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Gratitude and appreciation

Allah will raise those who have believed among you and those who were given knowledge, by degrees."

(Surah Al-Mujadila – Verse 11)

All praise is due to Allah, by whose grace all good things are accomplished.

Praise be to the One who illuminated our hearts with the light of knowledge, who made the paths of learning accessible to us, and who granted us the patience and perseverance to complete this academic journey.

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May Allah reward you abundantly and elevate you in knowledge and virtue.

Dedication

I dedicate this thesis to all those who stood by me throughout this journey.

To my parents, for their unconditional love, unwavering support, and countless sacrifices, which have been the foundation of my success.

To my entire family, for their constant encouragement and kind presence.

To my loyal friends, for their attentive ears, precious help, and the shared moments that lightened the load of this adventure.

To you all, from the depths of my heart—thank you.

Abdesslame Djellabi

Abstract

This thesis investigates the integration of Sun Tunnel systems—also known as Sun tunnels—within the design of commercial architecture, particularly shopping centers located in hot and arid climates such as Biskra, Algeria. The work is structured into three main chapters: a theoretical overview of natural lighting in architecture, a comparative analysis of international and national commercial case studies, and a practical project proposal supported by a functional prototype.

The theoretical chapter explores the evolution and benefits of natural light, the principles of visual comfort, and the technical characteristics of tubular daylighting systems. The analytical chapter presents six commercial buildings analyzed across criteria such as spatial organization, circulation, and lighting strategies. The findings reveal significant gaps in daylighting integration in Algerian shopping malls.

The practical chapter proposes a shopping center design that incorporates a Sun Tunnel system tailored to local environmental and urban constraints. A physical prototype with a solar tracking mechanism was built and tested, demonstrating the system's efficiency in delivering daylight to deep interior zones with zero energy consumption.

This study concludes that Sun Tunnels offer a viable, sustainable solution to improve energy efficiency, indoor comfort, and architectural quality in commercial environments. The research also establishes a replicable methodology that bridges environmental technology and architectural design.
Keywords: Sun Tunnel, Light Pipe, Daylighting, Visual Comfort, Sustainable Architecture, Shopping Center, Biskra, Energy Efficiency, Solar Tracking, Architectural Integration.

الملخص

تتناول هذه الأطروحة دمج نظام الأنابيب الضوئية (Sun Tunnels) في تصميم المراكز التجارية، لا سيما تلك الواقعة في المناخات الحارة والجافة مثل مدينة بسكرة، الجزائر. تم تقسيم البحث إلى ثلاثة فصول رئيسية: فصل نظري يستعرض تطور الضوء الطبيعي في العمارة، فصل تحليلي يقارن بين مشاريع تجارية دولية ووطنية، وفصل تطبيقي يتضمن مشروعًا معماريًا مدعومًا بنموذج تجريبي فعلي.

يستعرض الفصل النظري مزايا الضوء الطبيعي، ومتطلبات الراحة البصرية، والخصائص التقنية لأنظمة الإضاءة الطبيعية الأنبوبية. ويقدم الفصل التحليلي دراسة مقارنة لستة مراكز تجارية من حيث التنظيم الفضائي، والحركة، واستراتيجيات الإضاءة، ويُظهر وجود نقص كبير في استغلال الضوء الطبيعي في المراكز التجارية الجزائرية.

أما الفصل التطبيقي، فقد تم فيه اقتراح تصميم لمركز تجاري يدمج نظام الأنابيب الضوئية، مع مراعاة المعطيات المناخية والحضرية المحلية. وقد تم تصنيع نموذج تجريبي مزود بآلية تتبع شمسي، أظهر فعاليته في إيصال الضوء الطبيعي إلى أعماق الفضاء الداخلي دون استهلاك للطاقة.

خلصت هذه الدراسة إلى أن الأنابيب الضوئية تمثل حلاً فعالاً ومستداماً لتحسين كفاءة الطاقة، وراحة المستخدم، وجودة التصميم المعماري في الفضاءات التجارية. كما قدمت منهجية قابلة للتطبيق تعزز التكامل بين التكنولوجيا البيئية والتصميم المعماري.

الكلمات المفتاحية: الأنابيب الضوئية، الإضاءة الطبيعية، الراحة البصرية، العمارة المستدامة، المركز التجاري، بسكرة، كفاءة الطاقة، التتبع الشمسي، التكامل المعماري.

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Introductory chapter

I Introduction

The architectural discipline has long recognized the profound impact of natural light on the built environment. As famously stated, "L'architecture est le jeu savant, correct et magnifique des volumes assemblés sous la lumière" (Thongtha, A., Lee, S., & Kim, J, 2023) architecture is inherently shaped and defined by light. Over the years, the rapid pace of urbanization and technological growth has placed enormous stress on global energy systems, with buildings accounting for nearly 40% of total energy consumption and a significant portion of greenhouse gas emissions. This has intensified the urgency of adopting sustainable architectural practices that reduce energy use and enhance indoor environmental quality. Among these, natural lighting strategies—particularly daylighting—have emerged as both environmentally responsible and architecturally enriching solutions.

Natural lighting, the use of sunlight to illuminate interior spaces, serves both aesthetic and functional purposes in architectural design. Beyond its visual and psychological benefits, daylighting plays a vital role in energy conservation. Artificial lighting alone accounts for 20–30% of the total energy consumed in commercial buildings and up to one-third in office spaces (Song, X., Wang, L., & Zhang, Y, 2023).Reducing this dependency through daylight integration has become a core goal in energy-conscious design. Well-implemented daylighting systems can save up to 63% of lighting energy with manual operation and up to 68% in automated setups, offering significant operational cost reductions and environmental advantages.

Historically, daylight was the primary source of illumination until the widespread electrification of the mid-20th century. However, the energy crises of the 1970s reawakened architectural interest in natural lighting. Since then, advances in materials, optical devices, and digital simulation tools have enabled a more precise and efficient approach to daylight design. Today, daylighting goes beyond energy savings—it is increasingly recognized as a driver of health, productivity, and occupant well-being. Exposure to natural light has been shown to regulate circadian rhythms, improve cognitive function, and reduce stress (ronstad, T. V., Bjorvatn, B., & Pallesen, S, 2022).

Among the most promising innovations in daylighting are sun tunnel systems, also known as sun tunnels. These systems are designed to transmit daylight into deep or enclosed interior zones that lack direct access to windows or skylights. A typical sun tunnel consists of three components: a rooftop collector (or dome) that captures sunlight, a highly reflective tubular shaft that channels the light, and a diffuser that distributes the light uniformly within the interior space. By employing the principle of total internal reflection, sun tunnels can deliver full-spectrum natural light to spaces that would otherwise rely entirely on artificial lighting.

According to (Thongtha, A., Lee, S., & Kim, J, 2023), the use of horizontal hollow light tubes—particularly in windowless or deep-plan buildings—can significantly reduce lighting energy demands. Sun tunnels offer unique advantages compared to traditional glazing or skylight systems. They provide excellent thermal insulation, minimize glare, eliminate heat gain, and adapt well to both new construction and retrofit applications. These characteristics make sun tunnels especially valuable in dense urban environments, where building adjacencies often obstruct lateral daylight penetration.

However, their performance is influenced by several key parameters, including the length and diameter of the tube, the quality of the reflective material, and the solar angle throughout the day. As the pipe length increases, transmission efficiency decreases due to cumulative reflection losses. To overcome such limitations, hybrid daylighting systems have been developed that combine sun tunnels with heliostats (sun-tracking mirrors) or Fresnel lenses to enhance light collection and transmission under varying solar conditions.

Comparative analyses have shown that light pipes perform best over short to medium distances and offer an ideal solution for many small- to mid-sized building zones. In contrast, optical fiber systems can transmit light over longer distances with greater design flexibility but at higher costs and with more complex maintenance needs. Heliostats provide dynamic light redirection capabilities suited for large-scale or atrium-type spaces, albeit with increased system complexity and cost (Song, X., Wang, L., & Zhang, Y, 2023).

The growing emphasis on sustainable urban development, supported by frameworks such as the United Nations Sustainable Development Goals (SDGs), has further elevated the importance of natural lighting strategies in architecture. As climate change and urban densification challenge our ability to access and distribute daylight equitably, scalable and low-impact systems like sun tunnels offer practical, affordable, and environmentally aligned solutions. Their ability to enhance indoor quality, reduce energy loads, and support biophilic design principles positions them as essential tools in the future of building design.

II Problematic

As urban centers grow denser and more complex, the design of commercial buildings such as shopping centers increasingly demands solutions that are not only functional but also energy-efficient and responsive to human comfort. Among the pressing challenges in such spaces is the high reliance on artificial lighting, which contributes significantly to operational energy consumption and environmental impact. In this context, harnessing natural daylight through architectural systems offers a sustainable alternative. However, conventional daylighting strategies often fall short in reaching deep or windowless zones commonly found in large-scale commercial structures.

Sun Tunnels, or tubular daylighting devices, have emerged as a promising solution for delivering natural light into interior spaces that lack direct access to exterior walls or roofs. These systems are designed to capture, channel, and diffuse sunlight into building interiors, using reflective tubes and diffusers to optimize light distribution. Their application is particularly relevant in commercial environments such as shopping centers, where deep floor plans and complex spatial layouts create challenges for daylight penetration.

In exploring the potential of Sun Tunnels as an innovative daylighting solution within commercial architecture, two critical questions arise:

To what extent can Sun Tunnel systems provide sufficient natural lighting inside commercial spaces?

How effective are these systems in reducing energy consumption related to artificial lighting?

These questions are central to understanding the viability of Sun Tunnels not only as a passive lighting technology but also as a contributor to sustainable development goals in architecture. A study by (AlQudah, A. A., & Freewan, A. A., 2020) emphasizes that traditional daylighting methods often fail to meet the lighting requirements of enclosed architectural spaces, particularly in urban contexts. In such scenarios, Sun Tunnel systems have been proposed to bridge the gap by extending daylight deeper into the interior, thereby enhancing the quality of illumination and reducing energy dependence.

The effectiveness of such systems has been demonstrated in controlled environments, such as tunnels, where daylighting technologies based on optical fibers or similar principles have significantly reduced artificial lighting loads while improving luminance uniformity and visual comfort (Shi, J., Li, Q., & Sun, Y., 2023)Although the architectural application context differs, these results highlight the energy-saving potential and lighting quality achievable through advanced daylighting strategies.

Despite these promising outcomes, challenges remain. Variations in solar availability, orientation constraints, and building geometry affect the consistency and adequacy of natural light provided by Sun Tunnels. Furthermore, their integration into commercial spaces must consider architectural constraints, regulatory limitations, and user comfort expectations. The degree to which these systems can contribute to both functional lighting and measurable energy savings in a shopping center context remains an open and important inquiry.

III Hypothesis

The integration of the Sun Tunnel system into architectural design, when based on carefully studied geometric, dimensional, and architectural criteria, is presumed to lead to measurable improvements in architectural comfort. This hypothesis suggests that by achieving adequate levels of natural lighting through established design standards, Sun Tunnels will reduce the need for artificial lighting, thereby lowering energy consumption and contributing to more sustainable building performance.

IV Objectives

In response to the growing demand for sustainable and energy-efficient architectural solutions, this study evaluates the integration of the Sun Tunnels system into shopping center design to ensure acceptable levels of natural lighting and reduce reliance on artificial lighting, thereby enhancing energy efficiency and environmental performance. The study aims to achieve the following specific objectives:

- To study the geometric, dimensional, and architectural characteristics of sun tunnels relevant to building design.
- To test the amount of daylight that Sun Tunnels can deliver in indoor commercial spaces.
- To estimate the reduction in artificial lighting and electricity consumption due to the use of Sun Tunnels.
- To develop simple design strategies for integrating Sun Tunnels into shopping center architecture.

V Research methodology

The research methodology outlines the systematic approach employed to investigate and address the research questions concerning natural lighting solutions and energy saving in the built environment. This chapter provides a detailed explanation of the methods, tools, and processes used to collect, analyze, and interpret data. It ensures the reliability, validity, and relevance of the findings to the study's objectives.

The research will be organized into four main chapters:

- **Introductory Chapter**: This chapter will provide a general introduction, including the problem statement, the hypothesis and the research objectives.
- **Theoretical Chapter**: This section is divided into three parts. The first part will focus on defining natural lighting, its role in architecture and its history, as well as the systems that have been created to provide it in sustainable buildings. The second part of this chapter will define this system in detail, its advantages, disadvantages, elements, and even its importance in architecture. The last part will define commerce and the center, as well as all the criteria for designing shopping centers and their organizational spaces.
- **Practical chapter**: This section includes two parts. The first is the analytical part, which includes analyzing examples to understand the various project criteria, including formal, functional, constructive, structural, and other aspects, and proposing a program. In addition, we will analyze the site and its climatic features using specialized climate analysis programs that help in the design process. As for the second, which is the application topic, this chapter will be devoted to the proposed project, detailing the project program, the methodology through which the project was formed, the various graphic representations, and the project's working method.

Theoretical chapter

Introduction

Natural lighting has long been recognized as a fundamental element in architectural design, not only for its aesthetic and psychological benefits but also for its role in promoting energy efficiency and environmental sustainability. As the built environment increasingly moves toward low-energy and occupant-centered solutions, daylight has emerged as a powerful tool for reducing reliance on artificial lighting and improving indoor comfort.

This theoretical chapter explores the importance of natural light in architecture by tracing its historical evolution, physical characteristics, and impact on human perception and well-being. It then focuses on systems developed to optimize daylight distribution—particularly light pipes (sun tunnels)—which have proven effective in bringing natural light into deep or enclosed interior spaces. Their components, performance factors, advantages, and challenges are examined in depth.

The chapter concludes by situating these concepts within the context of shopping centers, highlighting how daylighting strategies, and specifically light pipe systems, can contribute to more sustainable, energy-efficient commercial environments. This theoretical foundation supports the practical application and analysis that follow in the later sections of the thesis.

VI First part

VI.1 The history of evolution of natural light in architectural

Natural light has undergone a major transformation in built spaces. Initially the sole light source, sunlight has gradually been supplemented—and often replaced—by artificial lighting. The past century's rapid adoption of electrical lighting has prioritized consistent illumination levels, often at the cost of a dynamic indoor atmosphere shaped by the sun's natural movement and seasonal changes. This transition not only heightens energy demands but also weakens the connection between interior and exterior environments.

Primitive uses of natural light can be traced back to the strong rays penetrating the darkness of caves (Singh AP, 2018, p. 28)Throughout history, natural light has served as a primary source of illumination, utilized with varying degrees of control in different shelters built by humans in their quest for survival and comfort. The artistic intuition behind the design of light openings in various surfaces has created a unique sense of place. Daylight has also been associated with significant symbolic meanings based on how it enters a space and casts shadows on different surfaces.

Daylight is often linked to symbolic meanings such as cleanliness, purity, knowledge, and the divine, in addition to its primary function of illuminating spaces. The periods have been classified chronologically into three categories of preindustrial, industrial, and postindustrial architectural periods in line with the technological developments witnessed during each period. ((Florence nyole, 2004, p. 10)

VI.1.1 Preindustrial architecture

In the preindustrial period, daylight served as the main source of illumination, symbolizing cleanliness, purity, knowledge, and the divine. While artificial lighting from candles and lamps supplemented natural light, building designs were primarily adapted to maximize daylight in interior spaces.

This era encompassed various architectural styles, including Ancient Egyptian, Greek, and Roman, as well as Early Christian, Byzantine, Romanesque, Gothic, Renaissance, and Baroque architectures. In regions with abundant sunlight, architects often minimized window sizes and employed diffusing mediums like grilles or glass to manage light entry.

Notably, light was strategically admitted only where necessary, giving special significance to openings in the design. This created varied lighting levels throughout buildings, highlighting specific areas for important functions or events. For example, altars in churches or ancient statues were deliberately placed in locations with optimal lighting conditions to enhance their prominence (Florence nyole, 2004, p. 12).

VI.1.2 Ancient Egypt

Daylight played a central role in Egyptian architecture, with designs aimed at minimizing glare and excessive sunlight. Openings were limited due to structural constraints and were often supported by massive lintels.

- **Strategies for Daylighting:**

Clerestories were used to illuminate deeper spaces, while thick walls helped diffuse light. Roof slits, small windows, and entrance doors were carefully positioned to manage sunlight effectively. (Florence nyole, 2004, p. 12)

Figure I.1 : Indication of different strategies used at the Great Temple of Ammon i.e. clerestories and roof slits.
Source: Author’s sketch and greatbuildings.com

VI.1.3 Ancient Greece

Greek architecture emphasized outdoor life and visual drama. Buildings featured colonnades and porticoes that provided shade and enhanced spatial layering.

- **Strategies for Daylighting:**

Openings were mainly symbolic, used to highlight statues and decorative elements. Temples were oriented eastward to illuminate divine figures. Small openings and narrow shafts of light were typical, with town layouts ensuring solar access for both lighting and heating. (Florence nyole, 2004, p. 13)

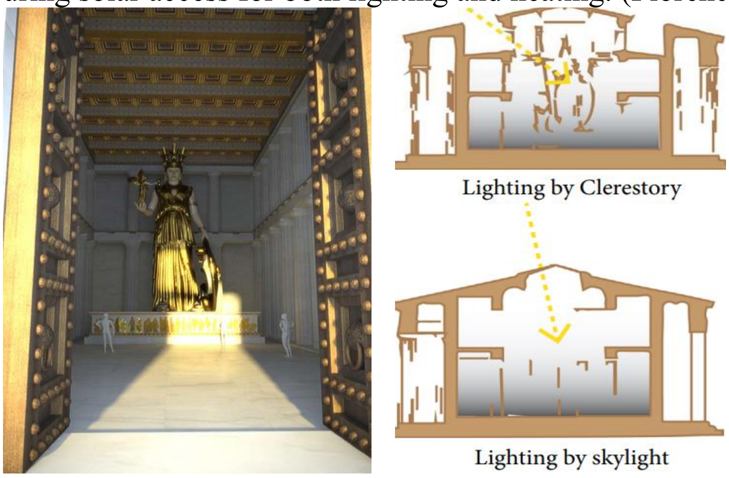


Figure I.2 Comparative lighting strategies by the Greek through clerestories of skylights. the buildings were planned and oriented to have the openings facing the East significant with the morning illumination.
Source: Archaeology of the Bible: Ancient Religio

VI.1.4 Ancient Rome

Roman innovations like the arch, vault, and dome allowed for wider openings and better daylighting than earlier periods.

- **Strategies for Daylighting:**

Circular and square-headed openings, some with glazing, were common. Skylights and clerestories brought light into larger interiors. Building orientation (east-west) maximized exposure to southern sunlight during winter. (Florence nyole, 2004, p. 13)

FigureI. 3 : the unglazed skylight of the Pantheon in Rome as well as clerestories were the main strategies being used due to development of the arch, vault and dome by the Romans. Giovanni Paolo Panini, Interior of the Pantheon, c. 1734, oil on canvas, 128 x 99 cm
Source: Archaeology of the Bible: Ancient Religio

VI.1.5 Early Christian (A.D. 313–800)

The basilica form was adapted for religious use, but timber roofs reduced opportunities for clerestory lighting.

- **Strategies for Daylighting:**

Numerous small clerestory windows created dim interiors suited to religious atmosphere. High-level windows focused light toward the altar, enhancing its visual and symbolic prominence. (Florence nyole, 2004, p. 14)

Figure I.4 St. Peter Rome A.D. 330 by Constantine with a 5no. aisled loor plan. Light timber trusses reduce bearing on side walls allowing larger openings but height limited by sloped side aisle roof geometry. Windows focus attention towards apse.
Source: Archaeology of the Bible: Ancient Religio

VI.1.6 Byzantine (A.D. 330–1453)

Centralized domed structures defined this era.

- **Strategies for Daylighting:**

Light entered through small, clustered openings at the dome base, often using stained glass or translucent marble to create a glowing, ethereal effect. Openings were typically arched or horseshoe-shaped. (Florence nyole, 2004, p. 15)

FigureI. 5 St. Sophia in Constantinople A.D. 532 - 537 now present-day Turkey with a ring of 40 windows making dome to appear to loat and the pendentive allowed support of the dome at four points over a rectangular space
Source: Archaeology of the Bible: Ancient Religio

VI.1.7 Romanesque (A.D. 800–1100)

Round arches and vaults reappeared, and churches evolved into cruciform plans with groin vaults.

- **Strategies for Daylighting:**

Windows remained small, especially in Italy, while France saw slightly larger ones. Rose windows appeared in non-load-bearing walls. Recessed openings with decorative jambs and shafts defined this style. (Florence nyole, 2004, p. 17)

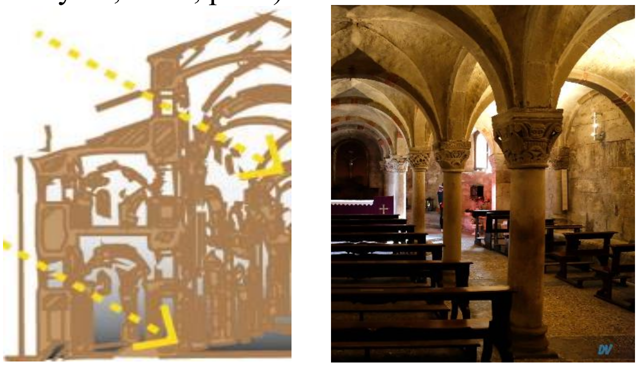


Figure I.6 St. Michele Pavia, Italy, c. 1100 - 1160 with masonry vaults required massive walls with small openings
Source: Archaeology of the Bible: Ancient Religio

VI.1.8 Gothic (A.D. 1100–1600)

Innovations like the pointed arch and flying buttress allowed for massive stained-glass windows.

- **Strategies for Daylighting:**

Walls were freed from load-bearing duties, enabling expansive windows. South-facing façades were especially effective in capturing daylight, while cathedral layouts (typically east-west) enhanced the lighting of key spaces. (Florence nyole, 2004, p. 17)

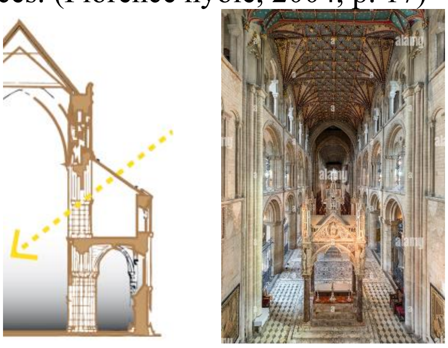


Figure I.7 : St. Petersborough, England A.D. 1117 and 1190 which is a typical Gothic Cathedral construction with the lying buttress allowing large window openings.
Source: Archaeology of the Bible: Ancient Religio

VI.1.9 Renaissance (A.D. 1400–1830)

A revival of classical proportion and harmony defined this era.

- **Strategies for Daylighting:**

Openings were fewer but larger and more carefully placed. Their design varied by region and climate. Thick walls allowed for recessed windows that created rich lighting effects, and domes guided light through layered spaces. (Florence nyole, 2004, p. 18)

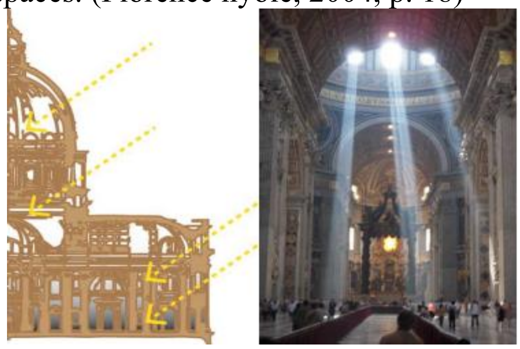


Figure I.8 St. Peter's Rome (AD 1506 - 1625)
Source: Archaeology of the Bible: Ancient Religio

VI.1.10 Baroque (A.D. 1575–1770)

Architecture became theatrical and emotionally charged.

- **Strategies for Daylighting:**

Dramatic lighting effects were achieved using hidden and recessed openings. Upper areas were bathed in light, while lower zones remained darker, reinforcing spiritual and spatial drama. (Derek Phillips, 2004, p. 28)

Figure I.9 daylight strategy in a church baroque era
Source: greatbuildings.com

VI.1.11 Industrial Architecture

Before the 1800s, daylight was the main source of illumination, with window placement tailored to climate and orientation. The Industrial Revolution introduced structural frames and new glass technologies. (Fletcher Banister , 1905, p. 10)

- **Daylighting Strategies:**

Larger windows became possible, increasing daylight but also introducing challenges like glare and thermal discomfort. Walls became lightweight enclosures rather than structural elements.

Figure I.10 Crystal palace lighting system
Source: google .com

VI.1.12 Modern Movement (1900s)

Pioneers like Wright, Le Corbusier, and Aalto embraced daylighting but relied increasingly on mechanical systems, leading to higher energy use despite innovations.

- **Strategies for Daylighting:**

Although daylighting principles remained, architecture began to detach from environmental context due to reliance on artificial systems and technologies. (Fuller Moore, 1991, p. 23)

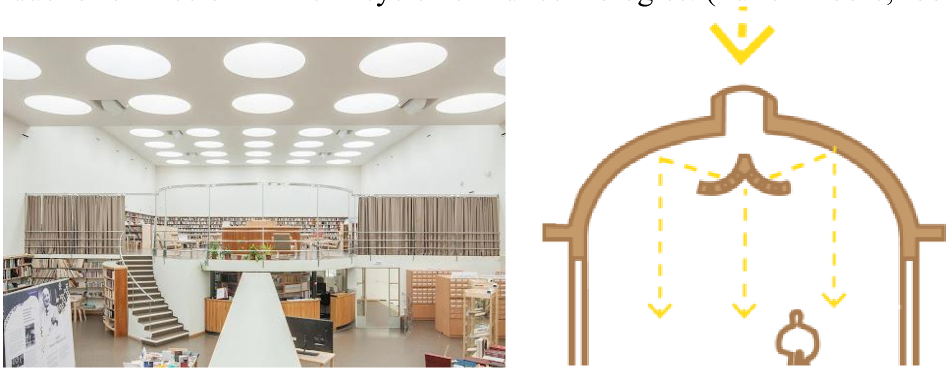


Figure I.11 Alvar Aalto's Vipuuri Library Louis Kahn's Kimbell Art Museum

Source: greatbuildings.com, Author's Sketch

VI.1.13 Post-Industrial Era (after 1973)

The oil crisis revealed the energy inefficiency of modern buildings, triggering a shift back to passive, sustainable strategies.

- **Strategies for Daylighting:**

Architects began reintegrating environmental awareness and technical knowledge into their designs, focusing on daylight as a key element of sustainable architecture. (Fletcher Banister , 1905, p. 32)

VI.2 The role of light in human perception

Light shapes human perception of surroundings, making it a powerful but intangible element. Perceptions about an object in the mind derive from its appearance when exposed to light, and individuals do not have exactly the same perception of one object, (Jay PA, 1971, p. 19) Natural daylight creates the best perception of surroundings, offering uniform illumination across surfaces. This uniformity resembles light reflected from objects, enabling clear visibility. Conversely, artificial lighting often alters perceptions, highlighting certain areas and changing how an object appears compared to its look in natural daylight.

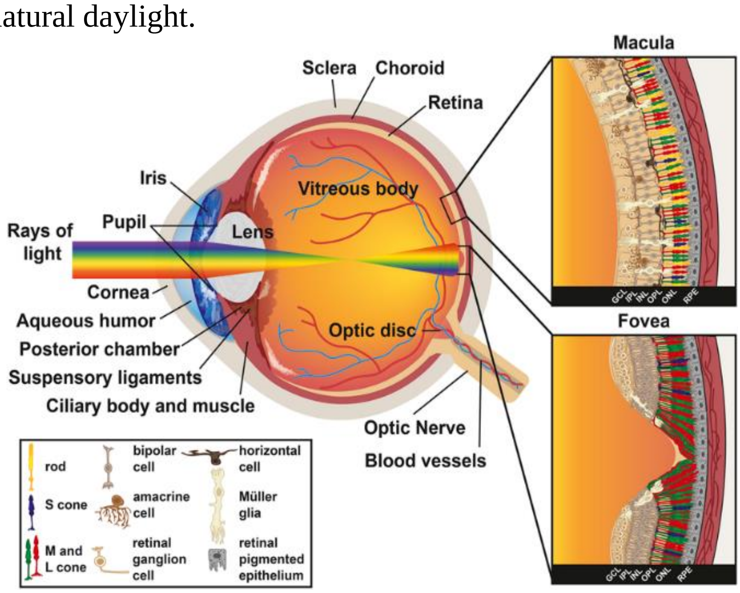


Figure I.12 human eye perception

Source; ResearchGate.com

VI.3 The benefits of using natural light in architecture

Natural light offers numerous benefits:

- Energy Conservation: Reducing reliance on artificial lighting can cut electricity usage by up to 10%.
- Healthier Indoor Environment: Natural light reduces bacteria and fungi, especially in damp areas like bathrooms and cellars, lowering the risk of chronic respiratory issues.
- Improved health due to vitamin D: Sunlight can help prevent vitamin D and B1 deficiencies, reducing risks of diseases such as rickets and beriberi. (javadnia M, 2016, p. 09)
- Enhanced Workplace Efficiency: Studies show that access to natural light improves employee performance.
- Visual Appeal in Interior Design: Natural lighting remains a favored element in design, adding beauty and creating unique structural challenges.
- Supports Biological Rhythms: Ultraviolet rays in daylight help regulate natural rhythms within biological systems.
- Impacts Indoor Conditions: Natural light positively affects indoor temperature, humidity, and overall space quality.
- Connection to Nature: Exposure to daylight supports eye health, reduces anxiety, and promotes a sense of well-being by fostering a natural connection with the outdoors (Javadnia M., 2016, p. 26)

VI.4 Requirements and criteria of visual comfort

Visual comfort, as defined by the European standard EN 12665, is “a subjective condition of visual well-being induced by the visual environment” It is influenced by three main factors: the physiology of the human eye, light quantity and spatial distribution, and the spectral characteristics of the light source. Studies on visual comfort typically examine several key elements in relation to human needs and lighting, including light levels, light uniformity, color rendering quality, and glare potential for occupants. (Thorseth A. , 2024, p. 23)

VI.4.1 Amont of light

Adequate visibility depends on having a suitable amount of light that allows occupants to complete tasks comfortably. Discomfort arises when light levels are either too low or too high. Illuminance—the measure of light reaching a specific surface or work area—is commonly used to quantify this. Illuminance-based indices often rely on annual weather data to provide instantaneous or time-aggregated assessments. These assessments compare indoor lighting conditions to predefined optimal illuminance thresholds, which vary based on the typical tasks performed in that environment. (Reinhart CF, 2011, p. 46)

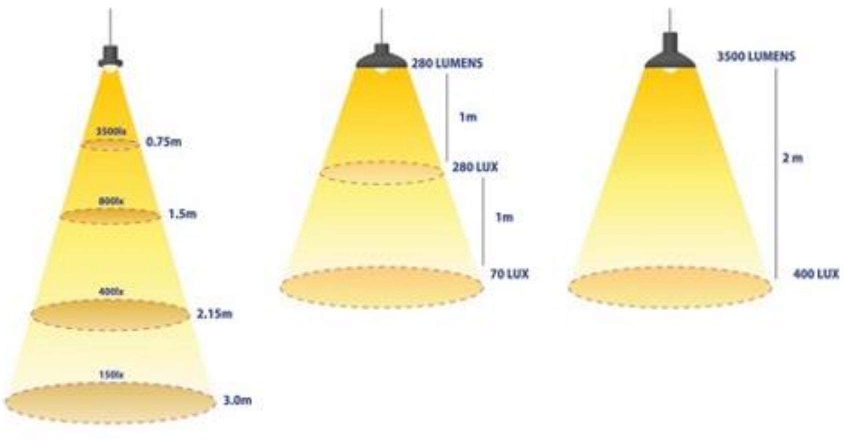


Figure I.13 different level of amount of light
Source; ResearchGate.com

VI.4.2 Uniformity of light

Light uniformity refers to how consistently light is distributed across a task area. Good uniformity reduces visual stress by minimizing frequent eye adjustments between over-lit and under-lit areas, which in turn lowers the likelihood of discomfort. Physically, this is represented by uniformity in illuminance across the task zone. "It is an effective parameter for describing a lighting environment, as a simple illuminance average may yield similar conclusions even in cases with very different light distributions, such as highly uniform versus highly variable lightin" (Andersen M, Kleindienst S, Yi L, Lee J, Bodart M, , 2008, p. 36)

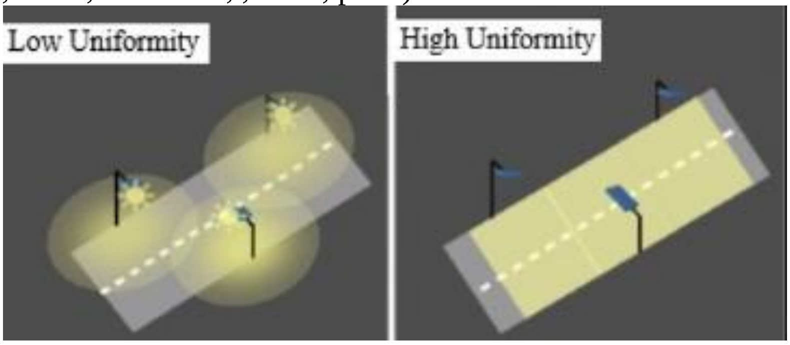


Figure I.14 the importance of light uniformity
Source: Sustainable Transport and Livability journal

VI.4.3 Glare

Glare is one of the most disruptive aspects of visual comfort. It occurs when excessively bright areas within the field of view hinder the ability to see clearly. Glare is classified into two main types:

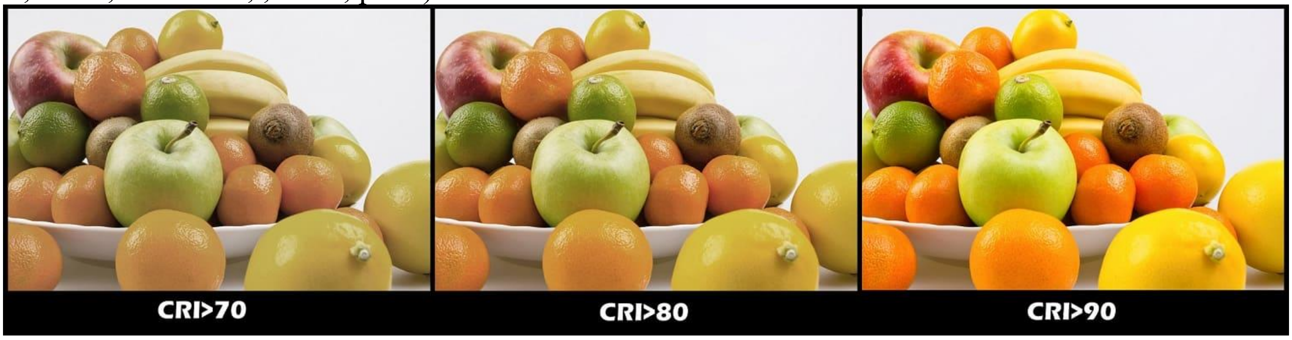
- Disability glare: an immediate reduction in visibility, often provoking reflexive behaviors like squinting or turning away from the light source.
- Discomfort glare: a more gradual and subjective form of visual fatigue caused by high brightness contrast or excessive light levels over time.

Glare perception is complex and varies with individual sensitivity, eye adaptation, and viewing angles. Despite the development of various metrics to quantify discomfort glare, predicting it accurately remains challenging due to the diversity of human responses and spatial conditions. (Bellia L, Bisegna F, Spada G., 2011, p. 53)

Figure I.15 Examples of three main types of glares -(a) discomfort glare; (b) disability glare; (c) dazzling or blinding glare
Source: ResearchGate.com

VI.4.4 Quality of light in rendering colors

Natural daylight is widely preferred over artificial lighting due to its ability to render colors accurately, enhance mood, and improve well-being. It offers dynamic variations in intensity and color temperature throughout the day, helping to regulate circadian rhythms and maintain a connection with the natural environment. These benefits contribute to increased satisfaction and productivity in both work and living spaces. However, while daylight offers superior color rendering and variability, it can also create excessively bright or non-uniform environments if not controlled properly—especially in settings like offices where consistent visual conditions are required. (Andersen M, Kleindienst S, Yi L, Lee J, Bodart M, , 2008, p. 45)



FigureI. 16 the importance of color rendering index
Source: thelightingoutlet.com

VI.4.5 The visual comfort indices

"Although the aforementioned factors are possibly correlated with each other, an index usually focuses only on one of them" A total of 34 indices have been compiled from a review of scientific literature and lighting standards. Most of the collected indices are devoted to assessing or predicting firstly glare (17/34; 50 %), secondly the amount of light (9/34; 26 %); then, the light quality (7/34; 21 %) and lastly the light uniformity (1/34; 3 %). The time evolution of the cumulated number of such indices seems to be far from a saturation state) Fig.I.17 illustrates an initial increase in glare assessment indices around 1995, followed by another rise from 2005 to 2010, and a notable focus on evaluating light levels in 2012. Over the past two decades, research has predominantly targeted metrics for assessing glare and light quantity. Despite these efforts, no current metric can singlehandedly summarize overall visual comfort in a specific lighting environment. The following sections offer a classification and critical review of the available indices (McCluney R, 1990, p. 35)

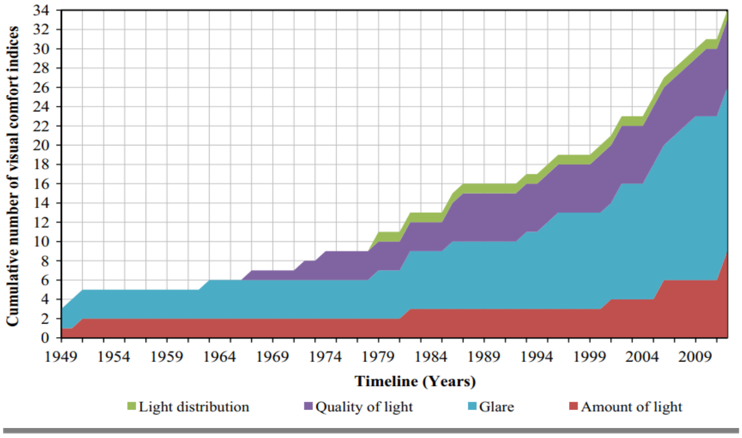


Figure I.17 The cumulative number of visual comfort indices proposed over
Source: ResearchGate.com

VI.5 The physical characteristics of natural light

VI.5.1 Radiation and the electromagnetic spectrum

Electromagnetic radiation refers to the disturbance of electric and magnetic fields, with the photon serving as its vector. In classical physics, it is characterized as an electromagnetic wave, which involves the propagation of a magnetic field and an electric field, oriented perpendicularly to each other, moving in a straight line from a source that results from the alternating motion of electric charges. By breaking down electromagnetic radiation into its various components—such as frequency, photon energy, or wavelength—we obtain an electromagnetic spectrum, in which visible light represents a small segment of this extensive range. (Javadnia M., 2016, p. 60)

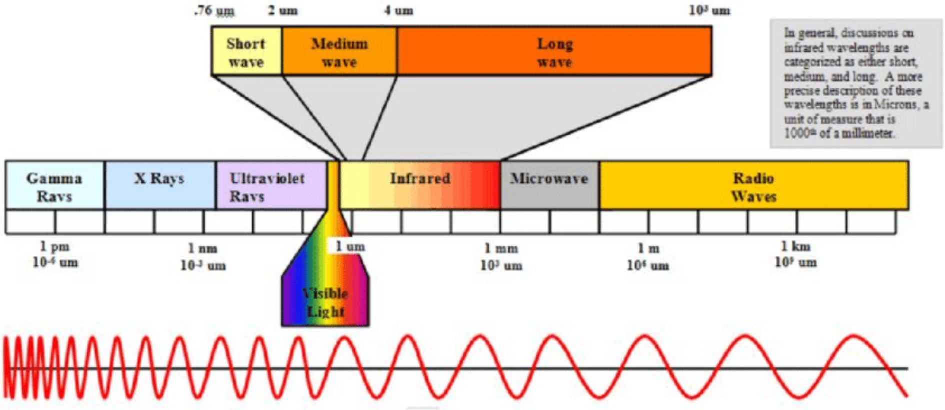


Figure I.18 The electromagnetic spectrum where the infrared and visible light spectrums within it are seen as well
Source: en.openei.org

VI.5.2 Light Spectrum

The term "white light" or "solar light" refers to the typical light of daylight. This light consists of multiple waves at different frequencies, perceived by the human eye as various colors—red, orange, yellow, green, blue, and violet. Together, these waves create parallel bands, forming what is known as the light spectrum. The rainbow's colors demonstrate this spectrum as sunlight breaks down into its components. Essentially, the light spectrum represents the range of monochromatic radiations obtained through a dispersive system. It encompasses all potential vibrations of the electromagnetic field. There are two primary types of light spectrum: the emission spectrum, produced directly from a light source, and the absorption spectrum, observed when white light passes through a gas or liquid. Human vision is sensitive only to a small section of this field, the visible spectrum, which ranges from wavelengths of 400 nm (violet) to 700 nm (red); wavelengths outside this range are undetectable by the human eye. (Javadnia M., 2016, p. 61)

VI.5.3 The physical phenomena of light

- **The propagation of light**

Light travels in a straight line when it moves through a homogeneous, transparent medium—meaning a material with uniform properties throughout. This linear path changes only when the medium is non-uniform or when light encounters obstacles. Light propagation can be described in two complementary ways: as spherical waves that radiate uniformly in all directions, or as rays that indicate the direction of wave travel, perpendicular to the wavefronts. Unlike sound, light does not require a medium and can travel through a vacuum at a constant speed of approximately 300,000 km/s (3.0×10^8 m/s). The direction of light can be altered through physical phenomena such as reflection, refraction, diffraction, or diffusion. (Rhea Jariz Eleazar , 2012, p. 45)

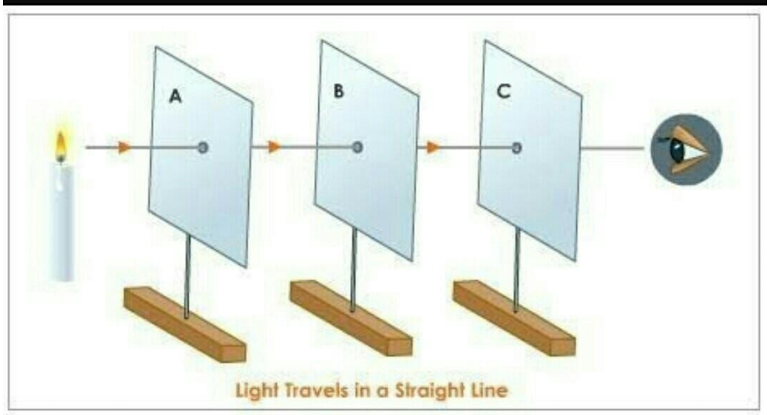


Figure I.19 rectilinear propagation of light with an experiment
Source: ScienceDiect.com

- **The reflection**

When a light ray strikes a polished surface, it is reflected at an angle equal to its angle of incidence. This reflection can occur in three main forms—specular, diffuse, or mixed—depending on the surface's characteristics.

Specular reflection occurs on smooth surfaces, where the incident ray reflects cleanly in one direction. Although ideally all the light's energy is reflected, some may be absorbed or scattered. A surface acts as an ideal mirror when its imperfections are smaller than the light's wavelength.

Diffuse reflection happens on rough surfaces, causing the light to scatter in multiple directions. This results in broad energy distribution and can be either perfect (even scattering) or partial (random scattering), allowing light to illuminate areas not directly exposed to the source.

Mixed reflection combines both behaviors, with light scattering broadly but still favoring a general direction, common on semi-smooth surfaces. (Andersen M, Kleindienst S, Yi L, Lee J, Bodart M, , 2008, p. 52)

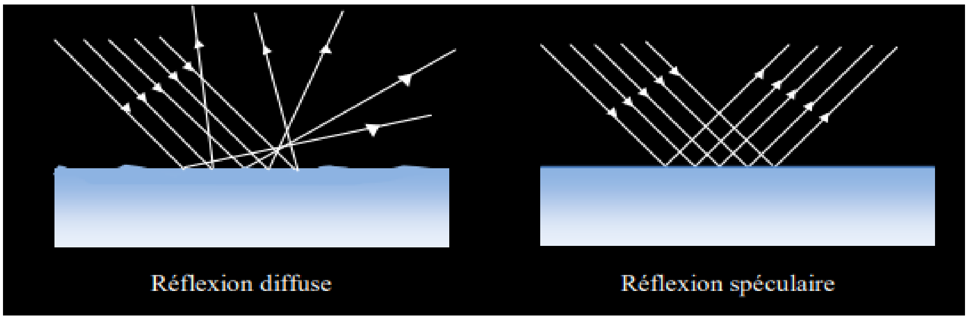


Figure I.20 presente the two types of reflection
Source: Academia.edu

- **The refraction**

Refraction is the phenomenon where a light ray changes direction as it crosses the boundary between two media with different light propagation speeds, meaning the wave deviates when its speed varies. This directional change follows the principles outlined by the Snell-Descartes laws of optical geometry. Refraction commonly occurs at the interface between two materials or when there's a shift in the medium's impedance. For instance, when white light passes through a prism, it splits into its various color components due to the fact that the light ray's angle of deviation in a transparent medium increase as the wavelength decreases. (Andersen M, Kleindienst S, Yi L, Lee J, Bodart M, , 2008, p. 53)

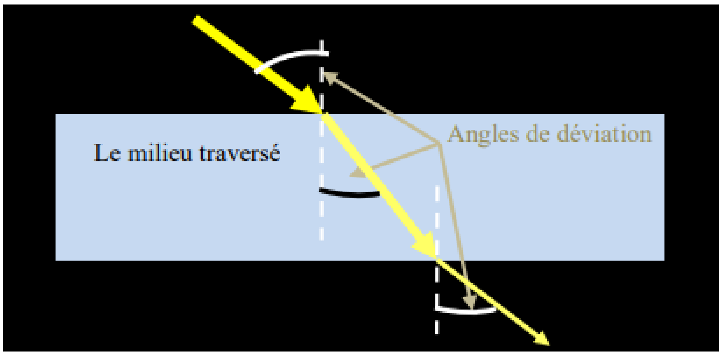


Figure I.21 present the refraction phenomenon
Source: Academia.edu

- **Diffusion**

occurs when light is scattered in multiple directions upon interacting with particles or irregular surfaces. This scattering can be isotropic (uniform in all directions) or anisotropic (directional), depending on the medium's properties. It can happen at boundaries between different media or within a single medium containing elements like dust or moisture. As a result, even observers not aligned with the original light path can perceive the dispersed light, giving the effect of a visible beam—commonly observed in foggy or smoky environments.

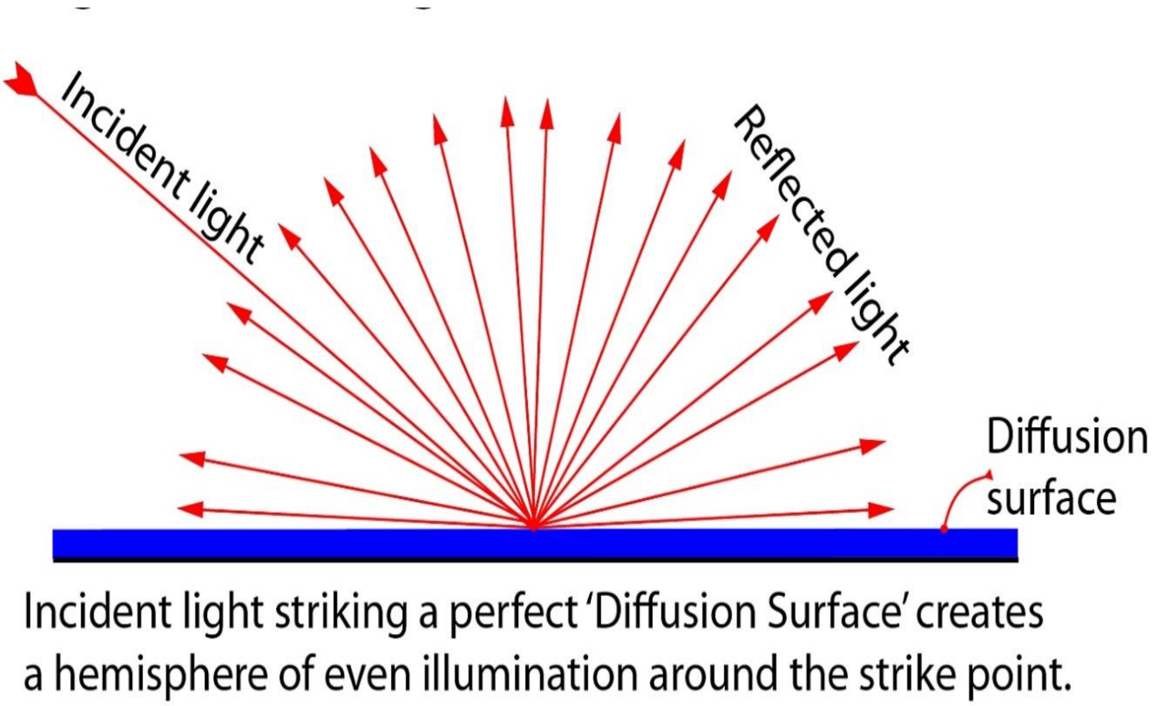
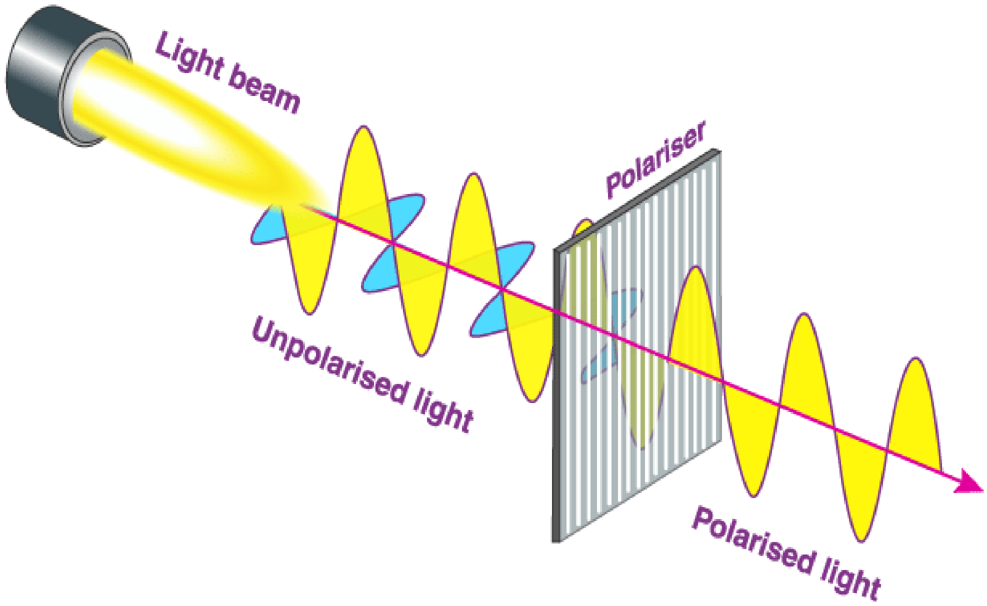


Figure I.22 showing diffuse reflection
Source: ScienceDiect.com

- **Polarization**

Polarization involves the alignment of light waves so that their vibrations occur in a specific direction. This typically results from reflection or refraction and can be produced using polarizers, especially linear ones, which restrict the electric field's oscillation to one plane. According to electromagnetic theory, light consists of electric and magnetic fields oscillating perpendicularly to each other and to the direction of travel. In natural (unpolarized) light, vibrations occur in all directions. After passing through a polarizer, only waves vibrating in a particular direction remain, resulting in linearly polarized light. (Rhea Jariz Eleazar , 2012, p. 56)



FigureI. 23 shows the polarization effect
Source: ScienceDiect.com

- **Absorption**

Absorption describes how certain materials capture and converts light energy, often transforming it into heat. Different materials absorb different wavelengths of the electromagnetic spectrum. The color of an object results from the wavelengths it reflects; for example, a green leaf appears green because it absorbs other colors and reflects green light. Transparent materials absorb very little visible light, while opaque materials absorb more, diminishing the intensity of transmitted light.

- **Transmission**

Transmission refers to the passage of light through a material. Depending on the medium's uniformity and surface characteristics, light may travel straight, bend at interfaces, or scatter. There are three main types of transmission:

- Directional transmission, where light passes through at the same angle as incidence;
- Perfect diffuse transmission, where light spreads evenly in all directions;
- Random diffuse transmission, where scattering is irregular but biased toward a direction.
- Mixed transmission blends these modes, with light scattering diffusely but favoring a general direction. Materials are classified as transparent, translucent, or opaque based on how much light they transmit. Additionally, the light transmission coefficient (Tl) quantifies the proportion of visible solar radiation that passes through a material, and this can vary depending on its thickness. (Andersen M, Kleindienst S, Yi L, Lee J, Bodart M, , 2008, p. 58)

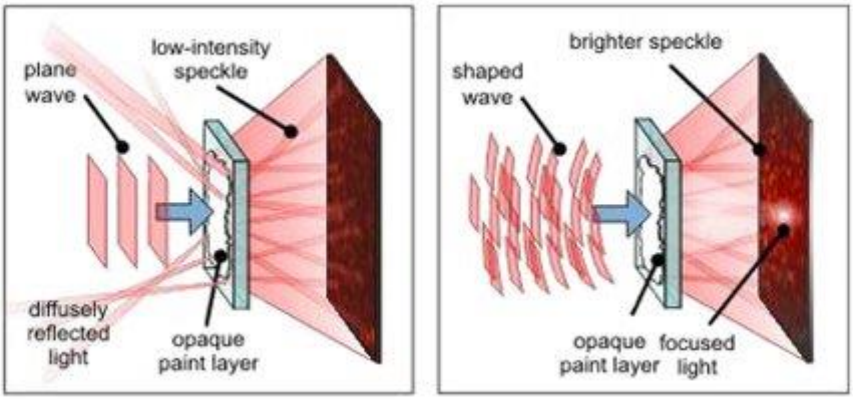


Figure I.24 Physicists Transmit Light through Opaque Materials
Source: en.openei.org

VI.6 Overview of Natural Light Modeling Systems

Natural light modeling systems are architectural tools and technologies designed to optimize the distribution and use of daylight within interior spaces. These systems address the challenges of uneven daylight penetration—such as excessive brightness near windows and darkness at the rear of rooms—by promoting a more uniform light distribution. The ultimate goal is to enhance visual comfort and reduce dependence on artificial lighting, thereby improving energy efficiency.

The most common types of natural light modeling systems include:

- Skylights: installed in roofs, skylights capture direct sunlight and introduce it into interior spaces below. They are especially useful in buildings without external windows or in areas far from façade openings.
- Light Shelves: these are reflective horizontal surfaces placed above windows that redirect incoming sunlight toward the ceiling, dispersing it more evenly throughout the room. Light shelves help reduce glare and allow better control over direct sunlight entry.
- Light Pipes (Sun Tunnels): light pipes transport natural light through reflective tubes, channeling it into deep or windowless areas of a building. They are particularly effective in basements or rooms with limited façade access. (McCluney R, 1990, p. 41)

- Special Glazing and Reflective Facades: these include prismatic or directional glass surfaces that redirect sunlight deeper into the interior. Some glazing solutions also diffuse light to reduce glare and distribute it more evenly across the space.

Together, these systems play a vital role in reducing daytime energy consumption by limiting the need for artificial lighting. Beyond their technical performance, they contribute to occupant well-being by creating naturally lit environments that are visually comfortable and psychologically beneficial.

In contemporary sustainable architecture, such systems are increasingly integrated to design buildings that maximize daylight while minimizing unwanted effects like glare and overheating. They offer a balanced approach to daylight design, supporting both energy savings and user comfort.

VI.6.1 Natural light modeling systems comparison

table 1 present natural light modeling systems comparison

Source: natural light illumination system, Conference paper2018

Natural Light Modeling System	Description	Pros	Cons	Why sun tunnels are Most Important
Skylights	Brings natural light into spaces without windows, using a dome, light conduit, and diffuser.	Illuminates dark spaces, reduces energy consumption.	May cause heat loss in winter or direct sunlight in summer.	Skylights are effective but only for spaces directly under the roof, limiting their use in multi-story buildings.
Anidolic Ceiling	Distributes light using parabolic mirrors, effective in cloudy weather.	Provides balanced light in deep spaces, saves energy.	Less effective in overcast conditions.	While effective in deep spaces, it doesn't offer direct light transport to areas far from the windows.
Light Shelf	Installed near windows, redirects light to the ceiling for deeper space illumination.	Achieves deep, uniform natural lighting, reduces artificial lighting.	May cause direct lighting issues if placed too low.	Effective for larger spaces, but still relies on light from windows, limiting its range in deeper rooms.
Sun tunnels	Transports natural light to spaces without direct windows.	Illuminates spaces unreachable by windows, ideal for deep or windowless areas.	Installation is complex, requires maintenance.	Light Pipes are essential for lighting areas without direct windows, such as basements or interior rooms, and they ensure natural light is distributed even in the absence of windows. This makes them ideal for spaces lacking natural light access.
Reflective Blinds	Blinds used to reduce glare and redirect light into the room.	Provides control over natural light and reduces glare.	May be ineffective in changing weather, needs regular adjustments.	Reflective blinds only control glare but do not provide the depth of light penetration or wide coverage that Light Pipes can.
Special Glazing	Uses directional or prismatic glazing to redirect light into the room.	Improves even light distribution inside.	May block external views and requires maintenance.	Special glazing enhances light control but is limited in its ability to transport light deeply into rooms compared to Light Pipes.

VIISecond part

VII.1 Sun tunnel system

Daylight transport devices, often referred to as light pipes or light guides, are systems designed to collect and transmit natural light over long distances within buildings. These devices enhance efficiency in spaces where natural light is essential for health, economic, or architectural benefits. In 1990, Little Fair recognized Tubular Daylighting Guidance Systems (TDGS) as one of the most innovative daylighting technologies. Various terms have been used in the literature to describe these systems. Below is a non-exhaustive list of the names commonly found in research (Malet-Damour B, Bigot D, Boyer H, 2020, p. 46)

- Light pipe
- Light tube
- Light guide
- Sun pipes
- Solar pipes
- Solar light pipes
- Daylight pipes
- Tubular skylight
- Sun scoop
- Tubular daylighting device
- Tubular Daylight Guide Systems

The components of daylight transport devices can be categorized into three primary elements:

1. Collector (at the tube inlet):
   - Designed to optimize light capture by tracking the sun's movement or redirecting sunlight into the tube for further transport.
2. Tube (light transport system):
   - Facilitates the transfer of light to the target area using materials with specific optical properties, such as reflective coatings, prismatic structures, lenses, or solid-core systems.
   - The presence of bends or elbows in the tube may affect its performance, depending on the system design and material characteristics
3. Diffuser (at the tube outlet):
   - Ensures even light distribution within the illuminated space or along the tube.
   - The choice of diffuser type can influence how light is spread across the target area. (Kadir AA, Ismail LH, Kasim N., 2007, p. 36)

A summary of technological advancements in these systems, from 1982 to 2019, is presented in this includes an overview of collection, transportation, and diffusion technologies as documented in the literature. A specific focus is placed on the industrial application of mirrored light pipes.

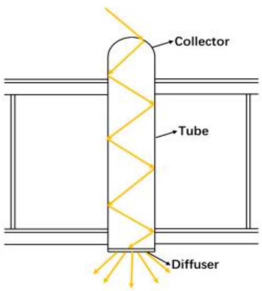


Figure I.25 The three zones of solatube system.
Source: ResearchGate.com

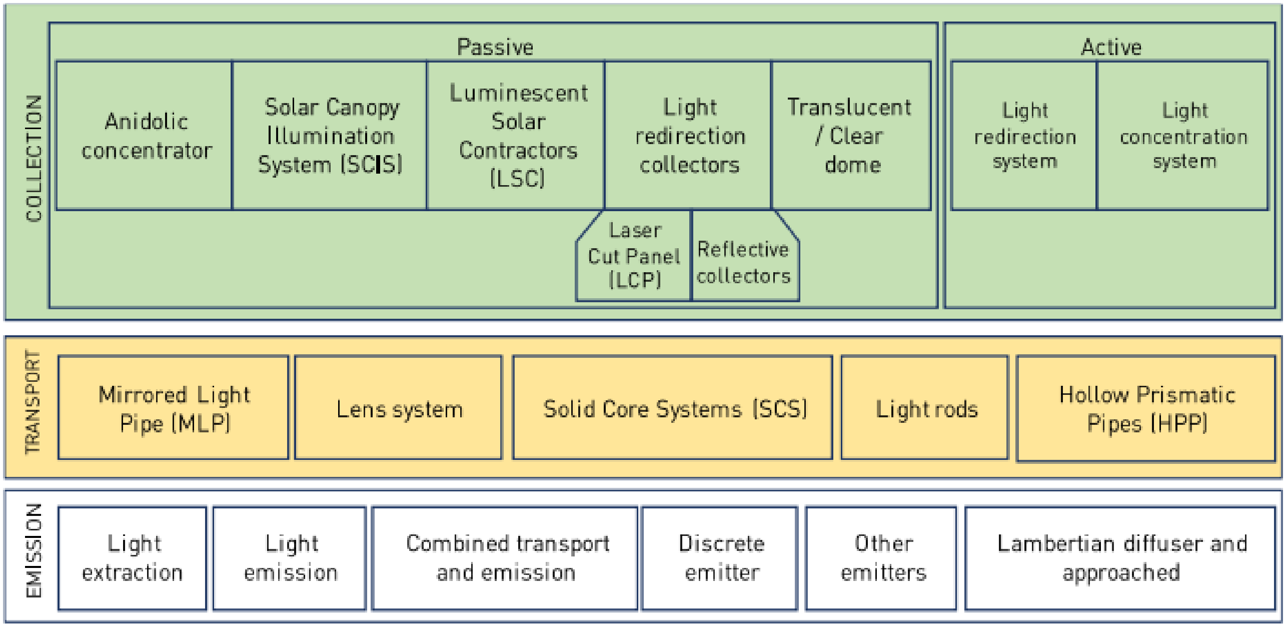


Figure I.26 Summary of collection, transport and emission processes with identified technologies in the literature
Source: ScienceDiect.com

VII.2 Sun tunnels Combined with Artificial Lighting

The performance of light pipes is influenced by several weather factors, including solar altitude, cloud cover, and external illuminance

- **Solar Altitude and Cloud Cover**
  - Luminous flux increases with solar altitude but decreases with more cloud cover.
  - Overcast conditions often provide slightly higher efficiency compared to clear skies.
  - Uniform light distribution is observed when the solar altitude is low.
- **Seasonal Impact**
  - Light output is higher in summer compared to winter. However, summer conditions may cause noticeable variations in brightness on the working plane.
- **External Illuminance**
  - External illuminance has the most significant effect on internal illuminance.
  - Research indicates an exponential relationship between external and internal illuminance levels.
- **Atmospheric Aerosols**

  Aerosols in the atmosphere can alter illuminance patterns and efficiency.

Since light pipes alone may not always meet indoor lighting requirements, artificial lighting is often used as a complement. Integrated systems combining light pipes and artificial lighting with advanced controls (e.g., occupancy sensors and daylight dimming) can enhance efficiency, achieving energy savings of up to 20%.

However, challenges arise, such as:

- **Color Rendering Differences:**
  - Disparities in the color rendering of natural and artificial light may lead to visual discomfort.
- **System Longevity and Cost:**
  - Frequent on/off switching of artificial lighting due to unstable daylight or the need for complex control systems can reduce service life and increase costs.

A study by Görgülü and Ekren demonstrated the use of light pipes with dimmable ballasts to illuminate a windowless room, maintaining a stable 350 lux level on the working plane throughout the day. (Wu Y, Jin M, Liu M, Li S, 2024, p. 14)

VII.3 Performance of Sun tunnel system

Several studies have highlighted the effectiveness of light pipe systems as natural daylighting solutions. Research confirms their efficiency in providing a reliable light source within buildings. An experimental study by in *Solar Energy* demonstrated that light pipes are highly effective for delivering daylight indoors. Additionally, a survey conducted by in *Applied Energy* examined 13 buildings and found that light pipe systems could contribute 25% to 50% of the required work plane illuminance while significantly reducing energy consumption for lighting. Another study further noted that interior illuminance levels on work surfaces could vary based on sky conditions. Figure shows the inter correlations between indoor illuminance and sky condition. This study was supported by Evaluation of Daylighting Effectiveness and Energy Saving Potentials of Light-Pipe Systems in Buildings Indoor and Built Environment through the prediction model, where there are strong associations between the daylighting performance of the light-pipe and local climate conditions (i.e.,solar altitude, sky clearness index, and external illuminance (G Oakley, S Riffat, L Shao, 2000, p. 70)

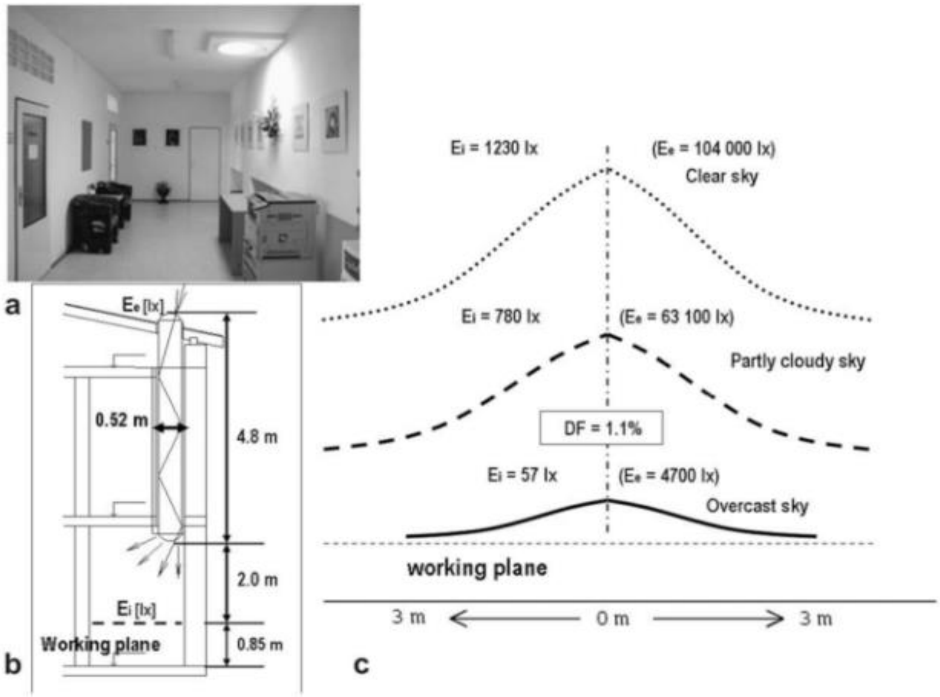


Figure I.27 Illuminance Measurements in the Windowless Corridor
Source: Mohelnikova, 2009

VII.4 Potential utilization of Sun tunnel system

Although there are challenges associated with the use of light pipe systems, they have been successfully implemented in various types of buildings worldwide, including offices, industrial facilities, and healthcare buildings. Studies have shown that light pipe systems offer the greatest energy savings in regions close to the equator.

Malaysia, being a tropical country situated around 10°N to 6°45' N latitude and 99°36' E to 104°24' E longitude, experiences a hot-humid tropical climate with uniform temperatures, high humidity, frequent rainfall, light winds, and ample sunshine. According to climate data from, the sky conditions in Malaysia are mostly intermediate, with 85.6% classified as predominantly intermediate, 14.0% overcast, and 0% clear. For studies on tropical daylighting, an intermediate sky condition is recommended.

Daylight data is important that need to be taken into account in designing buildings using daylight. Moreover, the quality of the external illuminance will affect the performance of daylight system. For Malaysia daylight availability, research done by showed that the illuminance exceeds

80,000 lx at noon during March when solar irradiation is the highest and reaches 60,000 lx even during December when solar irradiation is less intense (Reinhart CF, 2011, p. 66)

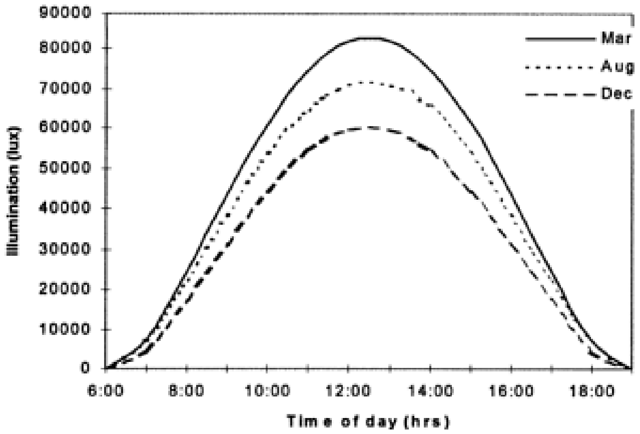


Figure I.28 Daylight Availability in Subang

Source: ResearchGate.com

Given the climate conditions described above, there is significant potential for utilizing the light pipe system as a daylighting solution in Malaysia. A study conducted by developed a conversion factor to predict the performance of light pipe systems under the tropical Malaysian sky conditions using a scale model. illustrates the high illuminance levels achieved during the daytime when light pipes are incorporated into buildings.

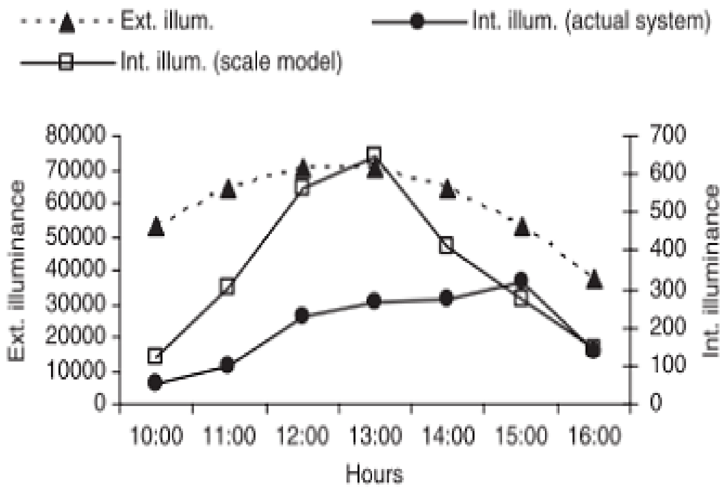


Figure I. 29 External and Internal Illuminance

Source: ResearchGate.com

VII.5 Advantages and disadvantages

Solatube technologies and its related accessories represent innovative and effective methods for introducing natural daylight into indoor spaces and incorporating additional functionalities such as ventilation and night lighting systems. Like any emerging technology, the application of Solatube technology should be critically evaluated in terms of its advantages and disadvantages. Table provides an overview of the various benefits and challenges associated with Solatube technology. (Singh AP, 2018, p. 18)

table 2 The advantages and disadvantages of Solatube daylight system

Source : singh AP, 2018

No.	Advantages	Disadvantages
1	Reduce lighting energy costs	Provide less light through long tubes
2	Eliminate the need for artificial lighting	Domes go yellow quickly
3	Improve human performance and productivity	Humid climate causes water condensation in the tube
4	Simple in installation and maintenance	Not equally suited to every home
5	Suitable for new green buildings	Depend on one source of energy (Sun)
6	Conform with most green building standards	Relatively high manufacturing cost
7	Achieve internal thermal and psychological comfort	Performance is related to the clearness of the sky
8	Minimize solar gain in summer	Strongly affected by climate changes
9	Reduce the energy cost of air conditioning	Partially suitable for some existing buildings
10	Improve retail sales, especially for food	/
11	Offer healthy working conditions	/
12	More secure than traditional skylights	/
13	Block ultraviolet (UV) solar radiation	/
14	Energy Star rated and meet building codes	/
15	Provide a great source of vitamin D	/

VII.6 Challenges in utilizing Sun tunnel system

While many studies on Solatube technology demonstrate positive performance, there are several challenges to its application, particularly in the context of the building sector in Saudi Arabia. These challenges can be categorized into economic considerations, maintenance requirements, and issues related to user awareness. (Singh AP, 2018, p. 20)

VII.6.1 Economic Considerations

The initial cost of installing a Solatube system may be relatively higher compared to artificial electric systems and conventional windows. As the space expands and the integration of associated advanced technologies increases, the upfront cost of the Solatube system becomes a significant factor.

VII.6.2 Maintenance

The Solatube system requires regular cleaning to maintain optimal efficiency by removing dirt and dust. This requires well-prepared maintenance programs. Additionally, certain components of the system may need to be replaced due to optical distortions or damage, impacting the overall performance.

VII.6.3 User Awareness

Similar to any emerging technology, user awareness plays a crucial role in the acceptance and widespread adoption of the Solatube system within the building sector. The mere reduction in electricity costs may not be sufficient to justify the high initial cost to users. Therefore, increasing awareness about the additional benefits of the Solatube system—such as improved visual comfort, reduced environmental pollution, healthier indoor conditions, and productivity improvements—can enhance user acceptance and adoption. (Reinhart CF, 2011, p. 65)

VII.7 Daylight from water-filles Sun tunnels

Water in these pipes acts as a filter, removing unwanted infrared (heat) and ultraviolet radiation, while minimally affecting visible light. Effect of Water Absorption on Light Color

When light passes through water, its correlated color temperature increases, indicating a shift toward cooler, bluer tones. This happens because the red component of the light is absorbed more strongly than the blue component, causing the transmitted light to appear bluer. Due to this selective absorption, the practical maximum length for transporting light through water without unacceptable color distortion is approximately 10 meters. (McCluney R, 1990, p. 35)

table 3 Water-filled Light Pipe Transmittances and Luminous Efficacy

Source : Mc Cluney R, 1990

Distance (m)	Radiant Transmittance	Lu minous Transmittance	Luminous Efficacy (lm/W)
0.001	0.9254	0.9999	130
0.01	0.8235	0.9990	145
0.1	0.6465	0.9898	184
1.0	0.4461	0.9064	244
4.0	0.2993	0.7031	281
10.0	0.1907	0.4712	296
16.0	0.1372	0.3366	294
64.0	0.0168	0.0351	250

- Water-filled light pipes can deliver filtered, cooler natural sunlight indoors.
- Absorption reduces red light and shifts the color toward blue, lowering CRI with distance.
- Maximum pipe length without significant quality loss is about 10 meters.

VIII Third part : shopping center

The term "commerce" originates from the Latin word commercium and refers to the activity of negotiating during the process of buying and/or selling goods and products. Additionally, commerce encompasses any shop, store, warehouse, or commercial establishment, as well as the broader category of merchants and traders.

VIII.1 Typology of commercial facilities

- **Grocery Store:** A small retail establishment offering food products and household items, typically operated by an independent merchant. Sales areas range from 20 to 200 m².
- **Hard Discount Store:** A self-service store predominantly focused on food, characterized by below-average prices, limited sales areas (less than 100 m²), and a narrow product assortment of fewer than 1,000 items.
- **Souk:** A market located in a medina where a variety of goods can be found, such as food, clothing, jewelry, and pottery. Souks are also known for the aromatic spices that fill the air in their alleys. They typically include shops, workshops, and sometimes residential spaces, with areas ranging from 200 to 100,000 m².
- **Bazaar:** A market or collection of shops available for buying and selling. It is considered the equivalent of the Arabic souk.
- **Fair:** A commercial or cultural event held in a city at a specific time and location. In modern contexts, fairs are often referred to as event exhibitions or trade shows.
- **Convenience Store:** A retail establishment with a sales area ranging from 120 to 400 m², primarily focused on food products.
- **Department Store:** A multi-specialty retail store typically located in city centers, with an average surface area of 5,700 m².

- **Supermarket:** A store with a sales area between 400 and 2,500 m², generating more than two-thirds of its revenue from food sales.
- **Hypermarket:** A large retail establishment with a sales area exceeding 2,500 m², earning over one-third of its revenue from food products. These are usually located in suburban areas. (Agnieszka Rochminska , 2017, p. 25)

VIII.2 Definition of a shopping center

A shopping center refers to a commercial complex comprising buildings that house shops, stores, and other points of sale, accompanied by a large parking area designed to accommodate customers. Beyond providing a retail offering, shopping centers also serve as spaces for leisure and entertainment.

This commercial format was significantly developed, structured, and professionalized by economic agents in the United States during the mid-20th century, where it was commonly referred to as a shopping center or mall. The concept was later adopted and replicated in various parts of the world.

Erom John A. Dawson's book titled "Shopping Centre Development", he points out that shopping Centre is defined as:

"A group of architecturally unified commercial establishments built on a site which is planned, developed, owned and managed as an operating unit related in its location, size and type of shops to the trade area that the unit serves. The unit usually provides on site or associated car parking in definite relationship to the types and total size of the stores." (Agnieszka Rochminska , 2017, p. 27)

VIII.3 The historical evolution of shopping centers

The concept of commercial spaces is not a recent development; it has existed since antiquity and has evolved through the ages. Each era has left its unique architectural imprint on the design of commercial spaces, reflecting the cultural, social, and economic contexts of the time. (Mark J, 2016, p. 15)

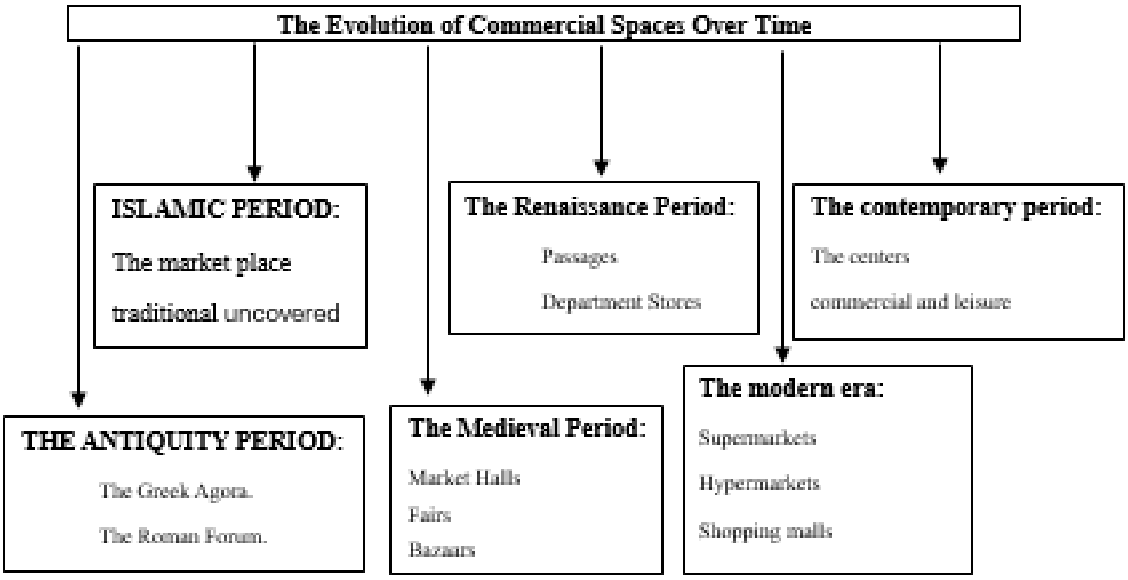


Figure I.30 The development of shopping malls throughout history
Source: Academia.edu

VIII.4 Classification of shopping malls according to CNCC

The CNCC (National Council of Shopping Centers) has classified shopping centres according to their GLA surface and the number of stores into five types:

table 4 typology of shopping malls
Source: CNCC

Super Regional Shopping Centres	Their GLA area is greater than 80,000 m2 and/or they total at least 150 stores and services.
Regional Shopping Centres	Their GLA area is greater than 40,000 m2 and/or they have at least 80 stores and services.
The Great Shopping Centres	Their GLA area is greater than 20 000 m2 and/or they have a total of at least 40 stores and services.
The small shopping centers	Their GLA area is greater than 5,000 m2 and/or they have at least 20 stores and services.
The thematic centres	These are specialized shopping centres, for example in home equipment or manufacturers' shops.
Discount store	300 to 500 m2 of sales area. They are located in central points of residential areas.
Supermarkets	400 to 500 m2 of sales area.

VIII.5 Typologies of shopping mall layouts

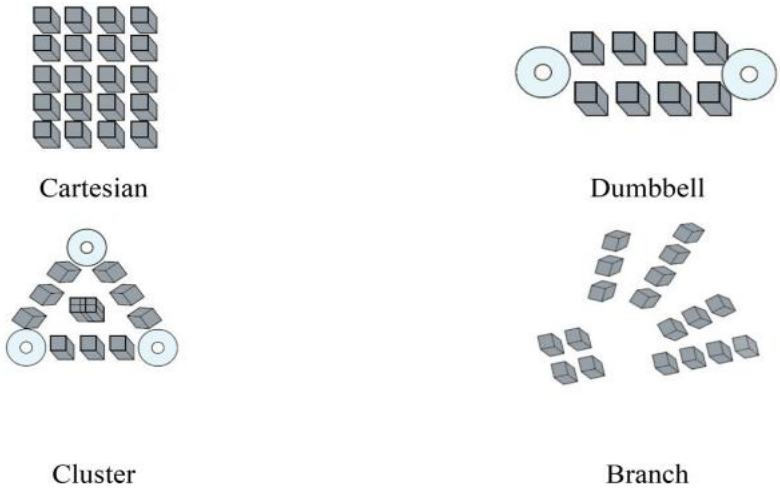
The functional planning of a building is guided by the identification of user requirements, operational processes, and contextual factors. These include considerations like the building's intended purpose, the profile of its users, its spatial accessibility, construction costs, and other design-related criteria. Similarly, shopping mall layouts are influenced by parameters such as site selection, zoning regulations, spatial organization, lighting and structural requirements, materials, security measures, and parking arrangements. Indoor spatial features significantly impact user behavior and environmental conditions in shopping centers.

Shopping mall layouts are typically adapted to the geometry of the available land. Factors such as access routes, building entrances, and exits play a key role in determining the final plan. Effective layouts should establish a clear pedestrian flow while maximizing visibility and accessibility for storefronts. Anchor tenants, entertainment zones, and mid-sized stores are strategically located to direct customer movement, enabling interaction with smaller retail outlets along the main circulation paths. The design must ensure simplicity and clarity, minimizing the likelihood of users becoming disoriented within the space. Furthermore, key elements like parking access, emergency exits, and vertical circulation systems should align seamlessly with pedestrian pathways. (Mark J, 2016, p. 26)

Four main typologies of shopping mall layouts can be identified, each reflecting a distinct spatial organization:

a) **Cartesian Plans**: Inspired by traditional covered markets, these plans feature intersecting circulation axes that organize shopping blocks in a grid-like arrangement.
b) **Branch Plans**: Developed to maximize leasable space, these plans incorporate branching pathways that extend from a central circulation spine. They facilitate multi-level connectivity through strategically placed vertical circulation points.
c) **Dumbbell Plans**: Characterized by a linear central axis, these plans position high-attraction zones such as anchor stores or entertainment hubs at opposite ends of the circulation path. This arrangement encourages movement and interaction along the central axis.
d) **Cluster Plans**: This typology groups stores and other functions along a pedestrian axis, often intersected by gathering nodes or plazas. It emphasizes spatial flexibility and user-oriented design.

Effective orientation within a shopping mall is essential for creating an intuitive user experience. The design of circulation spaces and storefront arrangements plays a critical role in guiding user movement and ensuring accessibility throughout the space.



FigureI. 31 Shopping mall plan types
Source: ResearchGate.com

VIII.6 Design Principles for shoping mal structures

The design process for shopping mall structures begins with developing flexible and modular spatial solutions. Modular units are conceptualized to support scalability, allowing them to be replicated and adjusted to form cohesive and functional layouts.

These modular systems are not intended as universal solutions but must adapt to evolving retail trends and user needs. By adhering to standardized guidelines and national regulations, shopping mall designs can also align with international architectural standards. This modular approach facilitates the creation of hybridized layouts that integrate various functions, enhancing the overall utility of the mall. (Agnieszka Rochminska , 2017, p. 30)

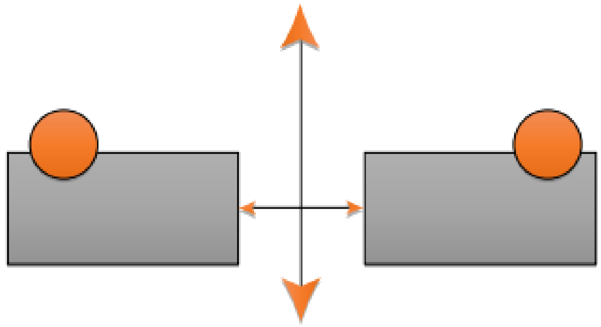


Figure I.32 Conceptual composition of shopping mall zones)
Source: ResearchGate.com

A critical aspect of designing shopping malls involves analyzing pedestrian movement patterns, particularly in high-traffic retail areas. Empirical observations of circulation paths within frequently visited zones help identify areas of high demand, such as corner stores, anchor tenants, and leisure or dining spaces. Effective layouts prioritize these areas, ensuring seamless connectivity and visibility to maximize user engagement and sales potential. (Jarosław Wiater, 2018, p. 32)

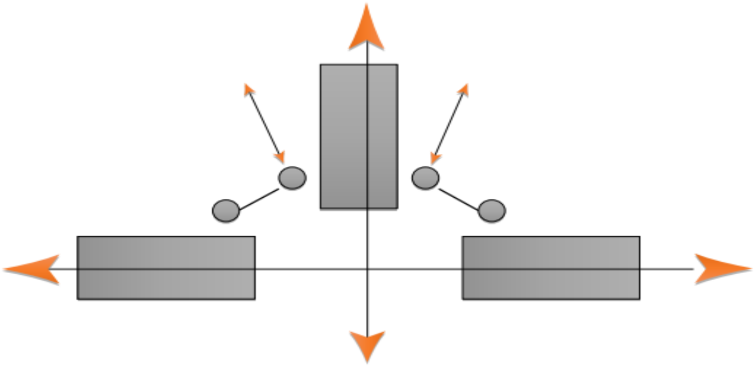


Figure I.33 Conceptual composition of shopping mall zones)
Source: ResearchGate.com

Furthermore, functional zones within shopping malls—including sales areas, warehouses, service blocks, and recreational spaces—must be strategically organized to promote ease of navigation and efficient operations.

Figure I.34 Functional organizational zones, shopping mall
Source: ResearchGate.com

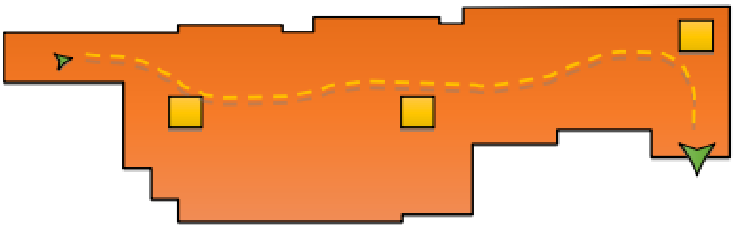


Figure I.35 Pedestrian circulation defines the geometry of mall
Source: ResearchGate.com

The geometric configuration of the mall is shaped by pedestrian circulation, emphasizing direct and accessible pathways to points of interest.

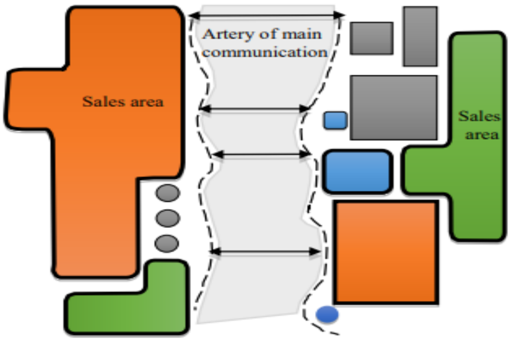


Figure I.36 Functional organizational scheme, points of interest
Source: ResearchGate.com

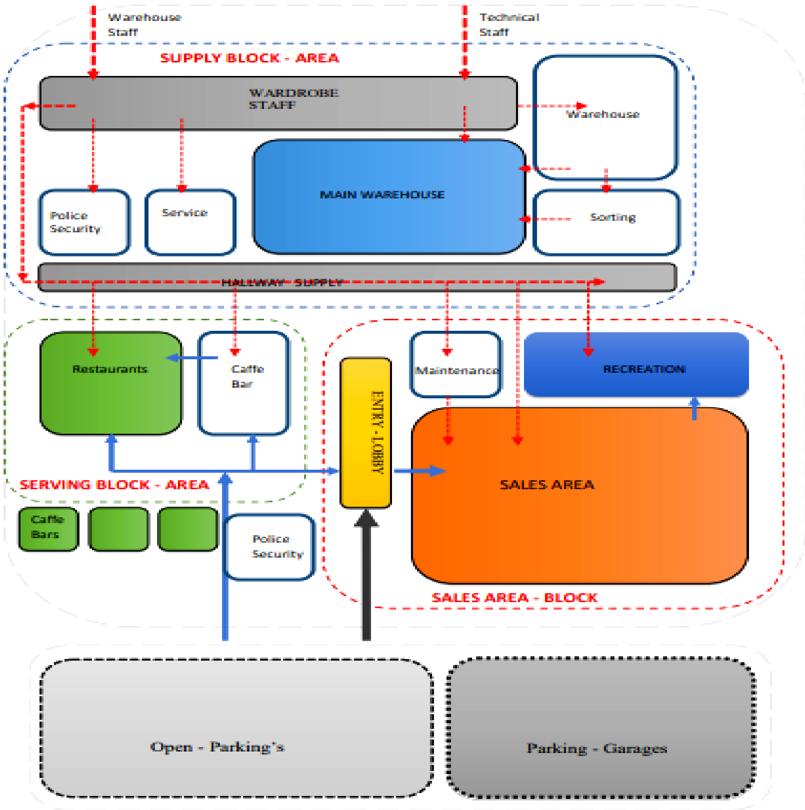


Figure I.37 Functional organizational scheme, shopping mall
Source: ResearchGate.com

By continuously integrating these spatial strategies into the design process, architects ensure the creation of dynamic retail environments that cater to both user convenience and commercial objectives.

VIII.7 General evaluation of daylight in shopping malls

Daylight in shopping malls is essential not only for reducing energy consumption by minimizing artificial lighting but also for enhancing the health, comfort, and productivity of occupants. According to Stevens and Rea, modern built environments have largely replaced natural light with artificial sources, negatively affecting human well-being. Loveland (ref. 37) highlights that daylighting improves the aesthetic value and marketability of commercial buildings, making them more attractive to customers and increasing rental value. Furthermore, proper use of daylight can reduce operational costs and improve visual comfort. Despite these benefits, many malls face issues with overheating, glare, and uneven daylight distribution, especially in multi-story layouts. Effective daylighting strategies must balance illumination with control measures to avoid discomfort and energy waste. In summary, maximizing daylight use in shopping malls supports sustainability goals, economic advantages, and occupant satisfaction, but requires careful architectural planning and innovative lighting solutions. (Agnieszka Rochminska , 2017, p. 45)

Conclusion

The theoretical chapter has demonstrated the essential role that natural light plays in contemporary architecture, both from a functional and environmental perspective. Tracing the historical evolution of natural lighting has highlighted how architectural strategies have continuously adapted to enhance daylight usage—from symbolic applications in religious architecture to modern sustainable design practices. Particular emphasis was placed on Sun Tunnels (light pipes), which emerge as an innovative solution to bring daylight into deep or enclosed interior spaces. Their technical configuration, performance parameters, and architectural implications have been analyzed thoroughly. Furthermore, the chapter has contextualized these systems within shopping center design, showcasing how their integration supports energy efficiency, visual comfort, and commercial value. This theoretical framework lays the foundation for the analytical and practical chapters by justifying the implementation of natural lighting strategies in commercial architecture as a sustainable and human-centered design approach

Analytical chapter

Introduction

In this chapter, we will focus on the analytical approach to the three aspects of our work. We will analyze several literary and current examples of shopping malls to better understand the functioning of these spaces. Next, we will analyze the context,

I The liste of exemples

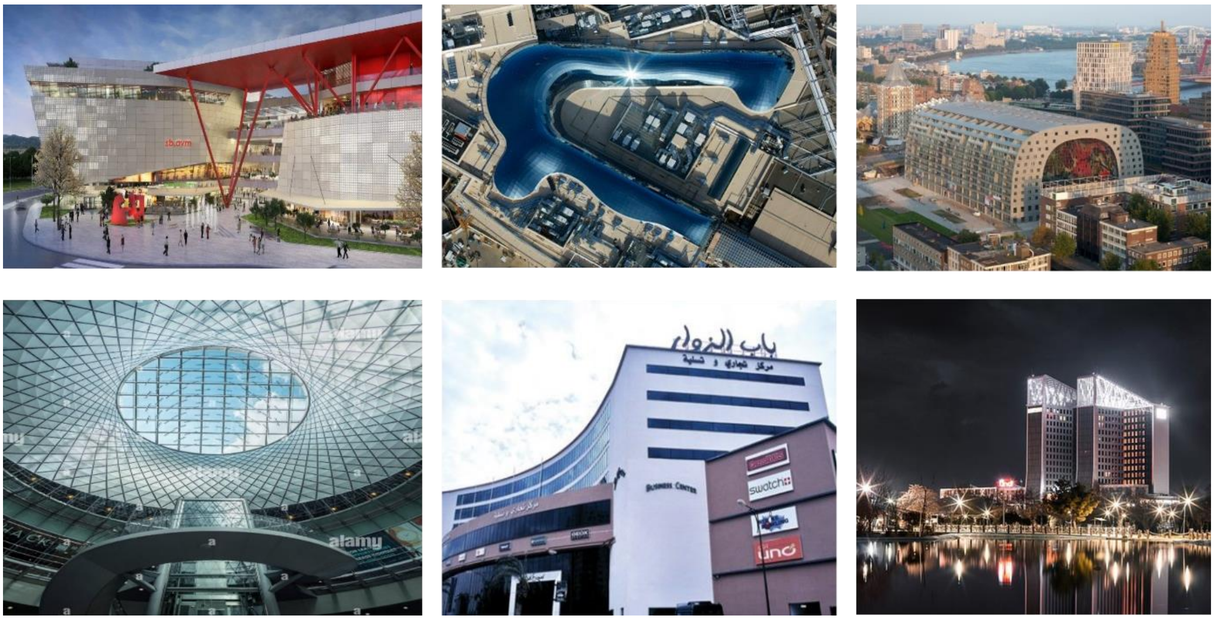


Figure II.1 the liste of exemples
Source: google.com

II The elements to be analyzed

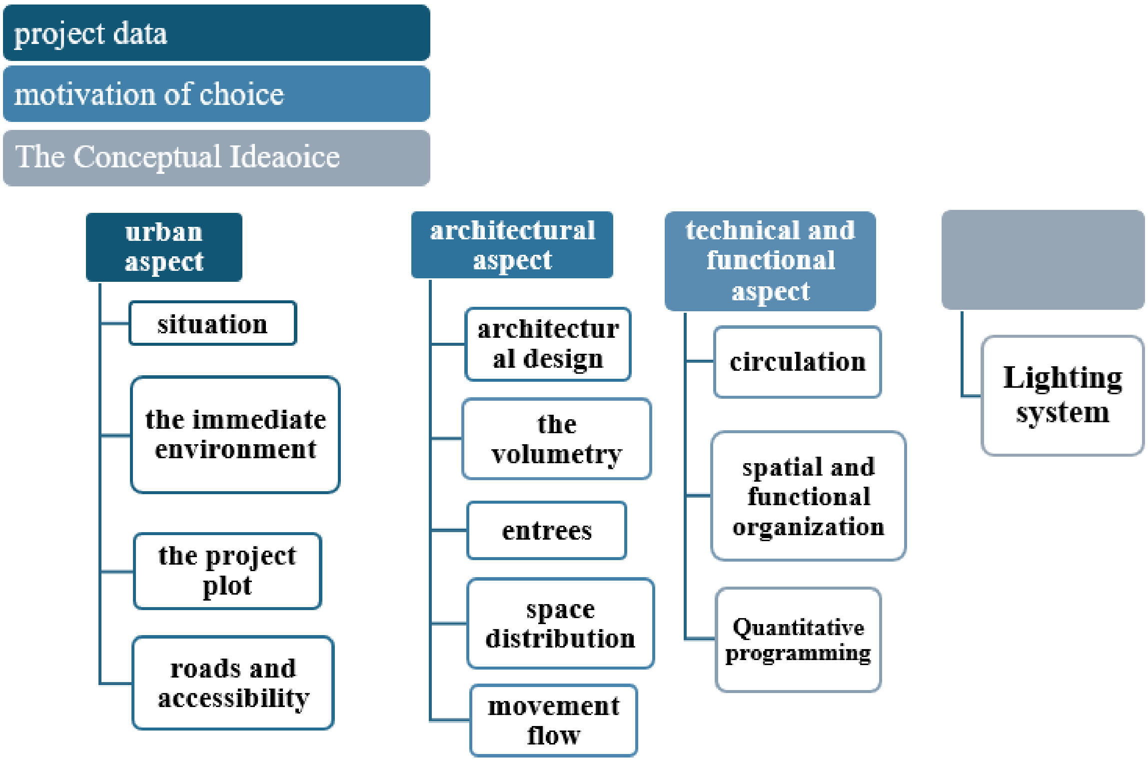


Figure II.2 the elements to be analyzed
Source: auteur,2025

III analysis of bookish examples

III.1 exemple 01: Atlaspark mall

- **Location:** Abdurrahmangazi District Sultanbeyl, Istanbul, TURKEY
- **Architect:** Ergun Mimarlik
- **Client\ owner:** Ziylan-Mesturkuaz-Uzman GYO
- **Land area:** 5.4 hectares
- **Completed:** 2015
- **Construction:** 2012
- **General Contractor:** Sultanbeyli Gayrimenkul Yatırım
- **Interior Designer:** Gorkem Volkan Design Studio
- **Lighting Designer:** Studio Dekor
- **Structural Engineer:** Fonksiyon Mühendislik
- **Ground Footprint Coefficient :** 1.75 hectares

Figure II.3 Atlaspark mall
Source: Pinterest.com

III.1.1 Description of the project

Atlas Park Mall, located in Sultanbeyli, Istanbul, spans 120,000 square meters over four floors and was completed in 2013. The mall is designed to address the lack of green spaces in the area, featuring a central recreational zone devoid of commercial activity. Its innovative use of natural light and wavy wooden ceiling panels creates a dynamic and welcoming environment that balances community needs with modern retail architecture.

III.1.2 Motivation of choice

Atlas Park Mall was chosen for its innovative approach to combining retail spaces with a community-focused design. Its central recreational area addresses the lack of green spaces in the Sultanbeyli district, emphasizing the mall's commitment to social and environmental needs. The thoughtful integration of natural lighting enhances the visitor experience and showcases sustainable architectural practices, making it a compelling subject for analysis.

III.1.3 The Conceptual Idea

Atlas Park Mall focuses on integrating functionality with a visually dynamic and community-sensitive design. The structure centers around a single gallery space that maximizes natural light, creating an inviting and open atmosphere. To address the monotony of long corridors, the design employs perforated, wavy wooden ceiling panels, which add a dynamic aesthetic and soften the linear layout.

Figure II.4 view of the project
Source: Pinterest.com

III.1.4 Situation

Atlas Park Mall is located in Sultanbeyli, a district in Istanbul, Turkey, an area that had limited green spaces and public recreational zones before the mall's construction. The mall's design was driven by the need to provide a community-centered environment in an urban setting that lacked such spaces. Strategically placed, the mall enhances the area's urban fabric while responding to the local context by incorporating a large green space in the center. This green zone, devoid of commercial activity, serves as a calm area for public use, particularly benefiting families and children

Figure II.5 the situation of the project
Source: google earth.com

III.1.5 The Immediate Environment

Situated in Sultanbeyli, Istanbul, a district with limited green spaces.

The area includes residential neighborhoods, commercial zones, and key transport connections, making the mall a central hub for the region.

The mall introduces a central recreational green area, offering a tranquil space in an urbanized environment.

Well-connected by roads and public transport, ensuring ease of access for local and regional visitors.

The mall serves as a much-needed public space, enhancing the area's quality of life by providing green space in an otherwise developed region.

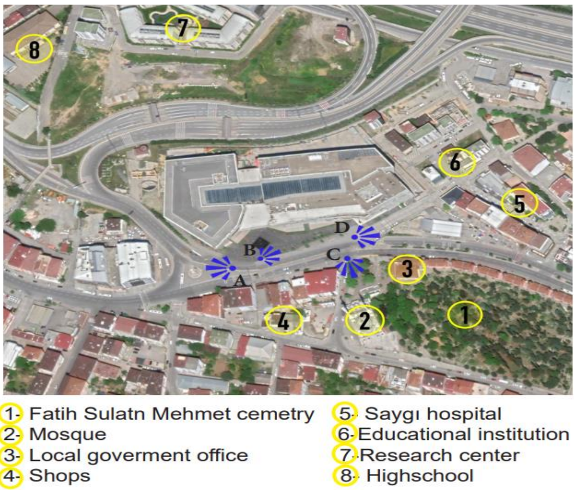


Figure 38 the immediate environment of the project
Source: auteur,2025

Figure II.7view of the environment of the project
Source: google.com

III.1.6 The Project Plot

Atlas Park Mall spans approximately 120,000 square meters. The majority of the space is built up with the retail structure, but the design incorporates a central green area on the ground floor, creating an open, non-commercialized space. This green space balances the built areas, enhancing the community and environmental aspects of the project. The remaining land around the mall includes pedestrian walkways and landscaping, offering a mix of built and open areas .

III.1.7 Limits

The land's boundaries of Atlas Park Mall feature a combination of geometric and organic forms. This unique shape results from the surrounding road network on two sides, which influenced the design to adapt to the more fluid, organic outline of the plot. The intersection of these structured and natural elements contributes to the mall's dynamic architectural integration with its environment

Figure II.8 limits of the project
Source: author treatment,2025

III.1.8 Form

Can notice that the project is influenced by The and contour which results in having a Geometric form where each line is parallel to the other "alignement"(Fig47)

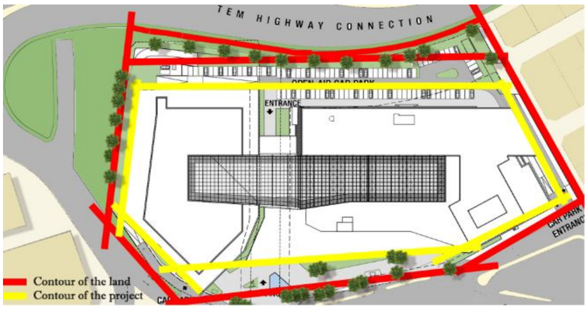


Figure II.9 project form
Source: author treatment,2025

III.1.9 Built and unbuilt

The mall is situated almost in the centre of the land. A parking lot and a plaza were placed at the extremities for noise isolation. Meanwhile, the east and west side for parking entrances. (Fig46)

Figure II.10 built and unbuilt
Source: author treatment,2025

III.1.10 roads and accessibility

We acknowledge that our project is well surrounded by bus stationts which achieve high accessibility to a greater number of populations. In addition, we notice it is localized between two major roads; therefore, it adds a value to our analysed project

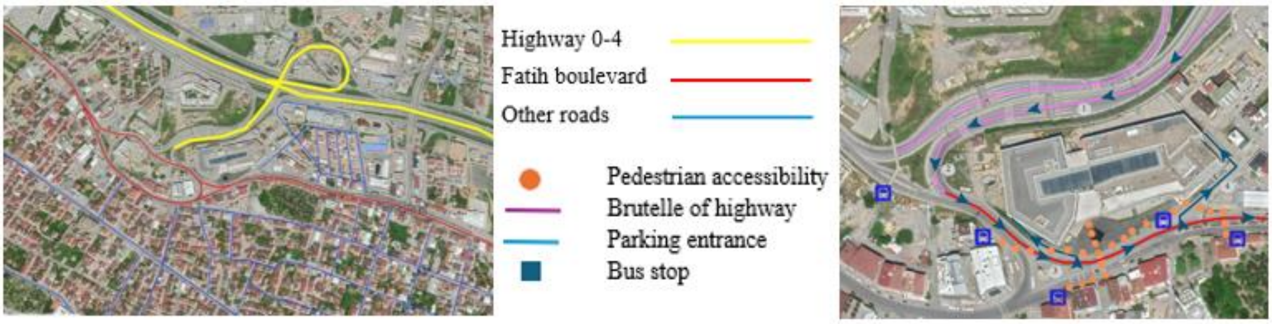


Figure II.11 roads and accessibility of the project
Source: author treatment,2025

III.1.11 The volumetry

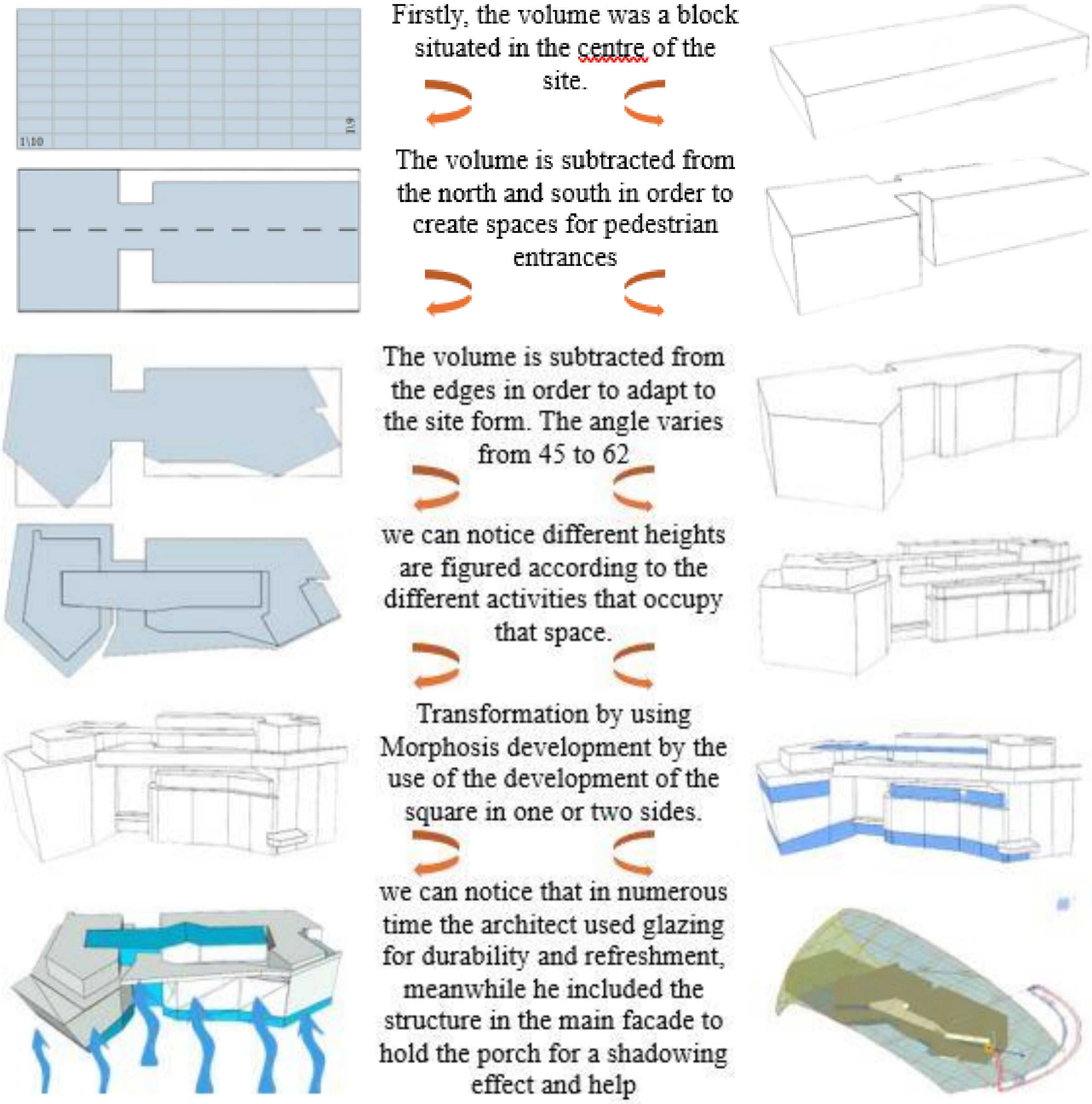


Figure II.12the development of the volumetry of the project
Source: archidaily.com

III.1.12 Pedestrian and cars entrances

The parking entrance of Atlas Park Mall is strategically located on Fatih Boulevard, facing the lower-density road to minimize traffic congestion. The main entrance is also situated on Fatih Boulevard, oriented towards the urban side of the city. This positioning provides easy, visible, and direct access for visitors, ensuring convenient entry for the surrounding population

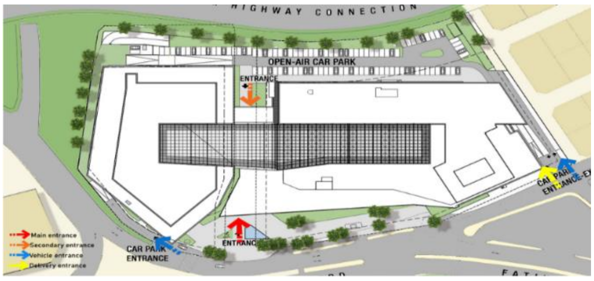


Figure II.13 Pedestrian and cars entrances
Source: author treatment,2025

Main entrance secondary entrance vehicale entrance delivery entrance

III.1.13 Main entrance

The main entrance of Atlas Park Mall is designed to stand out, with its distinctive height, texture, and irregular form, making it a striking architectural feature. These elements give the entrance an emblematic quality, enhancing its visibility and significance within the mall's overall design.

Figure II.14 view of the main entrance
Source: Pinterest.com

III.1.14 Circulation

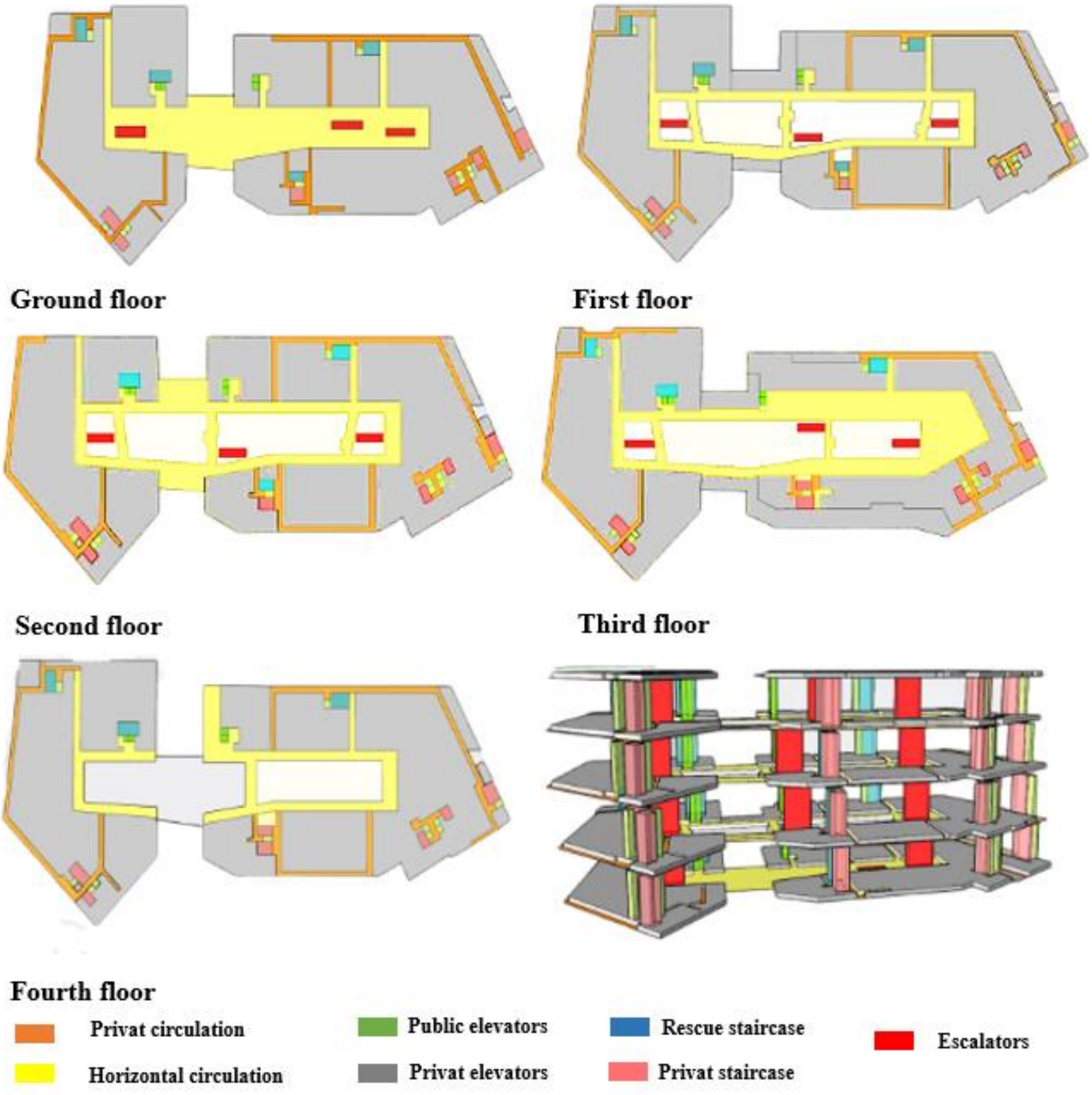


Figure II.15 circulation in the project
Source: author treatment,2025

The circulation in Atlas Park Mall is centralized, ensuring smooth movement throughout the space. Wide walkways and aisles are provided, facilitating easy navigation. Vertical circulation is efficiently managed through staircases and elevators located in central areas. The staircases are spacious, catering to high foot traffic without causing congestion, making the design well-suited for public use

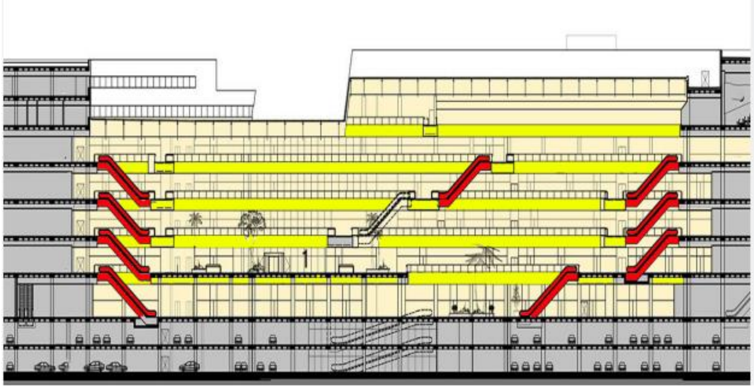


Figure II.16 vertical circulation
Source: author treatment,2025

III.1.15 Spatial and functional organization

Atlas Park Mall features a functional and efficient spatial organization with wide central walkways and strategically zoned retail, dining, and entertainment areas vertical circulation is facilitated by elevators and spacious staircases in central locations, ensuring smooth movement between floors. The ground floor integrates a non-commercial green space, enhancing the mall's role as both a shopping and community hub.

Permanent relation
Service area
Emergency and secondary lane
Strong relation
Ground floor
Last floor
All floors

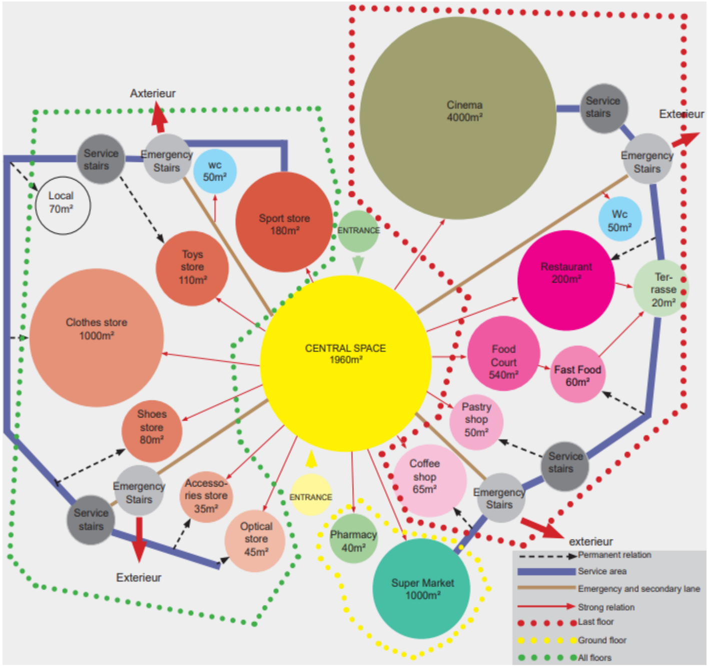


Figure 39 spaces organization in the project
Source: author treatment,2025

III.1.16 Lighting system

- **The central light-transmitting element**

In Atlas Park Mall, the central light-transmitting element is the main atrium or gallery. This architectural feature is designed to channel natural light deep into the interior of the building. Acting as a light well, it captures sunlight from the upper levels and disperses it through the mall, aided by reflective and strategically positioned surfaces. This element not only brightens the interior but also creates a visually dynamic and inviting environment, ensuring that light reaches even the lower floors

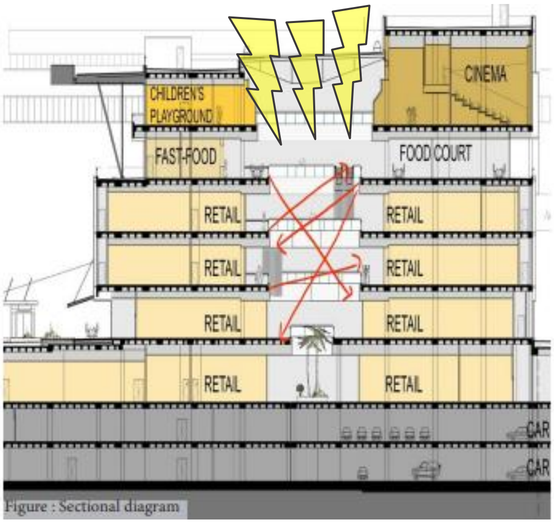


Figure II.18 central light-transmitting element
Source: author treatment,2025

- **Perforated Ceiling Panels**

The wavy wooden ceiling panels are perforated to allow filtered natural light to spread throughout the interior, creating a warm and dynamic atmosphere.

Perforated Ceiling Panels: The wavy wooden ceiling panels are perforated to allow filtered natural light to spread throughout the interior, creating a warm and dynamic atmosphere.

A central gallery acts as the main light well, capturing and directing sunlight into the heart of the mall, reducing the need for artificial lighting during the day.

Figure II.19 Perforated Ceiling Panels
Source: author treatment,2025

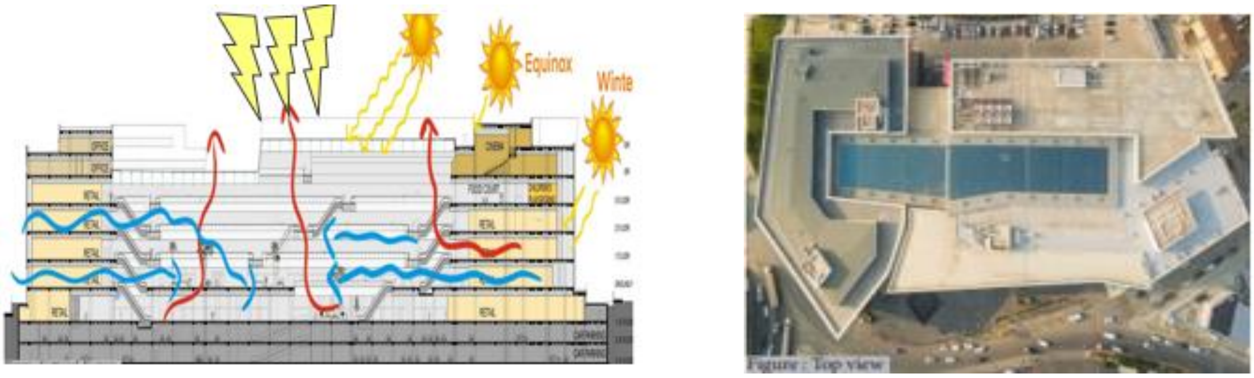
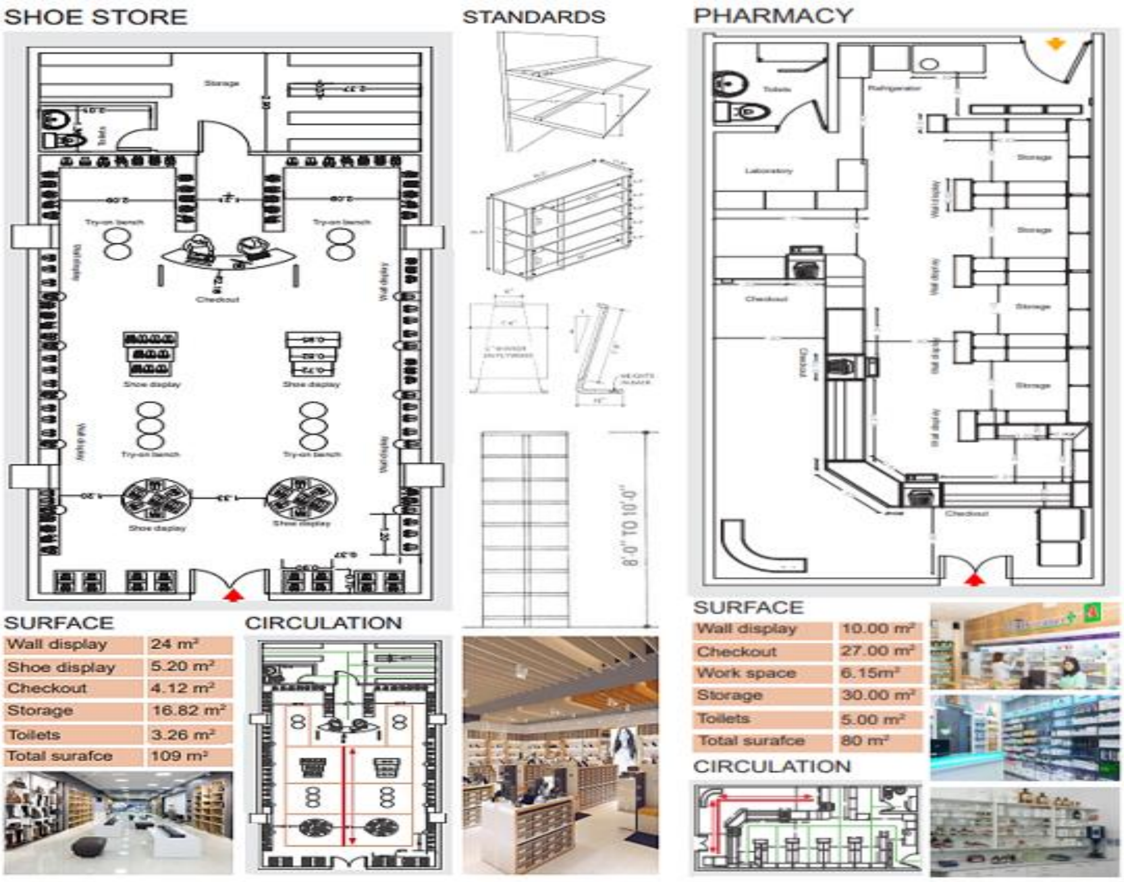
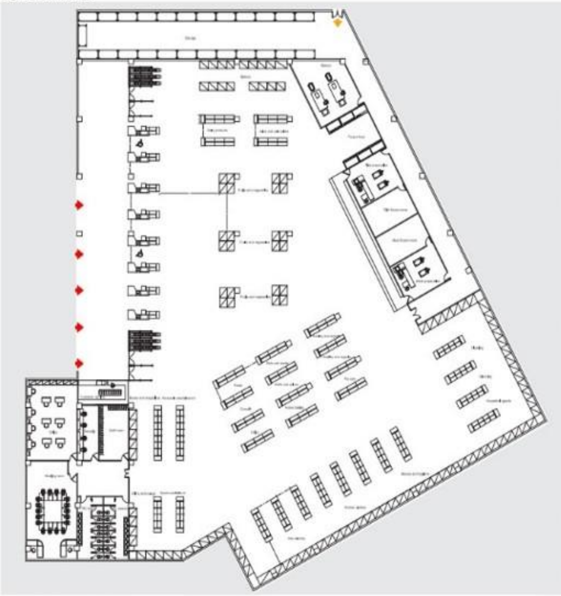


Figure II.20 lighting system
Source: author treatment,2025

III.1.17 Quantitative programming



SUPERMARKET



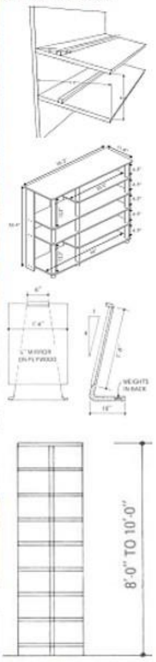
SURFACE

Cashier	175.4 m²	Cleaning	84.00 m²
Bakry	71.64 m²	Household goods	84.50 m²
Bakry preparation	47.61 m²	Beauty and hygiene	115 m²
Dairy products	36.00 m²	Women clothes	66.00 m²
Juice and cold drinks	36.00 m²	Men clothes	66.00 m²
Frozen food	38.34 m²	Shoes	40.00 m²
Fish preparation	32.52 m²	Books and magazines	33.00 m²
Fish freezer room	25.76 m²	Personal entartainement	26.00 m²
Meat preperation	32.52 m²	Office technology	33.00 m²
Meat freezer room	25.76 m²	Sports and leisure	26.00 m²
Fruits and vegetables	266.57 m²	Staff room	26.00 m²
Pasta	30.00 m²	Security room	18.40 m²
Cereals	30.00 m²	Office	65.70 m²
Nuts and seeds	30.00 m²	Customer Service	26.00 m²
Healthy and organic	30.00 m²	Meeting room	79.00 m²
Herbs and spices	30.00 m²	Storage	31 m²
Home baking	30.00 m²	Toilets	52.00 m²
Pet care	30.00 m²	Surface Total	3402 m²

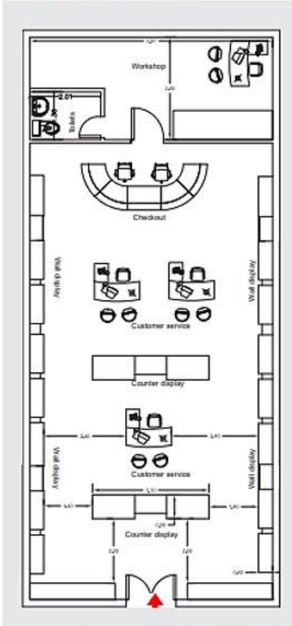
CIRCULATION

STANDARDS

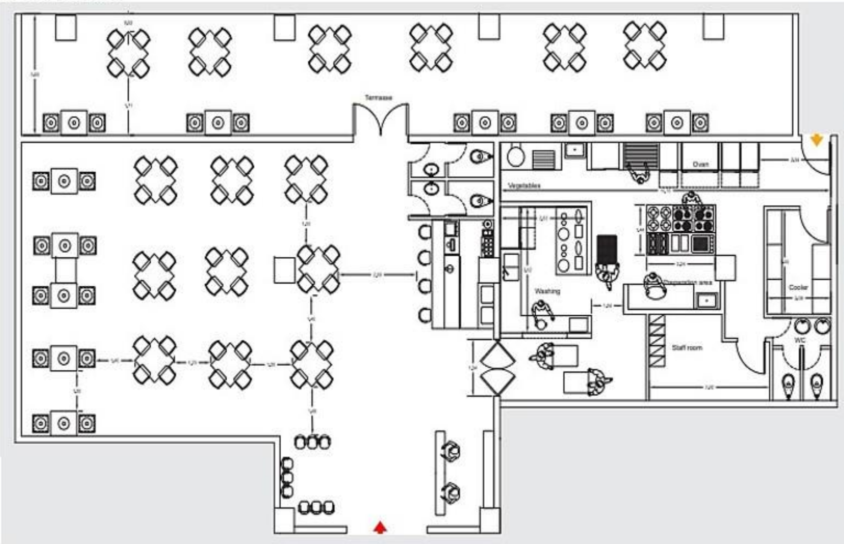
STANDARDS

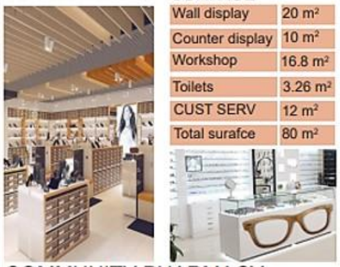


OPTICAL STORE



RESTAURANT

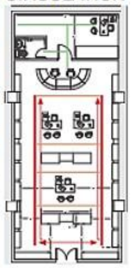




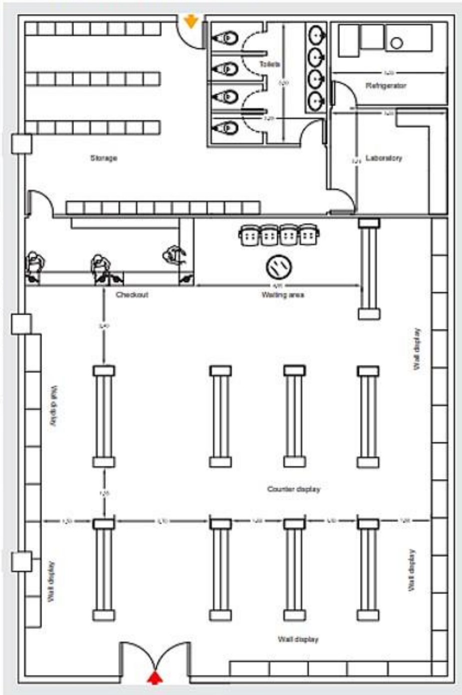
SURFACE

Wall display	20 m²
Counter display	10 m²
Workshop	16.8 m²
Toilets	3.26 m²
CUST SERV	12 m²
Total surafce	80 m²

CIRCULATION



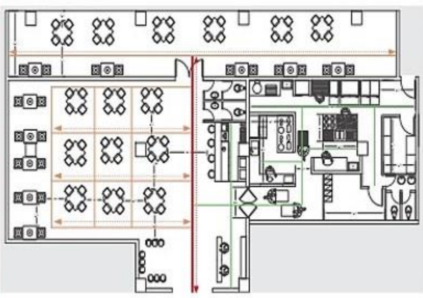
COMMUNITY PHARMACY



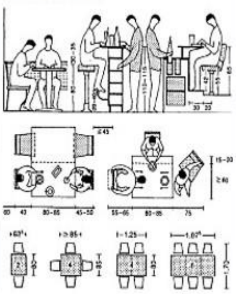
SURFACE

Bar	8.56 m²
Cooler	6.26 m²
Toilets	4.5 m²
Terrasse	85.74 m²
Entrance	30.25 m²
Staff room	8.5 m²
Dining area	115.49 m²
Ovens area	7.00 m²
Vegetables	3.26 m²
Washing area	6.5 m²
Public toilets	4.5 m²
Preparation area	10.36 m²
Total surface	334.30 m²

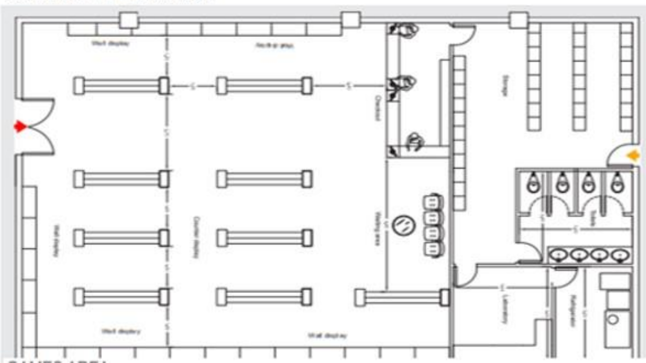
CIRCULATION



STANDARDS



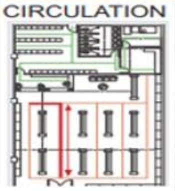
COMMUNITY PHARMACY



SURFACE

Wall display	29.7 m²
Counter display	81.42 m²
Waiting area	10.00 m²
Storage	36.42 m²
Laboratory	13.00 m²
Toilets	11.86 m²
Refrigerator	8.20 m²
Total surafce	233 m²

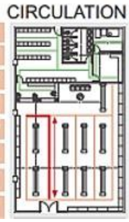
CIRCULATION



SURFACE

Wall display	29.7 m²
Counter display	81.42 m²
Waiting area	10.00 m²
Storage	36.42 m²
Laboratory	13.00 m²
Toilets	11.86 m²
Refrigerator	8.20 m²
Total surafce	233 m²

CIRCULATION



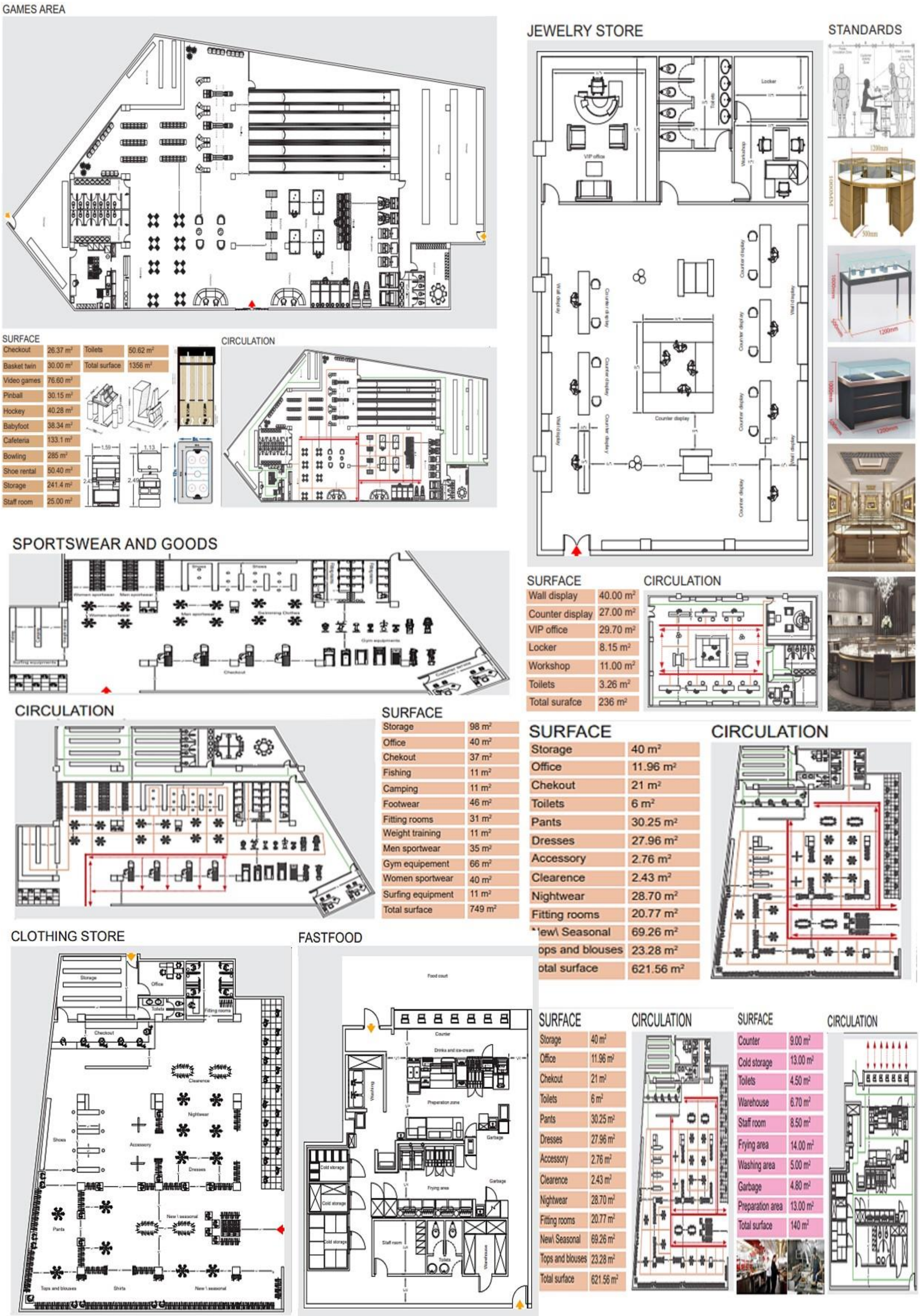


Figure II.21 different project spaces surfaces
Source : Ahmed Khaled, mémoire de master,2017.

III.2 Exemple 02 : Chadstone Shopping Centre

Figure II.22 Chadstonr Shopping Centre
Source: Pinterest.com

- **Location:** Melbourne, Australia
- **Total Area:** 212,000 square meters (gross leasable area)
- **Architects:** CallisonRTKL and Buchan Group
- **Key Feature:** A 7,000-square-meter gridshell glass roof, the first of its kind in Australia
- **Construction Technique:** Advanced 3D parametric modeling for precision
- **Design Focus:** Structural efficiency, natural light integration, and aesthetic appeal
- **Purpose:** Retail, leisure, and entertainment
- **Year of Completion**: 2016 expansion

III.2.1 Description of the project

Chadstone Shopping Centre, located in Melbourne, Australia, is a landmark of modern retail architecture. Known for its iconic glass-domed roof, the design emphasizes natural light and sustainability while offering a luxurious shopping experience. With over 550 stores and diverse amenities, it combines functionality and elegance, making it a premier destination in the Southern Hemisphere.

III.3 Motivation of choice

Adstone Shopping Centre was selected for its iconic design, showcasing a unique glass gridshell roof and sustainable architectural solutions. Its role as a major retail and leisure hub, combined with innovative natural lighting, efficient circulation, and integration with its urban context, makes it a compelling case for analysis.

III.3.1 The Conceptual Idea

The design of Chadstone Shopping Centre focuses on creating a luxurious, light-filled space centered around its iconic glass roof, which enhances natural lighting and openness. The project blends form and function with sustainability and user comfort, offering a modern and eco-conscious retail experience

Figure II.23 view of the project
Source: Pinterest.com

III.3.2 Situation

Chadstone Shopping Centre is situated in Melbourne's southeastern suburbs, positioned strategically near the Monash Freeway for convenient regional access. The location integrates suburban residential and commercial zones, establishing Chadstone as a central hub for retail, leisure, and entertainment. Its design maximizes connectivity and accessibility, making it a key destination within Melbourne's urban fabric

Figure II.24 situation of the project
Source: google earth

III.3.3 The immediate environment

Chadstone Shopping Centre is located in Melbourne's southeastern suburbs, surrounded by residential neighborhoods and commercial zones. Its proximity to the Monash Freeway enhances connectivity, while nearby bus stops and train stations provide public transport access.The surrounding area supports the centre's role as a regional hub, with complementary facilities like hotels and offices contributing to a vibrant mixed-use environment. Landscaping and pedestrian pathways integrate the centre with its surroundings, enhancing the visitor experience and maintaining harmony with the urban context.

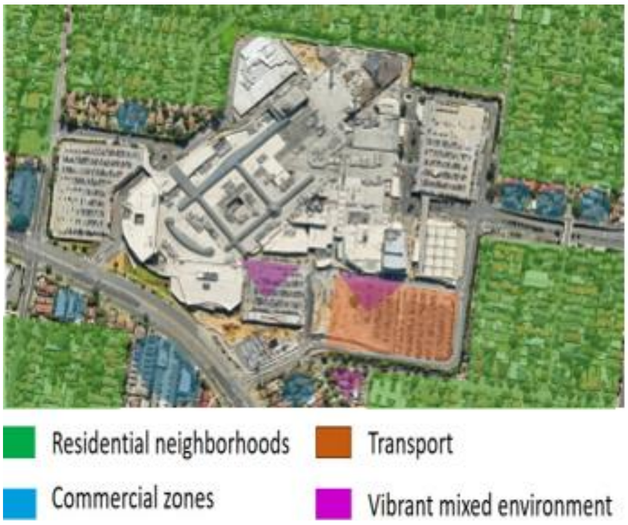


Figure II.25the immediate environment of the project
Source: author treatment,2025

III.3.4 The Project Plot

Chadstone Shopping Centre is situated on a large urban plot, with a total land area designed to accommodate its massive structure and surrounding infrastructure.

Built-Up Area: Over 212,000 square meters of leasable retail space.

External Spaces: Landscaped areas, parking zones, and pedestrian pathways

Figure II.26 the project plot
Source: author treatment,2025

III.3.5 roads and accessibility

Transportation Access Strategically located with direct access to the Monash Freeway, supported by bus and train links.

the Monash Freeway
Main road in the vicinity of the project
Road to Project
Bus station

Parking: Ample parking spaces, including dedicated areas for disabled visitors.

parking

Pedestrian Movement: Easy navigation with wide walkways and clear signage. Inclusive Design: Fully accessible facilities, ramps, and entrances for people with disabilities.

Figure II.27 roads and accessibility to the project
Source: author treatment,2025

Connectivity: Links with surrounding areas ensure seamless movement for visitors of all mobility levels.

This framework highlights Chadstone's commitment to providing an inclusive and user-friendly environment.

III.3.6 Architectural Design

The design of Chadstone Shopping Centre merges modernity with iconic features, most notably the 7,000-square-meter gridshell glass roof. This roof, the first of its kind in Australia, enhances natural light and provides a visually striking centerpiece. The centre's layout is expansive and fluid, with a focus on clear circulation paths and an inviting atmosphere. The integration of sustainability features, like energy-efficient materials and natural lighting, ensures a functional yet luxurious shopping experience, balancing aesthetic appeal with environmental responsibility

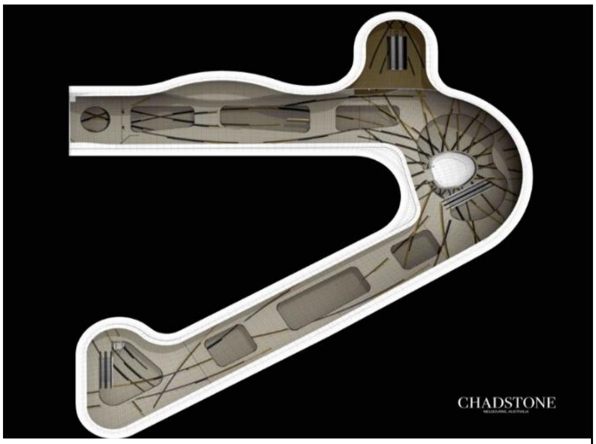


Figure II.28architectural design of the project
Source: Pinterst.com

III.3.7 Space Distribution

Chadstone Shopping Centre features a spacious, open layout designed to maximize visitor flow. Retail areas are strategically placed to create a seamless shopping experience, with large atriums and wide walkways facilitating easy access to all sections of the centre.

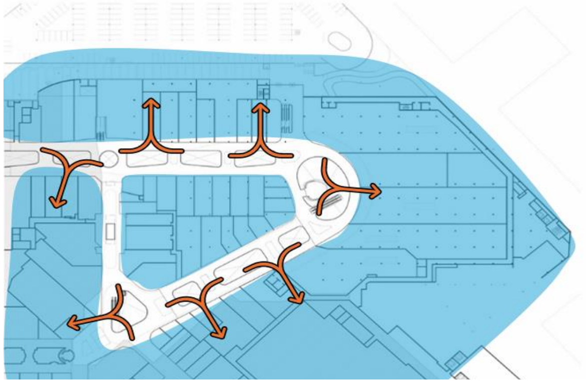


Figure II.29 space distribution of the project
Source: author treatment,2025

III.3.8 Movement Flow

The design emphasizes smooth, intuitive movement through the centre, with clear paths connecting various retail, dining, and entertainment zones. Central spaces act as gathering points, while directional signage and open spaces further enhance circulation and minimize congestion

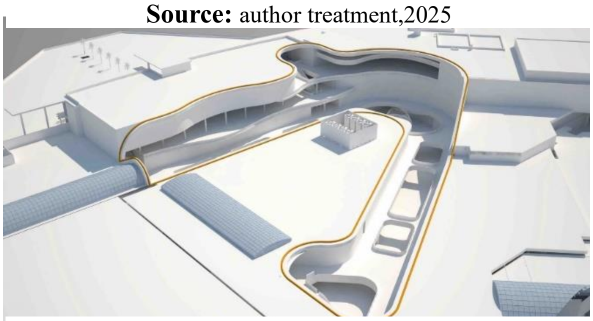


Figure II.30 movement flow of the project
Source: archidaily.com

III.3.9 Circulation (horizontal/vertical)

Chadstone Shopping Centre is designed to optimize both horizontal and vertical circulation. Horizontal movement is facilitated by wide corridors and clearly defined pathways that allow smooth access to various retail zones. Vertical traffic is managed through strategically placed escalators, elevators, and ramps, connecting the multiple levels. These elements work together to ensure efficient and comfortable circulation throughout the centre, allowing visitors to easily navigate between different floors and spaces. The layout supports a seamless experience for both pedestrians and those with mobility needs

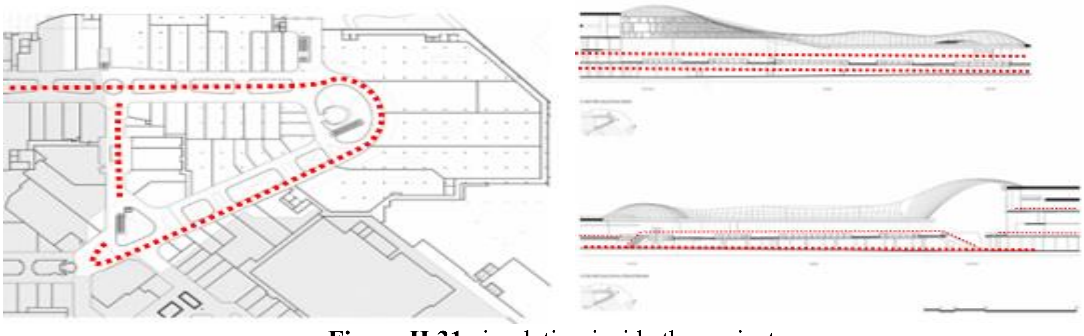


Figure II.31 circulation inside the project
Source: author treatment,2025

III.3.10 Lighting system

The centre's design incorporates abundant natural light, particularly through the signature glass roof. This not only improves the aesthetic experience but also enhances energy efficiency by reducing the reliance on artificial lighting. The clever integration of light creates a bright and welcoming atmosphere throughout the space.

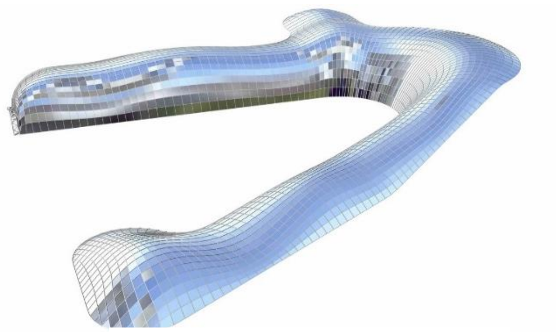


Figure II.32 lighting system
Source: archidaily.com

III.3.11 Natural lighting to the bottom

To bring natural light to the lower levels of Chadstone Shopping Centre, the design uses a combination of light wells, reflective surfaces, and the strategic placement of openings in the building. These features help channel and diffuse light from the large glass dome down through the center, ensuring that the lower floors receive ample natural light. This approach reduces the need for artificial lighting and creates a bright, welcoming atmosphere throughout the space.

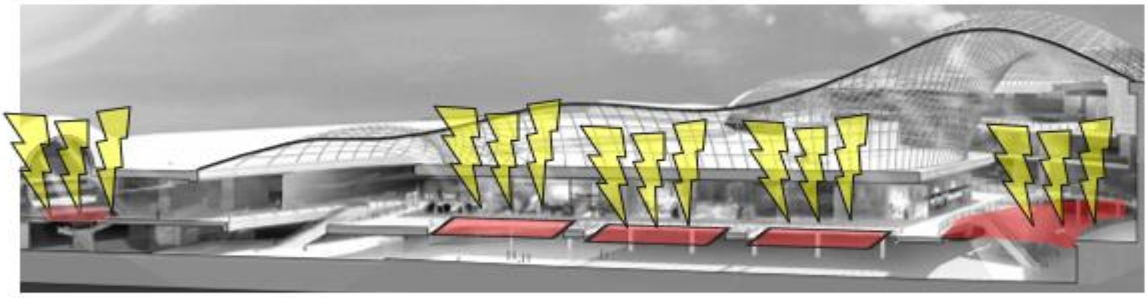


Figure II.33 natural lighting system
Source: author treatment,2025

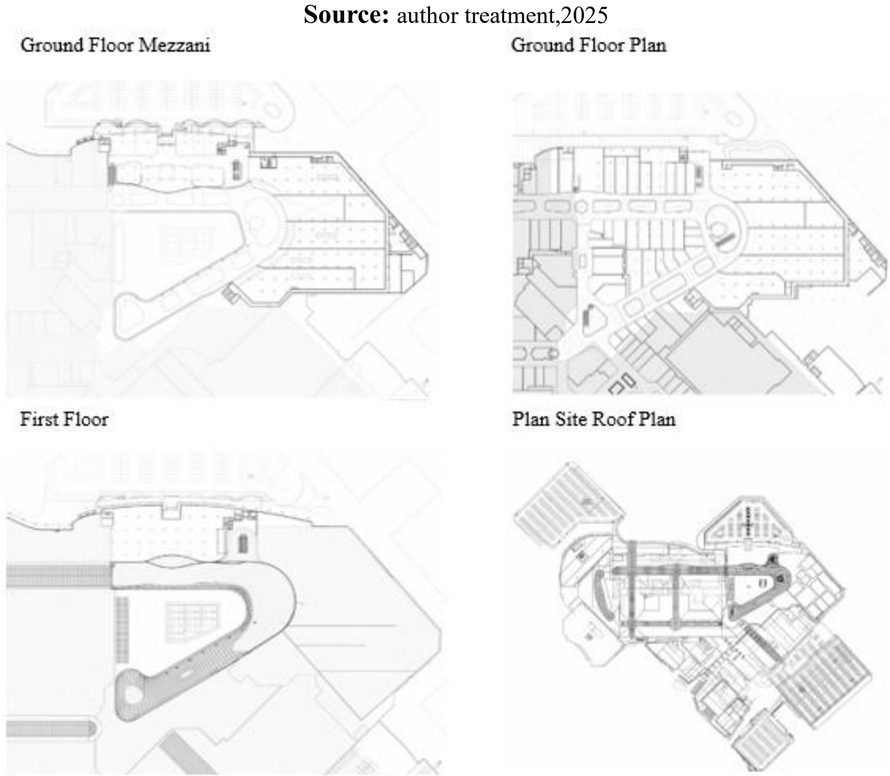


Figure II.34 different layouts of the project
Source: archidaily.com

III.4 Exemple 03: Markthal Rotterdam Shopping Center

- **Location:** Rotterdam, Holland
- **Architect:** MVRDV
- **Engineer:** INBO
- **Designed in:** 2004 - 2009
- **Built in:** 2009 – 2014
- **Height:** 40m
- **Width:** 70m
- **Length:** 120m
- **Floors:** 11
- **Land Area:** 8.400m²
- **Built-up Area:** 100.000m²
- **Façade :** Glass
- **Cost:** 175millones euros
- **Location :** Rotterdam, Holland

Figure II.35 Markthal Rotterdam Shopping Center
Source: Pinterest.com

III.4.1 Description of the project

Markthal in Rotterdam, designed by MVRDV, is a mixed-use project that combines a market hall, residential units, and commercial spaces under an arch-shaped structure. Its design features large glass facades that maximize natural light, enhancing comfort and reducing energy use. This analysis explores how natural light contributes to a sustainable environment and impacts functionality and user experience

III.4.2 Motivation of choice

Markthal was chosen for its innovative use of natural lighting through large glass facades and strategically placed skylights. These roof openings allow daylight to flood the interior, improving brightness and ambiance while enhancing energy efficiency. This makes Markthal an ideal case study for exploring the role of natural light in retail spaces, aligning with the focus of my thesis on lighting solutions in shopping centers

Figure II.36 view of natural light of the project
Source: Pinterest.com

III.4.3 The Conceptual Idea

The concept of Markthal is to combine a market, residential units, and commercial spaces in a single horseshoe-shaped structure. It focuses on openness, connectivity, and natural light through large glass facades and skylights, promoting energy efficiency. The design creates a vibrant, sustainable environment that enhances user experience and revitalizes Rotterdam's urban landscape.

Figure II.37 the conceptual idea of the project
Source: archidaily.com

III.4.4 Situation

Markthal is located in the heart of Rotterdam, Netherlands, a city known for its modern architecture and innovative urban design. Situated in a vibrant, mixed-use district, Markthal serves as both a cultural landmark and a functional urban space. The project was designed to revitalize the surrounding area and provide a new model for urban living and shopping. By combining a public market with residential

Figure II.38 situation of the project
Source: google earth.com

and commercial spaces, Markthal addresses the need for sustainable, multi-use buildings that foster community interaction while meeting modern urban demands.

III.4.5 The Immediate Environment

Markthal is located in the center of Rotterdam, surrounded by a mix of commercial, residential, and cultural spaces. It is close to Rotterdam Central Station and the Laurenskwartier district, known for its shops and restaurants. The building's large glass facades connect it visually to the city, creating an open relationship with the surrounding urban environment.

Figure II.39 the immediate environment of the project
Source: archidaily.com

III.4.6 The project plot

Markthal is located on a prominent site in central Rotterdam, occupying a rectangular plot in the heart of the city. The plot is bounded by Dominee Jan van der Heydenstraat, Oude Binnenweg, and Grote Markt, placing it at the intersection of key urban routes. This location provides high visibility and accessibility, making it a central hub for both locals and visitors.

The plot was carefully chosen as part of Rotterdam's urban revitalization efforts, with the goal of transforming an underutilized area into a vibrant, multifunctional space. The building's horseshoe-shaped design maximizes the use of the plot, creating an open and dynamic space that connects the market hall, residential units, and commercial areas. The layout enhances pedestrian movement and integrates the structure into the surrounding urban fabric

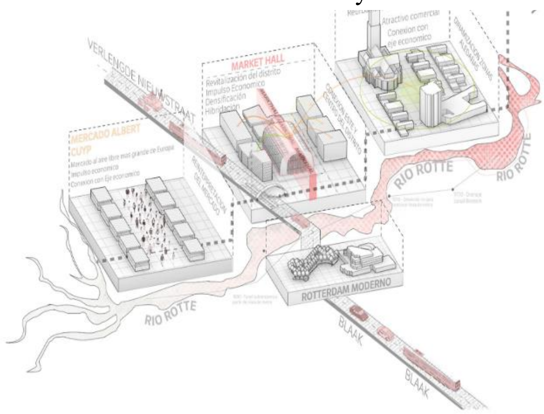


Figure II.40 the project plot
Source: archidaily.com

III.4.7 Road and accessibility

Markthal is easily accessible by major roads like Dominee Jan van der Heydenstraat and Oude Binnenweg. It is within walking distance of Rotterdam Central Station, which connects to trains, trams, and buses. The site is pedestrian-friendly and well connected to the city's cycling network, making it accessible by foot or bike.

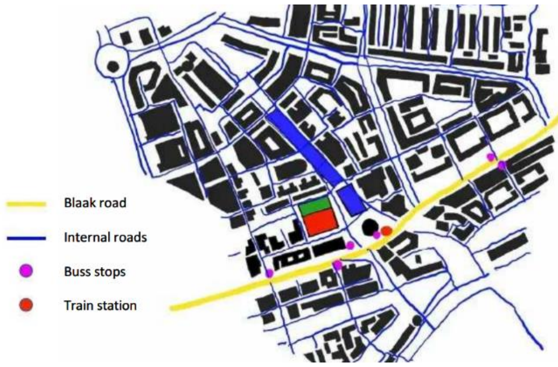
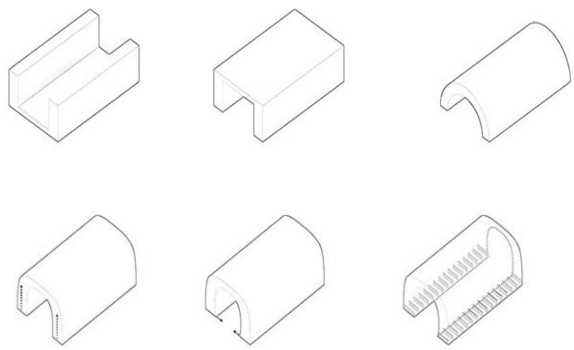


Figure II.41roads and accessibility to the project
Source: author treatment,2025

III.4.8 The volumetry

Markthal's design is characterized by its iconic horseshoe-shaped arch, creating a distinctive and bold volumetric form. The building consists of a large, enclosed market hall at its core, with residential units and commercial spaces integrated into the structure's outer edges

Main Volume: The central market hall is the dominant volume, with a large, open interior space covered by a curved glass and steel roof. This vast space is defined by its high ceilings, which contribute to a sense of openness and lightness



Residential and Commercial Spaces: The surrounding volumes consist of two floors of residential units and commercial spaces that are seamlessly integrated into the arch. These spaces are set back from the market hall, allowing for large open facades and views into the central area

Shape and Structure: The horseshoe shape of the building creates a sense of enclosure around the market while maintaining openness through the large glass facades and skylights. This volumetric form is both functional and visually striking, making Markthal a landmark in Rotterdam

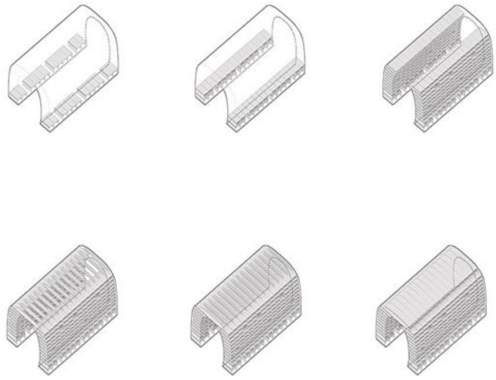


Figure II.42 the development of the volumetry of the project
Source: archidaily.com

III.4.9 Entrances

Markthal features multiple entrances, designed to facilitate easy access and flow for visitors and residents:

- **Main Entrance**

The primary entrance is located at the base of the horseshoe arch, providing direct access to the market hall. It is large and open, drawing visitors into the central space. This entrance is visually prominent, flanked by the expansive glass facades.

- **Side Entrances**

Additional entrances are located on the sides of the building, providing access to the surrounding commercial and residential areas. These are designed to blend seamlessly with the overall architecture while allowing for smooth transitions between the interior and exterior

These entrances are strategically placed to encourage foot traffic, enhance accessibility, and maintain the open, welcoming atmosphere of the building.

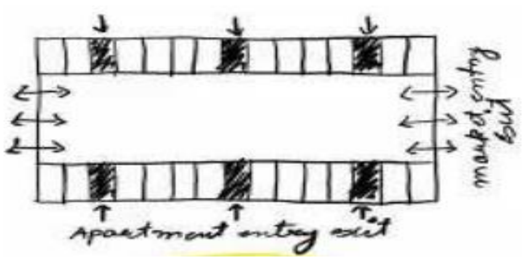


Figure II.43 different entrances of the project
Source: Pinterest.com

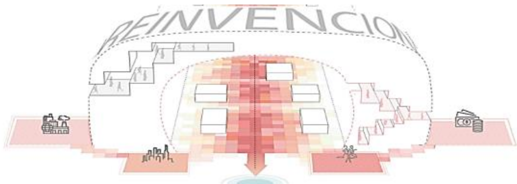


Figure II.44main entrance of the project
Source: Pinterest.com

Figure II.45 side entrances of the project
Source: archidaily.com

III.4.10 Circulation

- **Horizontal Circulation**

The layout of the market hall is designed for smooth horizontal circulation. Wide, open aisles connect various market stalls, allowing for an easy flow of people throughout the space. The large glass facades provide clear sightlines, enhancing orientation and guiding visitors naturally toward different areas.

Commercial and Residential Areas: The commercial spaces and residential entrances are designed to integrate seamlessly with the market hall. Horizontal circulation paths allow access to these areas while maintaining a clear division of spaces.

Figure II.46 horizontal circulation of the project
Source: archidaily.com

- **Vertical Circulation**

Elevators and Stairs: Vertical circulation is facilitated by strategically placed elevators and staircases, providing access to the residential and commercial floors above the market hall. These are designed to separate the different functions of the building (market, living, and shopping) while allowing easy access to upper levels.

Access to Underground: Markthal also includes underground levels with connections to parking and public transportation. Stairs and elevators provide access to these areas from the ground level.

Overall, both horizontal and vertical circulation are designed for efficiency, accessibility, and smooth flow, enhancing the building's multifunctional use while maintaining a sense of openness and connection between spaces.

Figure II.47 vertical circulation of the project
Source: author treatment,2025

III.4.11 Lighting system

Skylights and Roof Openings in Markthal (Architectural Perspective)

- **Architectural Integration**

The skylights and roof openings are seamlessly integrated into the horseshoe-shaped roof structure, blending function with aesthetic design. Their positioning enhances the building's overall form, complementing the sweeping, open curves of the architecture.

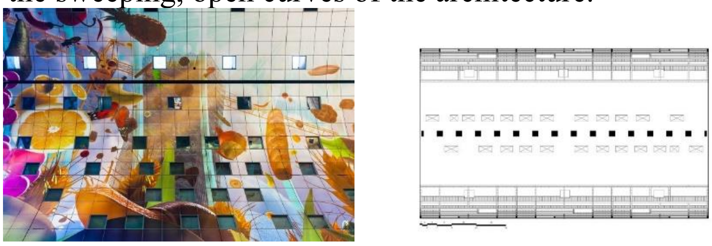


Figure II.48 lighting system of the project
Source: archidaily.com

- **Maximizing Daylight and Reducing Depth**

The roof openings are strategically placed to maximize natural light penetration into the interior. These openings help reduce the depth of the building by allowing daylight to reach deep into the market hall, addressing the challenge of lighting a large, enclosed space

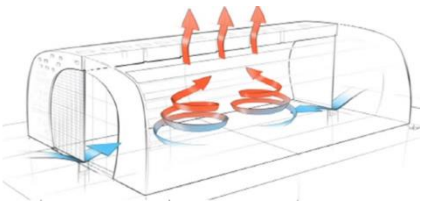


Figure II.49the openings system
Source: archidaily.com

III.4.12 Visual and Environmental Connection

The skylights connect the building with its environment, framing views of the sky and contributing to the interior's dynamic lighting changes throughout the day. This architectural choice enhances the user experience by fostering a connection between the interior space and the surrounding urban landscape.

Figure II.50 the project skylights
Source: archidaily.com

III.5 Example 04: Fulton Center

- **Project data**
- **Project Name:** Fulton Center
- **Location:** Manhattan, New York City, USA
- **Completion Date:** November 10, 2014
- **Architects:** Grimshaw Architects in collaboration with Arup
- **Client:** Metropolitan Transportation Authority (MTA)
- **Project Type:** Transportation and retail hub (mixed-use)
- **Area:** Approx. 27,870 square meters (300,000 square feet)

Figure II.51 Fulton Center
Source: Pinterest.com

III.5.1 Project description

Fulton Center in New York City is a modern, sustainable transit and retail hub designed by Grimshaw Architects and Arup. It connects nine subway lines and integrates natural lighting through the Sky Reflector-Net and glass oculus, illuminating underground spaces and reducing energy use. This project highlights how thoughtful design transforms infrastructure into a vibrant, user-focused public space, blending sustainability with functionality.

III.5.2 Motivation of choice

Fulton Center exemplifies innovative use of natural lighting in a dense urban context. Its Sky Reflector-Net and glass oculus transform a transit hub into a vibrant, energy-efficient space, showcasing the impact of daylight on sustainability and user comfort. This aligns perfectly with my research focus on natural light in architectural design.

III.5.3 The Conceptual Idea

The conceptual idea of Fulton Center focuses on enhancing connectivity and openness in a dense urban transit hub. Central to this is the use of natural lighting, particularly through the Sky Reflector-Net and glass oculus, which bring sunlight deep into the structure. This design improves energy efficiency, creates a welcoming environment, and connects underground spaces with the surrounding urban fabric, blending functionality and elegance.

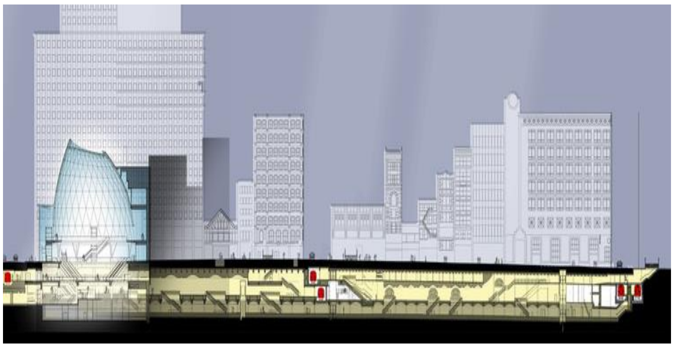


Figure II.52coupe of the project
Source: archidaily .com

III.5.4 Situation

Fulton Center is part of a larger urban renewal effort in Lower Manhattan, aimed at revitalizing infrastructure post-9/11. It enhances New York City's transportation network while promoting sustainability and connectivity. Located near key landmarks like the World Trade Center, it transforms transit spaces into multifunctional, energy-efficient environments, showcasing a shift toward integrating modern architecture and natural light in urban public spaces

Figure II.53situation of the project
Source: google earth.com

III.5.5 The Immediate Environment

Situated in Lower Manhattan, near key landmarks like the World Trade Center, Wall Street, and the Financial District.

Wall Street

Trade Center

the Financial District.

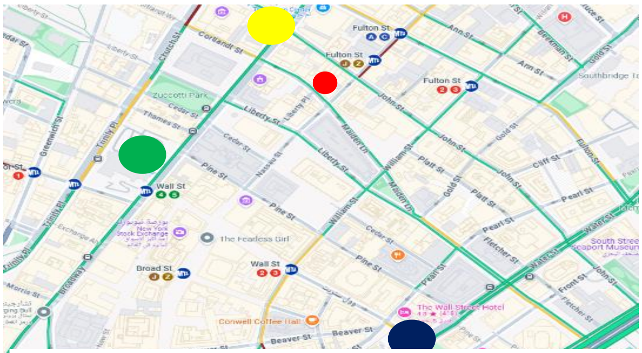


Figure II.54the immediate environment
Source: google map.com

Transportation Hub: Connects nine subway lines and the PATH train, making it a major transit nexus.

Retail and Commercial Spaces: Surrounded by offices, retail outlets, and cultural institutions, creating a dynamic environment

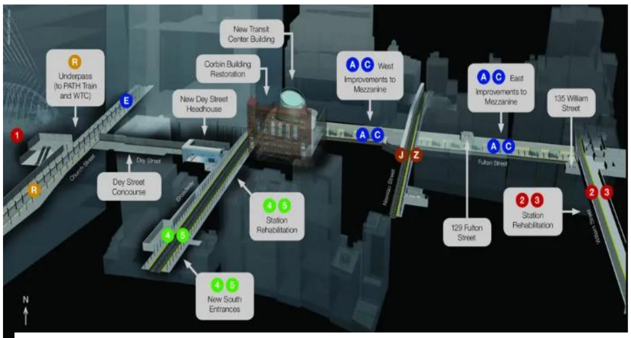


Figure II.55 environment of the proejct
Source: archidaily.com

III.5.6 The Project Plot

Size:Approximately 27,870 square meters (300,000 square feet)

Context: The plot is situated at the intersection of several major streets, including Fulton Street, Broadway, and Ann Street positioning it as a central transit and commercial hub within the city.

Surroundings: The project plot is surrounded by a mix of office buildings, retail spaces, and cultural landmarks. It is located near the World Trade Center, Wall Street, and is part of the Financial District.

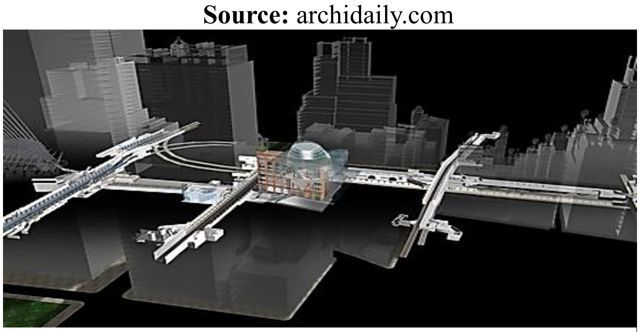


Figure II.56the project plot
Source: archidaily.com

III.5.7 Roads and Accessibility

- **Major Streets**
  - Fulton Street: The primary street running through the center, connecting the site to key areas in Lower Manhattan.
  - Broadway: A major avenue that runs parallel to Fulton Street, providing access to other parts of Manhattan.
  - Ann Street: Another adjacent road that provides easy access to the center from the surrounding neighborhoods.
- **Public Transit**
  - Subway Access:Direct access to nine subway lines (2, 4, 5, A, C, J, Z, R, W) through nearby entrances, making it one of the most connected transit hubs in the city.

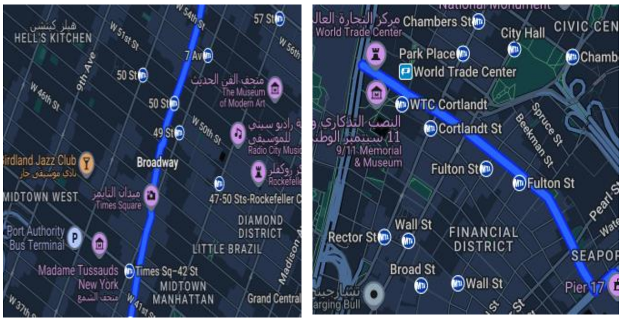


Figure II.57 roads and accessibility to the project
Source: street map.com

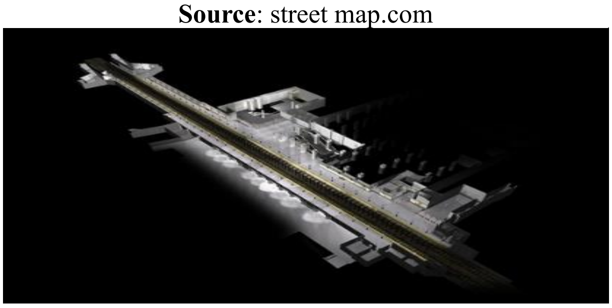


Figure II.58 public transit
Source: archicaily.com

- PATH Train Direct connection to the PATH train, linking commuters to New Jersey.

- **Pedestrian Access**

High foot traffic due to its location in the Financial District, with pedestrians easily accessing the center from surrounding streets.

Nearby sidewalks and pedestrian paths are designed to handle large volumes of people, providing seamless movement around the hub.

Figure II.59 pedestrian access
Source: archidaily.com + author treatment,2025

III.5.8 The Volumetry

The central atrium is the focal point of the building, with a large open volume that connects all floors. It is characterized by a soaring ceiling height of around 55 feet (16.8 meters), dominated by the glass oculus at the top, allowing natural light to flood the space.

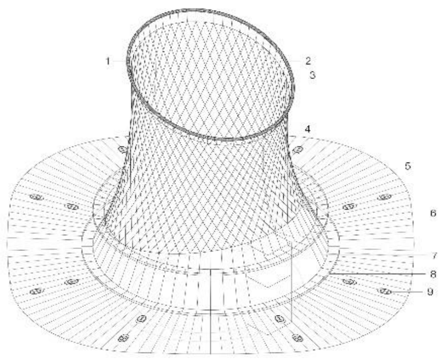


Figure II.60 the volumetry
Source: Pinterest.com

III.5.9 Levels and Layout

Above Ground: The retail spaces are situated on the lower levels of the building, while office spaces are positioned on upper levels, optimizing both commercial and functional use.

Underground: The space extends down to several lower levels, where the subway lines and PATH train connections are housed. The volumetric design ensures light reaches even these deeper areas via the Sky Reflector-Net, ensuring a sense of openness.

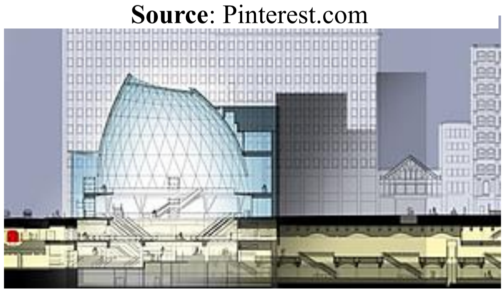


Figure II.61 coupe of the project showing different levels
Source: archidaily.com

III.5.10 Glass Dome (Oculus)

The glass dome, or oculus, is the most defining volumetric feature of the design. It has a 16-meter (53-foot) diameter and is designed to bring natural light deep into the building.

III.5.11 Vertical Circulation

The building's design also emphasizes efficient vertical circulation, with escalators and elevators that connect the various levels seamlessly, ensuring easy flow for commuters and visitors.

Overall, the volumetric design of Fulton Center focuses on creating a sense of openness and connection between different levels and spaces, maximizing natural light and encouraging a seamless flow between transportation, retail, and public areas.

Figure II.62 glass dome
Source: archidailycom

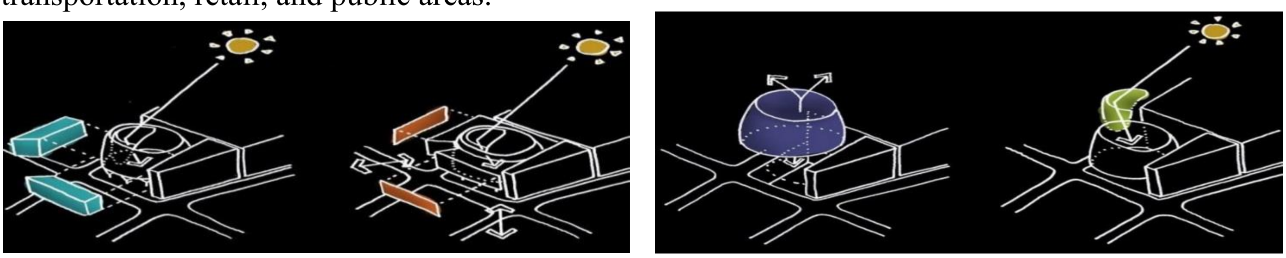


Figure II.63 the volumetric design
Source: archidailycom

III.5.12 Sky Reflector-Net

Suspended above the atrium, this complex network of aluminum panels helps diffuse daylight into the space, creating an open and airy atmosphere throughout the building

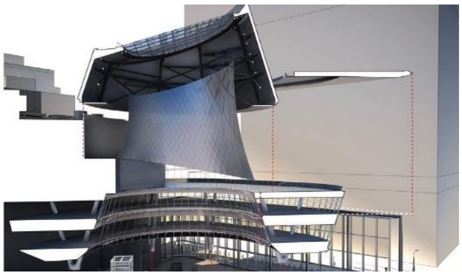


Figure II.64 sky reflector
Source: archidailycom

III.5.13 Entrances

- **Main Entrance (Fulton Street)**

The primary entrance is located on Fulton Street, one of the most significant pedestrian routes in Lower Manhattan. It provides easy access to the retail spaces, the central atrium, and the subway connections. The entrance leads directly into the open, light-filled atrium, creating a welcoming atmosphere for visitors.

Figure II.65main entrances to the project
Source: archidaily.com + author treatment,2025

- **Subway Entrances**

Multiple entrances from the subway lines are distributed around the building, facilitating easy access from different directions. These entrances are integrated into the surrounding streets, including Broadway and Ann Street, ensuring smooth transitions from the subway to the building's interior.

- **PATH Train Entrance**

Another key entrance connects to the PATH train system, linking commuters to New Jersey. This entrance is part of the integrated transit design, facilitating smooth movement between different forms of transportation.

Figure II.66 path and subway entrances
Source: archidaily.com + author treatment,2025

- **Pedestrian Entrances**

Several secondary entrances are located around the perimeter of the building, allowing pedestrians to enter from various surrounding streets, including Wall Street and Broadway, ensuring accessibility from multiple directions. These entrances provide easy access to both the retail spaces and the subway network.

- **Accessibility Features**

The entrances are designed to be universally accessible, with elevators and ramps providing smooth access for people with disabilities, ensuring inclusivity and convenience for all users.

Figure II.67pedestrian entrances
Source: archidaily.com + author treatment,2025

III.5.14 Circulation

- **Vertical Circulation**

The building features efficient vertical circulation with escalators, elevators, and staircases, connecting the above-ground retail and office spaces with the underground transit levels. The central atrium plays a key role in facilitating smooth movement between different floors.

Figure II.68 vertical circulation
Source: archidaily.com + author treatment,2025

- **Horizontal Circulation**

The atrium serves as the main circulation hub, connecting all levels horizontally and vertically. Visitors and commuters can easily navigate the building's open floor plan through this central space

- Retail Spaces: The ground floor and lower levels are dedicated to commercial and retail spaces, with clear pathways leading to various shops and amenities.
- Transit Areas: The underground subway concourses are designed for easy movement with wide walkways that lead to the subway platforms.

Figure II.69horizontal circulation
Source: archidaily.com + author treatment,2025

- **Flow and Accessibility**

The design focuses on unobstructed flow, ensuring that pedestrian traffic can move freely throughout the building.

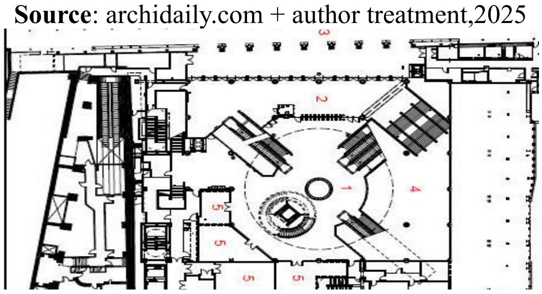


Figure II.70 flow and accessibility
Source: Pinterest

III.5.15 Spatial and Functional Organization

Fulton Center's layout is centered around a main atrium that connects all functional areas. The ground and lower-level house retail spaces, while the underground levels are dedicated to subway and PATH train connections, with natural light brought in through the Sky Reflector-Net. Upper levels may include office spaces or other public functions. Vertical circulation is facilitated by escalators and elevators, ensuring smooth movement between areas. The design zones the building into distinct areas for retail, transit, and office functions, ensuring efficient flow and accessibility.

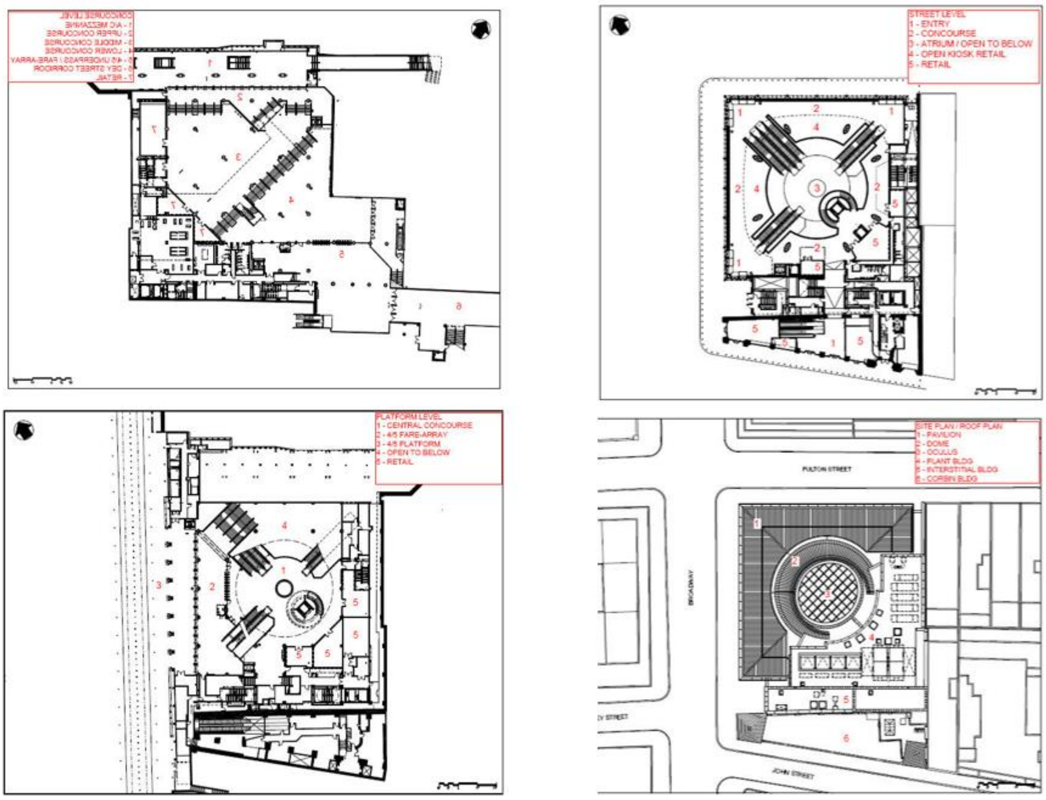


Figure II.71spatial organization of the project
Source: archidaily.com

III.5.16 Lighting system

- **Glass Oculus**

The glass oculus at the top of the atrium is the primary source of daylight. Its large, circular design allows sunlight to pour directly into the building, brightening the central atrium and creating a dynamic visual connection with the outside world

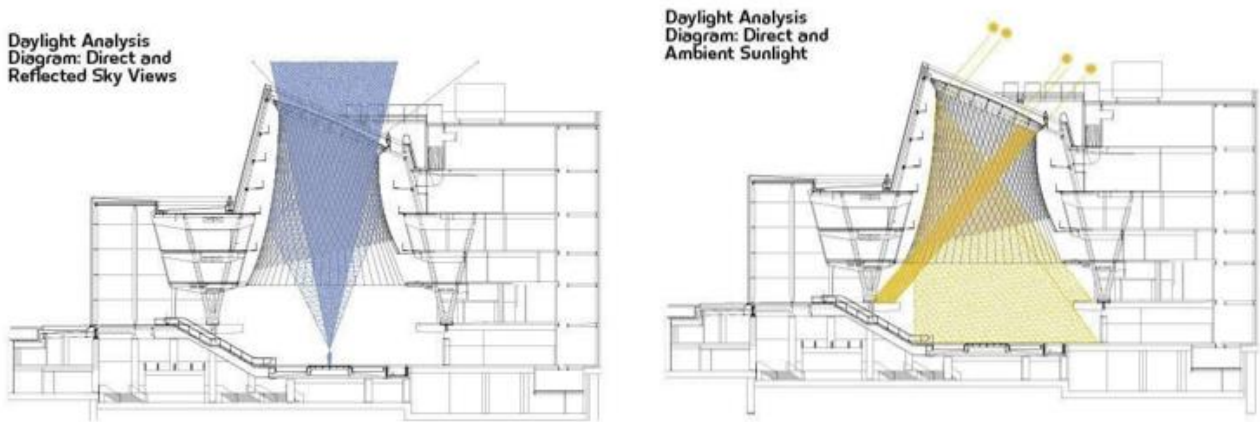


Figure II.72 class oculus lighting system
Source: archidaily.com

- **Sky Reflector-Net**

The Sky Reflector-Net is a key feature of the building's natural lighting strategy. This system of aluminum panels reflects and diffuses natural light deeper into the structure, particularly into the underground levels and the subway concourses. It channels light to spaces that would typically remain dark, enhancing the overall brightness of the building.

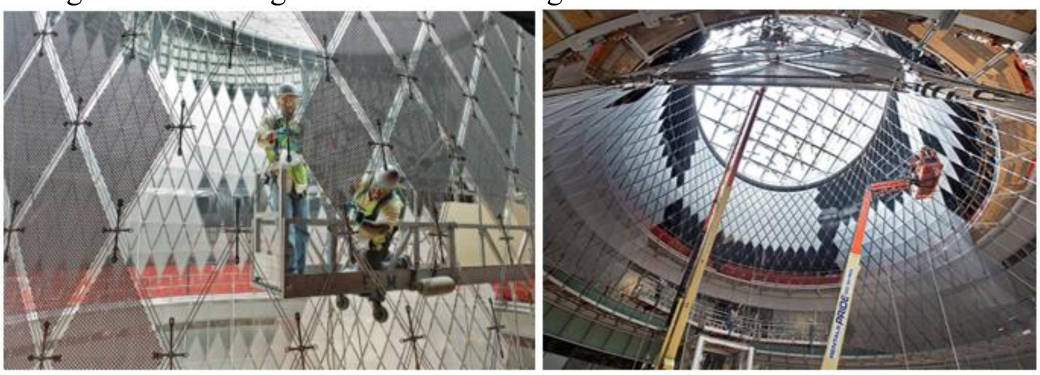


Figure II.73 sky reflector
Source: archidaily.com

- **Light Diffusion**

The integration of natural light with the Sky Reflector-Net ensures that sunlight is distributed evenly throughout the building, reducing the need for artificial lighting during the day and creating a comfortable and energy-efficient environment

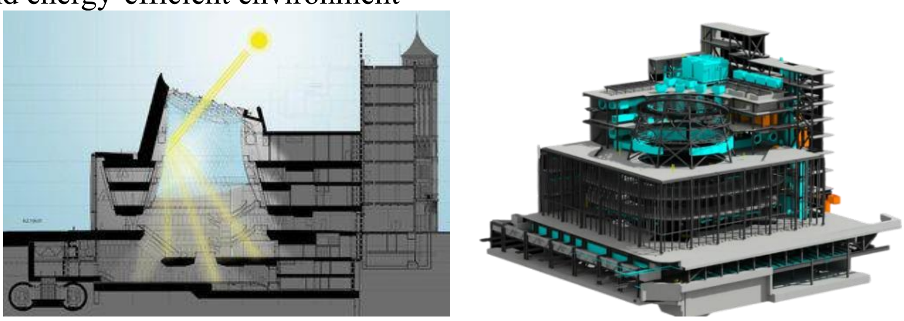


Figure II.74 light diffusion
Source: archidaily.com

IV Analysis of exicitng exemples

IV.1 Exemple 01: Bab El Zouar

- **Project Name:** Bab Ezzouar Shopping and Leisure Center
- **Location**: Bab Ezzouar, Algiers, Algeria
- **Completion Date**: August 2010
- **Architects**: Design and coordination by Valartis Consortium (France), with local partners
- **Client :** SCCA (Société des Centres Commerciaux d'Algérie)
- **Project Type**: Commercial and leisure center (mixed-use retail)
- **Area**: Approx. 45,000 square meters

Figure II.75 Bab El Zouar
Source: Pinterest.com

IV.1.1 Description of the project

The Bab Ezzouar Shopping and Leisure Center is a modern commercial complex located east of Algiers, designed by architect Philippe Weber, it combines retail, leisure, and service spaces over multiple levels, the center includes shops, restaurants, a hypermarket, cinemas, and underground parking for 850 vehicles, its open, symmetrical design reflects a welcoming and contemporary architectural style.

IV.1.2 The conceptual idea

The conceptual idea behind the Bab Ezzouar Shopping and Leisure Center is to create a modern, inviting urban landmark that serves both commercial and social functions. The architectural form—with its open, arc-shaped layout—symbolizes hospitality and accessibility, reflecting the center's role as a welcoming public space. The use of symmetry, transparency, and vibrant materials conveys a sense of order, openness, and modernity, aligning with its function as a retail and leisure destination. The integration of leisure areas within a structured commercial layout supports a fluid and engaging user experience.

Figure II.76 view of the project
Source: Pinterest.com

IV.1.3 Situation

The Bab Ezzouar Shopping and Leisure Center is located in the Bab Ezzouar business district, east of Algiers. It occupies a site within a 70-hectare development zone, just 15 minutes from the city center and 5 minutes from Houari Boumediene International Airport. This strategic location ensures excellent accessibility while avoiding the congestion of central Algiers. The site is surrounded by key institutions and developments, including the Ibis Hotel, Air Algérie, BNP Paribas, Mobilis Telecom, and Algeria Post, making it a central hub in a growing urban and economic area.

Figure II.77 situation of the project
Source: google earth.com

IV.1.4 The Immediate Environment

The Bab Ezzouar Shopping and Leisure Center is set within a dynamic and expanding urban environment. It is directly surrounded by a variety of institutional, commercial, and service buildings, including the Ibis Hotel, Air Algérie headquarters, BNP Paribas, Algérie Poste, Mobilis Telecom, Aigle Azur, and Crédit Populaire d'Algérie. These neighboring facilities contribute to a highly functional and active district. The center benefits from wide access roads, pedestrian pathways, and proximity to public transportation, creating a seamless connection with its surroundings and reinforcing its role as a central destination for both shopping and leisure.

Figure II.78 immediate environment
Source: Etude analytique des concepts de conception du Bab El Zouar (slideshare)

IV.1.5 Implantation Principle

The implantation of the Bab Ezzouar Shopping and Leisure Center follows both symbolic and functional logic. The building adopts an open-armed configuration, evoking a welcoming gesture that reinforces its public and commercial character. Positioned at the heart of a growing business district, the project takes advantage of its visibility and accessibility by aligning with major urban axes. Its symmetrical layout and centralized access points facilitate intuitive circulation, while the orientation and volumetry optimize spatial distribution across retail and leisure functions. The implantation strategy emphasizes openness, connection to the urban fabric, and efficient land use.

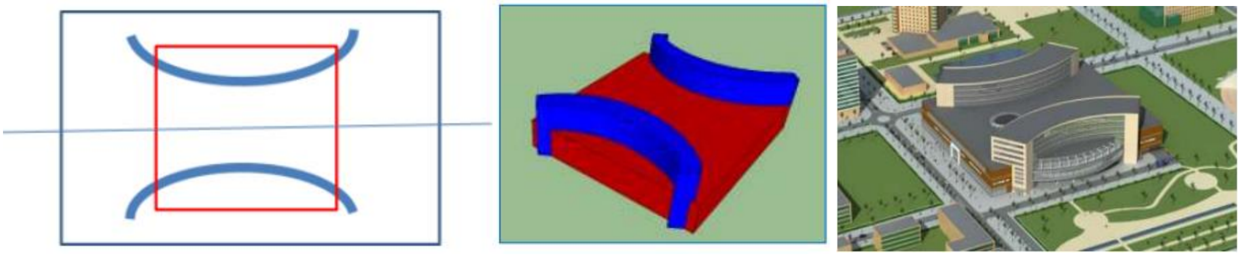


Figure II.79 implantation principle
Source: Etude analytique des concepts de conception du Bab El Zouar (slideshare)

IV.1.6 Roads and Accessibility

The Bab Ezzouar Shopping and Leisure Center enjoys excellent accessibility due to its strategic location near major transportation routes. Situated just 5 minutes from Houari Boumediene International Airport and 15 minutes from Algiers city center, it is easily reachable by both private and public transport. The site is well-connected through wide arterial roads and benefits from a direct link to urban infrastructure, minimizing traffic congestion. Additionally, the project includes underground parking with a capacity of 850 vehicles, as

Figure II.80 roads and accessibility to the project
Source:

well as pedestrian-friendly access points that enhance flow and convenience for visitors.

IV.1.7 Entrees

The Bab Ezzouar Shopping and Leisure Center has four access points, including a main entrance at the front that reflects the building's open-armed design and welcoming character. A secondary entrance connects directly to the underground parking, while two additional side entrances support pedestrian flow from the surrounding urban area, ensuring smooth and efficient access for all visitors.

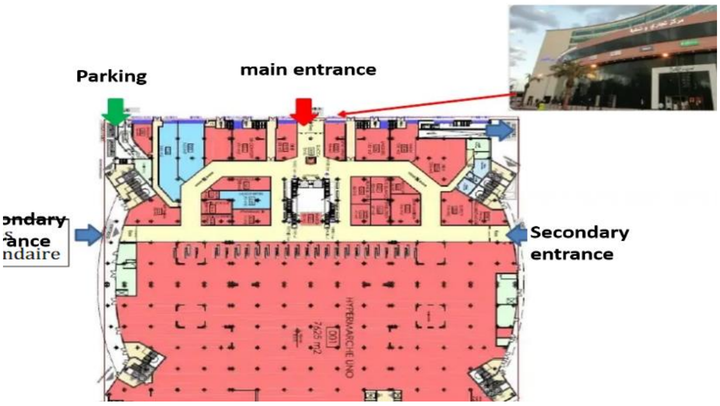


Figure II.81entrees of the project
Source : Etude analytique des concepts de conception du Bab El Zouar (slideshare)

IV.1.8 Circulation

The circulation system of the Bab Ezzouar Shopping and Leisure Center is designed to be clear, fluid, and user-friendly, ensuring optimal movement across all levels of the building. Vertical circulation is organized around a central core that includes panoramic elevators and double staircases, positioned symmetrically on either side of a mezzanine. This configuration creates a strong visual axis and allows visitors to easily navigate between floors.

The ground floor is anchored by the UNO hypermarket, which spans a large portion of the level and naturally channels foot traffic through the main retail areas. The first floor features a ring of shops encircling the mezzanine void, allowing visual connection between levels and maintaining a dynamic spatial experience. The second floor continues the retail circuit while integrating leisure spaces such as cinemas and restaurants.

Horizontal circulation is enhanced by wide corridors and open galleries, allowing comfortable visitor flow even during peak hours. The clear zoning of commercial, leisure, and service areas also supports intuitive orientation and efficient navigation throughout the complex.

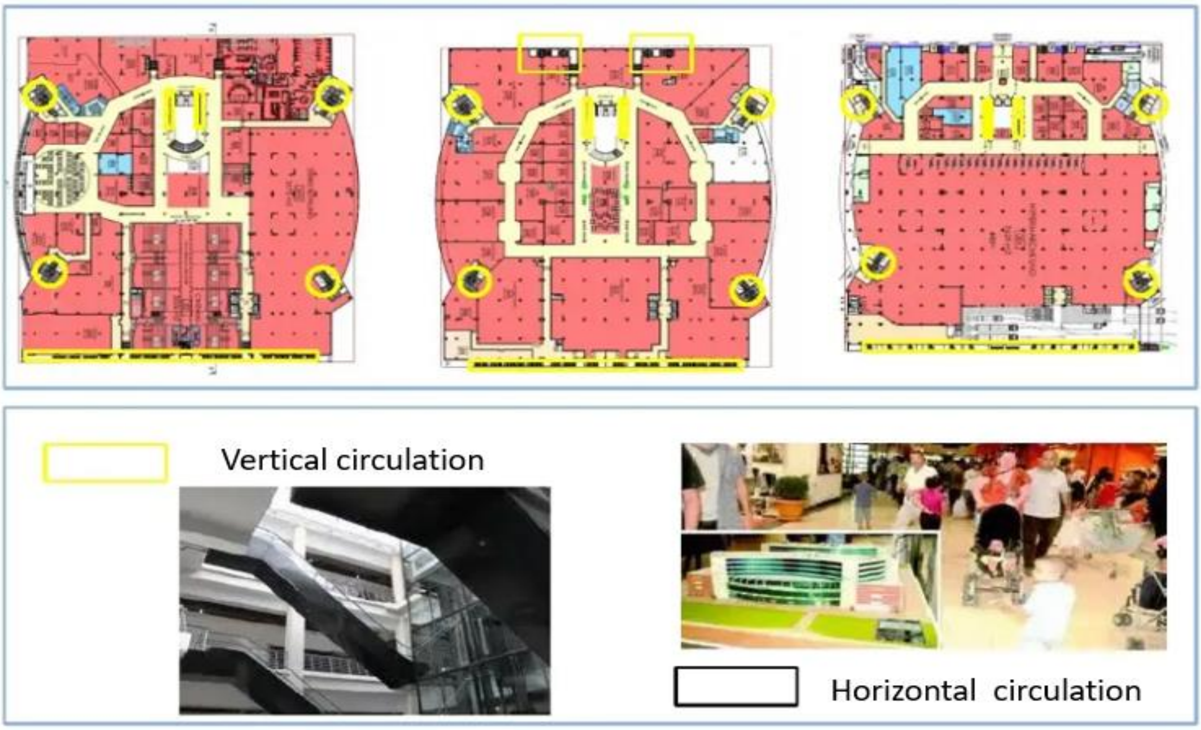


Figure II.82 circulation of the project
Source: Etude analytique des concepts de conception du Bab El Zouar (slideshare)

IV.1.9 Spatial and Functional Organization

The Bab Ezzouar Shopping and Leisure Center demonstrates a clear and rational spatial organization that prioritizes functionality, fluid circulation, and visitor comfort. The layout is distributed across multiple levels, with each floor assigned specific uses that support a logical vertical zoning.

- Ground Floor (RDC): This level serves as the commercial heart of the center, anchored by the UNO hypermarket, which occupies a large portion and draws high foot traffic. The presence of a double staircase and panoramic elevators at the center facilitates smooth vertical circulation.
- First Floor: Organized around a central mezzanine void, this level hosts a wide range of retail shops arranged in a circular pattern. The visual connection to the ground floor enhances spatial orientation and creates an open, dynamic shopping experience.
- Second Floor: This level continues the retail circuit but also introduces leisure functions, including cinemas, restaurants, and entertainment areas like a bowling alley, allowing for a diverse range of activities.
- Towers (4 floors each): Likely designed for office or administrative use, these two arc-shaped towers rise above the main volumes and are visually integrated into the overall structure.
- The underground levels are dedicated to parking (850 spaces) and service areas, ensuring that logistical and vehicular needs do not interfere with the public zones.

The spatial hierarchy is reinforced by the symmetry of the plan, wide circulation corridors, clear zoning between commercial and leisure functions, and vertical elements that structure the flow and enhance orientation. Overall, the design reflects a modern, user-centered approach with a strong emphasis on accessibility, legibility, and comfort.

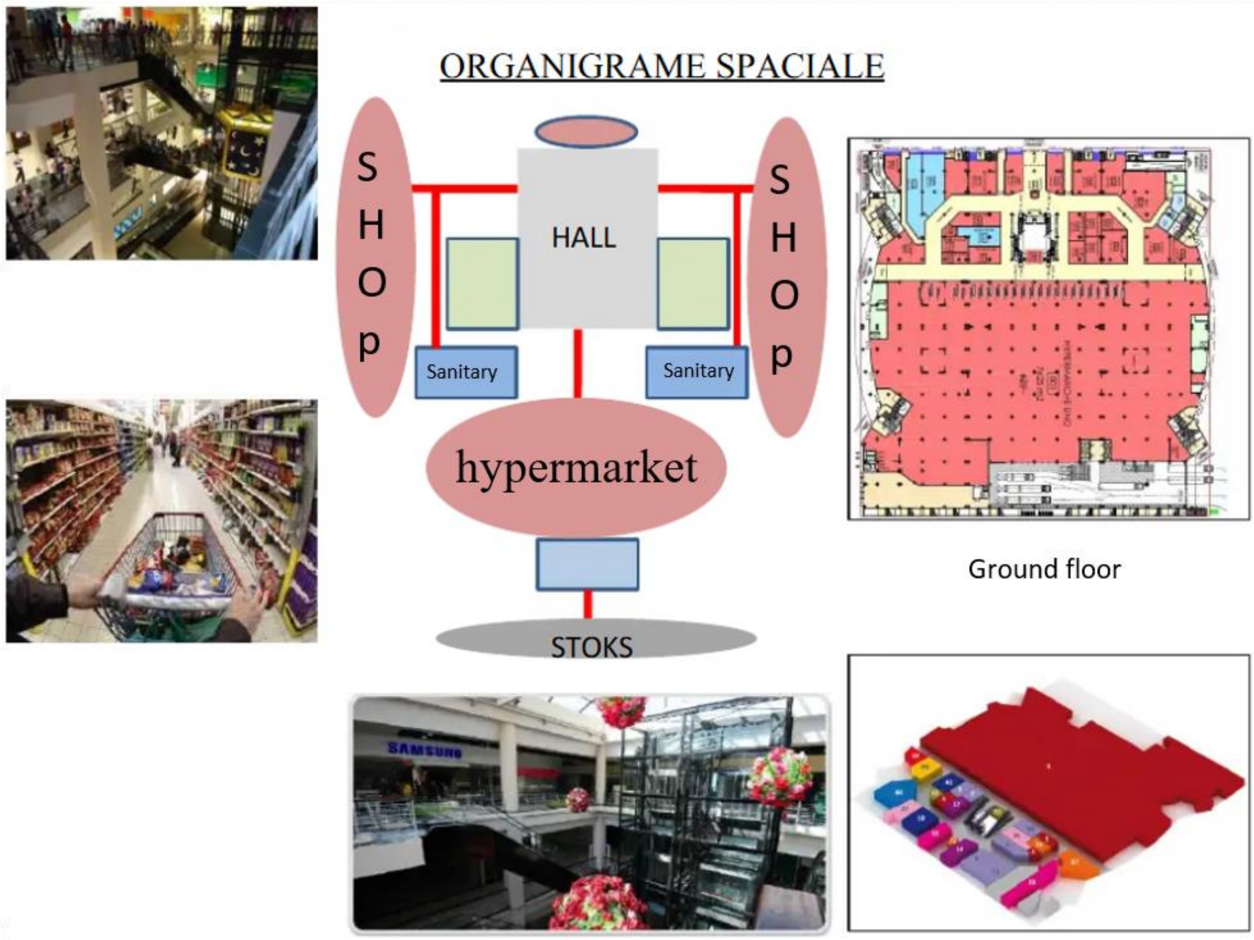


Figure II.83 ground floor

Source: Etude analytique des concepts de conception du Bab El Zouar (slideshare)

Figure II.84 first and second floor

Source: Etude analytique des concepts de conception du Bab El Zouar (slideshare)

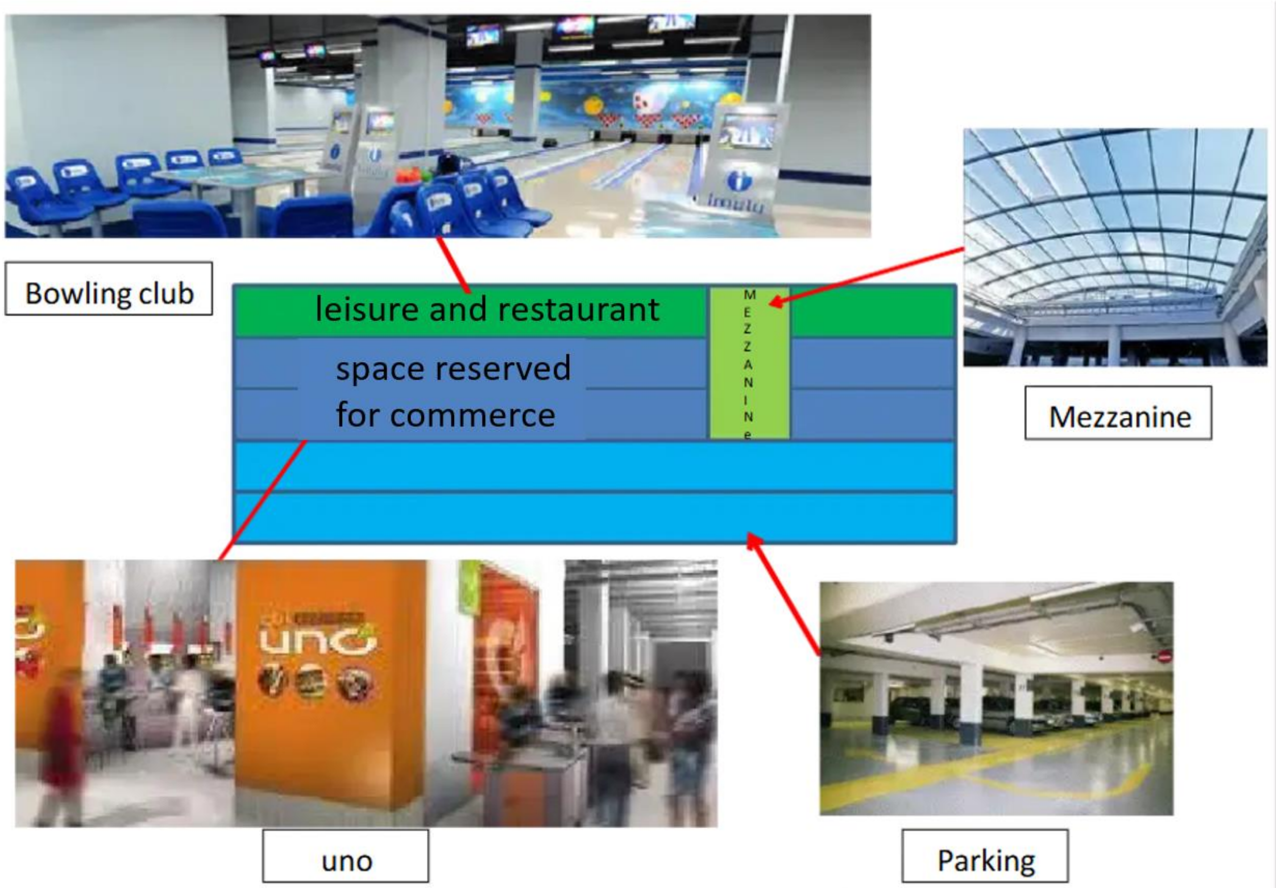


Figure II.85 coupe of the project
Source: Etude analytique des concepts de conception du Bab El Zouar (slideshare)

IV.1.10 Lighting system

The lighting system in the Bab Ezzouar Shopping and Leisure Center combines natural and artificial sources, integrated according to the building's architectural layout:

Natural Lighting:

• Utilizes large glazed façades on the main elevations for daylight penetration.

• A central mezzanine void allows natural light to pass vertically through the building's levels.

• translucent roofing elements (implied by the vertical openness of the space) provide top-down daylight to public circulation zones.

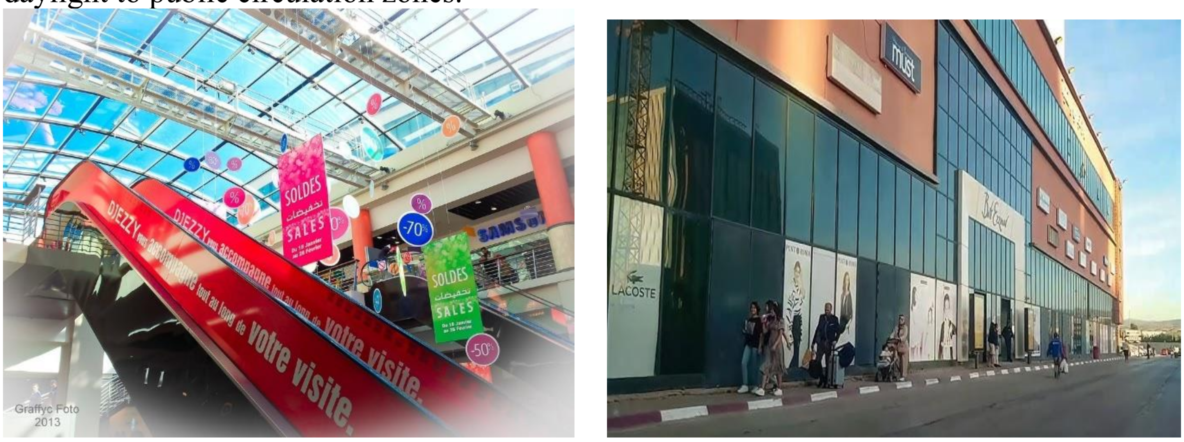


Figure II.86lighting system
Source: google.com

IV.2 Exemple 02: Parc Mall

- Project Name: Park Mall
- Location: City center of Sétif, Algeria
- Completion Date: February 4, 2016
- Architect / Developer: Prombati Group (private Algerian developer)
- Project Type: Mixed-use complex (commercial, leisure, hospitality, business)
- Construction Started: 2011
- Number of Levels:
- 4 underground levels (parking + commercial)
- Ground floor + 2 commercial floors (R+2)
- 17-floor hotel tower
- 18-floor business center

Figure II.87 Park Mall
Source: Pinterest.com

IV.2.1 Project description

Park Mall is a major mixed-use commercial and leisure complex located in the heart of Sétif, Algeria. As one of the tallest and most modern urban landmarks in the country, it redefines the city skyline with a structure that combines shopping, entertainment, hospitality, and business functions. Rising over 85 meters, the project includes a commercial center, a 17-story hotel, an 18-story business tower, and a dome-covered conference hall. With its wide retail offering, indoor leisure areas, panoramic restaurants, and multi-level parking, Park Mall serves as a regional economic and social hub. The project was developed by the private Prombati Group and inaugurated in 2016 after five years of construction.

IV.2.2 The conceptual idea

The conceptual idea behind Park Mall is to create a vertical urban landmark that consolidates commerce, leisure, and business into a single iconic structure within the dense fabric of Sétif's historic city center.Park Mall aims to redefine the city's skyline, introduce contemporary consumer culture, and serve as a new social and commercial magnet. The superposition of volumes, transparency of façades, and strong visual identity (accentuated by red metallic elements) reflect a design concept centered on visibility, accessibility, and functional diversity.

Figure II.88 view of the project
Source: Pinterest.com

IV.2.3 Situation

Park Mall is strategically located in the city center of Sétif, one of Algeria's major highland cities. It stands at the intersection of Rue de l'ALN and Rue du 8 Novembre, directly overlooking the Wilaya headquarters and one of the city's historically significant avenues. Surrounded by a mix of administrative, business, and tourism zones, the project benefits from a highly visible and accessible urban position. Its placement within a dense, low-rise urban fabric allows it to dominate the skyline

Figure II.89 situation of the project
Source: google earth.com

IV.2.4 The Immediate Environment

Park Mall is surrounded by a dense and active urban core, placing it in direct proximity to key civic and commercial institutions. The complex faces the Wilaya headquarters and is adjacent to Rue de l'ALN, a historically significant and heavily frequented avenue. The immediate environment includes administrative buildings, business offices, tourist infrastructure, and dense residential zones, making the site a strategic convergence point for daily urban flows.

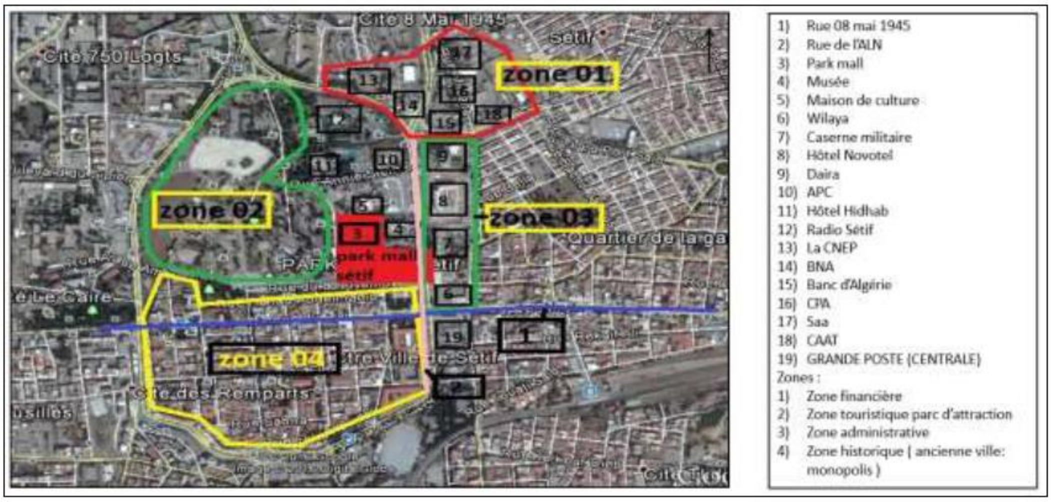


Figure II.90 immediate environment
Source : Etude analytique des concepts de conception du Park Mall (slideshare)

IV.2.5 Roads and Accessibility

Park Mall enjoys excellent accessibility thanks to its central location and connection to key urban arteries. The complex is directly accessible via Rue du 8 Novembre and Rue de l'ALN, two major roads that structure Sétif's city center. The main entrance is clearly identifiable, marked by a distinctive red metallic element that guides pedestrian flow and enhances visibility. The presence of a five-level underground parking facility ensures ample capacity for private vehicles, while the mall's proximity to public transport routes and pedestrian networks facilitates access for a broad demographic.

Figure II.91 roads and accessibility to the project
Source : Etude analytique des concepts de conception du Park Mall (slideshare)

IV.2.6 Mass plan

The mass plan of Park Mall is organized into distinct vertical volumes: a commercial base (R+2), a 17-story hotel, an 18-story business tower, and a dome-shaped conference hall. This composition creates a strong urban landmark within the low-rise city center. While the layout is functionally clear and visually dynamic, the absence of green spaces limits its environmental integration.

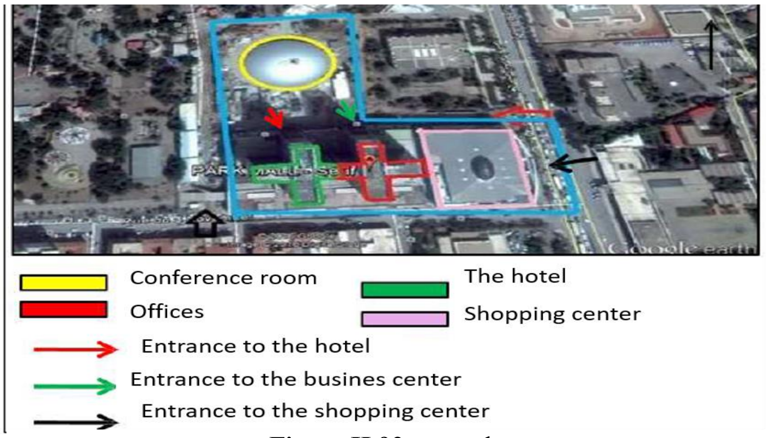


Figure II.92 mass plan

Source : Etude analytique des concepts de conception du Park Mall (slideshare)

IV.2.7 The Volumetry

The volumetry of Park Mall is based on simple, stacked rectangular forms, creating a clear vertical composition. The project is dominated by two tall symmetrical towers (17 and 18 stories) separated by a central axis, with a dome structure adding visual contrast. This design gives the complex a strong urban presence and dynamic architectural identity.

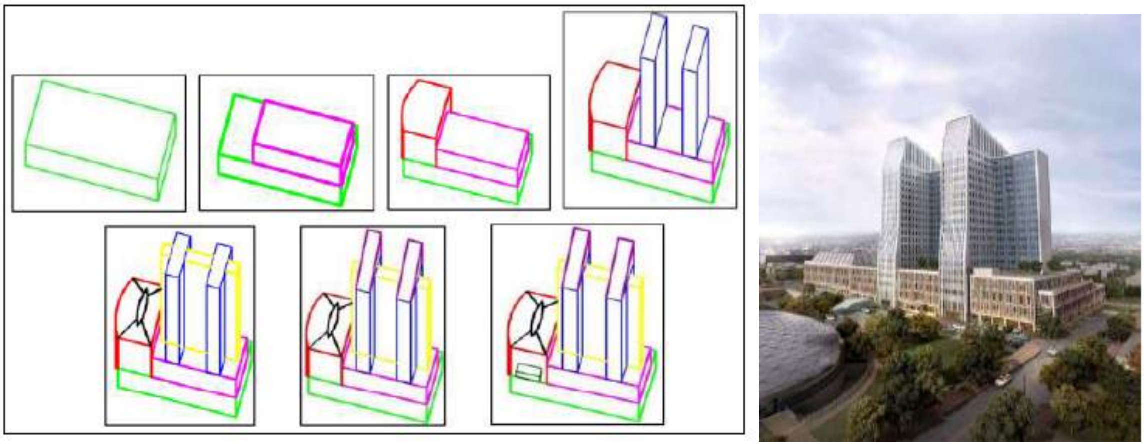


Figure II.93the volumetry of the project

Source : Etude analytique des concepts de conception du Park Mall (slideshare)

IV.2.8 facade treatment

The façades of Park Mall feature a modern design with extensive glazing, bold red accents, and contrasting colors that enhance visibility. Setbacks and projections break the flatness, creating dynamic volumes. The twin towers are symmetrical, and repeated decorative elements unify the architectural identity.

Figure II.94facade treatment

Source: author treatment,2025

IV.2.9 Spatial and Functional Organization

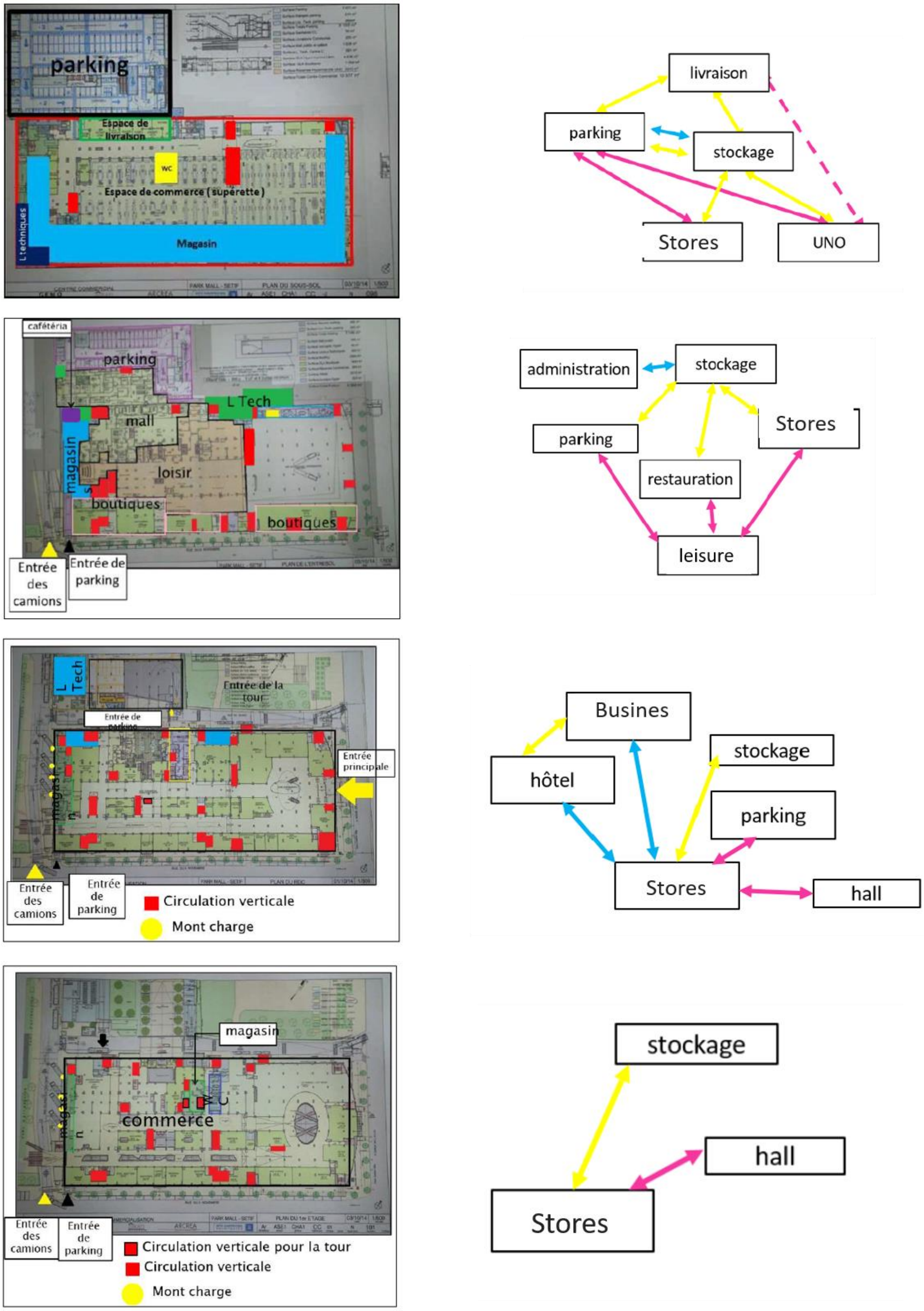


Figure II.95 spatial and functional organization of different layouts
Source : Etude analytique des concepts de conception du Park Mall (slideshare)+ author treatment,2025

IV.2.10 The grouping of services, activities and people

Services of the same nature in Park Mall are centralized (for example, the parking areas are located in the underground levels, the hypermarket is also in a basement, and luxury boutiques are found on the ground and first floors). This centralization aims to make services easily accessible to everyone.

Activities in Park Mall are divided into three main categories: parking, commerce, and leisure. This grouping is organized by floor, where the underground levels are dedicated to parking and retail, the ground floor and first floor host luxury retail, and the uppermost level is reserved for leisure and entertainment (e.g., game areas).

Park Mall effectively applies the concept of gathering people. Each activity or service attracts a specific group of users. This gathering can be structured in various ways—by size (limited or open height), by function, or even by color schemes.

The vertical connection between spaces is ensured through various types of stairways, including standard stairs, escalators, and elevators, creating direct and efficient links between levels.

The mall allows for a mixed flow of circulation in all directions, welcoming people of all ages and genders. This multidirectional circulation is facilitated through large halls, corridors, and open spaces, enabling both casual encounters and planned meetings.

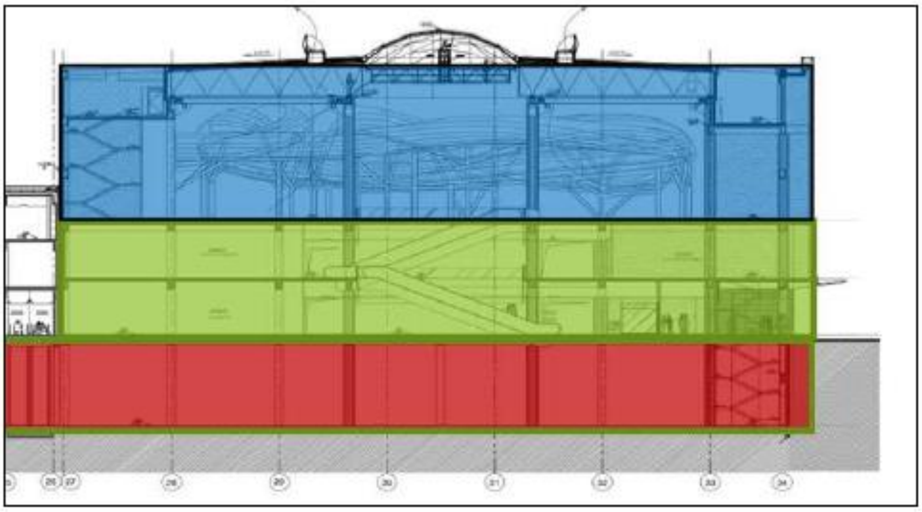


Figure II.96 coupe of the project
Source : Etude analytique des concepts de conception du Park Mall (slideshare)

IV.2.11 Light system

Park Mall benefits from a well-designed natural lighting system that relies primarily on its extensively glazed façades. Large glass surfaces on all elevations allow daylight to penetrate deep into the interior spaces, especially in circulation zones, retail galleries, and public areas. This strategy creates bright, welcoming environments and reduces the dependence on artificial lighting during daytime hours.

Figure II.97light system
Source: Pinterest.com

V Comparative synthesis table of case studies

table 5 comparative synthesis of case studies
Source: author treatment,2025

Theme / Criteria	Atlaspark Mall (Turkey)	Chadstone (Australia)	Markthal (Netherlands)	Bab Ezzouar (Algeria)	Parc Mall (Algeria)	Fulton Center (USA)
Conceptual Idea	Community-centered mall with green core	Luxurious retail with iconic gridshell	Mixed-use arch, market + housing	Modern, symbolic openness (arc)	Vertical multifunctional tower	Transit hub redefined by daylight
Location & Environment	Sultanbeyli, residential district	Melbourne suburb, near Monash Freeway	Central Rotterdam, urban renewal	Business district near airport	Historic urban center of Sétif	Lower Manhattan, Financial District
Plot & Integration	Between two roads, organic form	Flat expansive site	Central block, iconic visibility	70ha zone with 4 entrances	Prominent intersection, twin towers	Intersection of major streets
Form & Volumetry	Rectangular w/ central light gallery	Dome shape, fluid spaces	Horseshoe vault with central void	Symmetrical arc with twin towers	Vertical towers, stacked blocks	Central atrium + glass oculus
Built vs. Unbuilt Balance	Central built mass + green void	High built density + landscape edges	Built frame around public market	Balanced mass + open mezzanine	Mostly built, few green zones	Fully built but visually open
Circulation (H/V)	Clear galleries + vertical shafts	Wide corridors + multiple levels	Central horizontal loop + elevators	Clear vertical cores, panoramic lifts	Vertical + horizontal mix	Atrium links all levels + ramps
Entrances	4 (main, service, pedestrian)	Multiple transparent entries	Dual large public entries	4 entrances + underground access	Ground/main highlighted in red	Multiple: street, subway, PATH
Spatial Organization	Retail around light gallery	Atrium-based; zoned retail/dining	Market in center, units at shell	Level-based: retail, leisure, admin	Shopping base, hotel, business tower	Retail bottom, offices top, transit
Lighting Strategy	Light well + perforated ceiling	Gridshell dome, light wells, reflectors	Glass façade + skylights	Glass façades + mezzanine + dome	Full-glazed façades + red accents	Sky Reflector-Net + glass oculus
Natural Light Role	Comfort, community warmth	Luxurious ambiance + sustainability	Openness, indoor-outdoor continuity	Brightness + orientation clarity	Brightness + façade-based access	Daylight in deep spaces + identity
Sustainability Purpose	Reduce artificial light, indoor quality	Energy savings, visual comfort	Visual/thermal performance	Comfort, reduced electric lighting	Lighting efficiency in circulation	Energy efficiency in transport hub
Architectural Identity	Wooden textures, dynamic ceilings	Iconic dome, reflective glass	Monumental arch, artistic roof	Symmetry, openness, arc form	Twin towers + contrast materials	Iconic roof, daylight as symbol
Motivation for Selection	Social role + light integration	Light as spatial and formal generator	Landmark + natural light use	Algerian case of symbolic daylighting	National tower + natural light model	Light transforms infrastructure

VI Concluding synthesis table- ideal references by theme

table 6 concluding synthesis table
Source: author treatment,2025

Theme / Criterion	Ideal Case	Why It's the Best Example
Conceptual Idea	Markthal Rotterdam	Combines architecture, housing, and commerce with a strong identity and openness to the city.
Context Integration	Bab Ezzouar Mall	Perfectly blends symbolic form, accessibility, and surrounding urban services.
Plot Utilization	Atlaspark Mall	Balances built and unbuilt space with a green community zone central to the urban block.
Volumetry & Form	Fulton Center	Powerful central atrium + iconic oculus define hierarchy, direction, and architectural clarity.
Circulation Efficiency	Chadstone Centre	Well-zoned, intuitive horizontal & vertical circulation with multiple connection options.
Entrances & Accessibility	Markthal Rotterdam	Transparent, open-ended design fosters seamless pedestrian flow and symbolic urban openness.
Spatial Organization	Parc Mall	Functional mix of commerce, hotel, and offices in a clearly legible vertical structure.
Natural Lighting Strategy	Fulton Center	Sky Reflector-Net masterfully delivers daylight deep underground, redefining user experience.
Lighting Purpose	Chadstone Centre	Enhances both user comfort and energy efficiency with architectural elegance.
Sustainability Role	Markthal Rotterdam	Fully glazed façade + multifunctional program maximize energy use and community value.
Architectural Identity	Bab Ezzouar Mall	Iconic arc form expresses openness, identity, and civic pride while blending functionally.

VII Context analysis

This analysis is composed of two parts: In the first part, we will analyze the data of the city Biskra, a climatological and bioclimatic analysis that will be organized into two sections: the first is an analysis of the climate of the city of Biskra, and the second is the analysis of the chosen site. The purpose of this analysis is to take into consideration the specific climatic data of the region and the morphological data to better define the choices of strategies at the design level.

VII.1 Presentation of the city Biskra

The gateway to the desert, the capital of Zibans, Biskra, is located in the southeast of Algeria, in the eastern part of the northern Sahara. It serves as the transition between the folded Atlas Mountains in the north and the flat, desert expanses in the south.

VII.2 Geographic location

Biskra is a municipality in the northeastern Algerian Sahara. It covers an area of 22,379.95 km2,

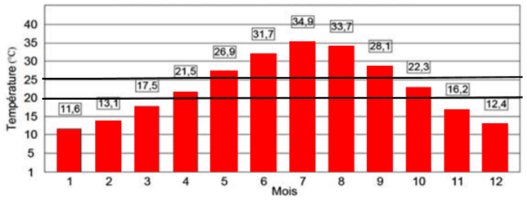
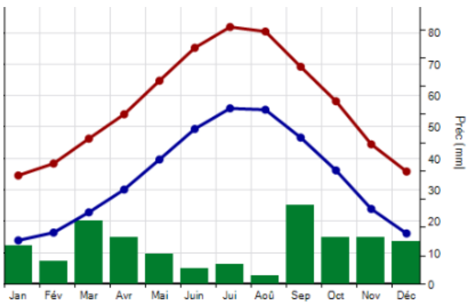
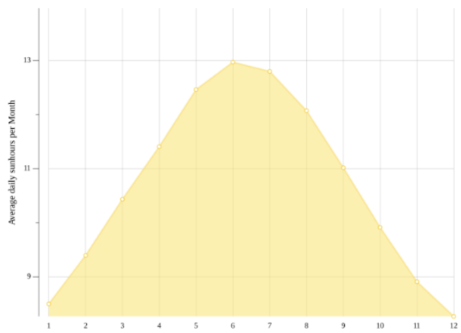
- Geographical coordinates of Biskra, Algeria:
- Latitude: 34° 51' 1" N
- Longitude: 5° 43' 40" E

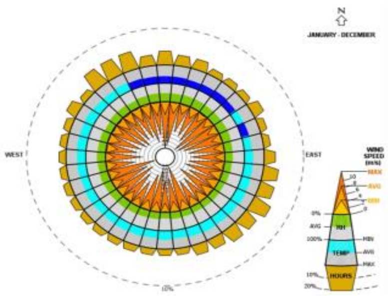
Figure II.98 (a)et(b), Situation géographique de la ville de Biskra ; (c) carte de découpage administratif, wilaya

Source: google.com

VII.3 Climatological analysis

The city's average altitude is 88 meters above sea level. Biskra has a subtropical desert climate, characterized by mild winters (with the potential for cold nights) and very hot, dry, and sunny summers.

	Graphs	Observation
Temperatur	 **Figure II.99**Average monthly temperature under shelter of the city of Biskra **Source**: climat consulltant0.6	It is noted that two types of temperatures primarily characterize this city. Very high temperatures persist during a long, hot period, while low temperatures occur during a short, cold period. This significantly influences the thermal behavior of construction, particularly during the summer.
Precipitation	 **Figure II.100**average monthly precipitation diagramme **Source**: climat consulltant0.6	The total annual precipitation amounts to 155 millimeters, indicating a desertic level of precipitation. In the least rainy month (August), precipitation reaches 2 mm, while in the most rainy month (September), it increases to 25 mm. Here is the average precipitation
Sunhours	 **Figure II.101**: average daily sunhours per month **Source**: Biskra Meteorological Station, 2016	In June, the highest number of daily sunshine hours on average is measured in Biskra. In June, there is an average of 12.8 hours of sunshine per day and a total of 396.79 hours of sunshine in the month. Conversely, in January, the lowest number of daily sunshine hours on average is recorded in Biskra. In January, there is an average of 8.27 hours of sunshine per day, with a total of 256.29 hours of sunshine for the month. Approximately 3900.03 hours of daylight are recorded in Biskra throughout the year. On average, there are 128.15 hours of daylight per month.

	 **Figure II.102** wind rose of Biskra **Source**: climat consulltant0.6	The winds are frequent during two periods of the year: relatively humid winds during the winter, and sand winds during the spring. The dominant wind directions are from the southeast and northwest

Bioclimatic analysis

The bioclimatic analysis of the city of Biskra are primarily based on the examination of climatic data, utilizing Mahoney's tables and Givoni's diagram. This approach provides recommendations that assist in the design process. (see annex A).

VII.4 Site analysis

VII.4.1 site location in relation to the city

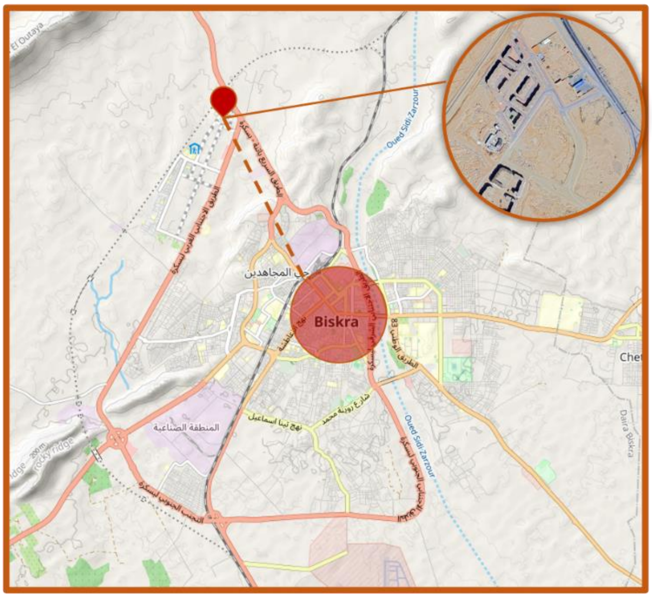


Figure II.103 site location
Source: author traitment,2025

VII.4.2 site morphology

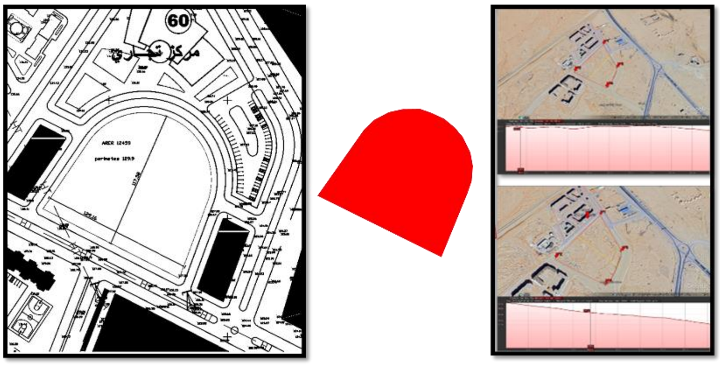


Figure II.104site morphology
Source: author traitment,2025

VII.4.3 site plot

The site is strategically positioned within the urban fabric of Biskra, offering a balanced proximity to both developed and developing zones. Its plot geometry and surrounding infrastructures suggest promising potential for integration into the city's expansion strategies.

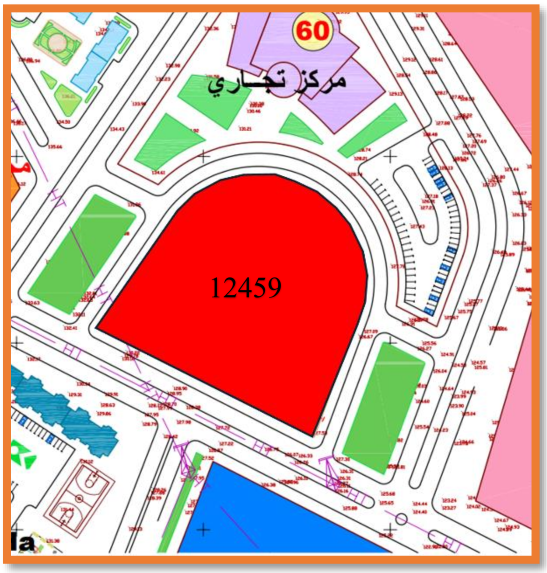


Figure II.105site plot
Source: author traitment,2025

VII.4.4 Environnement of the Project

The site is surrounded by a varied urban context, including collective housing and service structures. This diverse built environment supports potential synergies between new construction and existing functions, enabling a harmonious urban integration.

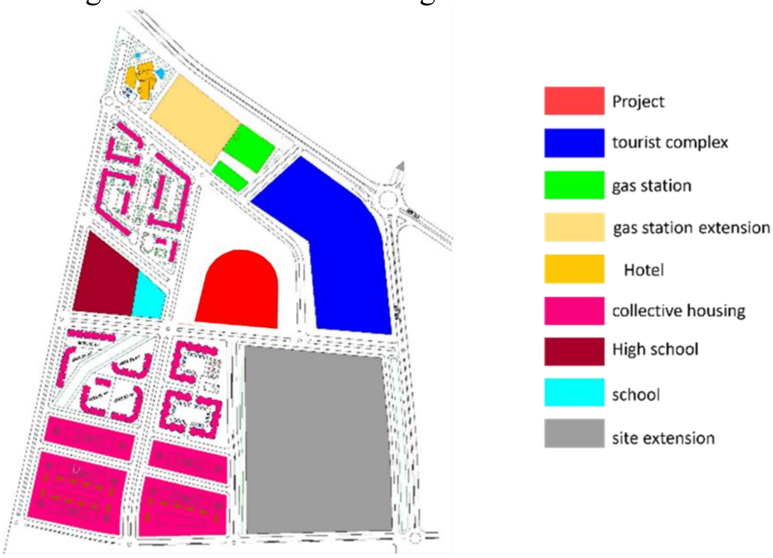
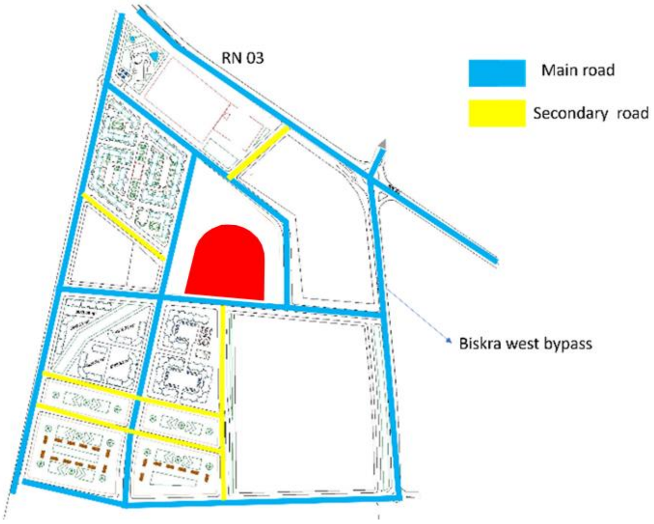


Figure II.106immediate environment of the project
Source: author traitment,2025

VII.4.5 Roads and accessibility

The site benefits from excellent vehicular connectivity due to its location near primary road arteries such as the RN 03 and the western bypass. This accessibility ensures smooth traffic flow and efficient regional integration, essential for any future development on the site.



FigureII.107 roads surrounding by the project
Source: author traitment,2025

The accessibility diagram highlights the site's high level of permeability from multiple directions, ensuring optimal movement of users and goods. This makes the location ideal for public or semi-public functions requiring ease of access.

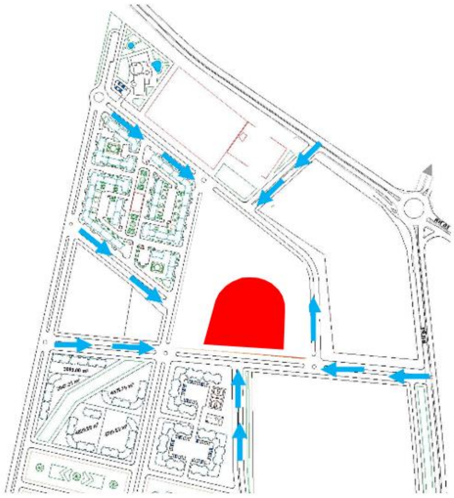


Figure II.108 accessibility to the site
Source: author traitment,2025

VII.4.6 Built and unbuilt

a clear imbalance between built and unbuilt areas, with the site appearing saturated by equipment and constructions. This overoccupation limits the availability of open or permeable spaces, which are essential for natural ventilation, green integration, and future expansion. The lack of unbuilt zones negatively affects the environmental quality of the site and restricts design flexibility. Addressing this density through careful reconfiguration or the introduction of breathing spaces will be crucial to improving spatial comfort and urban integration.

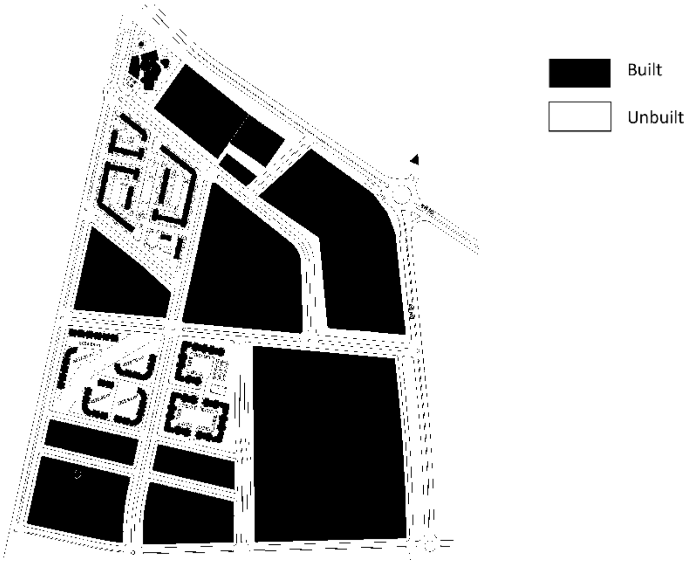


Figure II.109built and unbuilt spaces in the area
Source: author traitment,2025

VII.4.7 Green spaces

The analysis reveals a critical deficiency in green spaces within and around the project site. The area suffers from a near-total absence of landscaped or natural vegetation zones, which negatively impacts both the environmental quality and the visual comfort of the surroundings. In the context of Biskra's hot and arid climate, this scarcity of greenery exacerbates urban heat and reduces opportunities for passive cooling. Addressing this shortcoming should be a priority in the design process through the introduction of green infrastructure and shaded outdoor areas.

Figure II.110 green spaces in the area
Source: author traitment,2025

VII.4.8 Mobility

The presence of public transportation stations and nearby facilities like schools, high schools, tourist complexes, and hotels enhances the attractiveness of the site. These elements contribute to the creation of a dynamic and service-rich environment suitable for residential or mixed-use development.

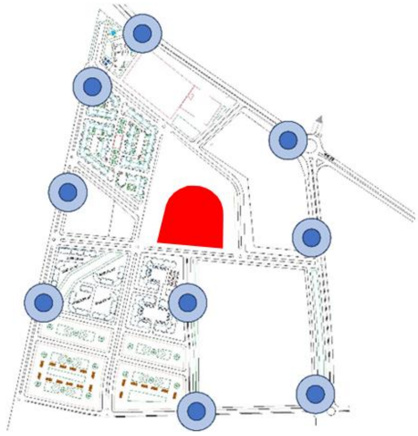


Figure II.111 public transportation station
Source: author traitment,2025

VII.4.9 Noise sources

The proximity to major roads and a gas station implies a potential presence of traffic-related noise pollution. This factor must be considered in the architectural design through buffer zones, vegetation barriers, or orientation strategies to ensure acoustic comfort.

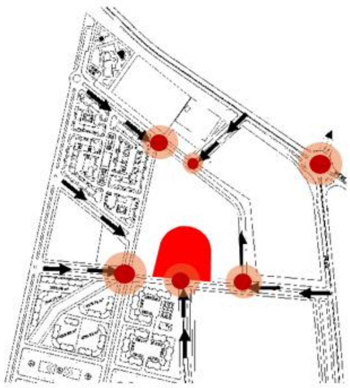


Figure II.112 traffic noises
Source : author traitment,2025

VII.4.10 Wind

The dominant wind directions are from the southeast and northwest

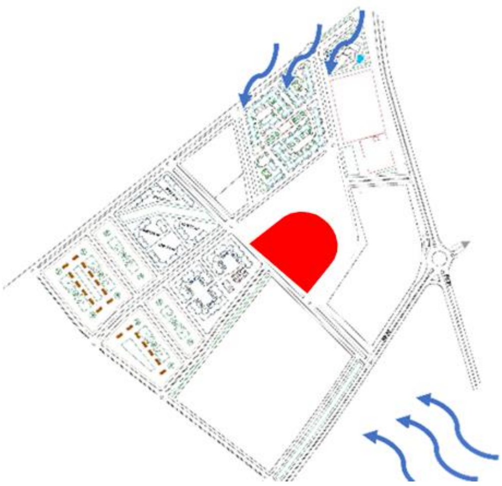


Figure II.113 wind direction
Source : author traitment,2025

VII.4.11 Sun

The site maximizes sunlight exposure during winter by strategically leveraging available sunlight from the south and west, while neighbouring buildings shield it from the east and north. In contrast, during summer, the project benefits from sunlight in all directions, taking advantage of the higher sun position in the sky

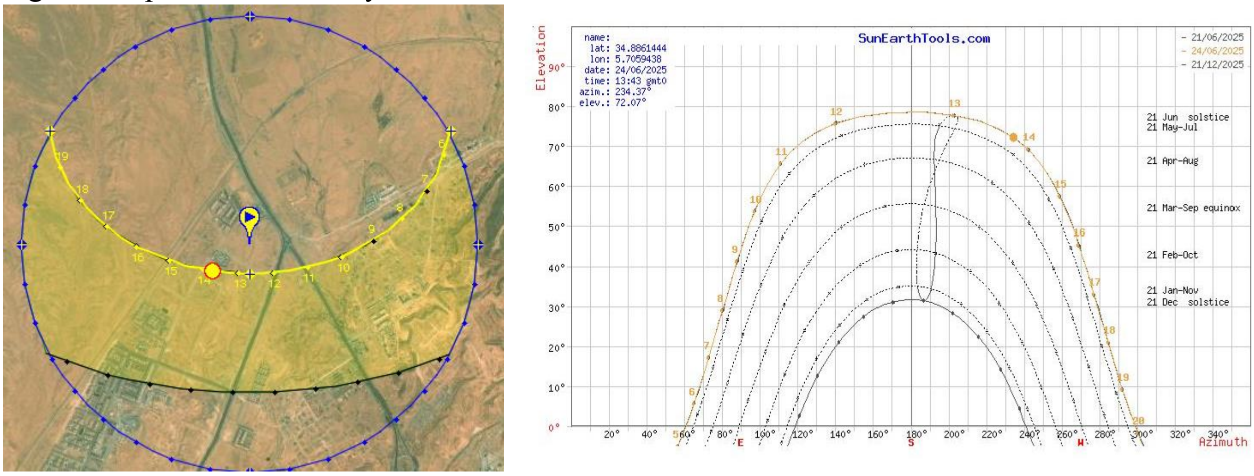


Figure II.114sun path
Source: Sun Earth Tools.com

VII.4.12 The existing building in the area

Existing buildings such as collective housing and gas stations shape the immediate urban context. Their presence provides functional references for the new project

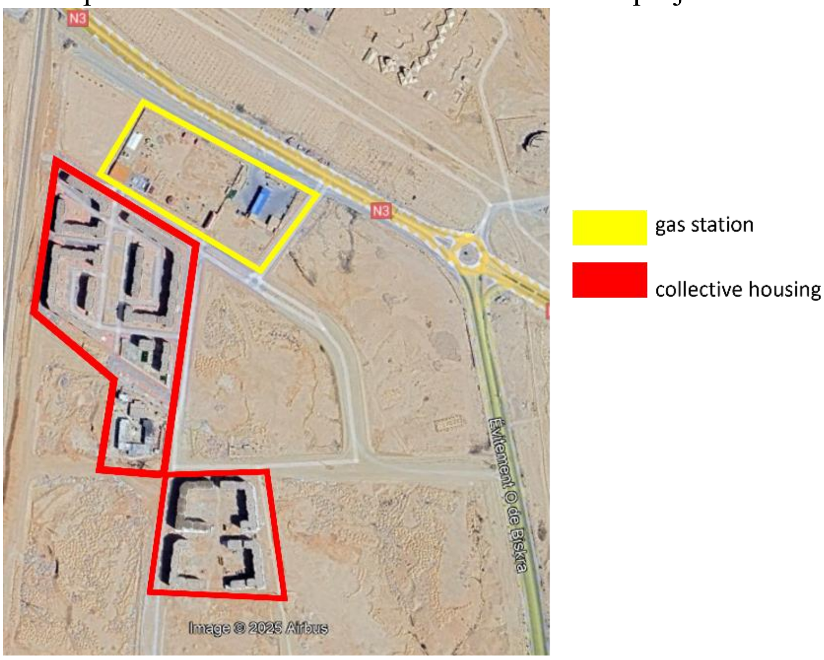


Figure II.115 the existing building in the area
Source: author treatment,2025

VII.4.13 Synthesis

Strength	Weakness
– Excellent accessibility: The site is well-connected to main roads (RN 03, Biskra West Bypass), allowing easy access for vehicles and pedestrians. – Proximity to public transport and facilities: Close to schools, hotels, a tourist complex, and service stations, which enriches the site's functional potential. – Sun exposure potential: High solar availability supports passive solar design and renewable energy integration. – Existing urban fabric: The site is embedded in a developed urban context with surrounding collective housing, promoting urban continuity.	– Lack of green spaces: The site and its immediate environment suffer from a noticeable absence of vegetation, which increases heat exposure and reduces visual comfort. – Saturation with built structures: There is a clear imbalance between built and unbuilt spaces, limiting design flexibility and ecological integration. – Noise pollution: The proximity to main traffic roads and a gas station may expose the site to consistent noise levels. – Exposure to harsh climate: The hot and dry desert climate requires strong thermal protection and limits outdoor comfort.

Opportunities	Threats
– Potential for urban regeneration: The site can be reimagined to introduce green infrastructure, shaded paths, and public spaces to improve microclimate. – Design innovation: The challenges posed by solar and wind exposure allow for creative architectural solutions (e.g., passive cooling, shaded courtyards, wind towers). – Strategic location: Its position between residential, touristic, and educational facilities makes it ideal for multifunctional or mixed-use development.	– Urban overheating: High built density combined with lack of vegetation can lead to urban heat island effects. – Traffic congestion: Increased development could worsen congestion near the RN 03 and surrounding roads if not planned with sufficient infrastructure. – Land use conflicts: The site's surrounding uses (e.g., gas stations) might restrict certain types of development due to safety or zoning constraints. – Environmental degradation: Continued urban pressure without proper planning could exacerbate land degradation and reduce livability.

Conclusion

The analytical chapter provided a comprehensive evaluation of six commercial projects across various global and local contexts. Through detailed case studies, the analysis explored multiple architectural parameters including volumetry, circulation, spatial organization, lighting strategies, and the relationship with the urban environment. Each example revealed distinct solutions to integrating natural light, especially through elements such as atriums, light wells, glass facades, and Sun Tunnels. The comparative analysis highlighted best practices and common shortcomings in daylight design across the samples. The synthesis confirmed that successful projects not only optimize natural light penetration but also prioritize user comfort, environmental integration, and multifunctionality. This analytical foundation has informed a well-grounded design approach for the proposed project by identifying the spatial and technical criteria needed to achieve sustainable, daylight-optimized commercial architecture

Practical chapter

Introduction

The practical chapter constitutes the operational translation of the theoretical and analytical foundations previously developed in this thesis. After establishing the conceptual framework of natural lighting in commercial architecture and studying international and local precedents, this section presents the project proposal through a dual structure: the architectural design of a shopping center in Biskra and the development of an integrated Sun Tunnel system. This chapter explores the articulation of spatial and technical strategies that enhance user experience, environmental performance, and energy autonomy. The aim is to synthesize spatial fluidity, functional hierarchy, and passive design principles into a coherent architectural solution. The final component of this chapter is the experimental validation of the daylighting system through a physical prototype equipped with a solar-powered sun-tracking mechanism. This design experiment highlights the feasibility of autonomous natural light redirection into deep interior zones, thus confirming the relevance of the adopted architectural strategies to the local climatic context.

Part one: Shopping center

I Programmatic approach

After analyzing various shopping center, conducting extensive research on commercial center spaces, and studying the differences in layouts among different projects, we have successfully derived the ideal library program that encompasses all necessary spaces and more.

table 7 the project programme

Source: author,2025

Function	Level	Units	Area per Unit (m²)	Total Area (m²)
Hypermarket	Ground Floor	1	1200	1200
Daily Shops (Grocery, Bread, Meat)	Ground Floor	1	180	180
Fruits and Vegetables	Ground Floor	1	60	60
Restaurants & Cafeterias	Ground Floor	6	120	720
Children’s Play Area	Ground Floor	1	120	120
Security Offices & Reception	Ground Floor	Various	-	90
Restrooms	All Floors	Several	15	-
Shops (Clothing, Footwear, Electronics)	Ground Floor	Various	60	-
Traditional Goods Display Room	First Floor	1	60	60
Cinema or Library	First Floor	1	Unspecified	-
Café Area with Interior View	First Floor	1	Unspecified	-
Offices (Lawyer, Travel, Insurance)	First Floor	Various	60	-
Administration Offices	First & Second	Various	45	-
Management Offices	Second Floor	Various	45	-
Fitness Center & Spa	Second Floor	1	180	180
Multi-purpose Hall	Second Floor	1	Unspecified	-
Deposits	All Levels	4	Varies	600
Technical & Maintenance Rooms	All Levels	2	Varies	160
Prayer Room	All Levels	1	40	40
External Storage & Miscellaneous	External Annexes	Various	Unspecified	-

II Conceptual approach

II.1 Concepts of the project

From the previous analyzes and synthesises, the following concepts emerged to create a shopping center in Biskra:

II.2 Improving the Length of Customer Stay

By creating a welcoming and interesting spatial experience, the project seeks to increase the amount of time that customers spend inside the shopping center. This is accomplished by applying important architectural ideas:

- **Transparency:** Visual links between areas promote investigation and lower mental obstacles. **Fluidity:** Soft transitions and curved pathways encourage organic movement and keep users from becoming weary.
- **Human Scale:** Areas are made to feel cozy and familiar, enticing visitors to stay longer.
- **Continuity:** By avoiding sudden changes, consistent spatial language helps guests navigate the center with ease.

Together, these tactics improve the customer experience and encourage more leisurely, prolonged visits.

II.3 Sustainability

The project makes sustainability a primary goal by using passive design techniques to reduce energy consumption and improve environmental comfort. Some of the key architectural concepts are:

- **Sun Tunnel System:** This system brings natural light into deep interior spaces, lowering the need for artificial lighting and improving visual comfort.
- **Cut-Out Terraces:** This design creates semi-outdoor spaces that can be used as resting terraces or green roofs, enhancing daylight, ventilation, and spatial diversity.
- **Indoor-Outdoor Integration:** This design promotes continuity between internal and external spaces, improving air flow and user well-being;
- **Environmental Porosity:** Strategic voids and open edges allow the building to "breathe," generating microclimates and naturally lowering thermal loads; these solutions support energy efficiency and offer a healthier, more pleasurve shopping experience.

II.4 Design ideas

- **Spiral Customer Journey**

The circulation is designed as a spiral path originating from a central hub, creating a progressive spatial sequence that encourages exploration without imposing direction. This promotes a sense of freedom, flow, and gradual discovery.

The central point acts as a constant spatial anchor, ensuring visual and physical orientation throughout the visitor's journey. Key architectural principles applied include:

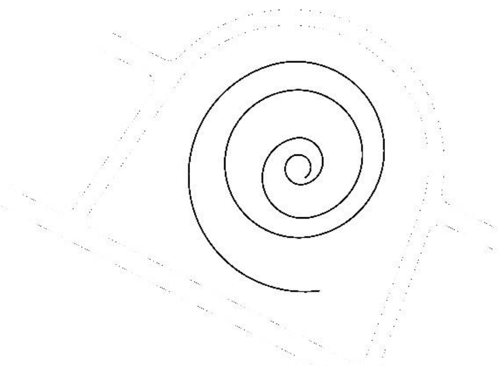


Figure III.1 spiral customer journey
Source: author,2025

Spatial Fluidity: Curved paths and continuous transitions.

Visual Connectivity: Open sightlines between functional zones.

Centralized Organization: The main atrium serves as a reference point and circulation cor.

- **Time-Based Functional Zoning**

The center is organized into functional rings: the inner core is dedicated to slow-time entertainment and immersive experiences, while the outer layers host retail, services, and fast-time leisure activities, forming a behavioral gradient that responds to user pace and needs.

Zoning Hierarchy: Organizing functions from intimate to public based on intensity.

Spatial Gradient: Creating a transition from fast to slow spaces.

Programmatic Layering: Stacking diverse functions in response to user time and energy.

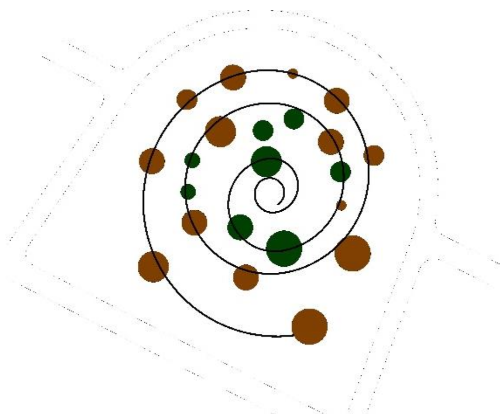


Figure III.2 time based functional zoning
Source: author,2025

- **Spatial Fluidity Across Overlapping Functional Rings**

To ensure the visitor's continuous connection with multiple functions without feeling constrained, the design adopts fluid spatial transitions and porous boundaries, allowing smooth interaction between different activity zones.

Rather than keeping these zones strictly separate, the design introduces organic merging between layers. Boundaries are treated fluidly, sometimes blending indoor and outdoor, other times linking fast and slow zones, creating a rich and connected spatial experience.

Porosity: Functional boundaries are softened, allowing spatial and programmatic overlap between zones.

Transparency: Visual openness connects interior and exterior, enhancing spatial legibility and curiosity.

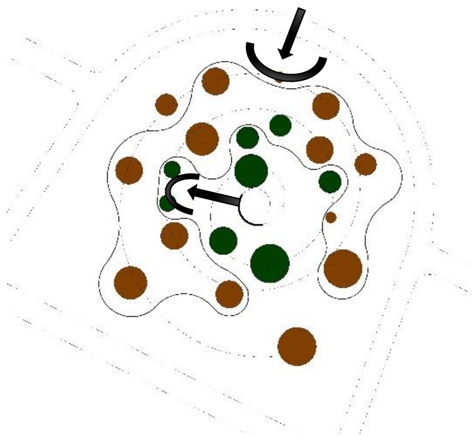


Figure III.3 spatial fluidity of the project
Source: author,2025

Fluidity: Curved circulation paths and organic transitions encourage natural movement and experiential continuity.

These elements work together to create a dynamic and inclusive shopping environment, where visitors remain engaged and oriented throughout their journey.

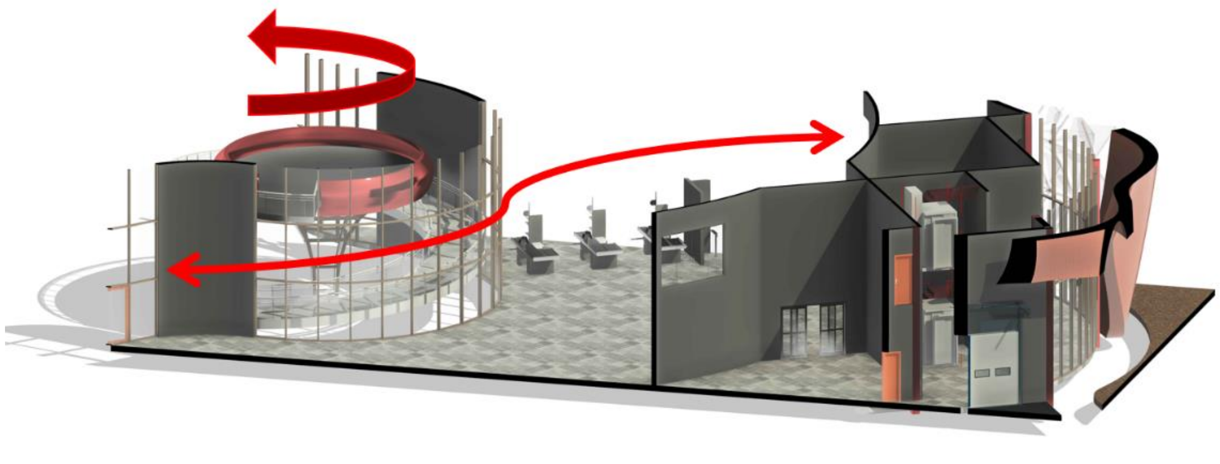


Figure III.4 Interpenetration of Spaces
Source: author,2025

- **Elevated Leisure through Spatial Differentiation**

– To enrich the spatial experience and emphasize functional hierarchy, leisure zones are designed with varied dimensions and volumes, creating visual contrast, psychological relief, and breaking the monotony of movement to keep the user engaged.
– Leisure areas are placed in open terraces, roof gardens, or elevated platforms.
– Their volumes differ in scale, proportion, and materiality from standard shop units.
– This creates a clear spatial hierarchy and adds rhythm to the overall form.
– The design promotes experiential diversity and supports user well-being.

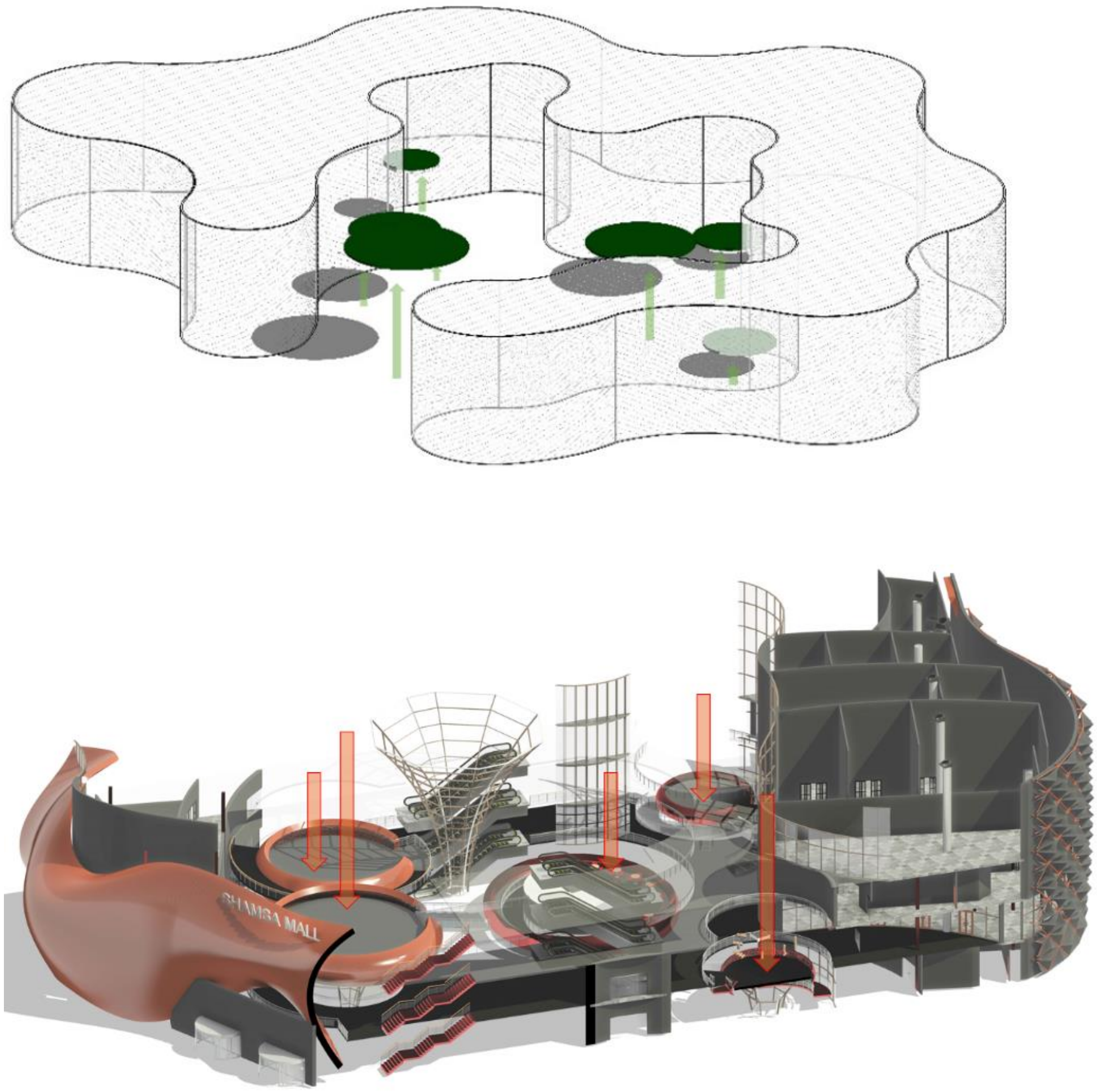


Figure III.5 elevated leisure of the project
Source: author,2025

- **Vertical Openness for Environmental Comfort**

The design applies a vertical openness strategy, with a more enclosed ground floor for control and insulation, while upper levels open to the exterior through terraces and voids. This layered approach enhances natural lighting, ventilation, and spatial diversity, contributing to the project's overall environmental sustainability.

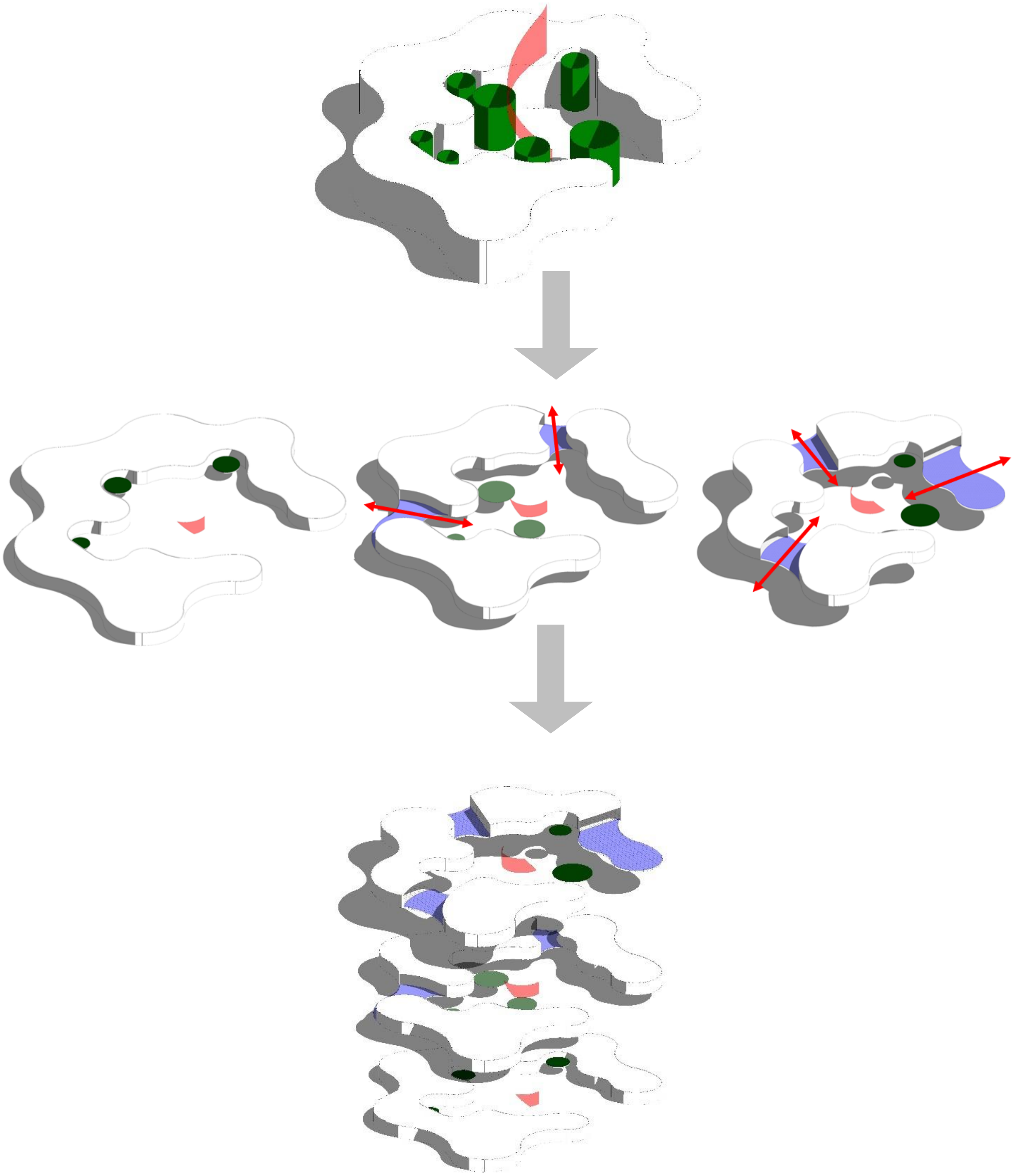


Figure III.6 the openings in the project for environmental comfort
Source: author,2025

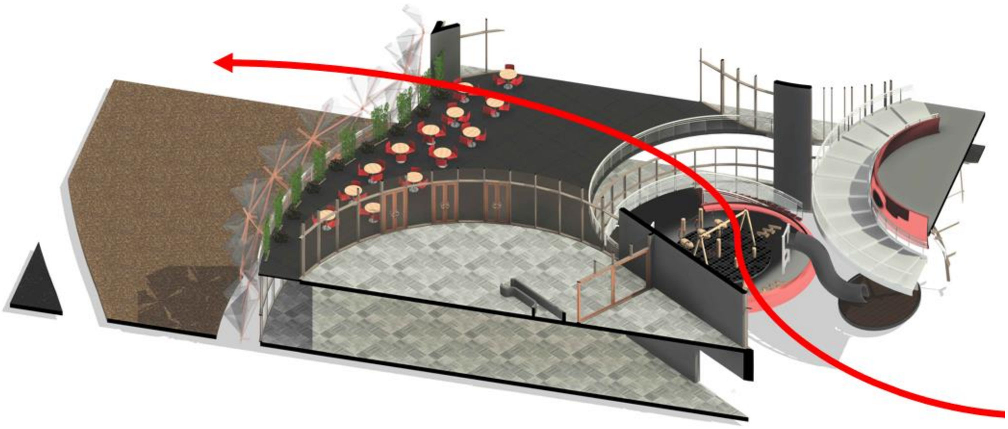


Figure III.7 Transparency of spaces from inside to outside
Source: author,2025

- **Sun Tunnel System for Daylighting**

To reduce energy consumption and enhance visual comfort through natural daylighting strategies.

The project integrates a Sun Tunnel (Light Pipe) system to bring natural light into interior zones that are distant from façades or skylights. This supports visual well-being, reduces reliance on artificial lighting, and aligns with the project's sustainability goals.

They are placed strategically in corridors, common areas, and enclosed retail zones to achieve uniform lighting distribution.

The system enhances energy efficiency, improves indoor ambiance, and contributes to the project's passive design strategies.

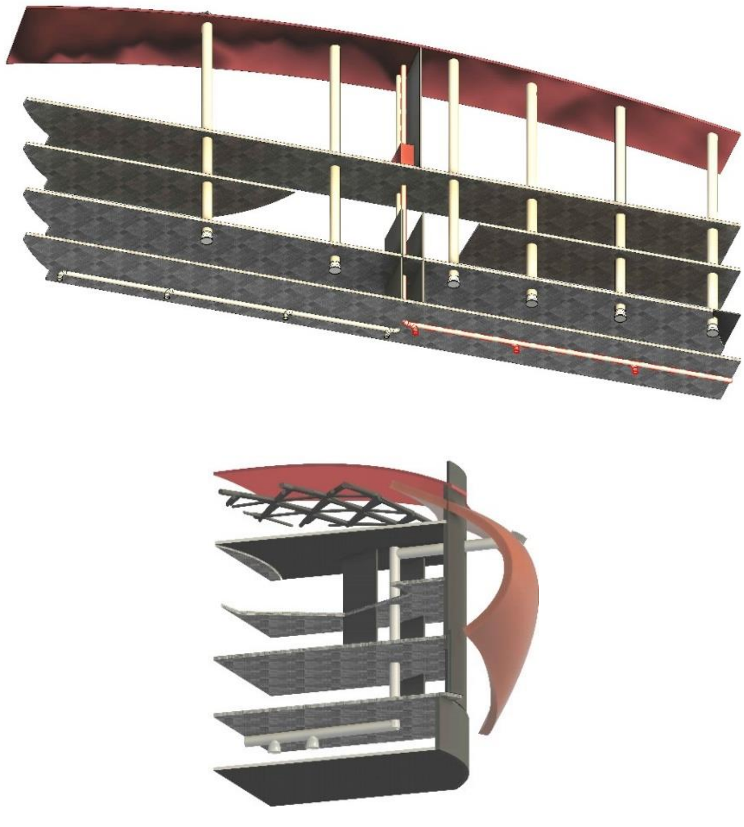


Figure III.8 sun tunnel system in the project
Source: author,2025

II.5 Architectural plans

II.6 Location plane

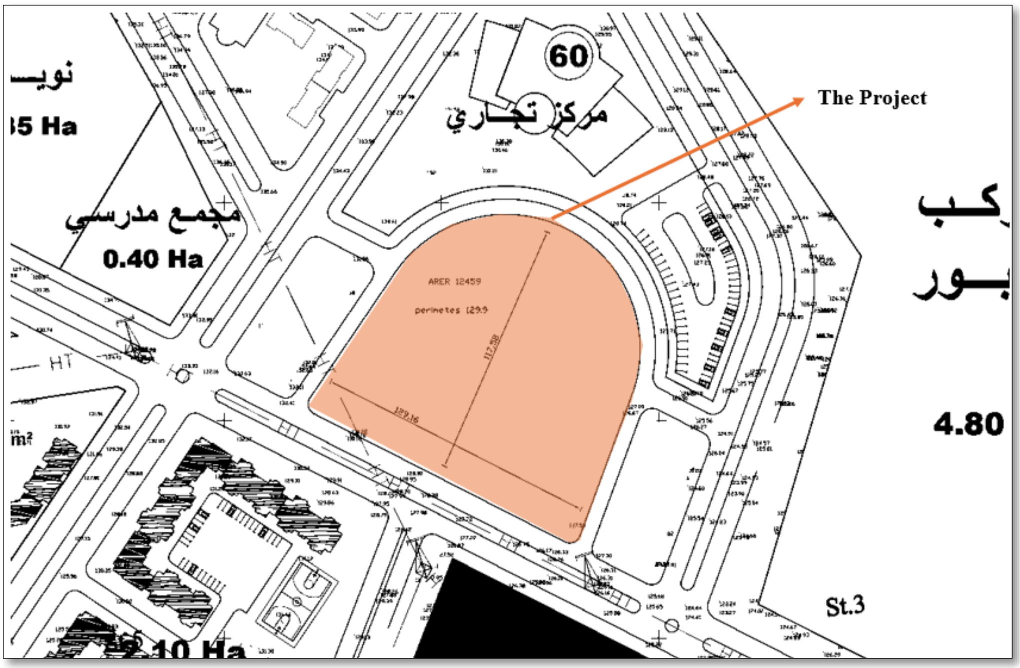


Figure III.9 location plan   scale 1/5000
Source: author,2025

II.7 Master plan

Figure III.10 master plan scale 1/200
Source: author,2025

II.8 Floor plans

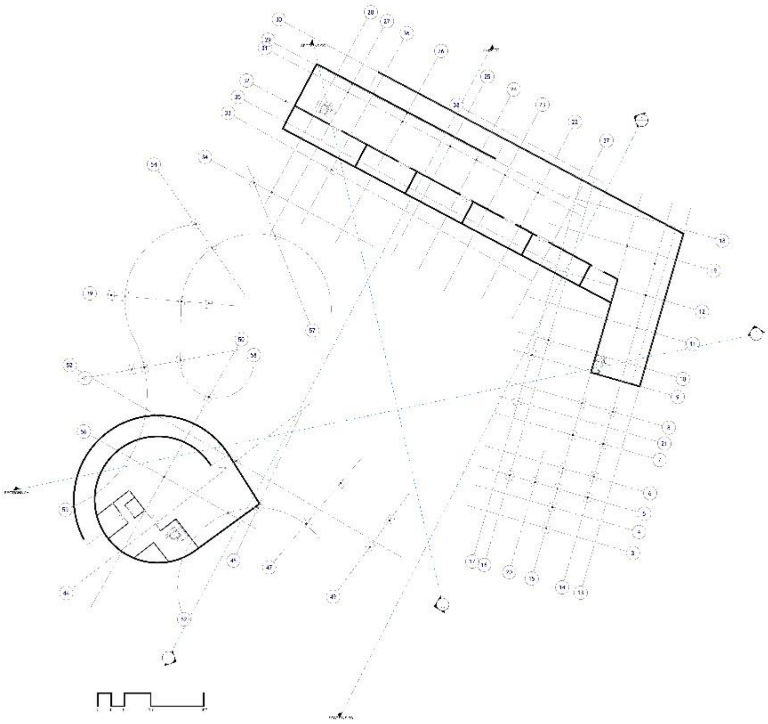


Figure III.11 underground floor scale 1/100
Source: author,2025

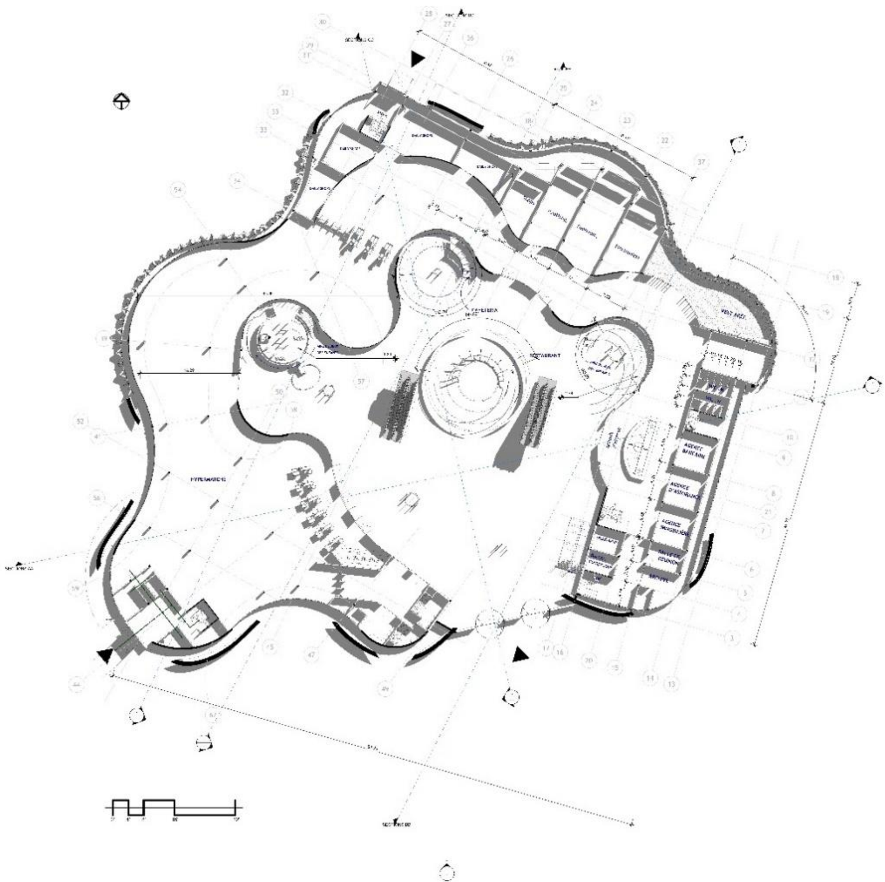


Figure III.12 ground floor scale 1/100
Source: author,2025

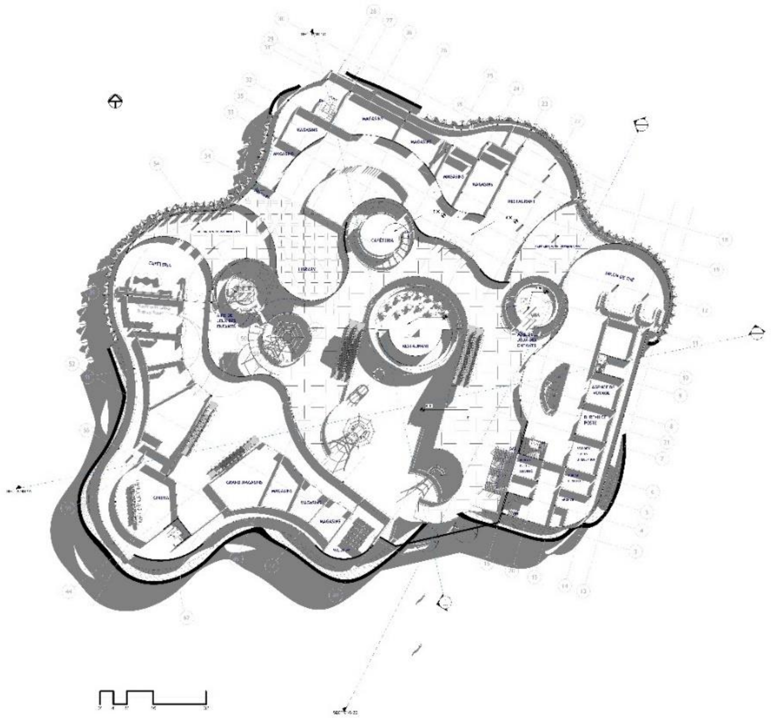


Figure III.13 first floor scale 1/100
Source: author,2025

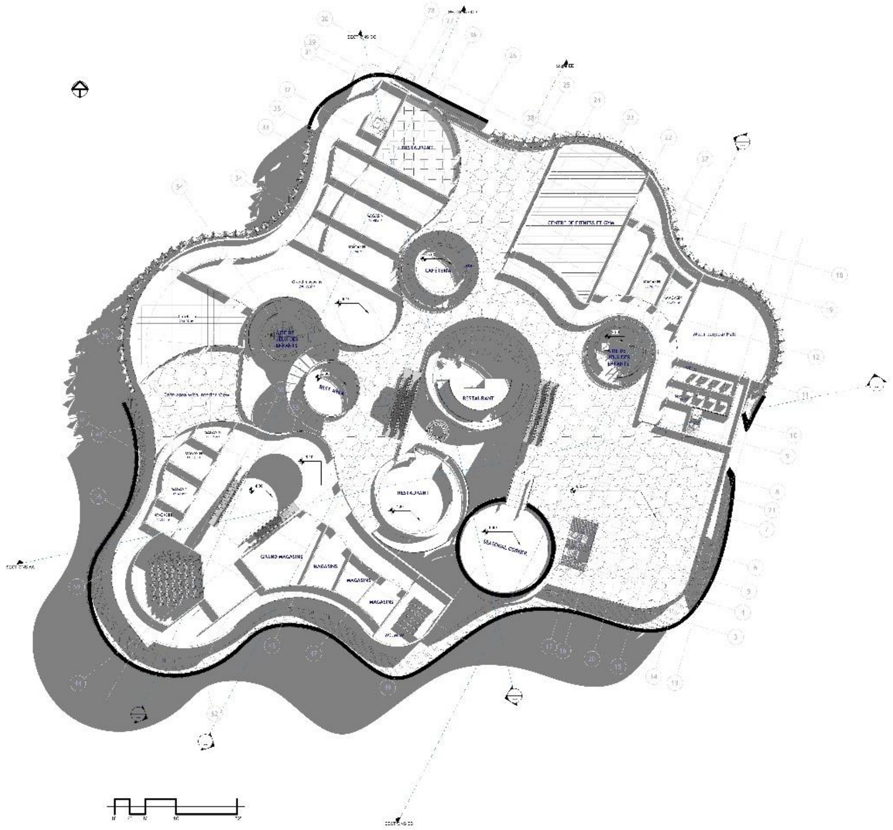


Figure III.14 second floor scale 1/100
Source: author,2025

II.9 Elevations

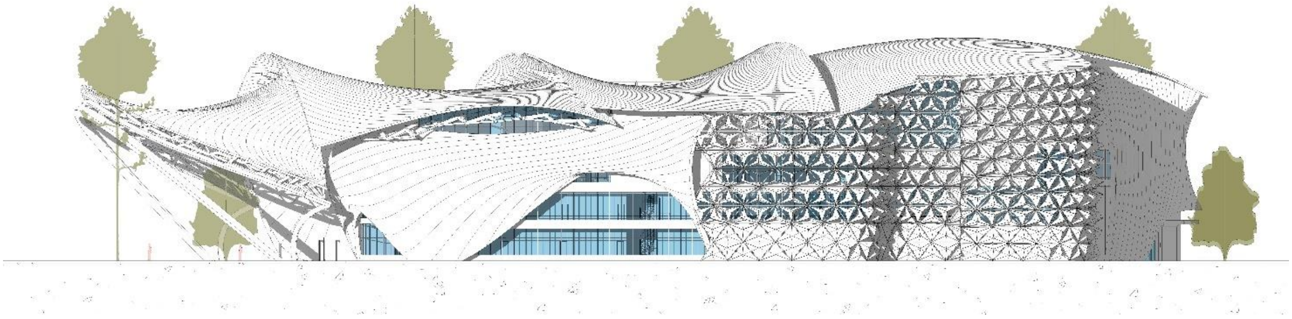


Figure III.15 Elevation East scale 1/100
Source: author,2025

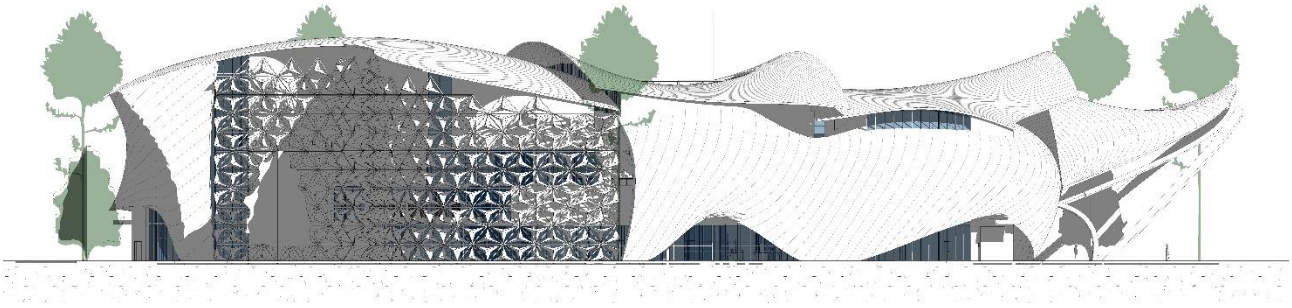


Figure III.16 Elevation west scale 1/100
Source: author,2025

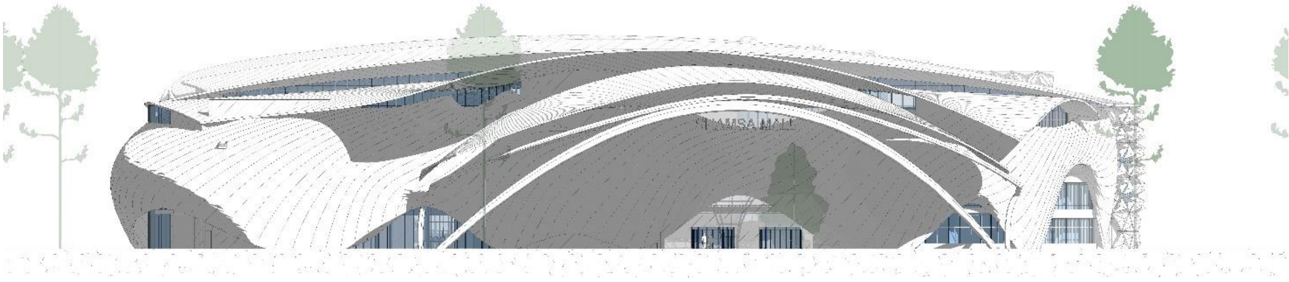


Figure III.17 Elevation South scale 1/100
Source: author,2025

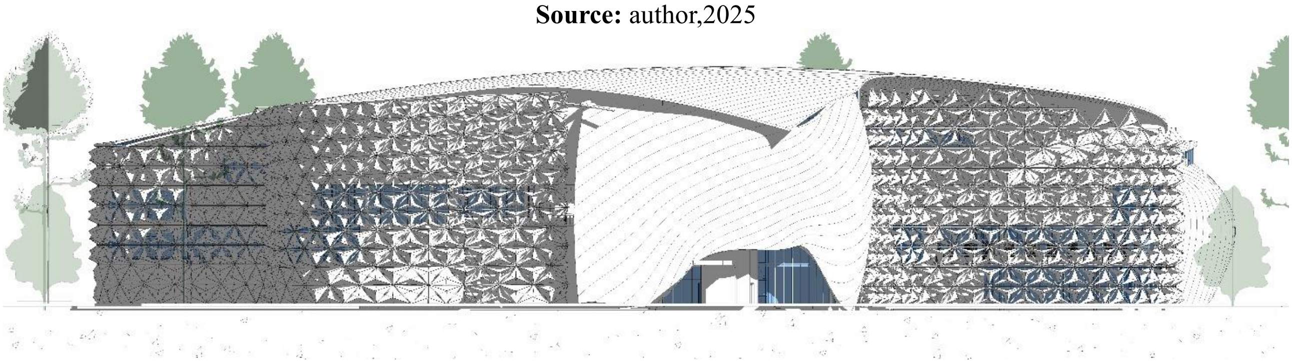


Figure III.18 Elevation North scale 1/100
Source: author,2025

II.10 Sections

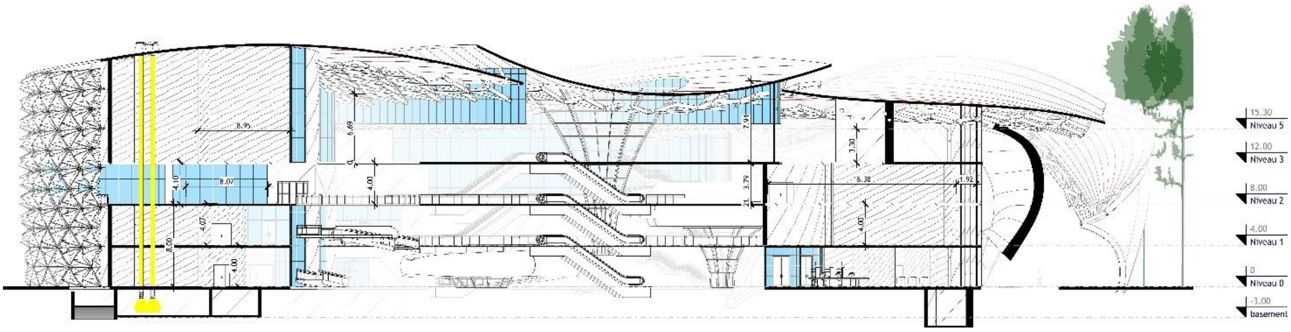


Figure III.19 Section E-E scale 1/100
Source: author,2025

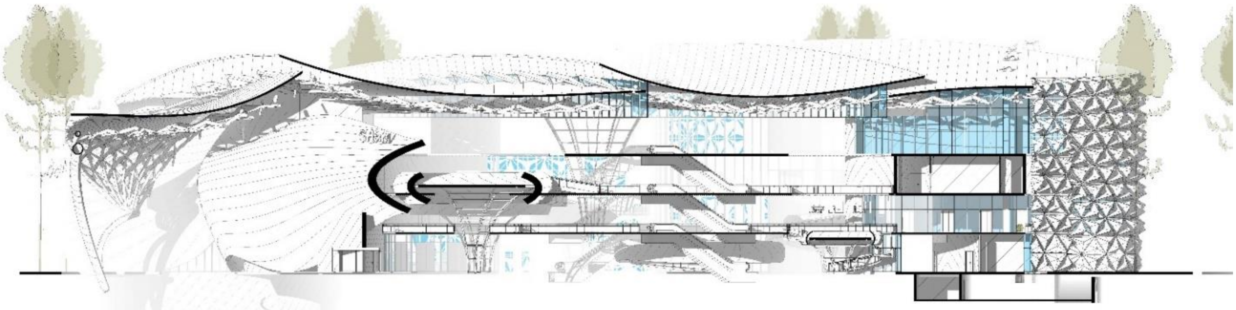


Figure III.20 Section B-B scale 1/100
Source: author,2025

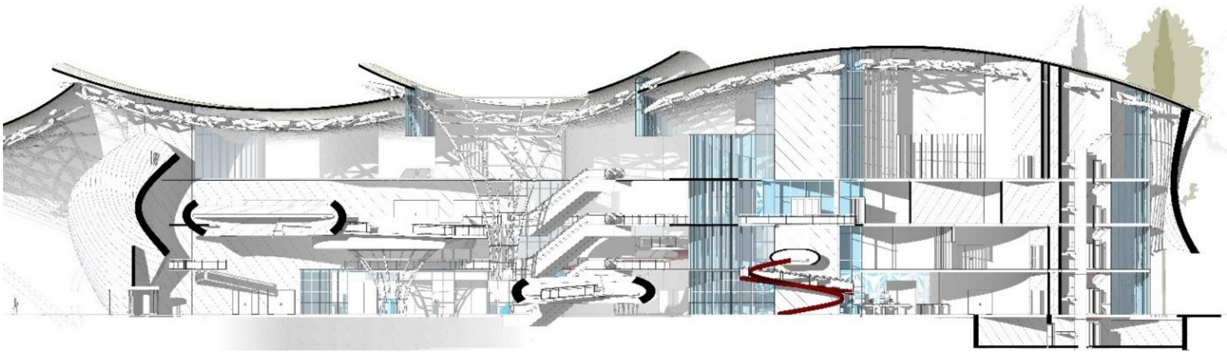
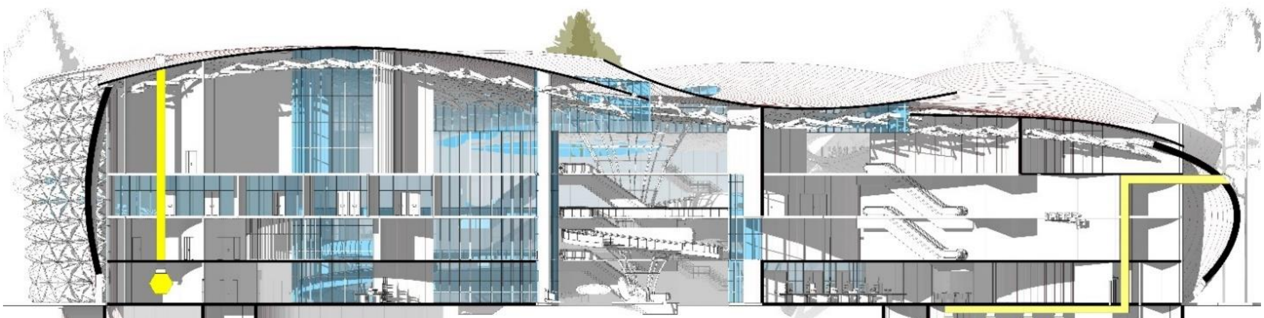


Figure III.21 Section C-C scale 1/100
Source: author,2025



FigureIII.22 Section D-D scale 1/100
Source: author,2025

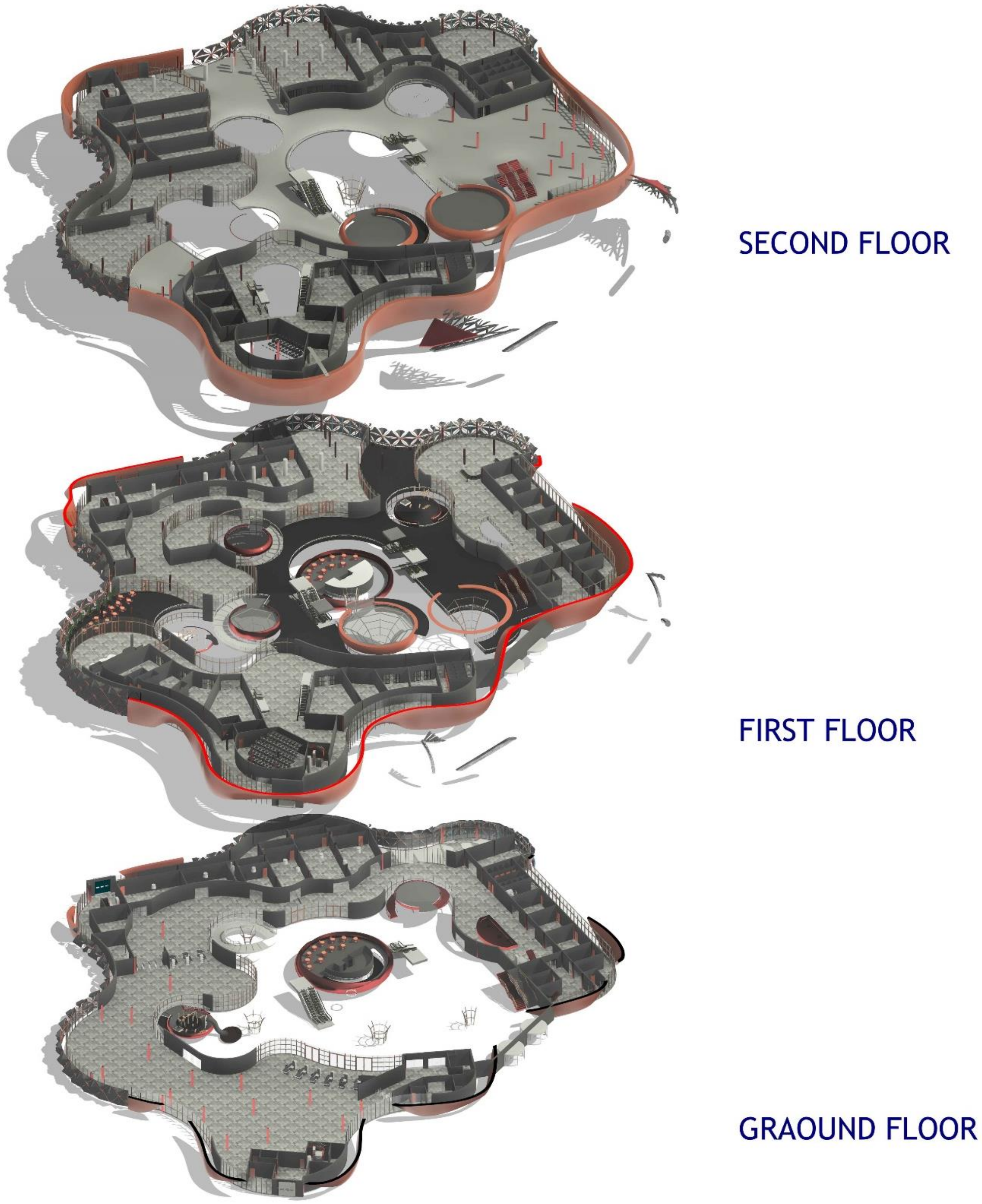


Figure III.23 different layouts of the project
Source: author,2025

II.11 Renders

Figure III.24 view of the project
Source: author,2025

Part two: Sun tunnel

In this final part, and based on the theoretical concepts discussed previously, we propose an adaptive daylighting system that will be integrated into a shopping center project. The system relies on a sun-tracking collector, controlled by an Arduino Uno and guided by LDR sensors, to follow the sun's position and optimize natural light capture throughout the day.

The collected sunlight is transmitted through Sun Tunnels, where it passes through transparent water layers designed to diffuse the light, reduce glare, and enhance indoor thermal comfort. This fully automated system contributes to reducing artificial lighting needs and supports energy efficiency within the commercial environment.

I Sun Tunnels System

In this project, we aim to design a sustainable shopping mall that integrates our pre-developed product — the **Sun Tunnels System** — to deliver natural daylight to interior areas with no direct access to the outside. The system will operate **automatically** and contribute to reducing overall energy consumption.

II Mechanism of the Sun Tunnel Lighting System

To improve energy efficiency and deliver natural daylight to interior spaces without direct access to the outside, the system operates as follows:

Polycarbonate Dome: fixed dome with internal 45° angles that redirect sunlight into the tunnel throughout the day.

- Sun-Tracking Collector: a dual-axis movable head, controlled by LDR sensors and an Arduino Uno, tracks the sun for optimal light capture.
- Solar-Powered Operation: the entire system runs on a small independent solar panel, making energy consumption from the grid nearly zero.
- Reflective Aluminum Tunnel: light travels through a polished aluminum tunnel, ensuring efficient reflection and deep light penetration.
- Water Layers Inside Tunnel: transparent water layers diffuse the light and absorb excess heat, improving both visual and thermal comfort.

This compact, automated system ensures sustainable daylighting while minimizing energy use and supporting environmental goals.

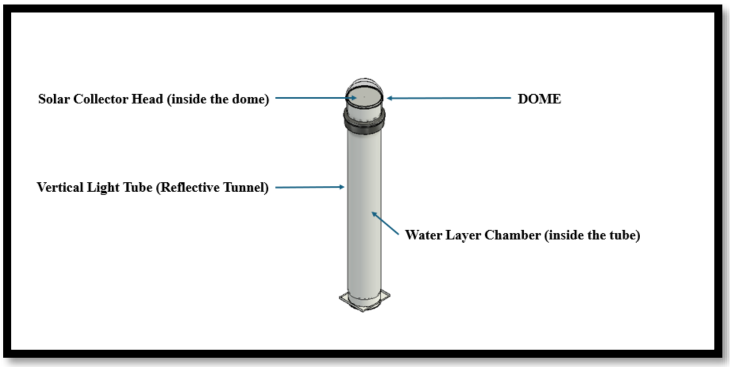


Figure III.25 sun tunnel system mechanism view
Source: author,2025

III Sun-Tracking System Program

In order to create a program that automates a sun-tracking collector, both hardware and software components are required. These include sensors, actuators, and a control system—an Arduino Uno in our case—to adjust the direction of the solar collector based on environmental inputs, such as sunlight intensity and direction.

Below is a simplified table listing the hardware components used in the prototype along with their respective functions:

table 8 hardware components used in the prototype
Source: ResearchGate

Component	Function	Image
Arduino Uno	Processes sensor input and controls the servo motor.	
LDR Sensors (×2)	Detect sunlight direction to determine the sun’s position.	
Servo Motor (×1)	Rotates the solar collector along one axis to follow the sun.	
Solar Panel	Supplies power to the system independently.	
Breadboard & Wires	Distribute power and connect all electronic components.	
Resistors	Protect the sensors and regulate voltage.	

With the components listed in the previous table and the source code uploaded to the Arduino Uno via the Arduino IDE, the solar tracking system operates automatically and is entirely powered by a dedicated solar panel, ensuring zero energy consumption from the grid.

The operating process is as follows:

- Automatic Tracking Mode:
- The system is powered by a small solar panel, making it completely energy-independent.
- Two LDR (Light Dependent Resistor) sensors are positioned on opposite sides of the collector head.
- Each LDR reads the sunlight intensity from its direction.
- The Arduino Uno compares the readings from both sensors.
- If there is a difference in light intensity, the Arduino sends a signal to a servo motor.
- The servo adjusts the collector's orientation along a single horizontal axis to face the sun.
- This tracking process repeats continuously throughout the day to ensure maximum sunlight enters the Sun Tunnel.
- The captured light is then reflected through a polished aluminum tunnel and filtered through internal water layers to reduce heat before entering the interior space.

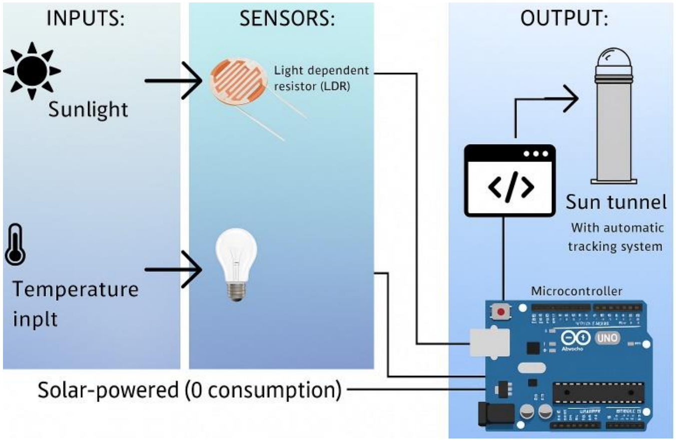


Figure III.26 Adaptive louvers program (Machine learning)
Source: author,2025

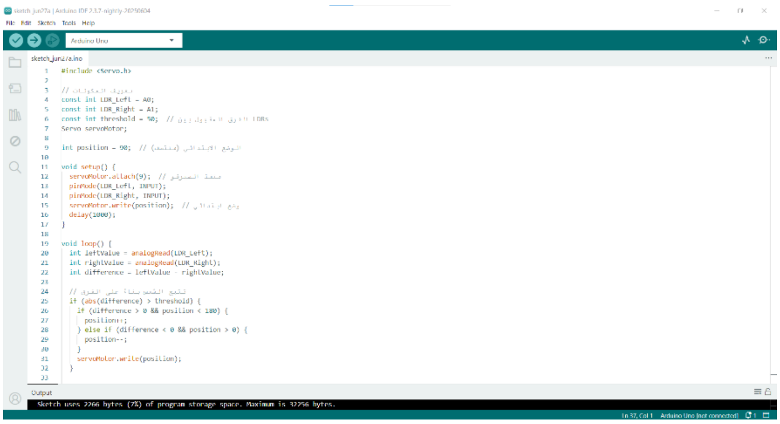


Figure III.27 Uploading the source code through Arduino IDE
Source: author,2025

IV Sun Tunnel – Physical Prototype Overview

To test and validate the concept of solar-driven daylight redirection, a scaled physical prototype of the Sun Tunnel system was built. The system includes a solar tracking collector, a reflective tunnel, and simulated thermal filtering layers. The prototype aims to demonstrate the system's potential in delivering natural light to isolated interior spaces

.

FigureIII.28 Prototype
Source: author,2025

IV.1 Prototype Objective

The prototype aims to simulate and test the concept of solar-powered daylight transmission through a Sun Tunnel system. The goal is to evaluate the ability of the system to:

– Capture sunlight using a sun-tracking collector
– Redirect it into a reflective tunnel

- Filter and soften the light using water layers
- Deliver light into isolated interior areas all while consuming zero external energy.

V Why the Reduced Model

To demonstrate and test the Sun Tunnel system in a controlled and practical way, we created a reduced-scale physical model. The objective was to visualize the concept and simulate the system's performance under realistic conditions using affordable and accessible materials.

The reduced model was chosen for the following reasons:

- It allows clear explanation of the concept in physical form.
- It enables observation of how light behaves through the tunnel in complex geometries.
- It reduces cost and complexity, making it ideal for academic validation.
- It allows easy integration of Arduino components due to its compact size.
- It is commonly used in architecture and electronics as a reliable testing method.

VI Prototype Building

The Sun Tunnel prototype consists of two segments:

- A horizontal tunnel: 15 cm in diameter and 60 cm in length
- A vertical tunnel: 60 cm in length, connected at a 90° angle
- The 90° bend was intentionally included to reflect real architectural constraints where vertical access is not available, making the light redirection more challenging and realistic.

VI.1 Materials Used

- Aluminum sheet (as the main tunnel material) due to its good reflectivity
- Pasteboard for external structure and support elements
- Transparent plastic dome to represent the solar collector cover
- Blue transparent film to simulate the water layers for glare and heat control
- Arduino Uno with 2 LDR sensors and a servo motor
- Small solar panel to supply autonomous power to the system

VI.2 Assembly Process

The reflective tunnel was shaped from aluminum and bent at a 90° angle.

Figure III.29 the material of the tunnel
Source: author,2025

A transparent plastic dome was mounted at the front

Figure III.30 the glasse dome
Source: author,2025

A separate aluminum collector component was placed beneath the dome, which is the true light-capturing element. It is connected to the servo motor to allow horizontal rotation for sun tracking.

LDR sensors were installed around the collector under the dome to detect sunlight.

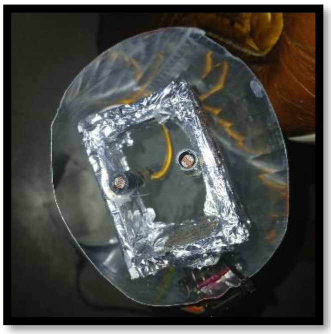


Figure III.31 LDR sensors
Source: author,2025

The servo was programmed to rotate the collector based on LDR readings.

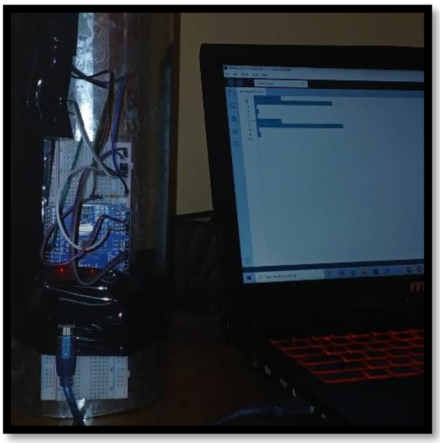


Figure III.32 LDR reading
Source: author,2025

The tunnel's output was directed into a closed model simulating an isolated indoor zone to observe illumination effectiveness.

- **Prototype Test:** after building the Sun Tunnel prototype and carefully preparing the Arduino code, we proceeded to test the prototype and obtained the following results.
- **Sun Tracking:** the collector element accurately follows the direction with the highest solar intensity during the day using LDR sensors and servo motor.
- **Light Transmission:** sunlight is successfully captured and redirected through the reflective tunnel segments, including the 90° bend, reaching the output point.
- **System Efficiency:** despite the angular configuration of the tunnel, the system effectively delivers light into the interior space.
- **Energy Consumption:** the entire system operates using a solar panel, achieving complete energy autonomy with zero electricity consumption
- **Indoor test (Simulation):**

– The prototype was tested in an indoor environment. A smartphone flashlight was used to simulate sunlight.
– LDR sensors detected the light direction.
– The servo motor rotated the aluminum collector to follow the light.
– Light successfully traveled through the reflective tunnel, including the 90° bend.

– The light reached and illuminated a closed model space, simulating an isolated interior zone.

Figure III.33 the light in dark area
Source: author,2025

- **Outdoor test**

On June 27th, 2025, at 10:00 AM, the prototype was tested in real outdoor conditions on an open rooftop. The system successfully tracked the sun’s position and redirected natural sunlight through the tunnel, reaching the interior of the model and confirming its effectiveness in real environmental settings.

Figure III..34 outdoor test
Source: author,2025

- **Future Goals**

One of the future development goals is to enable nighttime use by integrating a rechargeable battery system. This battery would store solar energy collected during the day and supply power to provide nighttime lighting, allowing the system to operate even after sunset.

Conclusion

The practical chapter demonstrated the translation of theoretical insights and analytical findings into a tangible architectural and technical proposition. The proposed shopping center, designed for the city of Biskra, applies innovative spatial concepts such as vertical openness, behavioral zoning, and experiential continuity, while optimizing the use of natural light. The integration of the Sun Tunnel system was developed not only as a design component but as a fully operational environmental technology. Through Arduino-controlled sun tracking, reflective aluminum tunnels, and water-based thermal regulation layers, the system achieved effective daylight redirection under both simulated and real conditions. The physical prototype validated the system’s autonomy, efficiency, and capacity to enhance indoor comfort without electrical energy consumption. Ultimately, this chapter confirms the potential of combining advanced environmental technologies with architectural design to meet sustainability, functionality, and user wellbeing objectives in commercial spaces located in arid regions.

General conclusion

This thesis has explored the potential of natural daylighting systems, specifically the Sun Tunnel (light pipe) technology, as a sustainable design strategy for enhancing visual comfort, reducing energy consumption, and improving the quality of interior environments in commercial architecture. Through a multi-scalar and multidisciplinary methodology, the work was structured into three main chapters: theoretical, analytical, and practical—each contributing distinct yet interrelated insights.

The theoretical chapter established a comprehensive understanding of natural light's role in architecture, tracing its historical evolution, psychological effects, and physical characteristics. It critically examined various daylighting systems, with an emphasis on light pipe systems, their constructional elements, advantages, and operational constraints. It also framed the shopping center typology as a particularly relevant context for integrating daylight-based solutions, due to their energy intensity and spatial complexity.

The analytical chapter presented a comparative study of six shopping centers—four international and two national (Bab Ezzouar and Park Mall)—analyzed across multiple dimensions including spatial organization, circulation, volumetric expression, and natural lighting strategies. This comparative analysis revealed a clear deficiency in the integration of daylight systems in Algerian case studies, especially in terms of penetrating deeper zones and optimizing energy efficiency. In contrast, international examples demonstrated more evolved approaches using skylights, central atriums, and dynamic façade systems. This chapter therefore served as a bridge between the theoretical aspirations and the practical challenges observed on the ground.

The practical chapter formed the core of this research, offering both an architectural proposal and an experimental validation. The architectural proposal, designed for the city of Biskra, responded to local climatic and urban constraints, with particular attention to spatial fluidity, functional zoning, and passive environmental performance. The Sun Tunnel system was integrated into the building both conceptually and technically. A physical prototype, equipped with a solar tracker and reflective tunnel, was fabricated and tested, validating the system's capacity to redirect daylight to deep interior zones with full energy autonomy. The experiment demonstrated effective illuminance levels, thermal neutrality, and user comfort potential—all essential to the functionality of commercial spaces.

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Appendices

Annexe –A

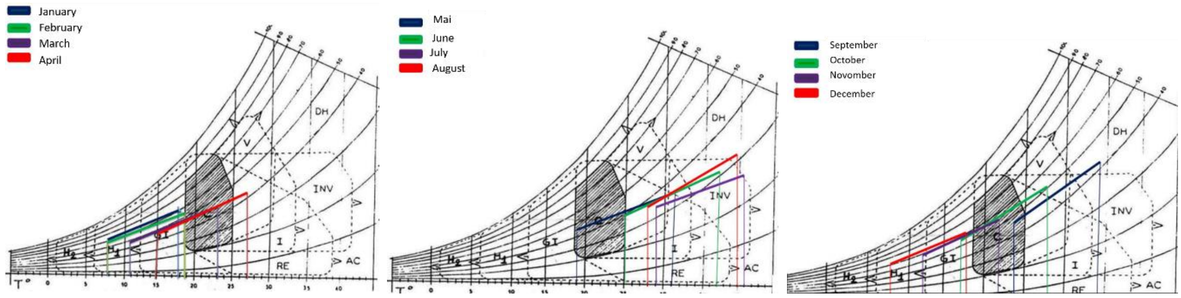
Givoni's diagram

a- Temperature

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

b- Humidity

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



Recommendations drawn from givoni diagrams

Month	recommandations	Month	recommandations	Month	recommandations
january	H1 , GI	mai	V , I , INV , AC	Septembre	V , I , INV , AC, DH
february	H1 , GI	june	V , I , INV , AC	Octobre	GI, C , V , I
march	H1 , GI , C	july	V , I , INV , AC	Novembre	H1 , GI
april	GI , C , V	august	V , I , INV , AC , DH	december	H1 , GI

H2: Active solar heating

H1: Passive solar heating

C: Comfort

V:ventilation

I Strong inertia

H: heating

GI: Internal gain

AC: cooling

DH: dehumidification

INV: Very high inertia and night ventilation

RE: Ventilation cooling

Mahoney's tables

a- Temperature

	J	F	M	A	M	J	J	A	S	O	N	D
Temp.Moy.Max	18	19	23	27	31	37	41	40	34	28	22	18
Temp.Moy.Min	8	8	11	15	19	25	29	28	24	17	12	8
E.D.T	10	11	12	12	12	12	12	12	10	11	10	10

La+haute	TAM
41	24.5
8	33
La+basse	EAT

b- Humidity , rain and wind

	J	F	M	A	M	J	J	A	S	O	N	D	Total annuel pluie
Humidité Rel.Max	61	56	51	47	44	40	35	38	47	55	57	60	
Humidité Rel.Min	60	51	46	42	36	31	26	31	42	50	55	59	
Humidité Rel.Moy	60.5	53.5	48.5	44.5	40	35.5	30.5	34.5	44.5	52.5	56	59.5	185.5
Groupe(G.H)	3	3	2	2	2	2	2	2	2	3	3	3	
Pluie(mm)	15.9	17.5	24.7	22.6	5.7	23.6	00.0	3.7	10.4	16.3	44.8	0.3	
Vent Dominent	4.5	4.7	5	4	5.2	4.6	2.9	2.9	2.9	3.4	3.8	3.2	
Vent Secondaire													

G.H	
< 30%	1
30-50	2
50-70	3
>70	4

c- Comfort

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

-Température:

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

-Stress thermique:

Jour	f	f	/	/	/	c	c	c	c	/	f	f
Nuit	f	f	f	f	/	c	c	c	/	/	f	f

d- Indicators

	J	F	M	A	M	J	J	A	S	O	N	D
H1									X			
H2												
H3				x	x					X		
A1			x									
A2							X	X				
A3	x	x				x					X	X

Architectural recommendations for Algeria (N.Ould Hnia)

a- summer climate zones

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

Recommandations	Les principes dans la période d'été
1.Orientation	Nord-sud (est et ouest à proscrire).
2.Espacement entre les bâtiments	Plan compact en diminuant l'exposition des murs avec l'extérieur
3.Ventilation ou aération d'été	Ventilation nocturne
4.Ouvertures/fenetres	Moyenne 25 à 40 %
5. Murs et planchers	Murs et planchers massifs. Forte inertie thermique multi journalière (hors période surchauffe) avec couleurs claires.
6.toiture	Massive. Forte inertie thermique multi journalière (hors période surchauffe) avec couleurs claires.
7.Isolation thermique	Toiture isolée
8.protection	Protection d'été. Occultation totale des ouvertures, ouvertures nord-sud
9.Espaces extérieurs	Emplacement pour le sommeil en plein air. Cuisine à l'extérieur
10. Végétation	Végétation ombrage murs et fenetres.
11. Chauffage passif	/

b- <u>winter climate zones</u>

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

Recommandations	Les principes dans la période d'hiver
1.Orientation	Nord-sud souhaitée avec occupation Verticale des espaces.
2.Espacement entre les bâtiments	Plan compact en diminuant l'exposition des murs en contact avec l'extérieur
3.Ventilation ou aération d'été	/
4.Ouvertures/fenetres	Sur surface totale ouvertures prévues,affecter pour captage soleil hiver surface vitrage sud égale à 0.15 par m² plancher.
5. Murs et planchers	Murs et planchers massif-inertie thermique journalière>8 heures compromis à prendre avec l'été.
6.toiture	Toiture massive et isolée.
7.Isolation thermique	Isolation thermique par toiture.
8.protection	D'hiver des vents de sable par plantation à feuilles persistantes qui poussent dans le sud .
9.Espaces extérieurs	/
10. Végétation	Végétation à feuilles persistantes pour vents dominants froids et surtout de sable.
11. Chauffage passif	Chauffage passif par stockage murs massifs inertie déphasage 8 à 12 heures ou vitrage sud.
12.Climatisation	/

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي و البحث العلمي

جامعة محمد خيضر بسكرة

عنوان المشروع:

نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

مشروع لنيل شهادة مؤسسة ناشئة في اطار القرار الوزاري 1275

صورة العلامة التجارية

الاسم التجاري

Sun tunnels

السنة الجامعية

2023 _ 2022

بطاقة معلومات:

حول فريق الاشراف وفريق العمل

1- فريق الاشراف:

فريق الاشراف	
المشرف الرئيسي (01): الاستاذ توفيق مزردي	التخصص: كلية الهندسة المعمارية والعمران والهندسة المدنية و الري

2- فريق العمل:

فريق المشروع	التخصص	الكلية
الطالب: جلابي عبد السلام	الهندسة المعمارية	كلية الهندسة المعمارية والعمران والهندسة المدنية و الري

فهرس المحتويات

عنوان المشروع : نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

المحور الأول: تقديم المشروع

بدأت فكرة مشروع نظام الأنفاق الشمسية لحلول الإضاءة الطبيعية من خلال ملاحظة التحديات الكبيرة التي تواجهها المباني الحديثة في توفير إضاءة طبيعية كافية داخل المساحات المبنية، بالإضافة إلى ارتفاع استهلاك الطاقة الكهربائية الناتج عن الاعتماد المكثف على الإضاءة الصناعية. وبتتبع الواقع والمشاكل المتعلقة بجودة الإضاءة داخل المباني، ظهرت الحاجة الملحة إلى حلول مبتكرة وصديقة للبيئة. وتدعم ذلك العديد من الدراسات والإحصائيات التي تبرز أهمية الإضاءة الطبيعية وفوائدها الصحية والاقتصادية، منها:

- تشير منظمة الطاقة الدولية إلى أن الإنارة تمثل حوالي 15% من استهلاك الكهرباء العالمي، وهو ما يرفع التكاليف ويزيد من الانبعاثات الضارة.
- أظهرت دراسة من الجمعية الدولية للضوء أن زيادة الإضاءة الطبيعية في المباني تحسن من راحة وسلامة المستخدمين، وتزيد من الإنتاجية بنسبة تصل إلى 20%.
- أشار تقرير من برنامج الأمم المتحدة للبيئة إلى أن تقليل الاعتماد على الإضاءة الصناعية يمكن أن يقلل استهلاك الطاقة الكهربائية في المباني بنسبة تصل إلى 40%.
- أفادت دراسات طبية أن التعرض للإضاءة الطبيعية يساهم في تحسين المزاج والصحة النفسية ويقلل من اضطرابات النوم بنسبة ملحوظة.
- أوضحت دراسات هندسية أن الأنفاق الشمسية المصممة بشكل صحيح تزيد من انتقال الضوء الطبيعي بنسبة كبيرة إلى الداخل، مما يخفف الحاجة للإضاءة الكهربائية خلال ساعات النهار.
- بالرغم من هذه الفوائد الواضحة، لا تزال الكثير من مشاريع البناء تتجاهل إدخال حلول إضاءة طبيعية مبتكرة، مما يزيد من التحديات المرتبطة بكفاءة الطاقة وجودة الحياة داخل المباني.

لذلك، يهدف مشروعنا إلى تطوير نظام أنفاق شمسية ينقل الضوء الطبيعي بكفاءة إلى داخل المباني بدون استهلاك اي طاقة، مما يساهم في تقليل تكاليف تشغيل المبنى، تحسين جودة الإضاءة مع تقليل الوهج وتلطيف الجو، دعم استدامة البيئة ، وتفير مصدر اضائة الطبيعة للمباني ذات التصميم المعماري الذي يحد من دخول الضوء الطبيعي.

مجال نشاطنا يتمثل في الصناعة البنائية والطاقة المستدامة

(تصميم وتصنيع وتركيب أنظمة أنفاق شمسية لنقل الإضاءة الطبيعية داخل المباني)

فكرة المشروع (الحل المقترح)

سيساعد نظام الأنفاق الشمسية المهندسين المعماريين والمصممين على توفير إضاءة طبيعية فعالة داخل المباني وحل لمشكل تصميم مساحات ليس لها واجهة مع الخارج او مصدر اضائة طبيعية .

يقوم النظام بجمع ضوء الشمس من خلال قبّة مثبتة على السطح تحتوي على جامع يتبع اتجاه حركة الشمس لضمان التعرض للاشعة في كل وقت من النهار ، ثم ينقله عبر أنابيب داخلية مصممة لتعكس الضوء دون فقد كبير وتكون مزودة بطبقات من الماء لتقليل الوهج واللون الاصفر ، ثم يتم نشرها عبر ناشر للضوء يمكن التحكم فيه ، وصولًا إلى نقاط التي تفتقر للضوء الطبيعي داخل المبنى .

من خلال هذا النظام، يمكن تقليل الاعتماد على الإضاءة الكهربائية خلال ساعات النهار، ما يؤدي إلى خفض استهلاك الكهرباء، توفير التكاليف، وتحسين الراحة البصرية للمستخدمين. ومصدر للضوء الطبيعي لتصميم العتم .

يتميز النظام بسهولة التركيب في مختلف أنواع المباني، بما في ذلك المباني السكنية، الإدارية، والمباني التعليمية وحتى التصنيعية ، مع إمكانية دمجه مع أنظمة التحكم الذكية لمراقبة جودة الإضاءة وكفاءتها.

تعريف المشروع

العنصر	الشرح
طبيعة المشروع	**تصميم وتصنيع وتركيب أنظمة أنفاق شمسية لنقل الإضاءة الطبيعية داخل المباني.**
اسم المشروع	**Sun Tunnels**
مجال النشاط	**تقنيات البناء المستدام وحلول الإضاءة الطبيعية.**
موقع المشروع	ولاية بسكرة
النطاق	وطني, دولي
الفئه المستهدفة	المهندسون المعماريون، شركات البناء، مالكو المباني، القطاع الخاص والعام و مناطق التي تفتقر للطاقة .
عدد العمال	08
تسمية النشاط	**نظام أنفاق الشمس لتوفير حلول الإضاءة الطبيعية وتوفير الطاقة في المساحات المبنية**
مضمون النشاط	توفير حلول مبتكرة لنقل الضوء الطبيعي داخل المباني لتقليل استهلاك الطاقة وتحسين جودة الإضاءة
الشكل القانوني للمؤسسة	شخص معنوي SARL

عنوان المشروع : نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

القيم المقترحة

- **حلول فعالة للمساحات الداخلية غير المزودة بواجهات خارجية:** يقدم المشروع تقنية مبتكرة تُمكّن من نقل الإضاءة الطبيعية إلى المناطق الداخلية في المباني التي تفتقر للنوافذ أو الواجهات المباشرة، مما يعزز من جودة البيئة الداخلية ويُحسن من قابلية استخدام هذه المساحات.
- **الكفاءة الطاقوية وتخفيض التكاليف التشغيلية:** يساهم النظام في استغلال الضوء الطبيعي بشكل أمثل، مما يقلل الاعتماد على الإضاءة الكهربائية ويخفض من استهلاك الطاقة، وبالتالي يقلل من التكاليف التشغيلية للمباني.
- **الاستدامة البيئية:** يلتزم المشروع بمبادئ التنمية المستدامة من خلال تقليل الانبعاثات الكربونية الناتجة عن استهلاك الكهرباء، ودعم استخدام مصادر الطاقة المتجددة والطبيعية.
- **تحسين جودة الحياة والراحة البصرية:** يوفر النظام إضاءة طبيعية صحية ومتوازنة تعزز راحة المستخدمين داخل المباني، وتحسن من الظروف النفسية والبدنية لهم.
- **الابتكار التكنولوجي:** يعتمد المشروع على استخدام تقنيات تصميم متقدمة تضمن توزيعاً مثالياً وفعالية عالية لنقل الضوء الطبيعي داخل المباني، مما يميز النظام عن الحلول التقليدية.
- **الملائمة للسوق المحلي:** يُصمم المشروع بحيث يتناسب مع الظروف المناخية والبيئية والمواد المتاحة في السوق المحلي، مع مرونة في التطبيق لمختلف أنواع المباني.
- **القيمة الاقتصادية:** يوفر النظام حلاً اقتصادياً بمدى عائد استثماري واضح، مع تكلفة مناسبة تؤدي إلى توفير مالي طويل الأمد للعملاء.

فريق العمل:

الطلبة	التخصص	الدورات التكوينية
جلابي عبد السلام	الهندسة المعمارية	1. دورة تكوينية لفائدة حاملي المشاريع المضغرة في مركز تطوير المقاولاتية جامعة بسكرة 2. تربص ميداني على مستوى مديرية الترقية والتسيير العقاري-بسكرة. 3. تربص ميداني على مستوى مكتب دراسات. 4. دورات تكوينية حول برامج المحاكاة 3D.

عنوان المشروع : نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

أهداف المشروع

أهداف قريبة المدى:

- تطوير نموذج أولي متكامل وفعال لنظام الأنفاق الشمسية قابل للتطبيق في المباني المختلفة.
- اختبار أداء النظام وتحسينه لضمان نقل الضوء الطبيعي بكفاءة عالية وجودة توزيع مثالية.
- بدء حملات ترويجية لجذب العملاء من المهندسين المعماريين وشركات البناء للاستفادة من النظام.
- بناء شراكات استراتيجية مع شركات المقاولات والموردين لتعزيز قنوات التوزيع والدخول إلى السوق المحلي.

أهداف متوسطة المدى:

- تطوير حلول تقنية متقدمة لزيادة كفاءة الأنفاق الشمسية وتحسين تصميمها بما يتناسب مع متطلبات المباني الذكية.
- تحقيق تأثير إيجابي على الاستدامة البيئية من خلال تقليل استهلاك الكهرباء وخفض الانبعاثات الكربونية.
- الاستمرار في البحث والتطوير لإضافة مزايا ذكية مثل التحكم التلقائي في توزيع الضوء وربطه بأنظمة الطاقة الشمسية الأخرى.

أهداف بعيدة المدى:

- تحقيق استدامة مالية من خلال زيادة المبيعات وتوسيع قاعدة العملاء مع تطوير نماذج تسعير متنوعة تناسب قطاعات مختلفة.
- الوصول إلى ريادة تكنولوجية في مجال حلول الإضاءة الطبيعية المستدامة وتصدير التقنية إلى الأسواق الإقليمية والدولية.
- دعم السياسات الحكومية الخاصة بالبناء الأخضر والطاقة المستدامة من خلال التعاون مع الجهات المختصة لتعزيز اعتماد الأنظمة الصديقة للبيئة.
- تعزيز التعاون الدولي مع مؤسسات بحثية وشركات عالمية لتطوير معايير وتقنيات جديدة في مجال الإضاءة الطبيعية.
- التوسع العالمي ليصبح النظام مرجعًا موثوقًا في توفير حلول الإضاءة الطبيعية في المباني الحديثة حول العالم.

الجدول الزمني لتحقيق أهداف المشروع :

الرقم	المرحلة	الأنشطة الرئيسية	الفترة الزمنية
1	الدراسة والتخطيط	إعداد دراسة جدوى شاملة وتصميم النموذج الأولي للنظام	الشهر 1 – الشهر 3
2	تطوير النموذج الأولي	تصنيع وتجميع النظام الأولي، إجراء اختبارات الأداء وضبط المعايير	الشهر 4 – الشهر 6
3	التسويق والتحضير	إعداد خطة تسويقية، بناء شراكات استراتيجية مع شركات البناء والموردين	الشهر 7 – الشهر 8
4	الإطلاق التجاري	بدء تركيب النظام في المباني الأولى وجذب العملاء	الشهر 9 – الشهر 12
5	التوسع والتطوير	توسيع نطاق المشروع، تطوير تقنيات إضافية وتحسين النظام بناءً على الملاحظات	السنة الثانية
6	الاستدامة والتصدير	دعم الاستدامة المالية، التوسع الإقليمي والدولي، تعزيز التعاون مع الجهات الحكومية والبحثية	السنة الثالثة

الجدول الزني لتحقيق اهداف المشروع1

المحور الثاني: الجوانب الابتكارية

-1طبيعة الابتكار: بيئي مستدام

-2المجالات الابتكارية :

- التميز :النظام الأول من نوعه في السوق المحلي الذي يوفر حلولًا فعالة لنقل وتوزيع الضوء الطبيعي في المناطق الداخلية التي لا تملك واجهات خارجية.
- حلول للمساحات الداخلية بدون واجهات: توفير إضاءة طبيعية للمناطق الداخلية التي لا تمتلك نوافذ أو فتحات مباشرة، وهو تحدٍّ لم تحله العديد من حلول الإضاءة التقليدية.
- تصميم هندسي متطور :استخدام مواد عاكسة وتقنيات هندسية مبتكرة تضمن تحقيق أقصى قدر من انتقال الضوء الطبيعي مع تقليل الفاقد.
- مرونة التطبيق :تصميم النظام ليكون مناسباً لأنواع مختلفة من المباني (سكنية، تجارية، تعليمية)، مع قابلية التخصيص حسب متطلبات كل عميل.
- الاستدامة البيئية :تقديم حلول تقلل من استهلاك الكهرباء وتخفض الانبعاثات الكربونية، مما يساهم في حماية البيئة والحفاظ على الموارد الطبيعية.
- تكامل مع مباني ذكية :قابلية دمج النظام مع أنظمة إدارة المباني الذكية لتعزيز التحكم وتحقيق تكامل شامل في بيئة المبنى.

المحور الثالث: التحليل الاستراتيجي للسوق

تحليل PESTE

العامل	التفسير والتأثيرات
سياسي (Political)	-دعم حكومي لمشاريع الطاقة المستدامة والبناء الأخضر - .استقرار سياسي نسبي يسهّل تنفيذ المشاريع - .وجود تشريعات تنظيمية للبناء والبيئة.
اقتصادي (Economic)	-ارتفاع تكاليف الطاقة التقليدية يدفع لاعتماد حلول توفيرية - .نمو قطاع البناء والعقارات يشكّل سوقاً واعدة . - تحديات مالية لبعض العملاء قد تؤثر على الاستثمار.
اجتماعي(Social)	-زيادة الوعي البيئي يعزز الطلب على الحلول الصديقة للبيئة - .رغبة السكان في تحسين جودة الحياة والراحة . - اهتمام متزايد بالصحة النفسية والبيئة الداخلية.
تكنولوجي (Technological)	-تطور المواد العاكسة وتقنيات الأنفاق الشمسية يحسن الكفاءة - .تقدم تقنيات التحكم الذكي والتكامل مع أنظمة المباني الذكية - .الحاجة لتدريب الفنيين على التركيب والصيانة.
بيئي (Environmental)	-الحاجة الملحة لتقليل الانبعاثات الكربونية - .المناخ المشمس في الجزائر يدعم استغلال الضوء الطبيعي - .تشديد المعايير البيئية يشجع على حلول مستدامة.
قانوني(Legal)	-وجود قوانين تنظيم البناء والسلامة والبيئة - .احتمالية إصدار معايير جديدة للبناء الأخضر - .ضرورة احترام حقوق الملكية الفكرية وحماية الابتكارات.

تحليل S.W.O.T

الفئة	المحتوى
القوة (Strengths)	**-تقنية مبتكرة غير موجودة بشكل واسع في السوق المحلي مطلقا.** **- تحسين جودة الإضاءة الطبيعية داخل المباني.** **- تقليل استهلاك الطاقة وخفض التكاليف.** **- دعم الاستدامة البيئية وتقليل الانبعاثات الكربونية.** **- تصميم مرن يناسب أنواع متعددة من المباني.** **-حل مشكلة المساحات المعزولة عن الواجهات الخارجية كحل للاضائة الطبيعية.**
الضعف (Weaknesses)	**-تكلفة أولية قد تكون مرتفعة مقارنة بالحلول التقليدية.** **- الحاجة إلى توعية السوق وفهم الفو ائد.** **- قلة الخبرة المحلية في تركيب وصيانة النظام.**

	- الاعتماد على الظروف المناخية (شدة الشمس).
الفرص (Opportunities)	**-زيادة الطلب على حلول الطاقة المستدامة في الجزائر.** **- دعم حكومي لمشاريع الطاقة النظيفة.** **- نمو قطاع البناء والبنية التحتية.** **- إمكانية التوسع في الأسواق الإقليمية والدولية.** **- تطوير شراكات استراتيجية مع شركات البناء والمقاولات.**
التهديدات (Threats)	**-المنافسة من تقنيات الطاقة الشمسية الأخرى.** **- التغيرات المحتملة في السياسات الحكومية.** **- محدودية الموارد أو ارتفاع أسعار المواد الخام.** **- تباطؤ السوق أو ضعف القدرة الشرائية للعملاء.**

تحليل القوى الخمسة لبورتر(Porter's Five Forces)

القوة	**التفسير الإيجابي لصالح المشروع**
تهديد دخول منافسين جدد	متوسط : دخول السوق يتطلب خبرة تقنية واستثمارًا عالياً، مما يقلل من احتمالية المنافسة المباشرة ويسمح لك بالحفاظ على ميزة تنافسية قوية.
قوة التفاوض لدى الموردين	متوسط: الموردون لمواد عاكسة وتقنيات خاصة محدودون، مما يمنحهم قدرة تفاوضية متوسطة، لكن يمكن تخفيفها بتعدد الموردين.
قوة التفاوض لدى العملاء	مرتفعة: العملاء يبحثون عن حلول مبتكرة ومستدامة ونوعية عالية، مما يتيح لك فرض أسعار مناسبة بسبب القيمة المضافة التي تقدمها تقنيتك.
تهديد المنتجات البديلة	منخفض :الأنفاق الشمسية تقدم حلولاً فريدة ومتخصصة لا توفرها الأنظمة التقليدية، مما يجعل المشروع خيارًا مفضلاً للعملاء الباحثين عن التميز والاستدامة.
التنافس بين المنافسين الحاليين	منخفض : السوق ناشئ بدون المنافسين، مما يمنح فرصة ريادة السوق وبناء سمعة قوية قبل دخول منافسين جدد بكثافة.

عنوان المشروع : نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

المزيج التسويقي

1) المنتج :

المنتج	خصائص ومميزات المنتج	الاحتياجات التي يلبيها
نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية.	• تصميم هندسي مبتكر لنقل الضوء الطبيعي للمساحات الداخلية بدون فتوحات . • استخدام نظام جامع لاشعة الشمس لضمان كفاءة كمية الضوء. • تقليل الحرار والوهج لضمان معايير راحة المستخدم. • نظام اضائة بدون استهلاك اي طاقة. • سهل التركيب والصيانة. • طويل المدى .	• توفير إضاءة طبيعية في الأماكن الداخلية التي لا تتوفر على إضاءة او اضائة طبيعية كافية. • تقليل استهلاك الكهرباء وتوفير التكاليف • تحسين جودة وراحة المستخدم داخل المباني . • دعم الاستدامة البيئية وتقليل الانبعاثات.

السعر :

تعتمد سياسة التسعير في مشروع نظام الأنفاق الشمسية على تحقيق توازن بين تقديم قيمة مضافة للعملاء وضمان تحقيق ربح مستدام للمشروع. يتم تحديد السعر بناءً على حجم المشروع ومتطلبات التركيب، مع مراعاة التكلفة الفعلية للمواد والعمالة بالإضافة إلى هامش الربح المعقول.

تشمل استراتيجيات التسعير المتبعة:

- **التسعير القائم على القيمة** :حيث يتم تحديد الأسعار بناءً على الفوائد التي يحصل علىها العميل من النظام، مثل توفير الطاقة وتحسين جودة الإضاءة، وليس فقط على تكلفة التصنيع. هذا يسمح بفرض أسعار تعكس الميزة التنافسية للنظام.
- **التسعير التنافسي** :مراقبة أسعار المنافسين في السوق، خاصة حلول الإضاءة والطاقة المستدامة، لضمان أن يكون السعر جذابًا للعملاء مع المحافظة على جودة الخدمة.
- **تسعير الحزم** :تقديم عروض سعرية مختلفة حسب حجم المشروع، مع إمكانية تقديم خصومات على المشاريع الكبيرة أو المتكررة لتعزيز جذب العملاء وتوسيع الحصة السوقية.

الترويج :

أداة الترويج	الهدف الرئيسي
التسويق عبر وسائل التواصل الاجتماعي	زيادة الوعي بالمنتج وجذب العملاء
ورش العمل والندوات المهنية	تعريف المهندسين وشركات البناء بالنظام
المشاركة في المعارض الصناعية	عرض المنتج أمام جمهور مختص
العروض التوضيحية والنماذج الأولية	تعزيز ثقة العملاء من خلال التجربة المباشرة
الشراكات الاستراتيجية	توسيع قنوات التوزيع والترويج
الترويج المباشر	التواصل المباشر مع العملاء المحتملين

التوزيع

قناة التوزيع	الهدف الرئيسي
شركات المقاولات	تركيب النظام في المشاريع الكبرى
مهندسو التصميم	دمج النظام في تصاميم المباني
متاجر مواد البناء	توفير المنتج للعملاء الأفراد والشركات
موزعو المعدات التقنية	توسيع نطاق التوزيع وزيادة الوصول

تحليل السوق

- حجم السوق :يشهد قطاع البناء في الجزائر نموًا ملحوظًا مع تزايد الحاجة إلى حلول مستدامة لتوفير الطاقة، حيث تمثل الإضاءة نسبة كبيرة من استهلاك الكهرباء في المباني. هذا يوفر فرصة واعدة لاعتماد تقنيات الأنفاق الشمسية التي تعزز الإضاءة الطبيعية.
- **العملاء المستهدفون:**
  - المهندسون المعماريون وشركات التصميم.
  - شركات المقاولات والبناء.
  - ملاك المباني السكنية والتجارية والمؤسسات التعليمية.
  - الجهات الحكومية والمنظمات المهتمة بالبناء الأخضر والطاقة المستدامة.

- **المنافسة المباشرون :**

المستوى	اسم المنافس	نبذة مختصرة	مدة الخبرة	نقاط القوة	نقاط الضعف
عالمي	Solatube international	الشركة الرائدة عالمياً والمتخصصة حصريًا في تصميم وتصنيع أنظمة الأنفاق الشمسية لنقل الضوء الطبيعي للمباني. تقدم حلول متقدمة تحظى بشهرة عالمية واسعة.	أكثر من 20 سنة	خبرة طويلة، جودة عالية، تقنيات مسجلة وبراءات اختراع، شبكة توزيع عالمية.	سعر مرتفع نسبيًا، اعتماد كبير على السوق الأمريكي والأوروبي.
	Sunoptics Simonton Windows	متخصصة في أنظمة الأنفاق الشمسية والإضاءة الطبيعية، تقدم حلولًا للمباني التجارية والتعليمية، مع تركيز على جودة الضوء وكفاءة النقل.	حوالي 20 سنة	تركيز على قطاع التعليم والتجاري، حلول متكاملة.	تغطية سوق محدودة نسبيًا خارج أمريكا الشمالية.
	Velux Solar Tubes	جزء من مجموعة VELUX العالمية، تقدم أنظمة أنفاق شمسية عالية الجودة ضمن حلول الإضاءة الطبيعية للمباني السكنية والتجارية.	أكثر من 15 سنة	علامة تجارية قوية، منتجات متنوعة، انتشار واسع.	الأنفاق الشمسية جزء من مجموعة أكبر، تركيز أقل على النظام فقط.
إقليمي	Brightsun Solar Solutions (الإمارات)	تقدم أنظمة أنفاق شمسية مصممة خصيصًا لمناخ الشرق الأوسط مع حلول للإضاءة الطبيعية للمباني السكنية والتجارية، متخصصة في الأنفاق الشمسية فقط.	حوالي 10 سنوات	تخصص في المناخ الصحراوي، حلول مخصصة للسوق الإقليمي.	شركة صغيرة نسبيًا، موارد محدودة، تنافس محدود خارج المنطقة.
	Solaright (مصر)	شركة مصرية تقدم حلول أنفاق شمسية متخصصة، مع تركيز على توفير إضاءة طبيعية فعالة داخل المباني، وتوفير الطاقة.	حوالي 8 سنوات	تركيز محلي وإقليمي، حلول متكاملة للطاقة والإضاءة.	نطاق سوق محدود، قدرة تسويقية أقل مقارنة بالشركات الكبرى
محلي (الجزائر)	/	السوق المحلي لا يحتوي على شركات مختصة حصريًا بأنظمة الأنفاق الشمسية. هناك شركات تقدم حلول طاقة شمسية عامة أو إضاءة	/	/	/

		طبيعية ولكن ليست متخصصة.			

المنافسون الغير مباشرون :

المنافس	نوع الحلول	التقدير السوقي	نقاط القوة	نقاط الضعف
شركات أنظمة الطاقة الشمسية الكهروضوئية	أنظمة طاقة شمسية لتوليد الكهرباء مع بعض حلول الإضاءة	كبيرة ومتنوعة حسب السوق	انتشار واسع، دعم حكومي، حلول متكاملة للطاقة	لا تقدم حلول أنفاق ضوئية متخصصة، تكلفة أعلى للأنظمة الكهروضوئية.
شركات الإضاءة الصناعية التقليدية	حلول إضاءة كهربائية تقليدية	كبيرة جدًا	تكلفة أولية منخفضة، توافر واسع	استهلاك كهرباء عالي، عدم استدامة بيئية . عدم توفير اضائة طبيعية .
شركات البناء تقدم حلول إضاءة طبيعية غير متخصصة	حلول تصميم معماري لتحسين الإضاءة الطبيعية	متوسطة	توافر محلي، قدرة على التخصيص حسب البناء	ليست حلول تقنية متخصصة، فعالية أقل في حالات غياب الواجهات.

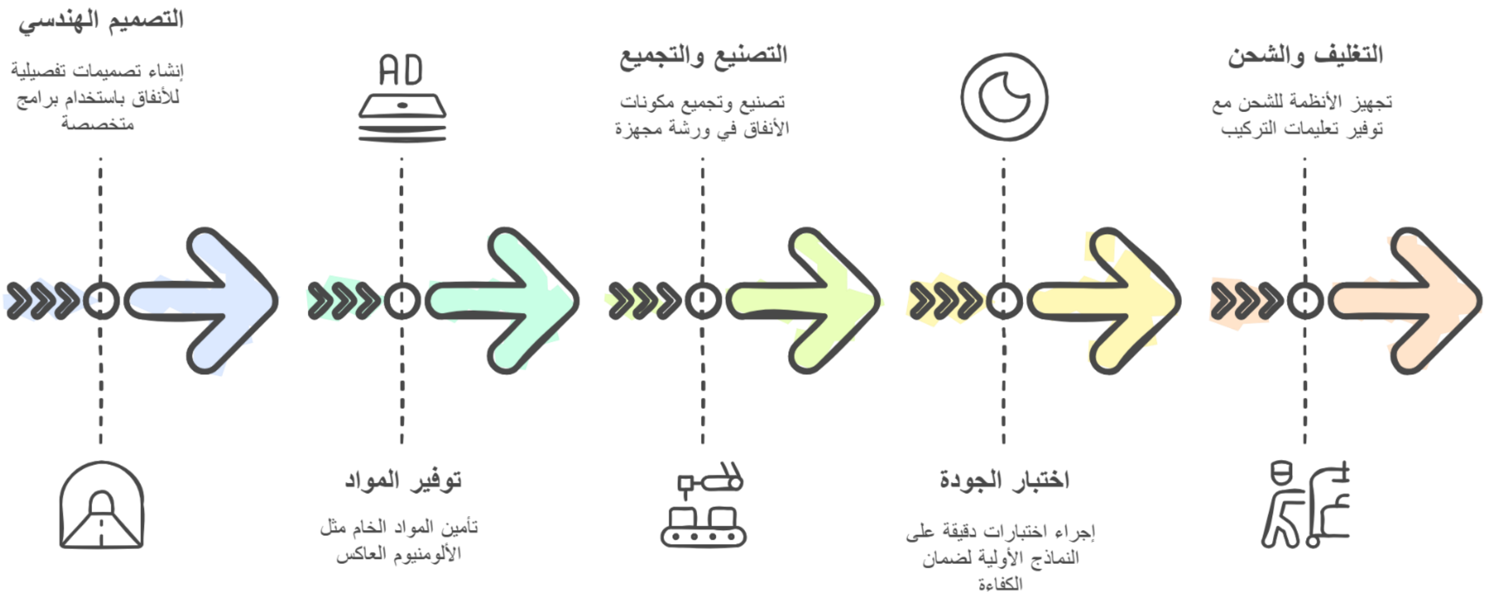
استراتيجية التسويق

- **التسويق المباشر :**التواصل المستمر مع المهندسين المعماريين وشركات البناء عبر ورش عمل وعروض تقديمية تطبيقية لتعريفهم بالنظام وفوائده.
- **الشراكات الاستراتيجية :**التعاون مع شركات المقاولات وموزعي مواد البناء لتعزيز قنوات التوزيع وضمان وصول المنتج إلى أكبر عدد من العملاء.
- **التسويق الرقمي :**استخدام وسائل التواصل الاجتماعي والإعلانات الرقمية لنشر المحتوى التعريفي والتوعوي حول فوائد الأنفاق الشمسية.
- **المعارض والفعاليات :**المشاركة في المعارض الصناعية ومؤتمرات البناء والطاقة لتعزيز شبكة العلاقات وعرض النظام أمام جمهور مستهدف.
- **خدمات ما بعد البيع :**توفير دعم فني وصيانة مستمرة لضمان رضا العملاء واستمرارية أداء النظام.

المحور الرابع: خطة الإنتاج والتنظيم

خطة الإنتاج

يعتمد المشروع على عملية إنتاج متكاملة تهدف إلى تصميم وتصنيع أنظمة الأنفاق الشمسية عالية الجودة لنقل الضوء الطبيعي داخل المباني. تشمل خطوات الإنتاج ما يلي:



التنظيم الإداري والفني

- الإدارة العامة :مسؤولة عن التخطيط والمتابعة والتنسيق بين جميع فرق المشروع، وضمان تحقيق الأهداف في الوقت المحدد.
- فريق التصميم والتطوير :يضم مهندسين مختصين في التصميم الهندسي والمواد، مسؤولين عن تحديث وتحسين المنتج باستمرار.
- قسم التصنيع :يضم الفنيين والعمال المتخصصين في تصنيع وتجميع الأنظمة.
- قسم الجودة :مسؤول عن مراقبة الجودة في كل مرحلة من مراحل الإنتاج.
- قسم التسويق والمبيعات :يشرف على الترويج، بناء الشراكات، وإدارة علاقات العملاء.
- الدعم الفني والصيانة :فريق مختص لتقديم خدمات التركيب، الصيانة، وخدمة ما بعد البيع.

التموين

- تأمين المواد الخام ذات الجودة العالية مثل الألمنيوم العاكس، الأنابيب الخاصة، الزجاج المقوى، وأجهزة التحكم الذكية.
- اختيار الموردين بناءً على معايير جودة صارمة وأسعار تنافسية لضمان استمرارية الإنتاج.
- إدارة الخدمات اللوجستية لنقل المواد إلى ورشة التصنيع ومواقع التركيب بكفاءة وفي الوقت المحدد.
- بناء علاقات شراكة طويلة الأمد مع الموردين لضمان استقرار الأسعار وتوفير الدعم الفني المستمر.
- مراقبة ومتابعة المخزون لضمان توافر المواد دون تأخير في مراحل الإنتاج والتركيب.
- تقييم دوري لأداء الموردين لضمان الالتزام بمعايير الجودة والمواعيد.

اليد العاملة :

الفئة	العدد المتوقع	المهام والمسؤوليات
مهندسو تصميم	2	إعداد التصاميم الهندسية والتقنية للنظام
فنيون تصنيع وتجميع	3	تنفيذ عمليات التصنيع والتجميع وضمان جودة المنتج
فريق تسويق ومبيعات	1	الترويج للمنتج، بناء علاقات العملاء، تنفيذ الحملات
فريق دعم فني	2	تركيب النظام، الصيانة، وخدمة ما بعد البيع
التدريب والتطوير	دوري	برامج تدريب لتحسين مهارات العاملين وتطويرها

الشراكات الرئيسة

- التعاون مع شركات المقاولات والبناء لتسهيل دمج نظام الأنفاق الشمسية ضمن مشاريع البناء الكبرى.
- عقد شراكات مع موردي المواد الخام مثل الألمنيوم والمواد العاكسة لضمان جودة مستمرة وأسعار تنافسية.
- التعاون مع الجهات الحكومية والمؤسسات البيئية لدعم المشروع والحصول على التراخيص والتسهيلات اللازمة.
- بناء علاقات مع شركات التصميم الهندسي لتضمين النظام في التصاميم المعمارية الحديثة.
- التنسيق مع الجامعات ومراكز البحث العلمي لتطوير وتحسين التقنيات المستخدمة في النظام.
- شراكات مع شركات التوزيع واللوجستيات لضمان وصول المنتجات للعملاء بكفاءة وفي الوقت المناسب.

التكاليف والاعباء

البند	التكلفة التقديرية (دج)	ملاحظات
التكاليف الاستثمارية		
شراء المعدات والآلات	1,500,000,000	آلات تصنيع وتجميع عالية التقنية
المواد الخام	100,000,000	الألمنيوم العاكس، الأنابيب، أجهزة تحكم
تجهيز الورشة	30,000,000	تجهيز المكان والمرافق
شراء/استئجار الأرض والمباني	150,000,000 سنويا	حسب الموقع
البحث والتطوير	1,000,000	تصميم ونماذج أولية
التراخيص والتصاريح	300,000	رسوم قانونية وإدارية
التكاليف التشغيلية		
رواتب وأجور الموظفين	60,000,000سنوياً	مهندسون، فنيون، تسويق، دعم فني
المواد المستهلكة	60,000,000سنوياً	شراء مستمر للمواد الخام
المصاريف الإدارية	10,000,000سنوياً	كهرباء، ماء، إنترنت، صيانة
التسويق والترويج	800,000سنوياً	حملات إعلانية وورش عمل
النقل واللوجستيات	500,000سنوياً	نقل المواد والمنتجات
خدمات ما بعد البيع	600,000سنوياً	دعم فني وصيانة

إجمالي التكاليف

- **إجمالي التكاليف الاستثمارية:**

1,500,000,000 + 100,000,000 + 30,000,000 + 1,000,000 + 300,000 = 1,631,300,000دج

- **التكاليف التشغيلية السنوية:**

150,000,000 + 60,000,000 + 60,000,000 + 10,000,000 + 800,000 + 500,000 + 600,000 = 281,900,000دج/سنة

طرق ومصادر الحصول على التموين

- الموردون المحليون: الاعتماد على موردي المواد الخام المتوفرين في السوق المحلي، مثل الألمنيوم والأنابيب والمواد العاكسة، لتقليل تكاليف النقل والوقت.

- الموردون الإقليميون: التعاون مع شركات إقليمية في شمال أفريقيا والشرق الأوسط توفر مواد متخصصة وجودة عالية، خاصة عند الحاجة لمكونات تقنية غير متوفرة محليًا.
- الموردون العالميون: استيراد مواد وتقنيات متقدمة من الشركات العالمية الرائدة لضمان جودة عالية وابتكارات حديثة في تصنيع الأنفاق الشمسية.
- العقود طويلة الأمد: إبرام اتفاقيات وشراكات طويلة الأمد مع الموردين الرئيسيين لضمان استمرارية التوريد وتثبيت الأسعار.
- المناقصات والعطاءات: المشاركة في مناقصات للحصول على أفضل العروض والأسعار من الموردين المحليين والدوليين.
- المخزون الاستراتيجي: تكوين مخزون احتياطي من المواد الأساسية لتجنب توقف الإنتاج نتيجة تأخر الشحن أو نقص التوريد.

كيفية استرداد الأموال (جدول العوائد)

حساب نقطة التعادل (بناءً على 10 ملايين دج للوحدة)

- التكاليف الاستثمارية 1,631,300,000 :دج
- التكاليف التشغيلية السنوية 281,900,000 :دج
- سعر البيع لكل وحدة 10,000,000 :دج
- افتراض هامش ربح صافٍ لكل وحدة 30% :من سعر البيع ⟵ 3,000,000 دج ربح صافٍ لكل وحدة (يمكن تعديل النسبة لاحقًا).

$$\text{نقطة التعادل} \left(\text{وحدات}\right) = \frac{\mathbf{1,631,300,000 + 281,900,000}}{\mathbf{3,000,000}} = \frac{\mathbf{1,913,200,000}}{\mathbf{3,000,000}} \approx 638 \text{ وحدة}$$

يعني يجب بيع حوالي 638وحدة لتغطية جميع التكاليف والوصول إلى نقطة التعادل.

السنة	الإيرادات (دج)	التكاليف التشغيلية (دج)	صافي الربح (تقديري) (دج)	التدفق التراكمي (دج)
1	4,000,000,000 (400 وحدة)	281,900,000	1,118,100,000	1,118,100,000
2	6,000,000,000 (600 وحدة)	281,900,000	2,318,100,000	3,436,200,000
3	8,000,000,000 (800 وحدة)	281,900,000	3,518,100,000	6,954,300,000

رقم الاعمال

	N-2	N-1	N	N+1	N+2	N+3	N+4	N+5
Quantité produit	-	-	-	400	600	800	1000	1200
Prix HT (دج)	-	-	-	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
Ventes (دج)	-	-	-	4,000,000,000	6,000,000,000	8,000,000,000	10,000,000,000	12,000,000,000
CHIFFRE D'AFFAIRES GLOBAL (دج)	-	-	-	4,000,000,000	6,000,000,000	8,000,000,000	10,000,000,000	12,000,000,000

جدول حسابات النتائج المتوقعة

السنة	إجمالي المبيعات (دج)	إجمالي الأعباء (دج)	الربح أو الخسارة (دج)
1	4,000,000,000	441,900,000	3,558,100,000
2	6,000,000,000	441,900,000	5,558,100,000
3	8,000,000,000	441,900,000	7,558,100,000
4	10,000,000,000	441,900,000	9,558,100,000
5	12,000,000,000	441,900,000	11,558,100,000

حساب احتياجات رأس المال العامل(BFR)

البند	القيمة (دج)	ملاحظات
المخزونات	150,000,000	قيمة المواد المخزنة
الديون الزبائنية	200,000,000	الأموال المستحقة من العملاء
الديون الموردين	(100,000,000)	المستحقات للموردين (خصوم)
رأس المال العامل(BFR)	250,000,000	(150+200) - 100 = 250مليون دج

هذا يعني أن المشروع يحتاج إلى 250 مليون دج كتمويل داخلي لضمان سير دورة التشغيل بسلاسة دون الحاجة إلى قروض.

المحور السادس النموذج الاولي التجريبي

قائمة الملاحق :

الملحق رقم 01: ميزانية المؤسسة الناشئة

نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

ACTIF

Poste	**N-2**	**N-1**	**N**	**N+1**	**N+2**	**N+3**	**N+4**	**N+5**
Immobilisations Incorporelles	0	0	0	0	0	0	0	0
Immobilisations Corporelles	0	0	0	1 500 000 000	1 500 000 000	1 500 000 000	1 500 000 000	1 500 000 000
Terrain	0	0	0	150 000 000	150 000 000	150 000 000	150 000 000	150 000 000
Bâtiment	0	0	0	200 000 000	200 000 000	200 000 000	200 000 000	200 000 000
Autres Immobilisations Corporelles	0	0	0	50 000 000	50 000 000	50 000 000	50 000 000	50 000 000
Impôts différés actif	0	0	0	0	0	0	0	0
ACTIF NON COURANT	0	0	0	1 900 000 000	1 900 000 000	1 900 000 000	1 900 000 000	1 900 000 000
ACTIF COURANT								
Stocks et encours	0	0	0	150 000 000	200 000 000	250 000 000	300 000 000	350 000 000
Créances et emplois assimilés	0	0	0	100 000 000	150 000 000	200 000 000	250 000 000	300 000 000
Clients	0	0	0	100 000 000	150 000 000	200 000 000	250 000 000	300 000 000
Autres débiteurs	0	0	0	50 000 000	75 000 000	100 000 000	125 000 000	150 000 000

Impôts et assimilés	0	0	0	50 000 000	75 000 000	100 000 000	125 000 000	150 000 000
Autres créances et emplois assimilés	0	0	0	50 000 000	75 000 000	100 000 000	125 000 000	150 000 000
Disponibilités et assimilés	0	0	0	200 000 000	300 000 000	400 000 000	500 000 000	600 000 000
Trésorerie	0	0	0	150 000 000	200 000 000	250 000 000	300 000 000	350 000 000
ACTIF COURANT TOTAL	0	0	0	750 000 000	1 000 000 000	1 250 000 000	1 500 000 000	1 750 000 000
TOTAL ACTIF	0	0	0	2 650 000 000	2 900 000 000	3 150 000 000	3 400 000 000	3 650 000 000

PASSIF

Poste	N-2	N-1	N	N+1	N+2	N+3	N+4	N+5
CAPITAUX PROPRES								
Capital émis	0	0	0	1 500 000 000	1 500 000 000	1 500 000 000	1 500 000 000	1 500 000 000
TOTAL CAPITAUX PROPRES	0	0	0	1 500 000 000	1 500 000 000	1 500 000 000	1 500 000 000	1 500 000 000
PASSIFS NON COURANTS								
PASSIFS COURANTS								
Fournisseurs et comptes rattachés	0	0	0	100 000 000	150 000 000	200 000 000	250 000 000	300 000 000
Impôts	0	0	0	50 000 000	75 000 000	100 000 000	125 000 000	150 000 000

Autres dettes	0	0	0	100 000 000	150 000 000	200 000 000	250 000 000	300 000 000
Trésorerie passif	0	0	0	0	0	0	0	0
TOTAL PASSIFS COURANTS	0	0	0	250 000 000	375 000 000	500 000 000	625 000 000	750 000 000
TOTAL PASSIF	0	0	0	1 750 000 000	1 875 000 000	2 000 000 000	2 125 000 000	2 250 000 000

الملحق رقم 02: جدول حسابات النتائج المتوقعة

COMPTE DE RUSULTAT PREVISIONNELDE STARTUP : نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية

Poste	N -2	N -1	N	N+1	N+2	N+3	N+4	N+5
Vente et produits annexes	**0**	**0**	**0**	**4,000,000,000**	**6,000,000,000**	**8,000,000,000**	**10,000,000,000**	**12,000,000,000**
Achats consommés	**0**	**0**	**0**	**1,200,000,000**	**1,800,000,000**	**2,400,000,000**	**3,000,000,000**	**3,600,000,000**
Services Extérieurs et autres consommations	**0**	**0**	**0**	**100,000,000**	**120,000,000**	**140,000,000**	**160,000,000**	**180,000,000**
Consommation de l'exercice	**0**	**0**	**0**	**1,300,000,000**	**1,920,000,000**	**2,540,000,000**	**3,160,000,000**	**3,780,000,000**

Valeur ajoutée d'exploitation	**0**	**0**	**0**	**2,700,000,000**	**4,080,000,000**	**5,460,000,000**	**6,840,000,000**	**8,220,000,000**
Charges de personnel	**0**	**0**	**0**	**60,000,000**	**70,000,000**	**80,000,000**	**90,000,000**	**100,000,000**
Impôts et taxes et versements assimilés	**0**	**0**	**0**	**20,000,000**	**30,000,000**	**40,000,000**	**50,000,000**	**60,000,000**
Excédent Brut d'Exploitation (EBE)	**0**	**0**	**0**	**2,620,000,000**	**3,980,000,000**	**5,340,000,000**	**6,700,000,000**	**8,060,000,000**
Autres charges opérationnelles	**0**	**0**	**0**	**100,000,000**	**120,000,000**	**140,000,000**	**160,000,000**	**180,000,000**
Dotations aux amortissements, Provisions	**0**	**0**	**0**	**150,000,000**	**150,000,000**	**150,000,000**	**150,000,000**	**150,000,000**
Résultat opérationnel	**0**	**0**	**0**	**2,470,000,000**	**3,810,000,000**	**5,200,000,000**	**6,550,000,000**	**7,930,000,000**
Résultat Ordinaire avant impôt	**0**	**0**	**0**	**2,470,000,000**	**3,810,000,000**	**5,200,000,000**	**6,550,000,000**	**7,930,000,000**
Impôt exigible sur	**0**	**0**	**0**	**500,000,000**	**700,000,000**	**900,000,000**	**1,000,000,000**	**1,200,000,000**

résultat ordinaire								
TOTAL DES PRODUITS DES ACTIVITÉS ORDINAIRES	**0**	**0**	**0**	**4,000,000,000**	**6,000,000,000**	**8,000,000,000**	**10,000,000,000**	**12,000,000,000**
TOTAL DES CHARGES DES ACTIVITÉS ORDINAIRES	**0**	**0**	**0**	**1,530,000,000**	**2,100,000,000**	**2,800,000,000**	**3,400,000,000**	**4,000,000,000**
RÉSULTAT NET DES ACTIVITÉS ORDINAIRES	**0**	**0**	**0**	**1,940,000,000**	**3,000,000,000**	**4,200,000,000**	**5,600,000,000**	**7,000,000,000**
RÉSULTAT NET DE L'EXERCICE	**0**	**0**	**0**	**1,940,000,000**	**3,000,000,000**	**4,200,000,000**	**5,600,000,000**	**7,000,000,000**

الملحق رقم 03: حسابات الخزينة

TABLEAUX DE FLUX DE TRESORERIE

نظام الانفاق الشمسية لحلول الإضاءة الطبيعية وتوفير الطاقة في المساحة المبنية : STARTUP

.

Rubriques	N-2	N-1	N	N+1	N+2	N+3	N+4	N+5
Flux de trésorerie provenant des activités opérationnelles								

Résultat net de l'exercice	0	0	0	1,940,000,000	3,000,000,000	4,200,000,000	5,600,000,000	7,000,000,000
Ajustements pour :								
- Amortissements et provisions	0	0	0	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000
- Variation des clients et autres créances	0	0	0	100,000,000	150,000,000	200,000,000	250,000,000	300,000,000
- Variation des fournisseurs et autres dettes	0	0	0	100,000,000	150,000,000	200,000,000	250,000,000	300,000,000
Flux de trésorerie générés par l'activité (A)	0	0	0	2,290,000,000	3,300,000,000	4,550,000,000	5,850,000,000	7,450,000,000
Flux de trésorerie liés aux opérations d'investissement (B)	0	0	0	(1,500,000,000)	0	0	0	0
Variation de trésorerie de la période (A+B+C)	0	0	0	790,000,000	3,300,000,000	4,550,000,000	5,850,000,000	7,450,000,000
Trésorerie de clôture (Fin de la période)	0	0	0	790,000,000	3,300,000,000	4,550,000,000	5,850,000,000	7,450,000,000
Variation de trésorerie	0	0	0	790,000,000	3,300,000,000	4,550,000,000	5,850,000,000	7,450,000,000

الملحق رقم 04: نموذج العمل التجاري

شرائح العملاء	العلاقات مع العملاء	القيم المقترحة	الأنشطة الرئيسية	الشركات الرئيسية
-**المهندسون المعماريون** : لتصميم أنظمة الإضاءة الطبيعية للمباني . -**شركات البناء والمقاولات** : لتطبيق حلول الطاقة الشمسية في المشاريع الكبرى . -**الأفراد** : أصحاب المنازل الذين يرغبون في تحسين الإضاءة الطبيعية وتقليل التكاليف الكهربائية. المناطق التي تفتقط لطاقة . المباني الموجهة للاستعمال النهاري .	الدعم الفني المستمر من خلال خدمات ما بعد البيع والصيانة . ورش عمل تدريبية للمهندسين المعماريين وشركات البناء حول كيفية دمج الأنفاق الشمسية . استشارات مخصصة للعملاء في تصميم الأنظمة المناسبة للمباني. **القنوات** **مبيعات مباشرة** عبر الإنترنت أو من خلال مندوبين مبيعات . **شراكات مع شركات البناء** لدمج الحلول في المشاريع الكبرى . **المعارض الصناعية** والفعاليات للترويج للمنتج.	-**حلول مستدامة** لتوفير الإضاءة الطبيعية وتقليل استهلاك الطاقة . -**تقليل التكاليف** من خلال استخدام الطاقة الشمسية لتوفير الكهرباء . -**تحسين الراحة البيئية** في المباني باستخدام تقنيات مبتكرة وصديقة للبيئة. **حلول لتصميم المعماري** المساحات التي لا تملك اتصال مباشر مع الخارج .	-**تصميم الأنفاق الشمسية** والتطوير المستمر للمنتجات . -**إنتاج الأنفاق** باستخدام المواد المتاحة والمعدات المتخصصة . -**التسويق والمبيعات** لجذب العملاء الجدد وتنمية السوق. التركيب والدورة الفنية . الخدمات بعد البيع . **الموارد الرئيسية** . -**الموارد البشرية** :فريق مهندسين متخصصين في الطاقة الشمسية والتصميم المعماري . -**الشراكات مع الموردين** :للحصول على المواد الخام مثل الألمنيوم والزجاج العاكس.	-**شركات البناء والتشييد** :للتعاون في دمج الأنفاق الشمسية في مشاريعهم . -**موردو المواد الأولية** :مثل الزجاج العاكس، الأنابيب، والمحركات . -**الجهات الحكومية أو الهيئات البيئية** :للحصول على الموافقات والشهادات البيئية.

المصادروالإيرادات	هيكل التكاليف
-**بيع الأنفاق الشمسية** للمشاريع السكنية والتجارية . -**خدمات الصيانة** والضمان لفترات محددة . -**استشارات** حول تصميم وتنفيذ الأنفاق الشمسية للمباني.	**تكاليف ثابتة:** اجار العاملين، تكاليف تهيئة المقر، تكاليف شراء الآلات والمعدات. **تكاليف متغيرة** : تكاليف الصيانة -**تكاليف الإنتاج** :مثل المواد الخام، الأجور، والتصنيع . -**التكاليف التشغيلية** :مثل التسويق، الإعلانات . -**الاستثمارفي البحث والتطوير** لتحسين المنتجات وتقنيات الإنتاج.