in the back of the store.	 Bakery functional diagram Source: Author	 	  	/
Retail x Culinary x Culture	Shopping	Display	• Check-out desk • Storage • Sanitary • Staff room	• All items (tableware or food) displayed in the store were used in the workshop.	• All 3 principal spaces have direct relation (visual and special) between them.  Restaurant with a workshop functional diagram Source: Author		   	• Natural and artificial lighting • Continuous natural and/or artificial ventilation • Acoustic absorbing material • Roger collector • Non slippery floor • Higher fire protection
	Reserve & eat	Dinning area	• Check-in & out desk • Kitchen • Storage • Sanitary • Staff room	• Dinning area with a view to the workshop and the store.				
	Cook it yourself	Workshop	• Storage • Sanitary • Staff room	• Open workshop.				

Table B.3. Qualitative programming, part 9. Source: Author

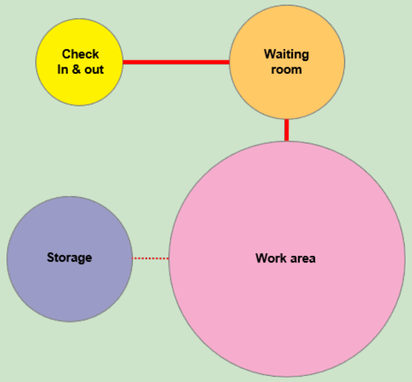
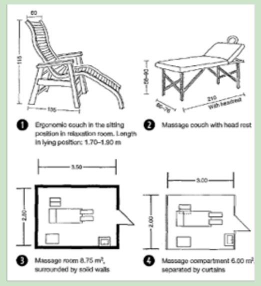
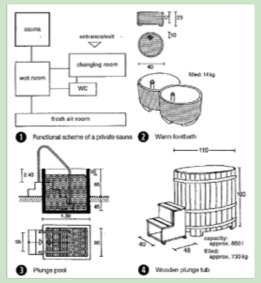
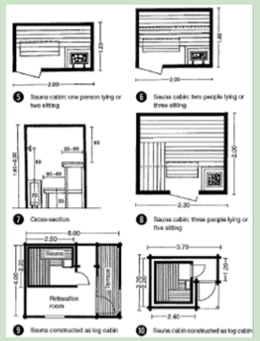
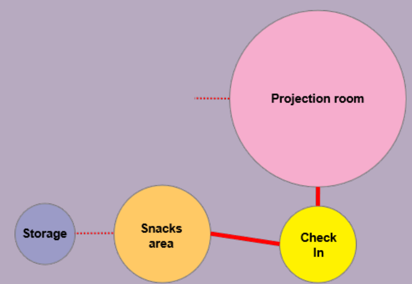
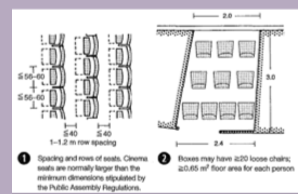
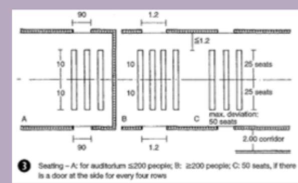
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Well being	Beauty & health related (beauty salon, SPA)	Work space (Hair & nail)	• Check-in & out desk • Waiting room • Washing area • Storage • Sanitary • Staff room	• An entrance with check-in&out desk and a waiting area • Work space area where different tasks are performed (cutting, blowing and styling hair, manicure and pedicure). • Hair washing area separated from the work space (wet/dry).	• Active space is separated from the entrance for intimacy reasons. • Changing room, checking room and work room have a strong direct relation.  Beauty salon functional diagram Source: Author	  	  	• Specific temperature for each room depends on its function • Continuous ventilation • Acoustic resisting rooms • Fire protection
		Work space (Massage)	• Check-in & out desk • Waiting room • Changing area • Storage • Sanitary • Staff room	• An entrance with check-in&out and a waiting room. • Active space has changing rooms, medical checking rooms and work rooms that have a number of beds.				
Leisure	Visual (Cinema)	Projection room	• Check-in • Projection cabin • Snacks area • Storage • Sanitary • Staff room	• Next to check-in where tickets are bought, a snack area is designed. • Projection room with a rectangle or trapezoidal form. • Projection cabin at the highest side of the projection room.	• Projection room is accessible to the public. • However, the projection cabin isn't accessible to the public.  Cinema functional diagram Source: Author	  	 	• Interrupted visual connection with baffled entry. • Continuous visual connection of seated person and platform • Acoustic resisting and absorbing

Table B.3. Qualitative programming, part 10. Source: Author

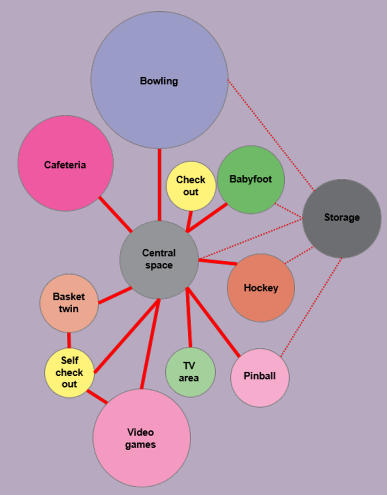
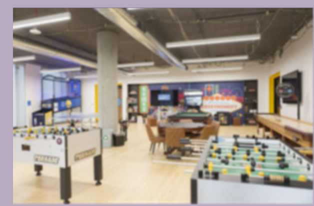
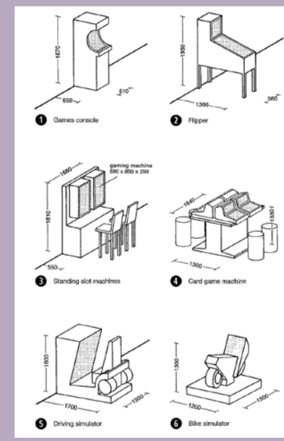
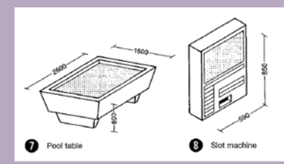
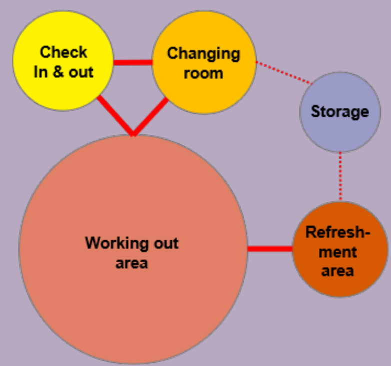
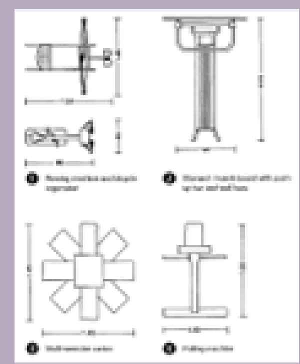
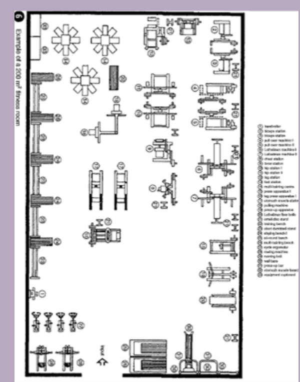
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Leisure	Gaming (Gaming room)	Gaming area	• Check-in • Snacks area • Storage • Sanitary • Staff room	• Check-in area at the entrance to buy tickets. • Gaming area is divided into zones, each has a type of game (hockey, bowling, arcade, baby foot, pinball and video-games) • A snack area close to the gaming area.	 Gaming room functional diagram Source: Author	   	 	• Focus on artificial (LED) lighting • Acoustic resisting and absorbing • Continuous ventilation
	Sport (GYM)	Working out area	• Check-in&out • Changing room • Refreshment area • Storage • Sanitary • Staff room	• Check in & out area at the entrance. • Changing room right next to the entrance to keep the working area clean. • Working out area is divided into different zones: cardio, weights, equipment and free training zone. • Refreshment area is an open space, found next to the working area. • Sanitary is connected to the changing room	 Gym functional diagram Source: Author	  	 	

Table B.3. Qualitative programming, part 11. Source: Author

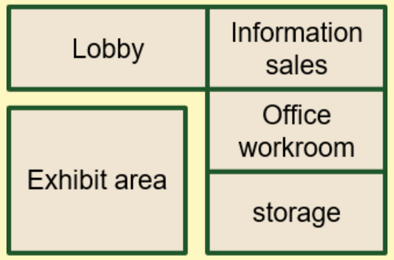
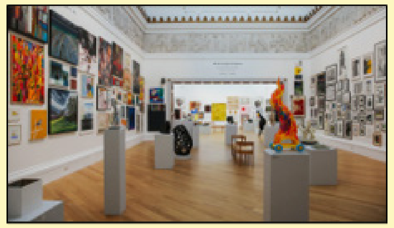
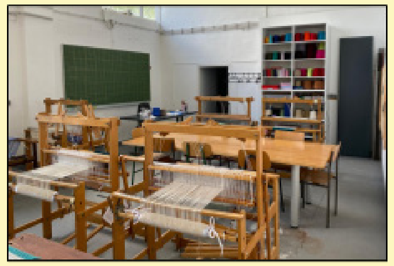
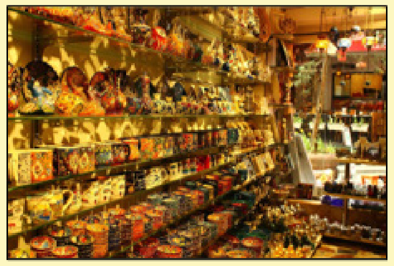
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Culture	Exposition	Exhibit area	• Lobby • Information sales • Office workroom • Collection storage	• Exhibit area: open plan, large and visually autonomous items on display, free circulation • Storyline of an exhibition may be translated to a loop where the essentially story line leads naturally back to beginning	• After each ''sikkas'' should be a visible art gallery. 	• Exhibited may be of four basic types: hanging or wall mounted, free standing, contained exhibits or display cases • Free circulation with no obstacles 	• Direct sunlight should not fall on any collection item • Noise levels should be controlled by appropriate choice of materials	• Security and cameras to monitor the shown collections • Walls with light colors • Lobby is the only public space with a direct relation to the exterior
	Artistic creation	Workshop	• Prep area • Kitchenette • Office workroom • Storage	• Flexible spaces	• Each art gallery should be accompanied by a workshop	• Tables and chairs • Small kitchenette 	• Natural light and ventilation • Sense of scale that relates to individual • Light colors in the walls	• Provide wall with a minimum sound transmission
	Shopping (Souvenir, antique)	Display	• Check-out • Sanitary • Collection Storage • Staff room	• Small surfaces • Open spaces	• Preferable to be situated near the entrances and in the main spine line of the commercial center	• Display tables and wall mounted 	• Direct sunlight should not fall on any collection item • Should be well organized for an easy circulation • Music in the background	/
	Exposition shopping	Kiosk (Henna, photobooth)	/	• In a form of a tent with traditional textiles	• Situated in the main spine line of the commercial center or outdoors • Should be visible • Situated near patios where people gather	• Tent, carpet and a table 	• Natural sunlight	/

Table B.3. Qualitative programming, part 12. Source: Author

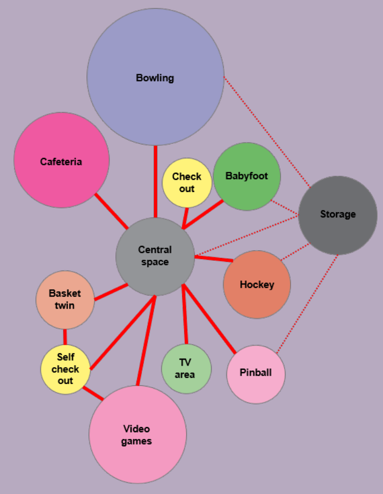
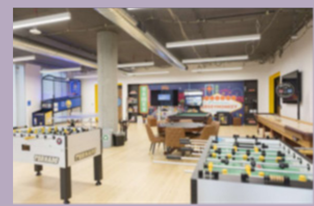
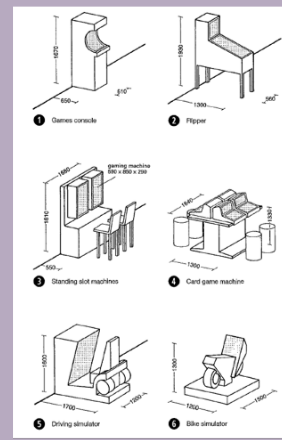
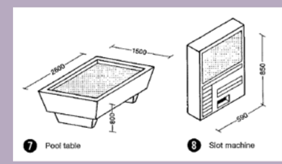
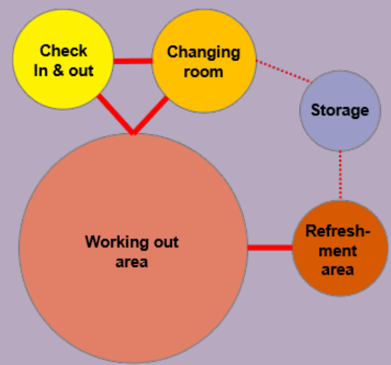
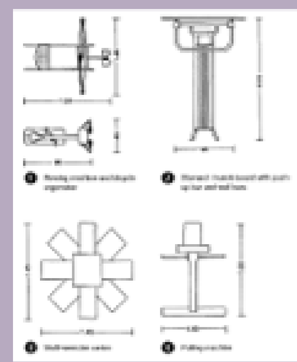
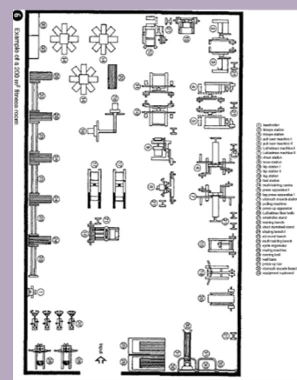
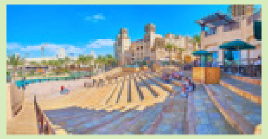
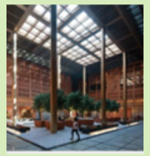
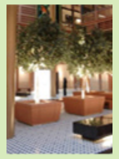
Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Leisure	Gaming (Gaming room)	Gaming area	• Check-in • Snacks area • Storage • Sanitary • Staff room	• Check-in area at the entrance to buy tickets. • Gaming area is divided into zones, each has a type of game (hockey, bowling, arcade, baby foot, pinball and video-games) • A snack area close to the gaming area.	 Gaming room functional diagram Source: Author	   	 	• Focus on artificial (LED) lighting • Acoustic resisting and absorbing • Continuous ventilation
	Sport (GYM)	Working out area	• Check-in&out • Changing room • Refreshment area • Storage • Sanitary • Staff room	• Check in & out area at the entrance. • Changing room right next to the entrance to keep the working area clean. • Working out area is divided into different zones: cardio, weights, equipment and free training zone. • Refreshment area is an open space, found next to the working area. • Sanitary is connected to the changing room	 Gym functional diagram Source: Author	  	 	

Table B.3. Qualitative programming, part 13. Source: Author

Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Educative	Reading (Book store)	Books display	• Checkout • Stationary • Group study room • Staff offices • Storage	• Open space • Group study room should be isolated from books display area • Fluid circulation between the aisles	• Checkout near the entrance • Should have a view to outdoor (upper levels) • Large window display for books • Make sure the aisles between shelves are wide enough for two customers • Situated next to coffee shop	• Use a variety of tables, shelves and other units to create distinct display areas. 	• Natural light • A wall with a minimum sound transmission • View to enjoy reading • Different type of seating for relaxation and socializing as a public space	• Carpet the store with sound-deadening heavy-duty carpet • Traffic routes larger than 1.20 m wide, clear distance between the shelves 1.30-1.40 • If possible, only one entrance and exist
	Meeting and communication (Club hub)	Meeting room	• Reception • Quiet rooms • Kitchenette • Work room • Storage	• Open workplace to enhance socializing with a kitchenette • Quite rooms should be isolated from working room	• Near the bookstore • Accessible by a corridor	• Different types of chairs and tables • White board • Shelves 	• Natural lightning • View to outdoor • A wall with a minimum sound transmission	/
Relaxation	Enjoying outdoor area	Garden (Oasis)	• Different zoning • Outside coffee shops • Plants exposition	• Organic pathways • Sensory experience • Distinct zones depending on the plant type • Coffee shops and restaurant to enhance public engagement • Open spaces to support artistic performances and temporary exhibitions	• Visible and should extend from views of trees and natural landscape	• A variety of urban furniture with shading options to adapts to the city's weather • Seating at frequent intervals to make public spaces more usable and comfortable 	• Trees and water that create a micro climate • Natural ventilation to provide fresh air • Provide different pleasing views while walking or relaxing	• Running water and rustling plants to mask unwanted noise

Table B.3. Qualitative programming, part 14. Source: Author

Function	Activity	Primary space	Secondary space	Formal character	Functional character	Furnishing & equipment	Comfort requirement	Technical requirement
Relaxation	Playing	Outdoor playing area	Different toys	• It should be situated from a distance from the streets for security • It should be messy • Different sections of plays	• The most functional shape is circle	• Different surfacing materials, colours, and patterns, picnic tables  	• Shading options • Surrounded by trees	• Sand ground for children's safety
	Watching	Outdoor theatre	Sitting area	• The shape of a cone	• A distance from street view	• Slope of seating 	• Isolated from street noise	• Slope of seating should not exceed 12 degrees
	Resting	Indoor patios	Sitting area	• Situated as a result of intersection of corridors • Play a role as circulation distributor	• Play a role as a thermal regulator and sunlight captor	• Different types of seating • Vegetations  	• Natural lighting • Natural ventilation • Pleasing views • Kiosks for more ambient atmosphere	• Rain recuperation
Management	Administration	Director's office	Toilet	• Rectangular form	• Entrance from secretary room	• Table and chair • Shelves	• Natural light	/
		Secretary	/	• Rectangular form	• Near the director's office	• Table and chair • Shelves	• Glazing walls to benefit from natural light	/
		Archives	/	• Rectangular form	• Near the offices	• Shelves • Printing materials	• Comfortable artificial lighting • Fluid circulation	/
		Office	• Toilet • Kitchenette	• Open space • Flexible spaces for private and public spaces	/	• Table and chair • Shelves	• Pleasant view • Natural lighting • Different type of seating to be more comfortable for the workers	• In case of private offices, the wall with a door should be in glaze to benefit natural light
		Meeting room	/	• Rectangular form	• Situated near the director's room • Provide entrance from the director's room	• Rounded table • Shelves • Data-show	• Natural and artificial lighting • Requires security, visual and acoustic privacy	• Windows with blackout shading in case of using datashow
		Multi-purpose room	Storage	• Large surface • Flexible connectivity interfaces	• Flexible connectivity interfaces	• Depends on the event	• Natural lighting • Visible access • SAS space	/

2. Programming:

2.2. Comfort programming

Table B.4. Comfort programming, part 1. Source: Author

Function	Activity	Thermal comfort	Acoustic comfort	Visual comfort	Olfactory comfort
Retail	Shopping (Clothing, shoes, sportswear, accessory, optical, jewellery, furniture, tableware, home appliance, electronics) Supermarket	Preferred temperature in a small store 18°C, large store 18°C and storage room 15°C. Clothing: Temperature in a cabinet of fresh products (chilled) +8°C, dairy products and cooked meats +3°C, fresh meats poultry and fish 0°C and frozen foods -18°C. Supermarket: Preferred temperature in a changing room 21°C.	• Maximum ambient noise level in a store 50-55dB and a staff room 35-45dB. • Maximum NR in a store 35-45 and staff room 30-40.	Standard service illuminances in shops and supermarket 500 lux and in staff rooms 150 lux.	• Air infiltration for a small shop 1 change/hour, a large shop ½ change/hour and a storage room ½ change/hour. • Ventilation allowance for a small shop 0,33 W/m3°C, a large shop 0,17 W/m3°C and a storage room 0,17 W/m3°C. Clothing: • Air infiltration in a changing room 1½ change/hour • Ventilation allowance in a changing room 0,5 W/m3°C Shoes: Keep the try-on area aside from the display area.
Culinary	Reserve & eat (Restaurant) Quick meal (Fast food & cafeteria) Try & buy (Bakery & spices)	Kitchen must not have a direct sun light (preferred position is north). Use ranger hood in kitchen.	• Maximum ambient noise level in a restaurant 40-55dB, a cafe 50-55dB, a kitchen 55-65dB and staff room 35-45dB. • Maximum NR in a restaurant 35-40, a café 35-45, a kitchen 40-50 and staff room 30-40. Restaurant: • Isolate the kitchen to prevent noise penetrating to the public area. • Add sound absorbing materials for the public area, such as	Maintain a visual connection with the outside. Restaurant: Aside from culinary workshop, there shouldn't be a visual connection between the kitchen and the public area.	• Ensure continuous ventilation (natural or artificial). • Use ranger hood in kitchen.
Well being	Beauty & health (Beauty salon & SPA)	• Temp: changing room 20-22°C, wash room 24-26°C, cooling room ~ 18-20°C, rest room 20-22°C, massage room 20-22°C. • Humidity: 100°C: 2-5% rei. humidity, 80°C: 3-10% rei. humidity, 70°C: 5-15% rei. humidity, 60°C: 8-28% rei. humidity. • Continuous ventilation	Each room shall be acoustic resisting and absorbing.	No continuous visual connection from one room to another, and use folding screen in the case of more than 1 bed per room.	/
Leisure	Visual (Cinema) Gaming (Gaming room) Sport (Gym)	Ensure continuous ventilation (natural or artificial) due to the great number of people (metabolism activity) in one enclosed space.	• Maximum ambient noise level in a cinema 30-35dB and staff room 35-45dB. • Maximum NR in a cinema 30-35 and staff room 30-40. Cinema: Dry or dead acoustic with no reflected sound from the platform	Cinema: • Maximum distance from platform to the very far seat is maximum 20m. • Ensure great seating arrangement. • No visual connection with the outside.	/

Table B.4. Comfort programming, part 2. Source: Author

Function	Activity	Thermal comfort	Acoustic comfort	Visual comfort	Olfactory comfort
Culture	Exposition	• Temperature: 20-22C • RH (%): 40-45 • Acceptable for display of local materials	Noise levels should be controlled within zones by appropriate choices of material finishes on floors, walls and ceiling and the shaping of interior spaces to prevent flutter and unwanted amplifying effects.	• Direct sunlight should not fall on any collection item and UV radiation must be effectively eliminated from all light reaching a collection item • 50 lux on the most sensitive material such as paper • 200 lux on other sensitive materials such as wood, leather, and oil paint	• Air supply rate: 8L/person • Naturel ventilation or mechanical
	Artistic creation	/	/	• Naturel lighting is seen as the primary light source • 500-1000 lux	Naturel ventilation or mechanical
Education	Shopping (Souvenir, antique)	Preferred temperature in a small store 18°C, large store 18°C and storage room 15°C.	• Maximum ambient noise level in a store 50-55dB and a staff room 35-45dB. • Maximum NR in a store 35-45 and staff room 30-40.	Standard service illuminances in shops and supermarket 500 lux and in staff rooms 150 lux.	• ir infiltration for a small shop 1 change/hour, a large shop ½ change/hour and a storage room ½ change/hour. • Ventilation allowance for a small shop 0,33 W/m3°C, a large shop 0,17 W/m3°C and a storage room 0,17 W/m3°C.
	Reading	• Temperature: 20 +/- 2 C • RH (%): 50 +/- 5%	Carpet the store with sound-deadening heavy-duty carpet	• In the user area 250-300 lux • Reading and working 500 lux • Avoid direct sunshine as UV and heat radiation destroy paper and bindings	Air change (flow of outside air) 20m3/h x no. of people
Management	Administration	Temperature: 19-26 C	Noise levels should be controlled within zones by appropriate choices of material finishes on floors, walls and ceiling and the shaping of interior spaces to prevent flutter and unwanted amplifying effects.	• Naturel lighting is seen as the primary light source • 300-500 lux	Naturel ventilation or mechanical

2. Programming:

2.3. Quantitative programming

Table B.5. Quantitative programming, part 1. Source: Author

Function	Activity	Primary space	Secondary space	Space surface			Activity surface	
				Primary space	Secondary space	Total	Total	Percentage
Retail	Shopping	Small store - Display area (Clothes, sportswear, shoes, accessory, jewellery, optical)	• Changing – try on room • Storage • Staff room	45	• 5 • 10 • 5	65 x 20 = 1625	5785	8.1%
		Medium store - Display area (Sports equipment, tableware, home appliance, electronics, pharmacy)	• Storage • Staff room	100	• 20 • 10	130 x 20 = 2600		
		Large store - Display area (Supermarket, furniture)	• Storage • Staff room	450	• 60 • 10	520 x 2 = 1560		
Culinary	Reserve & eat	Restaurant - Dinning area	• Kitchen • Storage • Staff room	170	• 50 • 30 • 10	260 x 5 = 1300	2535	3.5%
	Coffee shops	Cafeteria - Waiting room		70	• 30 • 20 • 10	130 x 5 = 650		
	Quick meal	Fast food - Food court		20	• 20 • 20 • 5	65 x 6 = 390		
	Try & buy	Pastry & spice - Waiting room		25	• 20 • 15 • 5	65 x 3 = 195		
Cultural	Exposition & creation	Exhibition (Weaving & traditional sewing) Exhibition (Artistic poetry) Exhibition (Sand painting) Exhibition (Stringed instruments) Exhibition (Temporary)	• Lobby • Information sales • Office workroom • Workshop • Storage	60	• 5 • 5 • 15 • 30 • 15	130 x 1 = 130	2380	3.1 %
		Exterior art gallery	/	65	/	65 x 3 = 195		
	Planting & inter-active exposition	Interactive exposition	• Lobby • Information sales • Office workroom • Workshop • Storage	115	• 5 • 5 • 15 • 40 • 15	195 x 1 = 195		
	Audio-visual	Multimedia projection room	• Storage	100	30	130 x 4 = 520		
	Shopping	Souvenir	• Check-out • Sanitary • Collection storage	50	• 2 • 3 • 10	65 x 4 = 40		
	Cultural experi-ence	Tent of Henna and taking picture	/	10	/	10 x 4 = 40		
	Cook the same at home	Restaurant, workshop & store	• Workshop • Store • Kitchen • Storage • Staff room	120	• 30 • 20 • 30 • 20 • 10	260 x 2 = 520		

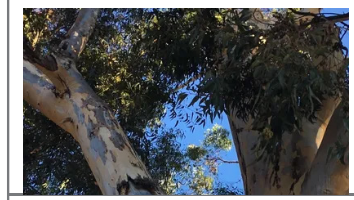
Table B.5. Quantitative programming, part 2. Source: Author

Function	Activity	Primary space	Secondary space	Space surface			Activity surface	
				Primary space	Secondary space	Total	Total	Percentage
Education	Reading	Bookstore	• Checkout • Stationary • Group study room • Staff offices • Storage	100	• 5 • 25 • 30 • 2 x 10 • 25	520	1040	1.4%
	Meeting & communication	Club Hub	• Reception • Quiet rooms • Kitchenette • Work room • Storage • Sanitary	31	• 2 • 2 x 10 • 2 • 2 x 10 • 15 • 10	260		
	Recycling	Workshop	• Lobby • Information sales • Office workroom • Storage	100	• 2 • 8 • 15 • 10	130 x 2 = 260		
Well being	Beauty & health	Beauty salon & spa (workspace)	• Reception • Waiting room • Storage • Staff room	85	• 2 • 8 • 15 • 10	130 x 2 = 260	260	0.3%
Leisure	Visual	Cinema (projection room)	• Reception • Snack area • Projection cabin • Storage • Staff room	180	• 10 • 20 • 10 • 30 • 10	260 x 4 = 1040	2860	4%
	Gaming	Gaming room (gaming area)	• Reception • Snack area • Storage • Staff room	680	• 10 • 40 • 40 • 10	780		
	Sport	Gym (work area)	• Reception • Refreshment area • Changing room • Sanitary • Storage • Staff room	60	• 2 • 8 • 15 • 20 • 20 • 5	260 x 2 = 520		
	Exploring (Kids area)	Game area	• Reception • Refreshment area • Changing room • Sanitary • Storage • Staff room	450	• 2 • 8 • 15 • 20 • 20 • 5	520		
Services	Welcoming	Reception	/	25	/	25	315	0.4 %
	Praying	Praying room	• Ablution • Shoes storage	50	• 10 • 5	65 x 2 = 130		
	Finance	Bank	• Reception • Storage • Director office	35	• 5 • 10 • 15	65 x 2 = 130		
	Emergency aid	Infirmary	/	30	/	30		

Table B.5. Quantitative programming, part 3. Source: Author

Function	Activity	Primary space	Secondary space	Space surface: Primary space	Space surface: Secondary space	Space surface: Total	Activity surface: Total	Activity surface: Percentage
Relaxation	Enjoying outdoor area	Garden (Oasis)	• Different zoning • Outside coffee shops • Plants exposition	/	/	3500	38195	53.6 %
	Playing	Outdoor playing area	• Different outdoor toys	/	/	/		
	Watching	Outdoor theatre	• Sitting area	75	/	75		
	Resting	Indoor patios	• Sitting area	780	/	78 x 4 = 3120		
Manage-ment	Administration	Director's office	Toilet	30	5	35	540	0.7 %
		Secretary	/	20	/	20		
		Archives	/	35	/	35		
		Offices	• Toilet • Kitchenette	30	• 10 • 10	30 x6 = 200		
		Meeting room	/	100	/	100		
		Multi-purpose room	Storage	130	20	150		
Support services	Technical ser-vices	Air conditioning room	/	40	/	40	970	1.3 %
		Heating room	/	40	/	40		
		Maintenance room	/	100	/	100		
		Security room	/	30	/	30		
		Storage	/	45	/	45 x15 = 675		
		Deposit area	/	45	/	45		
		Staff room	/	20	/	20 x 4 = 40		
Circulation		/			54750 x 30% = 16425			30%
Total				Total area: 71175	Building area: 2.5Ha			

Table C.1. Type of plants. Source: https://www.picturethisai.com/

Tree	Description	Water	Sunlight	Flower	Description	Water	Sunlight
	**Date palm** is an evergreen tree with a strong, upright trunk and gracefully arching, feather-like fronds.	Every 1-2 weeks	Full sun		Acacia flowers are common in Laghouat, and they produce small, white flowers that are a source of nectar for bees. The flowers are also edible and can be used to make tea.	Once a week	Full sun
	**Saharan cypress**: The Saharan cypress is a drought-tolerant tree that can grow in very dry conditions. They can grow up to 30 meters tall and have a distinctive, twisted trunk.	Every 1-2 weeks	Full sun		Desert roses are a type of succulent plant that grows in arid regions. The flowers are made up of tiny, overlapping petals that form a star-shaped pattern. Desert roses are often used as decorations or in traditional medicine.	Very little water, over watering can be harmful	Full sun
	**Acacia trees** are drought-tolerant and can grow in poor soil conditions. The trees produce small, white flowers that are a source of nectar for bees.	Every 1-2 weeks	Full sun		Hyacinths are a type of bulb flower They are known for their sweet scent and colorful blooms. Hyacinths can be grown in pots or in the ground, and they are a popular choice for springtime gardens.	Once every two weeks	-
	**Olive tree** is an evergreen tree or shrub with great agriculture importance. It represents peace and glory	Every 1-2 weeks	Full sun		Field Marigold is a species of flowering plant in the daisy family known by the common name field marigold.	Very little water, over watering can be harmful	Full sun
	**Juniper trees** are evergreen trees that can grow in very dry conditions. The trees produce small, blue berries that are edible. They are drought-tolerant and can survive with little water.	Every 1-2 weeks	-		Common Poppy is an annual herbaceous species of flowering plant in the poppy family Papaveraceae.	Once a week	Full sun
	**Arar tree** is an evergreen tree that is well-adapted to dry conditions. The arar tree is found in scattered locations throughout the Sahara	Every 1-2 weeks	-		Thymelaea virgata is a genus of about 30 species of evergreen shrubs and herbaceous plants in the family Thymelaeaceae, bearing small flowers ranging from yellow to green	Once a week	Full sun
	**River red gum** is a flowering tree provides shade from the intense heat.	Every 1-2 weeks	Full sun		Centaurea oranensis	Every 2-3 weeks	Full sun
	**Oriental plane** is a deciduous tree that will grow to 24m tall. Grow fast and make an excellent shade tree. It is usually a single-trunk tree with flaky brownish-gray bark and large maple- like leaves.	Every 3 weeks	Full sun		Starflower Pincushions is a species of flowering plant in the honeysuckle family, Caprifoliaceae. It is known by the common name starflower pincushions or starflower scabious. It is native to southwestern Europe and North Africa	Once a week	Full sun

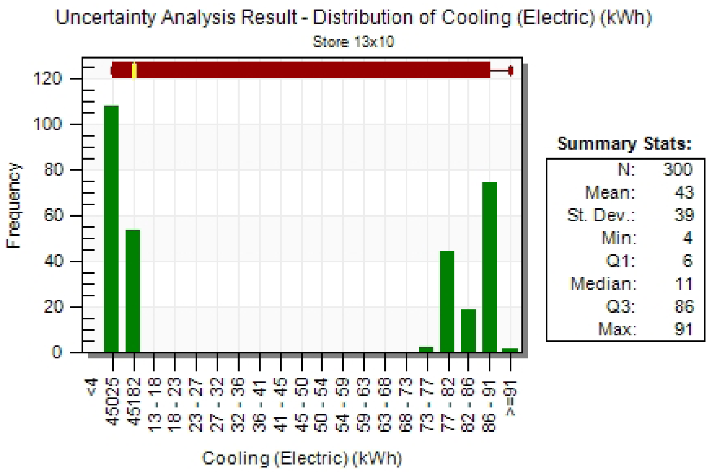


Figure C.1. Uncertainty analysis . Source: Design Builder

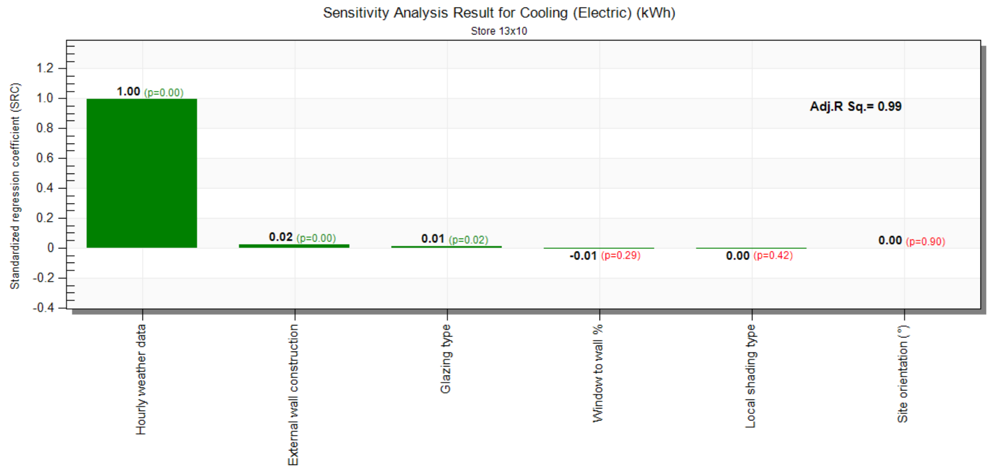


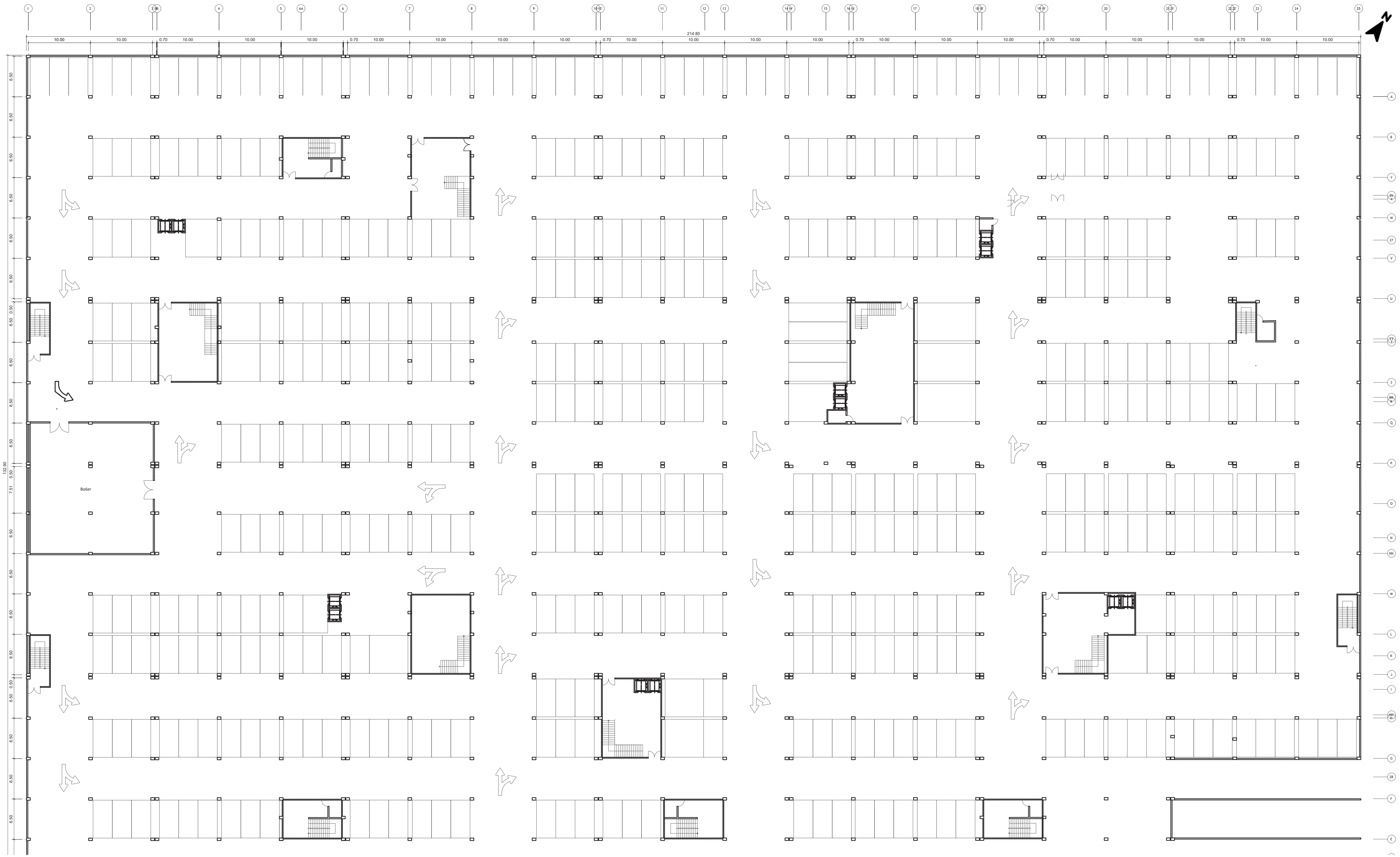
Figure C.2. Sensitivity analysis . Source: Design Builder

Iteration	Cooling (Electric) (kWh)	CO2 (kg)	External wall construction	Window to wall %	Glazing type	Local shading type	Site orientation (°)	Hourly weather data
127	4.388	25.459	Brick burned	10.000	Sgl Blue 6mm	Overhang + sidefins (1m...	315.000	Laghouat Last time plz
58	4.411	25.474	Brick burned	40.000	Sgl Blue 6mm	Overhang + sidefins (1m...	135.000	Laghouat Last time plz
49	4.476	25.513	Brick burned	40.000	Sgl Blue 6mm	1.0m projection Louvre	135.000	Laghouat Last time plz
287	4.514	25.531	Brick burned	30.000	Sgl Blue 6mm	Overhang + sidefins (1m...	180.000	Laghouat Last time plz
12	4.514	25.531	Brick burned	40.000	Sgl Blue 6mm	Overhang + sidefins (1m...	180.000	Laghouat Last time plz
267	4.534	25.531	Brick burned	40.000	Sgl Blue 6mm	Overhang + sidefins (1m...	270.000	Laghouat Last time plz
74	4.552	25.555	Brick burned	10.000	Sgl Blue 6mm	1.0m projection Louvre	45.000	Laghouat Last time plz
105	4.552	25.555	Brick burned	20.000	Sgl Blue 6mm	1.0m projection Louvre	45.000	Laghouat Last time plz
100	4.552	25.555	Brick burned	20.000	Sgl Blue 6mm	1.0m projection Louvre	45.000	Laghouat Last time plz
110	4.580	25.563	Brick burned	10.000	Sgl Blue 6mm	1.0m projection Louvre	270.000	Laghouat Last time plz
26	4.586	25.561	Brick burned	10.000	Sgl Blue 6mm	No shading	225.000	Laghouat Last time plz
290	4.586	25.561	Brick burned	40.000	Sgl Blue 6mm	No shading	225.000	Laghouat Last time plz
282	4.629	25.592	Brick burned	40.000	Sgl Blue 6mm	1.0m Overhang	180.000	Laghouat Last time plz
198	4.633	25.597	Brick burned	30.000	Sgl Blue 6mm	No shading	45.000	Laghouat Last time plz

Figure C.3. Simulation results . Source: Design Builder

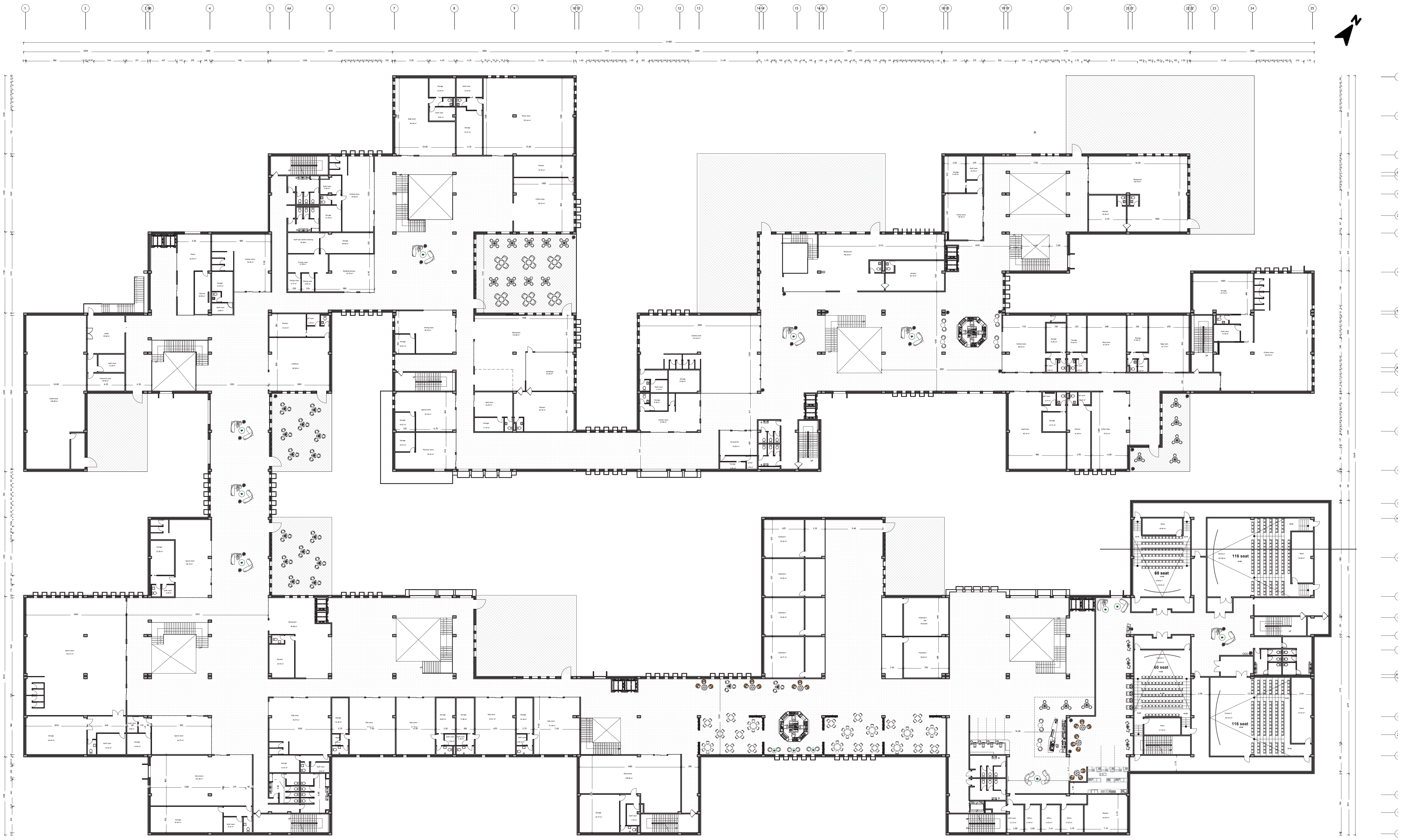
	Info	Extra Output	Extra Output	Variable1	Variable2	Variable3	Variable4	Variable5	Variable	
	Iteration	Cooling (Electric) (kWh)	CO2 (kg)	External wall construction	Window to wall %	Glazing type	Local shading type	Site orientation (°)	Hourly weather data	Identification of 4 combines vriables (1, 2,3 and 4) in each row
1	185	4.398	25.463	Brick burned	20	Sgl Blue 6mm	Overhang + sidefins (1m projection)	315	Laghouat Last time plz	Brick burned20Sgl Blue 6mmOverhang + sidefins (1m projection)
2	105	4.455	25.497	Brick burned	10	Sgl Blue 6mm	Overhang + sidefins (1m projection)	225	Laghouat Last time plz	Brick burned10Sgl Blue 6mmOverhang + sidefins (1m projection)
3	113	4.483	25.512	Brick burned	30	Sgl Blue 6mm	Overhang + sidefins (1m projection)	90	Laghouat Last time plz	Brick burned30Sgl Blue 6mmOverhang + sidefins (1m projection)
4	227	4.483	25.512	Brick burned	10	Sgl Blue 6mm	Overhang + sidefins (1m projection)	90	Laghouat Last time plz	Brick burned10Sgl Blue 6mmOverhang + sidefins (1m projection)
5	78	4.487	25.517	Brick burned	40	Sgl Blue 6mm	1.0m projection Louvre	135	Laghouat Last time plz	Brick burned40Sgl Blue 6mm1.0m projection Louvre
6	191	4.5	25.522	Brick burned	30	Sgl Blue 6mm	Overhang + sidefins (1m projection)	0	Laghouat Last time plz	Brick burned30Sgl Blue 6mmOverhang + sidefins (1m projection)
7	42	4.571	25.559	Brick burned	10	Sgl Blue 6mm	Overhang + sidefins (1m projection)	180	Laghouat Last time plz	Brick burned10Sgl Blue 6mmOverhang + sidefins (1m projection)
8	181	4.582	25.563	Brick burned	30	Sgl Blue 6mm	1.0m projection Louvre	270	Laghouat Last time plz	Brick burned30Sgl Blue 6mm1.0m projection Louvre
9	63	4.6	25.565	Brick burned	10	Sgl Blue 6mm	1.0m Overhang	270	Laghouat Last time plz	Brick burned10Sgl Blue 6mm1.0m Overhang
10	71	4.6	25.565	Brick burned	10	Sgl Blue 6mm	1.0m Overhang	270	Laghouat Last time plz	Brick burned10Sgl Blue 6mm1.0m Overhang
11	109	4.652	25.593	Brick burned	20	Sgl Blue 6mm	No shading	315	Laghouat Last time plz	Brick burned20Sgl Blue 6mmNo shading
12	125	4.664	25.61	Brick burned	40	Dbl Clr 3mm/13mm Arg	Overhang + sidefins (1m projection)	225	Laghouat Last time plz	Brick burned40Dbl Clr 3mm/13mm ArgOverhang + sidefins (1m projection)
13	131	4.669	25.616	Brick burned	30	Sgl Blue 6mm	No shading	135	Laghouat Last time plz	Brick burned30Sgl Blue 6mmNo shading
14	83	4.695	25.618	Brick burned	30	Dbl Clr 3mm/13mm Arg	1.0m Overhang	315	Laghouat Last time plz	Brick burned30Dbl Clr 3mm/13mm Arg1.0m Overhang
15	98	4.695	25.618	Brick burned	40	Dbl Clr 3mm/13mm Arg	1.0m Overhang	315	Laghouat Last time plz	Brick burned40Dbl Clr 3mm/13mm Arg1.0m Overhang
16	280	4.695	25.618	Brick burned	30	Dbl Clr 3mm/13mm Arg	1.0m Overhang	315	Laghouat Last time plz	Brick burned30Dbl Clr 3mm/13mm Arg1.0m Overhang
17	160	4.708	25.634	Brick burned	10	Sgl Blue 6mm	No shading	0	Laghouat Last time plz	Brick burned10Sgl Blue 6mmNo shading
18	115	4.71	25.636	Brick burned	40	Dbl Clr 3mm/13mm Arg	Overhang + sidefins (1m projection)	0	Laghouat Last time plz	Brick burned40Dbl Clr 3mm/13mm ArgOverhang + sidefins (1m projection)
19	140	4.716	25.639	Brick burned	20	Dbl Clr 3mm/13mm Arg	1.0m Overhang	135	Laghouat Last time plz	Brick burned20Dbl Clr 3mm/13mm Arg1.0m Overhang
20	76	4.732	25.648	Brick burned	10	Dbl Elec Abs Bleached 6mm/13mm Arg	Overhang + sidefins (1m projection)	45	Laghouat Last time plz	Brick burned10Dbl Elec Abs Bleached 6mm/13mm ArgOverhang + sidefins (1m
21	172	4.74	25.642	Brick burned	10	Dbl Elec Abs Bleached 6mm/13mm Arg	1.0m Overhang	315	Laghouat Last time plz	Brick burned10Dbl Elec Abs Bleached 6mm/13mm Arg1.0m Overhang
22	3	4.742	25.655	Brick burned	20	Dbl Clr 3mm/13mm Arg	1.0m Overhang	45	Laghouat Last time plz	Brick burned20Dbl Clr 3mm/13mm Arg1.0m Overhang
23	176	4.743	25.654	Brick burned	40	Dbl Elec Abs Bleached 6mm/13mm Arg	Overhang + sidefins (1m projection)	90	Laghouat Last time plz	Brick burned40Dbl Elec Abs Bleached 6mm/13mm ArgOverhang + sidefins (1m
24	177	4.743	25.654	Brick burned	20	Dbl Elec Abs Bleached 6mm/13mm Arg	Overhang + sidefins (1m projection)	90	Laghouat Last time plz	Brick burned20Dbl Elec Abs Bleached 6mm/13mm ArgOverhang + sidefins (1m
25	133	4.744	25.65	Brick burned	10	Dbl Clr 3mm/13mm Arg	1.0m Overhang	225	Laghouat Last time plz	Brick burned10Dbl Clr 3mm/13mm Arg1.0m Overhang
26	150	4.744	25.65	Brick burned	40	Dbl Clr 3mm/13mm Arg	1.0m Overhang	225	Laghouat Last time plz	Brick burned40Dbl Clr 3mm/13mm Arg1.0m Overhang
27	54	4.759	25.663	Brick burned	10	Dbl Elec Abs Bleached 6mm/13mm Arg	Overhang + sidefins (1m projection)	0	Laghouat Last time plz	Brick burned10Dbl Elec Abs Bleached 6mm/13mm ArgOverhang + sidefins (1m
28	241	4.766	25.671	Brick burned	30	Sgl Blue 6mm	No shading	90	Laghouat Last time plz	Brick burned30Sgl Blue 6mmNo shading
29	93	4.772	25.669	Brick burned	20	Dbl Clr 3mm/13mm Arg	1.0m projection Louvre	270	Laghouat Last time plz	Brick burned20Dbl Clr 3mm/13mm Arg1.0m projection Louvre
30	134	4.772	25.669	Brick burned	10	Dbl Clr 3mm/13mm Arg	1.0m projection Louvre	270	Laghouat Last time plz	Brick burned10Dbl Clr 3mm/13mm Arg1.0m projection Louvre
31	151	4.772	25.669	Brick burned	10	Dbl Clr 3mm/13mm Arg	1.0m projection Louvre	270	Laghouat Last time plz	Brick burned10Dbl Clr 3mm/13mm Arg1.0m projection Louvre
32	70	4.794	25.677	Brick burned	40	Dbl Elec Abs Bleached 6mm/13mm Arg	1.0m Overhang	225	Laghouat Last time plz	Brick burned40Dbl Elec Abs Bleached 6mm/13mm Arg1.0m Overhang
33	84	4.799	25.686	Brick burned	30	Dbl Clr 3mm/13mm Arg	1.0m Overhang	90	Laghouat Last time plz	Brick burned30Dbl Clr 3mm/13mm Arg1.0m Overhang
34	120	4.817	25.7	Brick burned	40	Dbl Clr 3mm/13mm Arg	1.0m projection Louvre	45	Laghouat Last time plz	Brick burned40Dbl Clr 3mm/13mm Arg1.0m projection Louvre
35	164	4.833	25.699	Brick burned	30	Dbl Elec Abs Bleached 6mm/13mm Arg	No shading	225	Laghouat Last time plz	Brick burned30Dbl Elec Abs Bleached 6mm/13mm ArgNo shading
36	231	4.836	25.708	Brick burned	30	Dbl Clr 3mm/13mm Arg	1.0m projection Louvre	180	Laghouat Last time plz	Brick burned30Dbl Clr 3mm/13mm Arg1.0m projection Louvre
37	242	4.836	25.708	Brick burned	10	Dbl Clr 3mm/13mm Arg	1.0m projection Louvre	180	Laghouat Last time plz	Brick burned10Dbl Clr 3mm/13mm Arg1.0m projection Louvre
38	210	4.847	25.711	Brick burned	40	Dbl Elec Abs Bleached 6mm/13mm Arg	1.0m Overhang	0	Laghouat Last time plz	Brick burned40Dbl Elec Abs Bleached 6mm/13mm Arg1.0m Overhang
39	243	4.86	25.724	Brick burned	20	Dbl Clr 3mm/13mm Arg	No shading	45	Laghouat Last time plz	Brick burned20Dbl Clr 3mm/13mm ArgNo shading
40	235	4.875	25.732	Brick burned	20	Dbl Elec Abs Bleached 6mm/13mm Arg	1.0m projection Louvre	45	Laghouat Last time plz	Brick burned20Dbl Elec Abs Bleached 6mm/13mm Arg1.0m projection Louvre
41	12	4.902	25.746	Brick burned	10	Dbl Clr 3mm/13mm Arg	No shading	180	Laghouat Last time plz	Brick burned10Dbl Clr 3mm/13mm ArgNo shading
42	167	4.902	25.746	Brick burned	30	Dbl Clr 3mm/13mm Arg	No shading	180	Laghouat Last time plz	Brick burned30Dbl Clr 3mm/13mm ArgNo shading

Figure C.4. Interpretation results in Excel . Source: Author

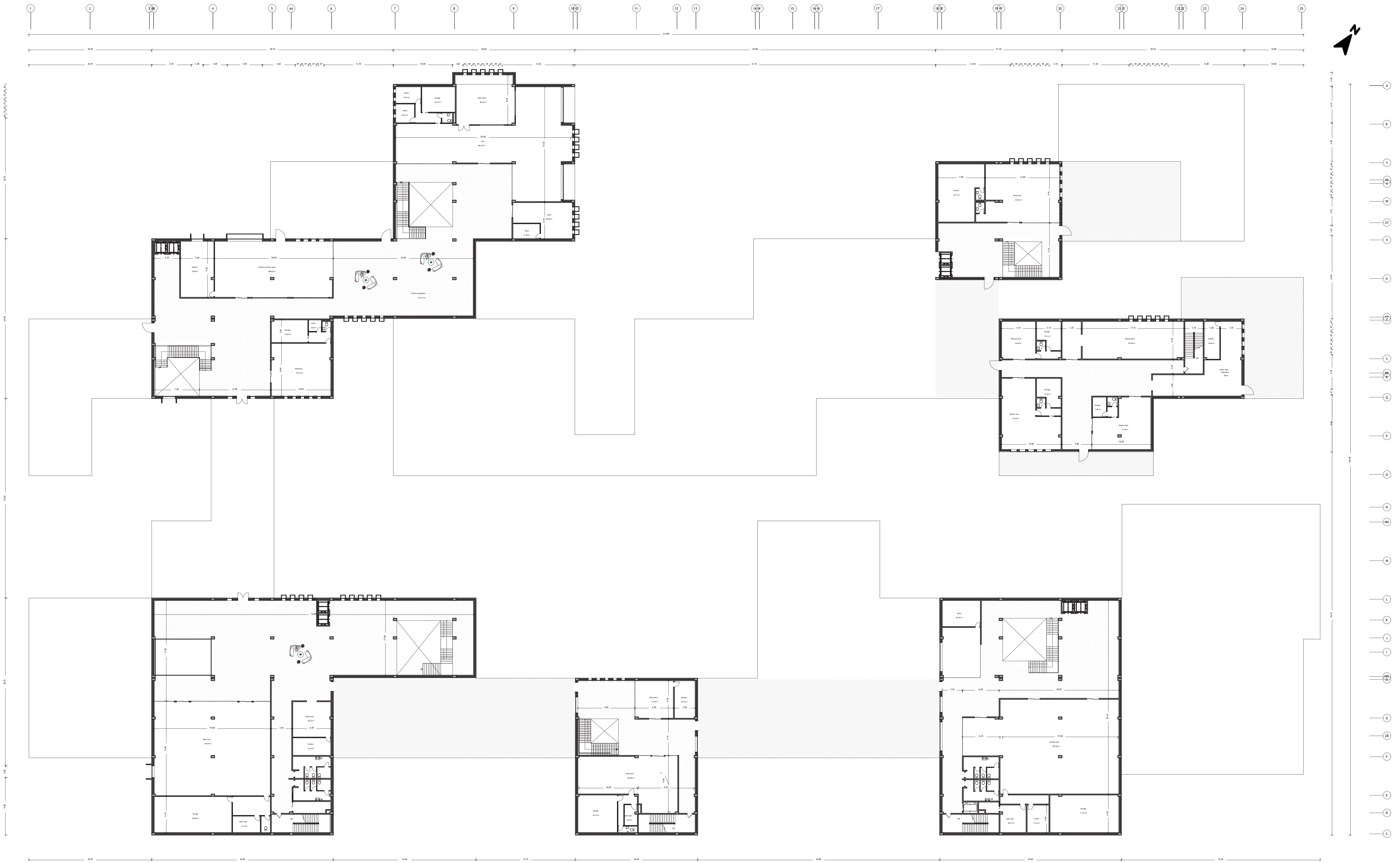


Underground floor plan scale: 1\600

Ground floor plan scale: 1\600

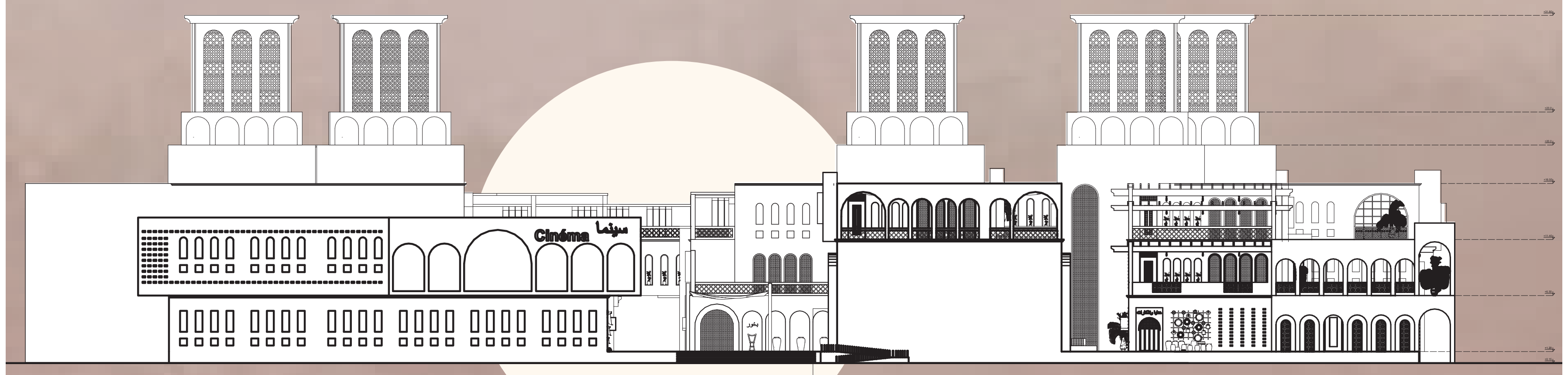


First floor plan scale: 1\600



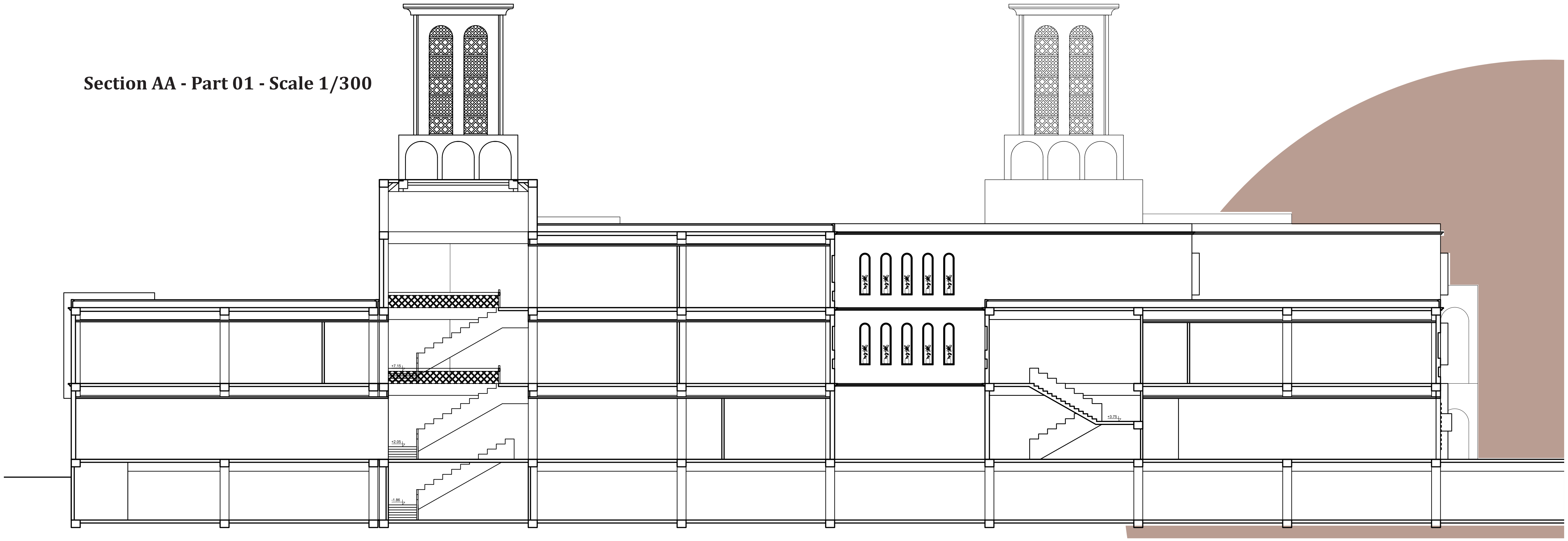
Third floor plan scale: 1\600

Urban elevation - Scale 1/600

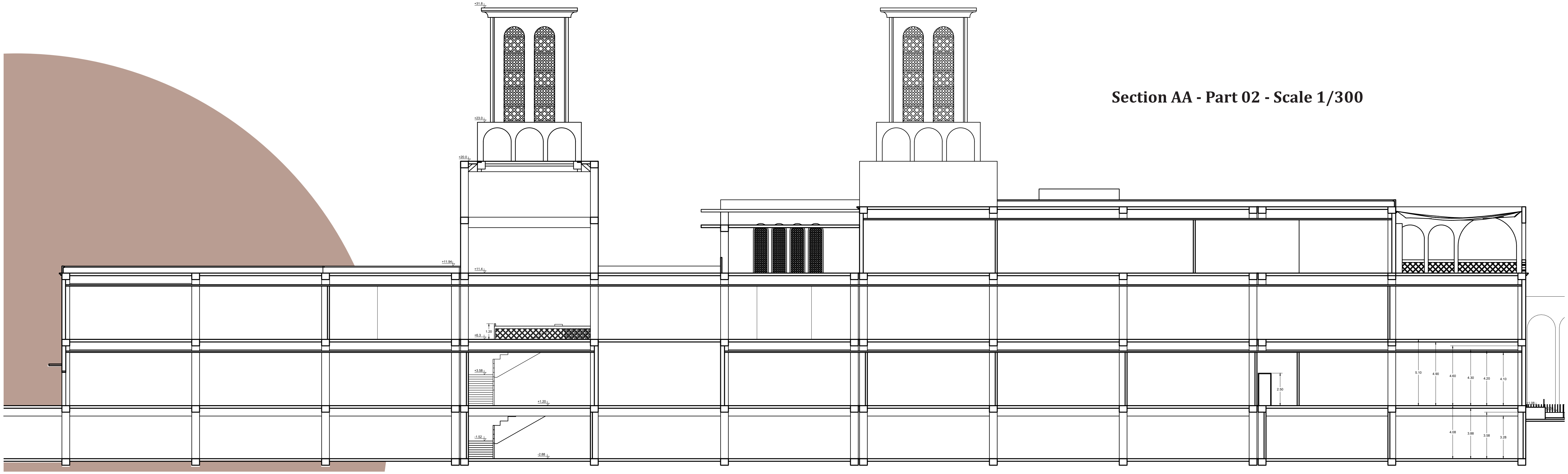


Secondary road elevation - Scale 1/600

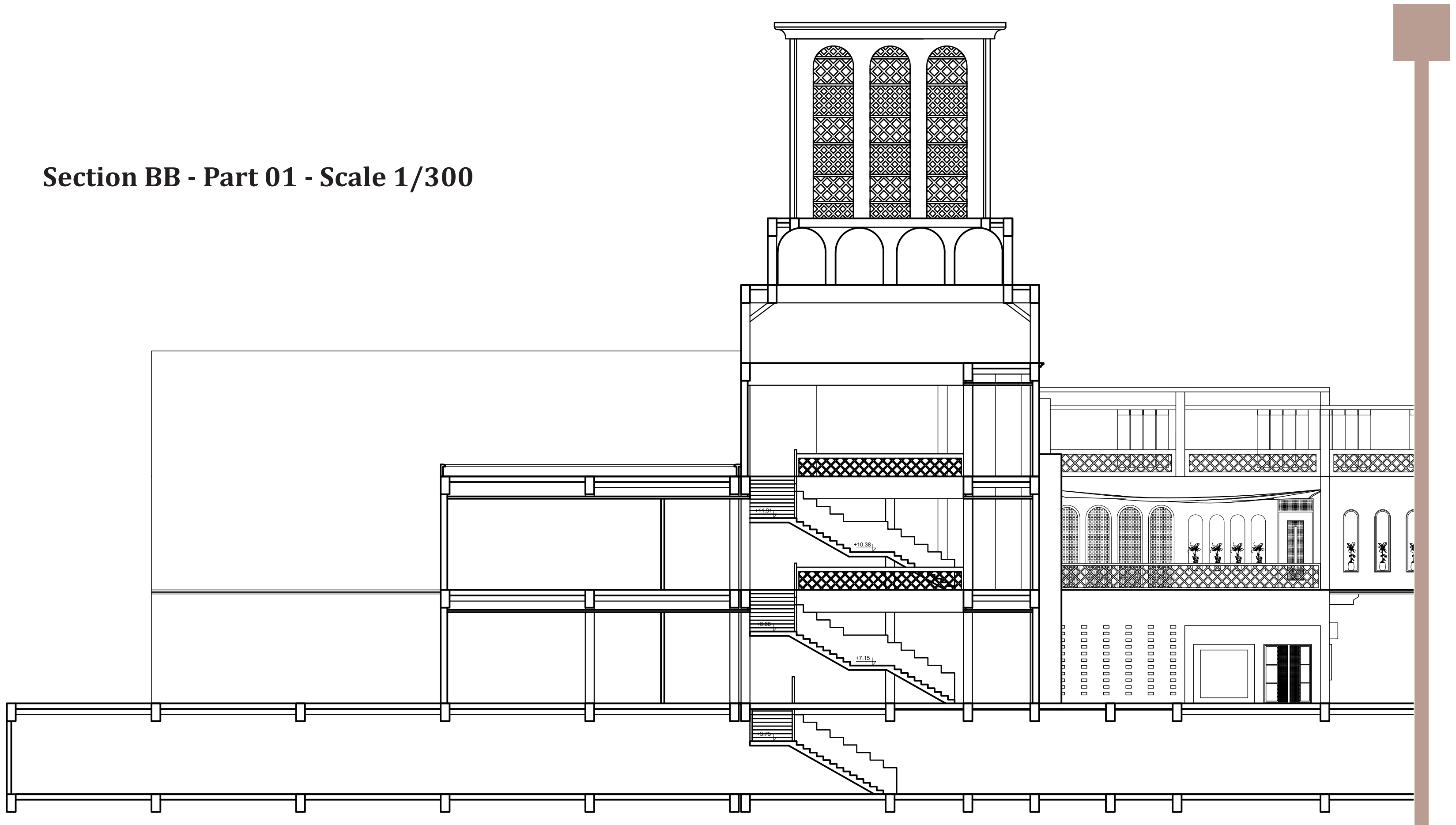
Section AA - Part 01 - Scale 1/300



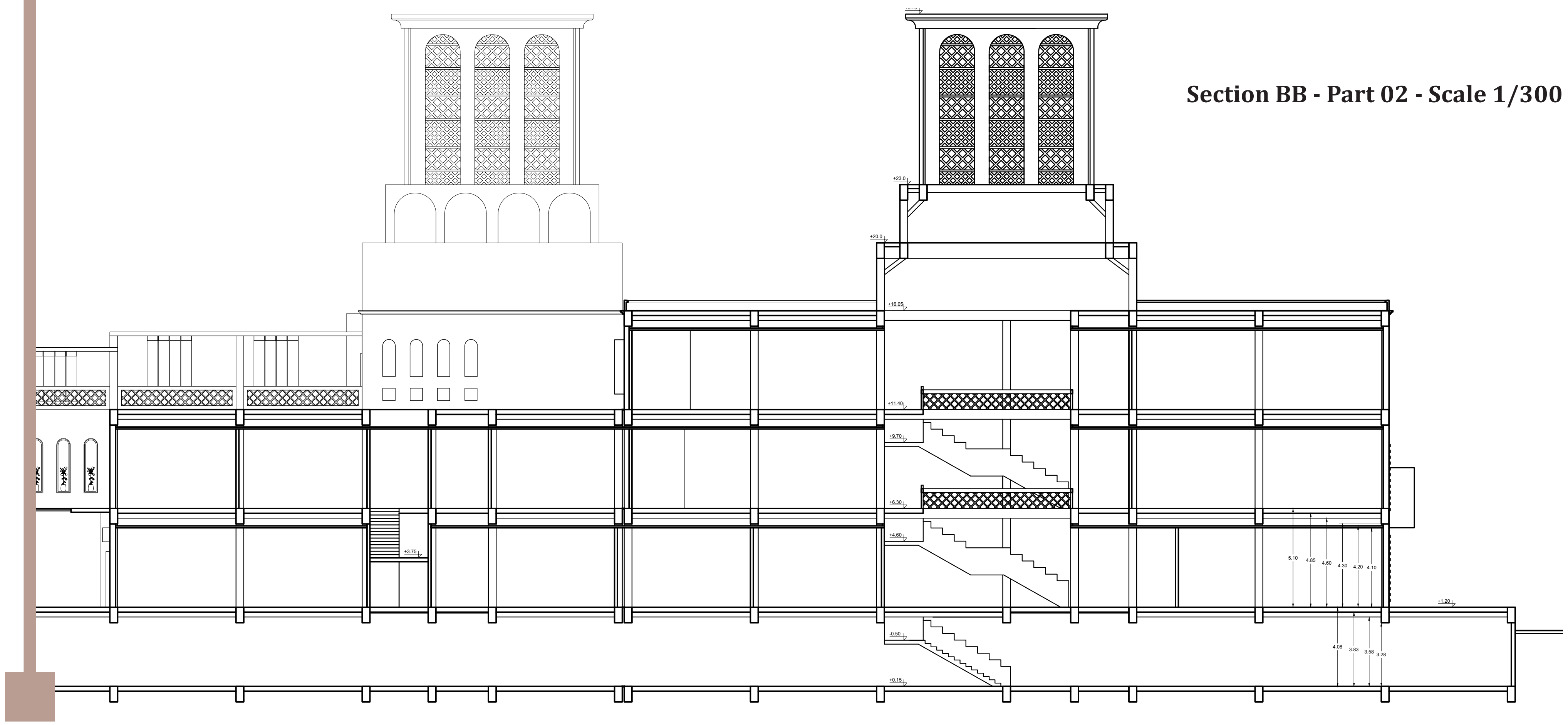
Section AA - Part 02 - Scale 1/300

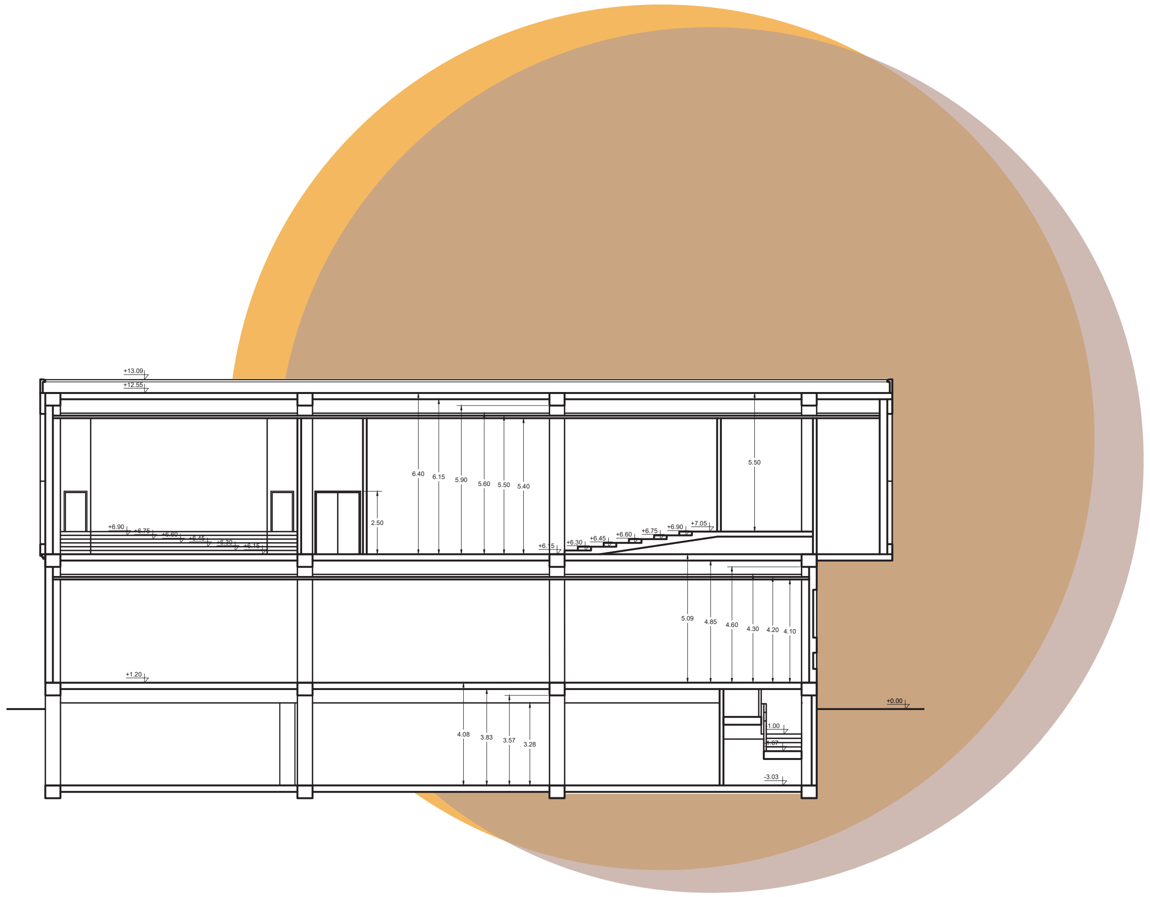


Section BB - Part 01 - Scale 1/300



Section BB - Part 02 - Scale 1/300





Section CC - Scale 1/300


Immersion exhibit


حانوت السجاد


محل البستنة


هدايا وتذكارات


ورشة موسيقى


محل الأثاث المنزلي


محل الورود