O. M. Beketov National University of Urban Economics
in Kharkiv

School of Architecture, Urban Planning and Design

Department of Architecture of Buildings and Constructions

ABSTRACT

for the master's degree

on the topic: **"Architectural principles of the sustainable design of mixed-use buildings"**

Completed: st. 2 course,
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19 Architecture and Construction
191 – Architecture and urban planning
(specialty)
Architecture of buildings and constructions
(department)
Matfi Soukaina

Supervisor: Borysenko A.S.

Reviewer: Martyshova L.S.

Kharkiv – 2026

O. M. BEKETOV NATIONAL UNIVERSITY OF URBAN ECONOMICS IN KHARKIV

Institute **School of Architecture, Urban Planning and Design**
Department **Architecture of Buildings and Constructions**
Educational and qualification level **Master degree**
Educational program **Architecture of Buildings and Structures**
Specialty **191 – Architecture and urban planning**

APPROVE
Head of ABaC department
Olga V. Smirnova
“19” May 2026 year

T A S K

FOR THE STUDENT'S QUALIFICATION WORK
MATFI SOUKAINA

Topic of the project (work): “Architectural principles of the sustainable design of mixed-use buildings”

1. Supervisor of project (work): A. S. Borysenko, PhD, Associate Professor, approved by order of the higher educational institution from 26 November 2025 № 1116-03

2. The deadline for student submission of the project (work): 21 May, 2026.

3. Initial data for the project (work): diploma design tasks, results of pre-diploma practice, theoretical studies, graphic-analytical materials.

4. The content of abstract (list of issues that need to be developed):

Section 1. “Analysis of theoretical and practical experience of sustainable design of mixed-use buildings”, Section 2. “Ecological characteristics and architectural principles in sustainable design of mixed-use buildings”, Section 3. “Approval of architectural principles of sustainable design of mixed-use buildings”, Section 4. “Calculation and Constructions”, Section 5. “Occupational health and safety”.

5. A list of graphic material (with a precise indication of mandatory drawings): scheme of the location of the territory in the structure of the city; scheme of the location of the territory in the structure of the district; scheme of the existing functional and transport organization; scheme of the project functional and transport organization; reference plan, general plan; photo fixation; plans, facades, section, perspective projections of the main angles of the building.

6. Consultants of project sections (works)

Section	Surname, initials and position consultant	Signature, date	
		Task issued	Task accepted
1	A.S. Borysenko, PhD, Assoc. prof.	01.12.2025	14.02.2026
2	A.S. Borysenko, PhD, Assoc. prof.	16.02.2026	14.03.2026
3	A.S. Borysenko, PhD, Assoc. prof.	16.03.2026	18.04.2026
4	A.V. Naboka, Ph.D., Senior Lecturer	20.04.2026	30.04.2026
5	V.V. Malysheva, Ph.D., Assoc. prof.	20.04.2026	30.04.2026

7. The date of issue of the task is December 1, 2025.

CALENDAR PLAN

№ s/p	Name of diploma project stages (work)	Term of project stages execution	Note
1	Clarification of the design task	December 2025	Done
2	Development of the staging part (relevance, problems, tasks, object, subject, research methods)	December 2025	Done
3	Approval of the plan for conducting scientific research (content of the qualification work)	February 2026	Done
4	Analysis of scientific literary sources on the topic of the master's qualification work (writing "Introduction", "Section 1" subsections 1.1, 1.2)	February 2026	Done
5	Analysis of prototypes (writing "Section 1" subsection 1.3, "Conclusions to Section 1"). Hypothetical model of an architectural project	February 2026	Done
6	Methodology and techniques of scientific research of an architectural object (writing "Section 2" subsections 2.1, 2.2)	February-March 2026	Done
7	Development and graphic design of analytical schemes (models) based on scientific research (writing "Section 2", subsection 2.3 and "Conclusions to Section 2")	March 2026	Done
8	Generalization of the conclusions of the conducted scientific research work and design of a graphic model of the design object (writing "Section 3" subsections 3.1, 3.2, 3.3, "Conclusions to Section 3")	March, April 2026	Done
9	Writing related sections ("Section 4" and "Section 5")	April 2026	Done
10	Preparation of the master's thesis	April 2026	Done
11	Defense of the master's thesis before the examination commission	May 2026	Done

Student Matfi Soukaina

Supervisor A. S. Borysenko

CONTENT

INTRODUCTION

Today, cities around the world are growing very fast. More people are moving to urban areas, and this creates many problems. Cities need more housing, more services, and more space. As a result, we can see problems like traffic congestion, pollution, lack of green spaces, and inefficient use of land.

Because of these challenges, architecture must find better and smarter solutions. Buildings today should not only be functional, but also comfortable, efficient, and respectful of the environment. One important solution is the development of mixed-use buildings.

Mixed-use buildings combine different functions in one place. For example, a building can include apartments, offices, shops, restaurants, and public spaces. This helps people live, work, and relax in the same area. It also reduces the need to travel long distances, which saves time and energy and reduces pollution.

Another important idea is sustainability. Sustainable design means creating buildings that use less energy, produce less waste, and are better for people and nature. Architects use natural light, natural ventilation, and eco-friendly materials to improve building performance. They also design buildings that can adapt to the climate and last for a long time.

In Morocco, and especially in Casablanca, these ideas are very important. Casablanca is a big and growing city with many people and activities. The city needs new solutions to manage space, improve living conditions, and protect the environment. Mixed-use buildings can help solve these problems by making better use of land and creating more dynamic and active urban spaces.

At the same time, it is important to respect Moroccan culture and architecture. Designers try to combine traditional elements, like courtyards and shading systems, with modern sustainable technologies. This creates buildings that are both modern and connected to local identity.

For all these reasons, studying the architectural principles of design of sustainable mixed-use buildings is important. It helps architects create better buildings and improve the future of cities like Casablanca.

The Purpose of the Work: to identify the principles of sustainable design for mixed-use buildings to learn how to design mixed-use buildings in a sustainable way and understand how this can improve buildings, make cities more efficient, and create better living spaces while reducing environmental impact and saving energy.

Objectives of the Study:

- to identify the basic principles of sustainable design for mixed-use buildings;
- to analyze how these principles improve building performance and comfort;
- to understand how mixed-use buildings can use space more efficiently in cities;
- to explore ways to reduce environmental impact and save energy in mixed-use projects;
- to show how different functions (living, working, services) can be combined effectively in one building.

Object: mixed-use buildings within the urban environment.

Subject: architectural and sustainable design principles used in mixed-use buildings.

Research methods

Historical Analysis: The study explores how mixed-use buildings have developed across different periods and regions. It includes examining traditional models where living, working, and trading coexisted within the same structure, as well as contemporary mixed-use developments. By analyzing past solutions, it becomes possible to identify which design principles have remained effective over time and how they can inform sustainable architectural approaches today.

Comparative Analysis: Several successful mixed-use buildings from different cities around the world are analyzed to understand their design strategies. This includes examining how functions such as housing, offices, and retail spaces are organized, the materials and technologies used in their construction, and how users interact with these environments. Through this comparative analysis, the most effective sustainable design strategies can be identified.

Urban Planning Analysis: The integration of mixed-use buildings within the broader urban context is analyzed by studying transportation access, pedestrian connectivity, public spaces, and zoning regulations. Understanding the surrounding environment ensures that such buildings contribute to urban efficiency, reduce travel distances, and enhance the overall quality of life within the neighborhood.

Sustainability and Structural Analysis: Methods for improving environmental performance and structural efficiency in mixed-use buildings are examined. This includes evaluating passive design strategies such as natural ventilation, daylighting, and climate-responsive facades, along with the use of sustainable materials and energy-efficient technologies. Structural considerations ensure that the building safely accommodates multiple functions while maintaining durability and long-term performance.

SECTION 1. ANALYSIS OF THEORETICAL AND PRACTICAL EXPERIENCE OF SUSTAINABLE DESIGN OF MIXED-USE BUILDINGS

1.1. Analysis of theoretical experience of the formation of sustainable design of mixed-use buildings

To understand the concept of sustainable design of mixed-use buildings and their architectural value, it is essential to examine the theoretical foundations presented by well-known authors in the field. Several key publications offer insights into the planning, design, and implementation of multifunctional buildings.

One of the earliest and most influential works is the "Mixed-Use Development Handbook" by Dean Schwanke, published in January 2003. This book serves as a practical guide for developing buildings that integrate homes, offices, and shops into one structure. It explains how to plan such developments, secure financing, follow regulations, and create functional, attractive spaces. Schwanke's work also explores real-life examples, helping professionals understand the benefits and challenges of this approach (Fig. 1.1) [1].

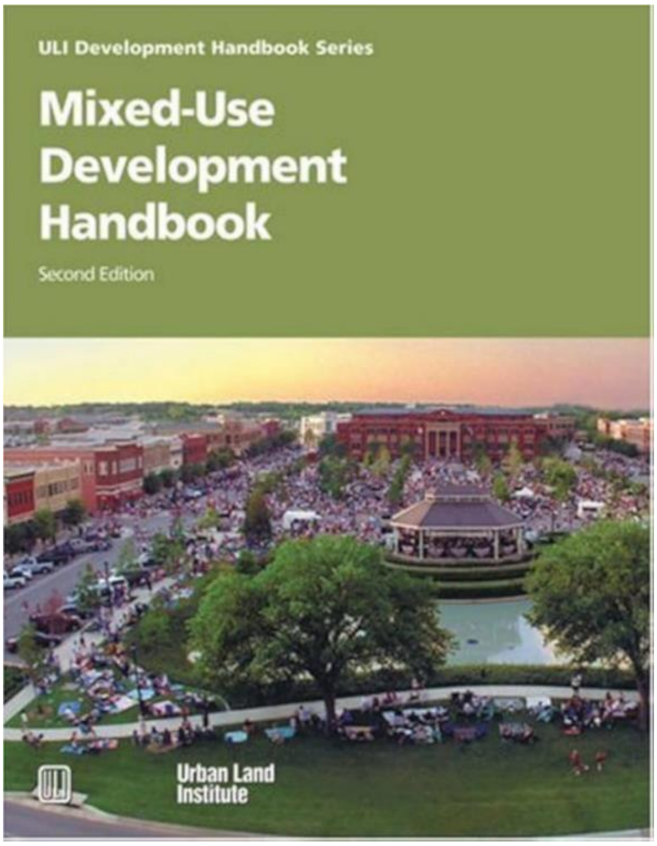


Figure 1.1. Mixed-Use Development Handbook by Dean Schwanke

Another important reference is "NewCity Landmark: Mixed-Use Architecture" by Michael D. Sorkin, published on 10 March 2015. Sorkin focuses on how mixed-use design can improve urban life by reducing traffic, encouraging community interaction, and supporting environmental sustainability. The book emphasizes how thoughtful architectural design can lead to more connected and livable cities. It promotes the idea that mixed-use buildings are not only functional but also vital for future urban growth (Fig.1.2) [2].

Figure 1.2. New City Landmark Mixed Use Architecture by Michael D. Beyard

Brandon E. Basso’s book, "Building Type Basics for Retail and Mixed-Use Facilities", published in January 2004, presents a more technical and design-based approach. Basso, an architect specializing in retail and mixed-use spaces, discusses the importance of creating buildings that balance beauty, function, and sustainability. His focus is on meeting both business and customer needs while working closely with clients to achieve successful results (Fig.1.3) [3].

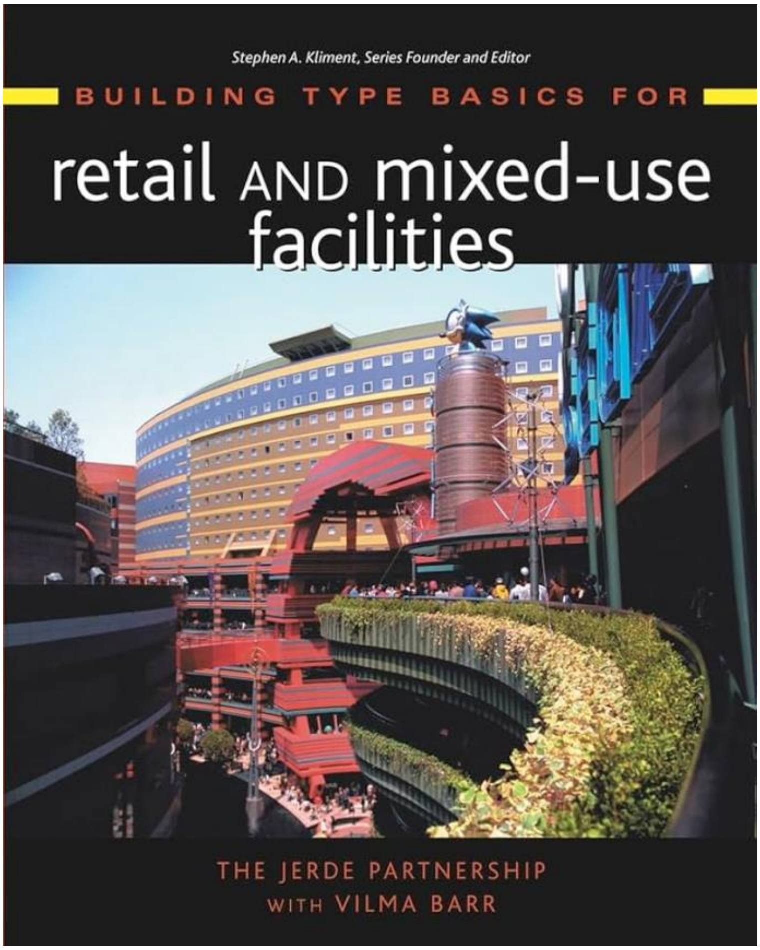


Figure 1.3. Retail and Mixed-Use Facilities by Brandon E. Basso

Lastly, Katherine Willis in her book "Technical Standards and Design Guidelines: Mixed-Use Buildings", published on 13 August 2018, contributes a comprehensive look at standards and guidelines. As an urban planner and architect, her work combines residential, commercial, and recreational functions with a strong focus on sustainability, space efficiency, and community value. Her book is especially useful for its technical advice and real-world examples that guide architects in designing well-integrated multifunctional buildings. Together, these works form a strong theoretical base for the development of mixed-use buildings. They highlight both the architectural strategies and urban benefits of combining multiple functions into one space. These references will serve as a key foundation for the analysis and design proposals in this project (Fig.1.4) [4].

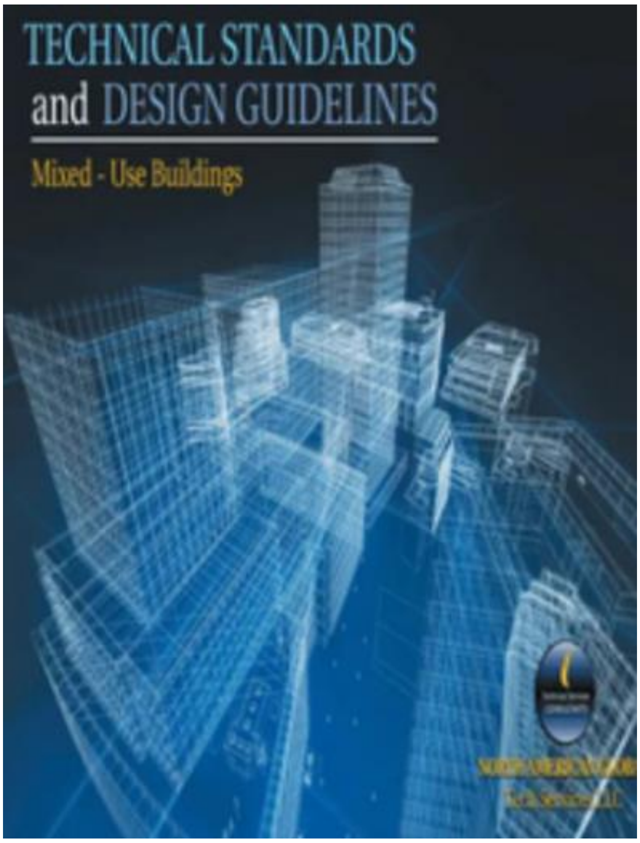


Figure 1.4. Technical Standards and Design Guidelines: Mixed - Use Buildings by Katherine Willis

"Sustainable Building Standards and Guidelines for Mixed-Use Buildings" by Ranjit Gunewardane (2018) is an important reference that focuses on the integration of sustainability principles in mixed-use developments. The book presents clear standards and guidelines for designing buildings that combine residential, commercial, and office functions while minimizing environmental impact. It discusses key aspects such as energy efficiency, water management, sustainable materials, and the use of green technologies. In addition, it emphasizes the role of proper planning, construction, and building operation in achieving long-term performance. This work serves as a practical guide for architects and planners aiming to create efficient, environmentally responsible, and well-integrated mixed-use projects (Fig.1.5) [5].

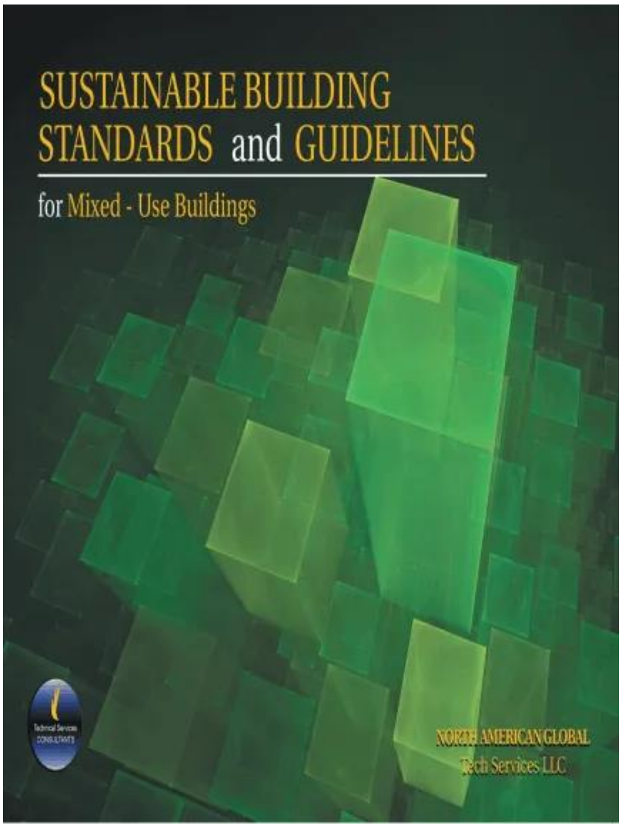


Figure 1.5. Sustainable Building Standards and Guidelines for Mixed-Use Buildings by Ranjit Gunewardane

“Handbook of Green Building Design and Construction” by Sam Kubba is an important reference that provides comprehensive guidance on the principles and practices of sustainable building design and construction. The book focuses on integrating environmental considerations into architectural and engineering processes, covering key topics such as energy-efficient systems, water conservation, sustainable material selection, indoor environmental quality, and green construction methods. It also addresses building performance evaluation and the application of green certification systems to improve environmental responsibility throughout the building lifecycle. This work serves as a practical resource for architects and designers seeking to implement sustainable strategies in contemporary building projects, including mixed-use developments (Fig.1.6) [6].

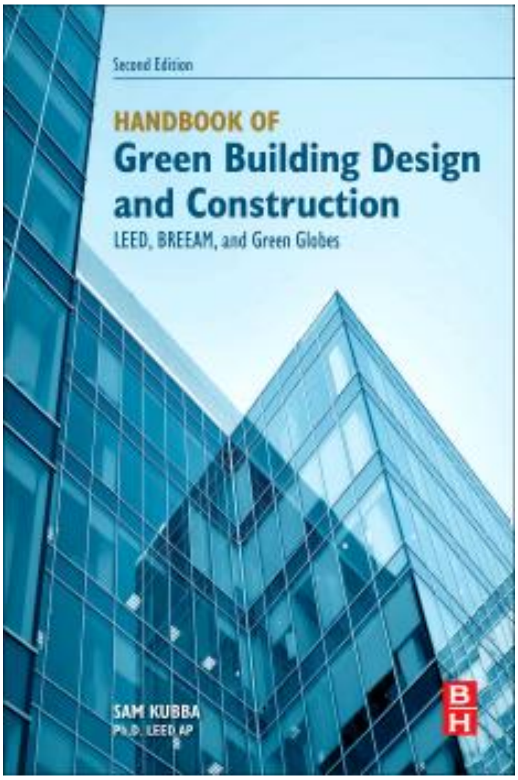


Figure 1.6. Handbook of Green Building Design and Construction by Sam Kubba

1.2. Analysis of practical experience of the formation of sustainable design of mixed-use buildings

One Central Park – Sydney, Australia [7]. Completed in 2014 and designed by renowned French architect Jean Nouvel in collaboration with botanist Patrick Blanc, One Central Park is a landmark example of sustainable and innovative mixed-use architecture. Located in the heart of Sydney, the project consists of two residential towers sitting above a retail podium, with integrated commercial spaces, restaurants, cafes, and public parks. What makes this project stand out is its impressive use of greenery—over 1,200 square meters of vertical gardens climb the facades, creating a living, breathing building that helps regulate temperature, improve air quality, and provide a visual connection to nature in the middle of the city. A striking heliostat—a system of motorized mirrors—sits on a cantilevered platform extending from the higher tower, reflecting sunlight down into the shaded areas and the gardens below. This project is a clear example of how mixed-use buildings can bring together environmental responsibility, urban density, and high-quality living. Residents have direct access to shopping, dining, and leisure spaces, reducing the need for transportation and promoting a compact, walkable lifestyle. One

Central Park has received numerous awards for its design, sustainability, and urban integration, and it continues to inspire architects and city planners worldwide (Fig. 1.7)

Figure 1.7. One Central Park photo by Simon Wood, John Gollings

Porta Nuova – Milan, Italy [8] is one of the largest urban redevelopment projects in Europe, transforming an abandoned industrial area in central Milan into a vibrant, modern district. Masterplanned by Pelli Clarke Pelli Architects and developed between 2010 and 2015, Porta Nuova spans over 290,000 square meters and includes residential buildings, office towers, public plazas, cultural centers, and retail spaces. The centerpiece of the project is the UniCredit Tower, Italy's tallest skyscraper at 231 meters, which symbolizes Milan's modern identity. Porta Nuova is a textbook example of mixed-use development: it integrates living, working, shopping, and recreation within a single connected neighborhood. Wide pedestrian streets, public transportation access, and large green areas like the Biblioteca degli Alberi (Library of Trees) park make the area walkable and people-friendly. It also emphasizes energy-efficient building technologies, sustainable materials, and smart infrastructure. Porta Nuova is not just a group of modern buildings—it is a model for future urban growth, showing how architecture and urban planning can bring together different functions in one coherent and attractive environment (Fig.1.8)

Figure 1.8. Porta Nuova – Milan, Italy by Jeff Goldberg

Vertikal Nydalen – Oslo, Norway [9] completed in 2020 and designed by the innovative Norwegian architecture firm Snøhetta, is a forward-thinking mixed-use tower located in Oslo's Nydalen district. The building represents a shift toward vertical urban living, where work, residential life, and social interaction are layered within a compact footprint. The project includes office spaces, apartments, retail units, and common areas designed to foster community and collaboration. The architecture is modern and minimal, with a focus on sustainability—featuring green roofs, natural ventilation, and materials selected for their low environmental impact. The vertical form not only maximizes land use in a growing city but also offers panoramic views of Oslo and its surroundings. Snøhetta's design encourages interaction among users, with shared terraces and open zones that blur the line between private and public. Vertikal Nydalen demonstrates how mixed-use buildings can create dynamic, energy- efficient environments in limited urban spaces while maintaining a strong connection to nature and community (Fig.1.9)

Figure 1.9. Vertikal Nydalen – Oslo, Norway by Lars Pettersen

Generali Tower by Zaha Hadid – Milan, Italy The Generali Tower [10], also known as “Lo Storto” (The Twisted One), is a striking skyscraper designed by Zaha Hadid Architects and completed in 2017. Located in Milan’s futuristic CityLife district, the tower rises 170 meters and features a distinctive twisted form, symbolizing movement and innovation. While the tower itself functions mainly as an office building—serving as the headquarters of the Generali Group—it plays a key role in the larger CityLife masterplan, which is a fully integrated mixed-use urban redevelopment. The area includes luxury residential buildings, a major shopping mall, public art installations, and expansive green spaces, all arranged in a car-free layout. The design of the tower emphasizes vertical circulation, fluid interior spaces, and energy efficiency. Even though the Generali Tower is primarily for commercial use, it contributes to a broader mixed-use vision where business, residential, cultural, and leisure spaces coexist in a walkable and sustainable urban ecosystem. It is a perfect example of how a single iconic building can support and elevate an entire mixed-use development (Fig.1.10)

Figure 1.10. Milan, Italy The Generali Tower by Luke Hayes

1.3. Factors influencing architectural formation of sustainable design of mixed-use buildings

Sustainable design of mixed-use buildings is influenced by several interconnected factors that work together to create efficient, comfortable, and environmentally friendly spaces. Environmental factors are very important, as architects must consider climate conditions such as sunlight, wind, and temperature to reduce energy consumption. Strategies like natural ventilation, daylighting, green roofs, and solar panels help lower environmental impact. Urban and legal factors also shape the design, because buildings must follow zoning laws, building codes, and sustainability standards while being well integrated into the city and connected to public transport. Functional factors ensure that different uses, such as residential, commercial, and office spaces, are well organized, with clear circulation and separation between public and private areas. Economic factors influence decisions about materials and technologies, as sustainable solutions may have higher initial costs but reduce energy and maintenance costs over time. Social and cultural factors are also important, as buildings should respond to users' needs, reflect local identity, and provide shared spaces that encourage interaction and well-being. In addition, technological factors contribute to sustainability through smart systems that manage energy, lighting, and water efficiently, as well as modern construction methods that reduce waste. Finally, aesthetic factors play a role by combining sustainability with attractive design, using natural materials and integrating greenery to create a pleasant environment. All these factors together help architects design mixed-use buildings that are sustainable, functional, and adapted to their context (Fig.1.11) [11].

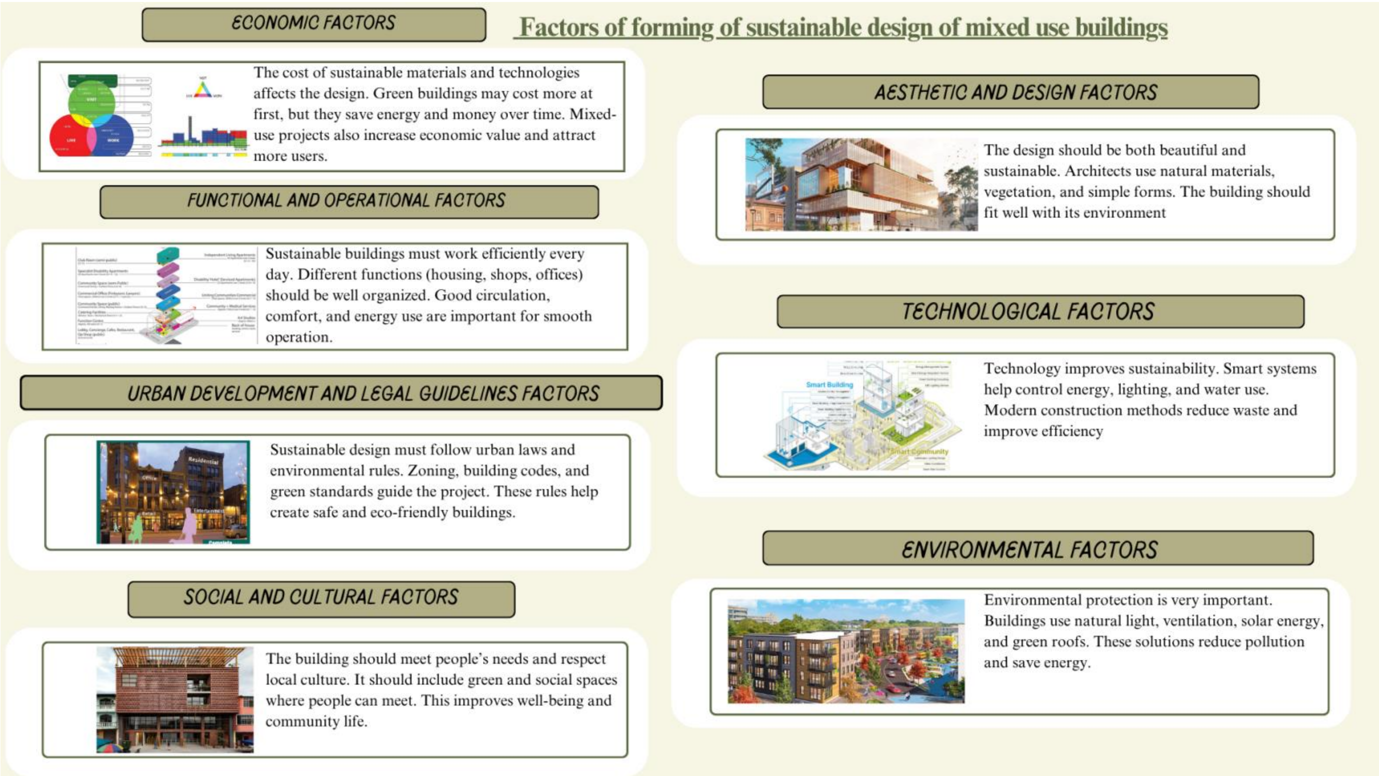


Figure 1.11. Factors of forming of sustainable design of mixed use buildings

Conclusions to Section 1

The analysis of theoretical and practical experience shows that sustainable design of mixed-use buildings is very important for modern cities. Theoretical studies explain that these buildings combine different functions such as housing, work, and services in one place. This helps to use land better and reduce problems like traffic and pollution. It also shows that sustainable design focuses on saving energy, using natural light and ventilation, and protecting the environment.

Practical examples confirm that these ideas can be applied successfully. Many real projects show how mixed-use buildings can create comfortable and attractive spaces for people. They also show how green elements, modern technologies, and good planning can improve building performance and urban life.

In addition, several factors influence the design of these buildings. These include environmental conditions, urban context, functional organization, economic aspects, and social needs. Architects must consider all these factors together to create balanced and efficient designs. It is also important to respect local culture and adapt the design to the place.

Overall, this section provides a clear understanding of sustainable mixed-use buildings. It shows that combining theory and practice helps to create better architectural solutions. These buildings can improve quality of life, make cities more efficient, and support sustainable development in the future.

SECTION 2. ECOLOGICAL CHARACTERISTICS AND ARCHITECTURAL TECHNIQUES IN SUSTAINABLE DESIGN OF MIXED-USE BUILDINGS

2.1. Modern trends in the formation of sustainable design of mixed-use buildings

Sustainable design of mixed-use buildings is based on several important principles that work together to create efficient and comfortable urban spaces. First, **the vertical use of space** (Fig.2.1) [12] allows different functions such as housing, offices, and shops to be organized on different floors within the same building. This helps save land, reduce urban sprawl, and make cities more compact and active. In addition, locating these buildings **near public transport** (Fig.2.2) [13] improves accessibility, reduces the need for cars, and helps decrease traffic and pollution.

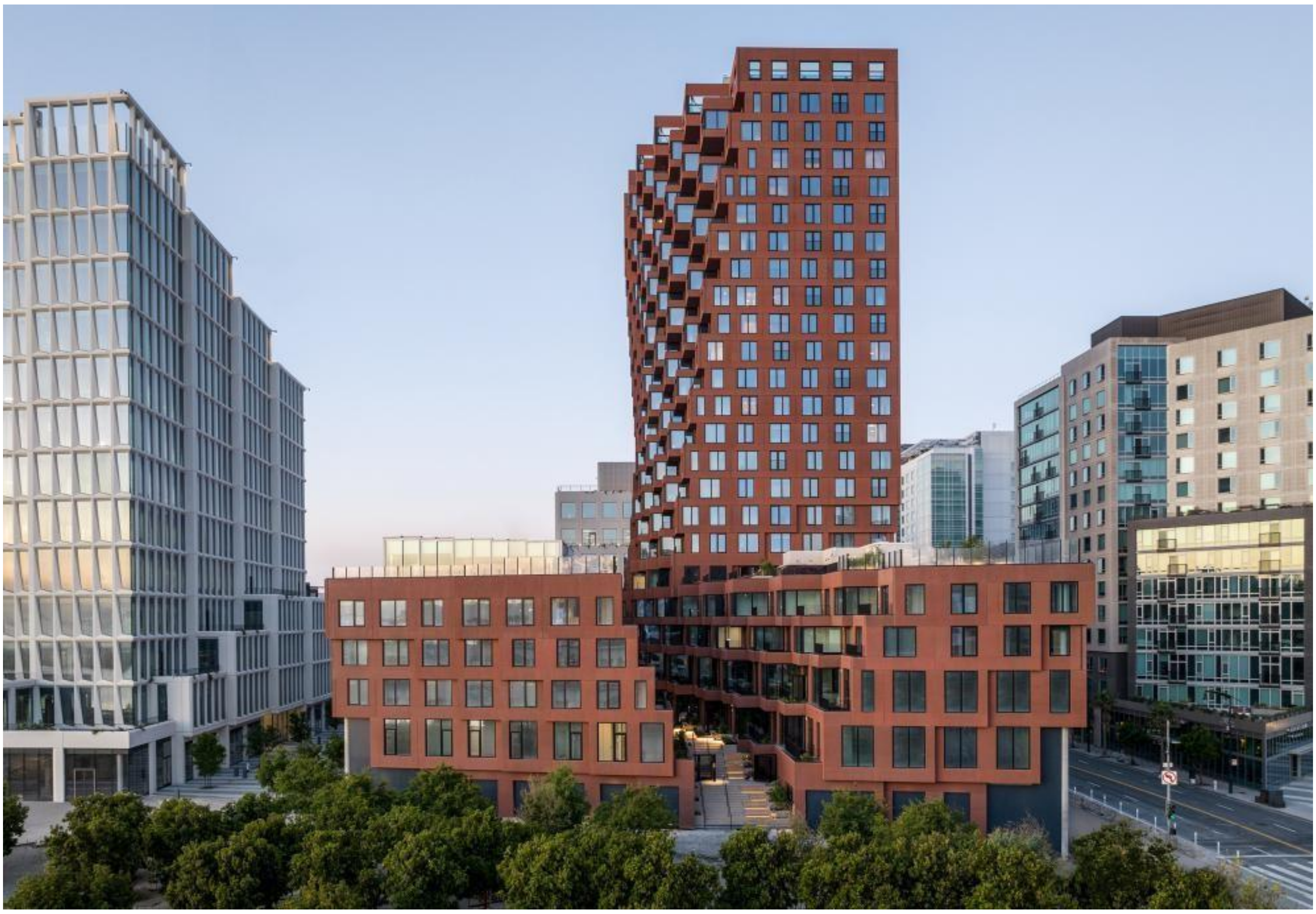


Figure 2.1. The Vertical use of space (The Canyon) by Jason O'Rear.

Figure 2.2. Placement of mixed use buildings near public transport, rendering by Gensler.

Another key principle is **green and eco-friendly design** (Fig.2.3) [14], which focuses on protecting the environment and improving building performance. This includes the use of plants, green roofs, solar panels, and natural ventilation to reduce energy consumption and create healthier spaces. **Public and social areas** (Fig.2.4) [15] are also important, as they provide places for people to meet, relax, and interact, such as plazas, cafes, and shared spaces, which help create a lively and connected community.

Figure 2.3. Green and eco-friendly design, Sky Green, WOHA by Kuomin Lee

Figure 2.4. Public and social areas, Assembly Food Hall by architect Gensler

Smart technology (Fig.2.5) is also an essential part of sustainable design, as it allows buildings to manage energy efficiently through automated systems for lighting, heating, and cooling. At the same time, respecting **local style and identity** (Fig.2.6) ensures that the building fits well within its cultural and urban context by using local materials and architectural elements. Furthermore, **flexible and changeable spaces** (Fig.2.7) allow buildings to adapt to different needs over time, making them more durable and efficient. Finally, focusing on **health and well-being** (Fig.2.8) ensures that users have access to natural light, fresh air, and comfortable spaces, which improves their quality of life. Together, these principles create sustainable mixed-use buildings that are modern, efficient, and environmentally responsible.

Figure 2.5. Smart mixed-use development project by Álvarez-Díaz & Villalón.

Figure 2.6. Santana Row mixed-use development, photographed by iStock contributor

Figure 2.7. Sustainable mixed-use building concept developed by Stora Enso

Figure 2.8. Cavendish Square mixed-use development in London by Reef Group.

2.2. Planning schemes of sustainable design of mixed-use buildings

Planning schemes for sustainable mixed-use buildings play a crucial role in organizing complex functions within a coherent and efficient spatial structure. These schemes aim to balance environmental performance, functional efficiency, and social interaction. By carefully distributing residential, commercial, office, and recreational spaces, planners can create integrated environments that reduce travel distances, optimize land use, and support sustainable urban growth. A well-developed planning scheme ensures that each function operates effectively while contributing to the overall performance of the building.

One of the key aspects of sustainable planning is zoning and functional distribution. Mixed-use buildings require a clear organization of spaces to avoid conflicts between different activities. Public functions such as retail and entertainment are typically located on lower floors to activate street life, while private functions like housing are placed on upper levels for privacy and comfort. Offices are often positioned in intermediate zones, creating a transition between public and private areas. This vertical and horizontal zoning helps improve accessibility, safety, and user experience while maintaining an efficient flow of movement.

Circulation planning is another essential component of sustainable schemes. Separate circulation systems for different user groups—such as residents, workers, and visitors—help maintain security and functionality. Vertical circulation cores, including elevators and staircases, must be strategically located to minimize travel distances and improve efficiency. In addition, pedestrian-friendly pathways, connections to public transport, and integration with surrounding urban networks encourage sustainable mobility and reduce reliance on private vehicles.

Environmental considerations are deeply integrated into planning schemes. The layout of spaces is often designed to maximize natural lighting and ventilation, reducing energy consumption. Open spaces such as courtyards, atriums, and green terraces are incorporated to improve microclimates and provide areas for social interaction. These elements also enhance air quality and thermal comfort, contributing to the well-being of users. Proper orientation and building spacing further support passive design strategies.

Flexibility and adaptability are also important in sustainable planning. Mixed-use buildings must respond to changing needs over time, whether due to technological advancements, economic shifts, or social changes. Flexible floor plans, modular design systems, and multifunctional spaces allow buildings to be easily adapted without major structural changes. This extends the lifespan of the building and reduces the need for future resource consumption.

Finally, planning schemes contribute to the social and urban integration of mixed-use developments. By creating accessible public spaces such as plazas, arcades, and shared amenities, these buildings become active parts of the urban fabric. They support community interaction, enhance urban vitality, and strengthen the relationship between the building and its surroundings. In this way, sustainable planning schemes not only improve building performance but also contribute to more livable and resilient cities (Fig.2.9)

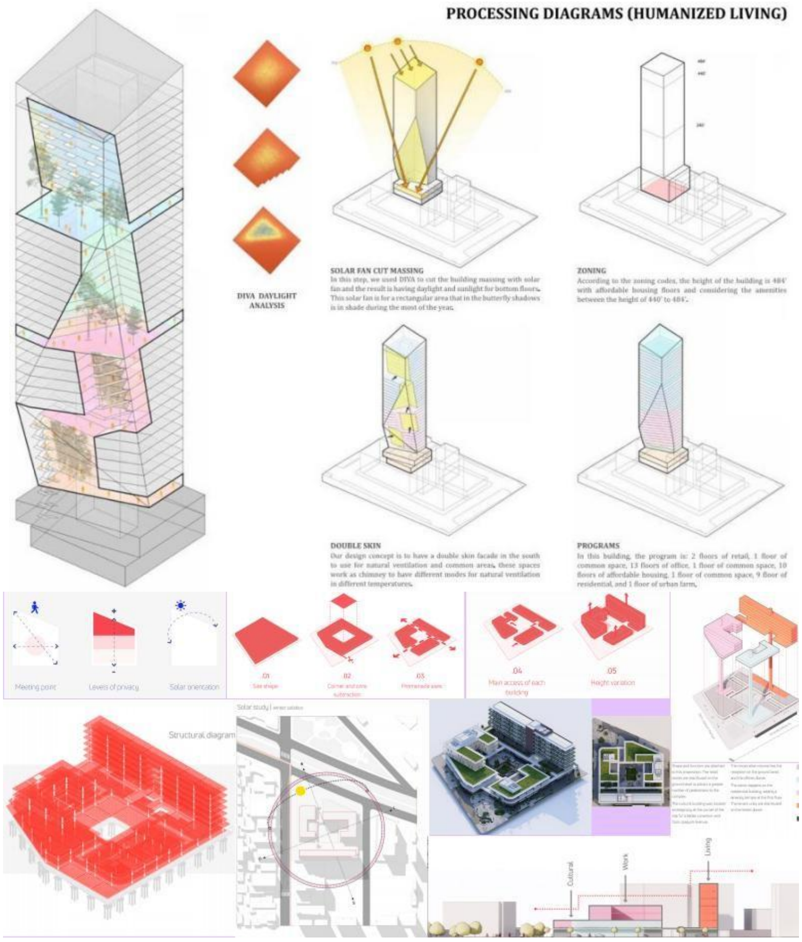


Figure 2.9. Planning Schemes (https://www.pinterest.com/zenxu14/tower-diagrams/)

2.3. Architectural and structural features of sustainable design of mixed-use buildings

Sustainable design in mixed-use buildings is based on a combination of architectural, structural, and environmental features that work together to create a balanced and efficient building. These buildings bring together different functions such as housing, offices, shops, and leisure spaces in one place, which reduces urban sprawl and improves daily life. To achieve this, architects must carefully plan how spaces are organized, how people move, and how the structure supports different uses. The goal is to create a building that is comfortable, flexible, and adapted to the needs of users while also respecting the environment.

One of the most important features is **functional zoning** , where different uses are clearly separated and organized inside the building. This zoning can be vertical, with functions stacked on top of each other, or horizontal, depending on the design. Public and active spaces like retail, restaurants, and services are usually placed on the lower floors to create a strong connection with the street and urban life. In contrast, private spaces such as apartments, offices, or hotel rooms are located on upper levels to provide calm, privacy, and better environmental conditions. This organization also helps optimize natural light, ventilation, and energy use, making the building more sustainable.

Another key feature is **efficient circulation**, which ensures that all users can move easily and safely inside the building. Because mixed-use buildings serve different types of users, it is important to design separate circulation systems. This includes different entrances, elevators, and corridors for residents, visitors, employees, and service staff. This separation reduces conflicts, improves security, and creates a better user experience. Vertical circulation elements such as elevators and staircases are designed to serve specific zones efficiently. In addition, accessibility is an essential aspect, with the use of ramps, lifts, wide passages, and clear wayfinding systems to ensure that the building is inclusive for everyone.

From a structural perspective, **transfer structures** are necessary to connect different spatial layouts within the same building. Lower levels often require large, open spaces for commercial or public functions, while upper levels are divided into smaller units. Transfer beams, slabs, or trusses allow loads from upper floors to be redistributed properly to the structural system below. This provides flexibility in design and allows architects to create different types of spaces without compromising safety. Alongside this, **composite structural systems** that combine steel and reinforced concrete are commonly used. Steel structures make construction faster and allow more flexible layouts, while concrete cores and walls provide strength, rigidity, and long-term durability.

To ensure resistance against external forces, **lateral stability systems** are integrated into the building design. These include shear walls, braced frames, and rigid cores, which help the building resist wind pressure and seismic activity. These elements are usually placed in central cores or structural zones so they do not affect the visual quality of the building. They play a critical role in ensuring safety, stability, and long-term performance.

At the scale of the city, **active street frontage** is a key feature that improves the relationship between the building and its surroundings. By placing shops, cafes, and public functions on the ground floor with transparent facades, the building becomes more open and attractive to people. This creates lively streets, encourages walking, and supports social interaction. It also reduces the need for transportation by bringing different activities closer together, which is an important aspect of sustainable urban design.

Finally, **environmental strategies** are essential in sustainable mixed-use buildings. These include the use of green roofs and terraces to improve insulation and reduce heat, solar panels to produce renewable energy, and rainwater harvesting systems to manage water efficiently. High-performance facades with good insulation and shading devices help control temperature and reduce energy consumption. Natural ventilation and daylighting are also used to improve indoor comfort. In addition, smart technologies such as Building Management Systems (BMS) are applied to monitor and optimize energy use, lighting, ventilation, and security systems. All these strategies work together to reduce environmental impact and create a healthier indoor environment (Fig 2.10).

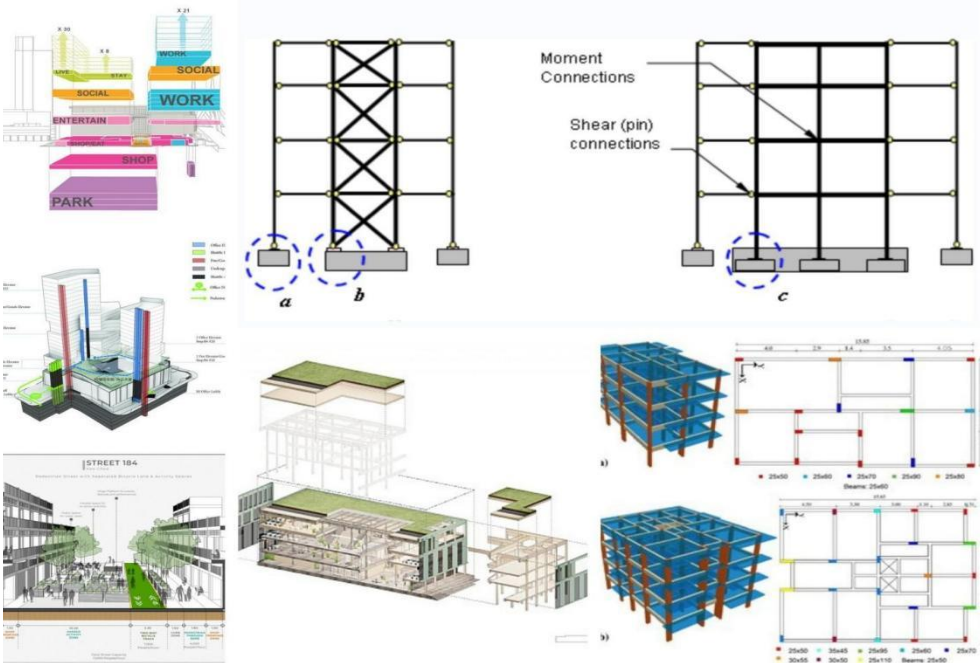


Figure 2.10. Architectural and Structural Features of mixed-use buildings

2.4. Architectural techniques of forming sustainable mixed-use buildings

In the evolving landscape of urban design, mixed-use buildings represent a strategic solution to increasing urban density, reducing commute times, and revitalizing city centers. Beyond the well-established techniques such as vertical stacking, podium-and-tower configurations, and atrium integration, architects utilize a broad range of advanced spatial strategies and contextual approaches to ensure both functionality and architectural quality.

Modular design and flexible floorplates. Modular design is becoming increasingly prevalent in the planning of mixed-use structures. By creating flexible floorplates, architects can accommodate changing tenant needs or future reconfiguration. A single floor may be subdivided into retail units, co-working spaces, or micro-apartments depending on evolving market demands. This adaptive reuse potential enhances the longevity of the building and allows it to respond to socio- economic shifts. Structural grids and service cores are designed to support these flexible transformations without requiring significant reconstruction.

Integrated circulation systems. An effective circulation strategy is essential for a mixed-use building to function efficiently. Architects implement integrated vertical and horizontal circulation systems that minimize conflict between users of different spaces. For example, a building might include dedicated elevators and staircases for residential occupants, while commercial users have access to separate routes. Parking facilities may also be segmented to ensure residents and visitors have distinct access zones. These circulation systems are often planned alongside fire safety and emergency egress strategies, ensuring the building meets safety standards without sacrificing spatial clarity.

Mixed-material façade treatments. To articulate the diverse functions within a single structure, architects often employ mixed-material facade strategies. These not only express the internal zoning externally but also enhance the building's aesthetic relationship with its context. For example, a stone or brick facade might be used on lower commercial floors to establish a solid, street-friendly presence, while glass or lightweight cladding on upper residential or office floors communicates openness and modernity. Material layering also assists in breaking down the perceived bulk of the building, lending it a more human scale.

Contextual integration and urban edge definition. Another key technique is the careful integration of the building into its surrounding urban fabric. Architects use contextual mapping and urban morphology studies to determine how the mixed-use development will interact with adjacent structures, public spaces, and streetscapes. Ground floors may be aligned with pedestrian pathways to promote accessibility and activity, while upper levels are shaped to preserve key view corridors or sunlight penetration into nearby areas. The urban edge—where the building meets the public realm—is often softened with arcades, colonnades, or canopies, offering shade and shelter while encouraging pedestrian movement.

Sustainability and green integration. Sustainability is an integral consideration in mixed-use architecture. Techniques such as green roofs, vertical gardens, and facade integrated photovoltaics are increasingly used to improve environmental performance and aesthetic value. Natural ventilation systems, cross- ventilated floor plans, and the use of passive solar design principles also enhance energy efficiency. In some cases, buildings feature on-site water recycling systems or shared energy facilities like cogeneration plants, especially in large-scale mixed-use complexes. These green strategies not only reduce the building's ecological footprint but also improve indoor environmental quality for occupants.

Community and social integration. At the core of mixed-use development is the principle of social inclusivity. Architects often incorporate community amenities such as libraries, fitness centers, shared workspaces, and child-care facilities to serve a broader user group. These functions are often placed at nodal points within the building—such as atriums, rooftops, or transitional floors—to facilitate interaction between different user groups. The deliberate design of these social intersections fosters a sense of belonging and enriches the urban experience.

Smart building technologies. The integration of smart technologies is transforming the operational capacity of mixed-use buildings. Architects now work in collaboration with engineers and digital planners to embed intelligent systems that manage lighting, heating, ventilation, and access control. Through Building Management Systems (BMS) and Internet of Things (IoT) devices, residents, businesses, and facility managers can monitor and adjust building performance in real-time. These technologies not only increase operational efficiency but also enable customized experiences for different building users, further enhancing comfort and convenience (Fig 2.11).

Figure 2.11. Architectural Techniques of forming mixed-use building

Conclusions to Section 2

The study of ecological characteristics and architectural techniques in sustainable mixed-use buildings demonstrates the importance of integrating environmental, functional, and social aspects within one architectural system. Sustainable mixed-use buildings are designed to create efficient urban environments that reduce energy consumption, improve land use, and support the quality of life of users. The analysis of modern trends shows that vertical organization of functions, integration with public transportation, green and eco-friendly solutions, and the creation of public spaces are essential principles in contemporary sustainable architecture.

The research also highlights the importance of planning schemes in organizing the different functions within mixed-use buildings. Proper zoning, circulation systems, and spatial organization help improve accessibility, comfort, and efficiency while ensuring a balance between public and private areas. Environmental strategies such as natural lighting, ventilation, green spaces, and passive design solutions contribute to reducing the environmental impact and improving indoor comfort.

In addition, architectural and structural features play a major role in achieving sustainability. Flexible spaces, smart technologies, adaptable structures, and the use of sustainable materials allow buildings to respond to future changes and user needs. These approaches increase the durability and efficiency of buildings while supporting environmental responsibility.

Overall, the analysis confirms that sustainable mixed-use buildings represent an effective solution for modern urban development. By combining ecological principles, innovative architectural techniques, and efficient planning strategies, these buildings contribute to creating more resilient, comfortable, and sustainable cities for the future.

SECTION 3. APPROVAL OF ARCHITECTURAL PRINCIPLES OF SUSTAINABLE DESIGN OF MIXED-USE BUILDINGS

3.1. Analysis of the design territory and master plan

Casablanca is the largest city in Morocco and the economic center of the country. The city is located on the Atlantic coast in the western part of Morocco and has an important position because of its business activities, transportation networks, and urban development. Casablanca contains many important districts for housing, commerce, offices, and public services. The city is also known for its modern urban character and continuous expansion. Because of its strategic location and strong infrastructure, Casablanca became one of the most important metropolitan cities in North Africa.

The selected project site is located in Casablanca Finance City (CFC), one of the most modern districts in Casablanca. CFC is an international business and financial center that includes offices, mixed-use buildings, green spaces, hotels, and residential projects. The area is characterized by contemporary architecture, modern urban planning, and good accessibility through the main roads of the city. The location of the project inside CFC gives strong potential for the development of a sustainable mixed-use building because the district represents a modern and dynamic urban environment in Casablanca (Fig 3.1).

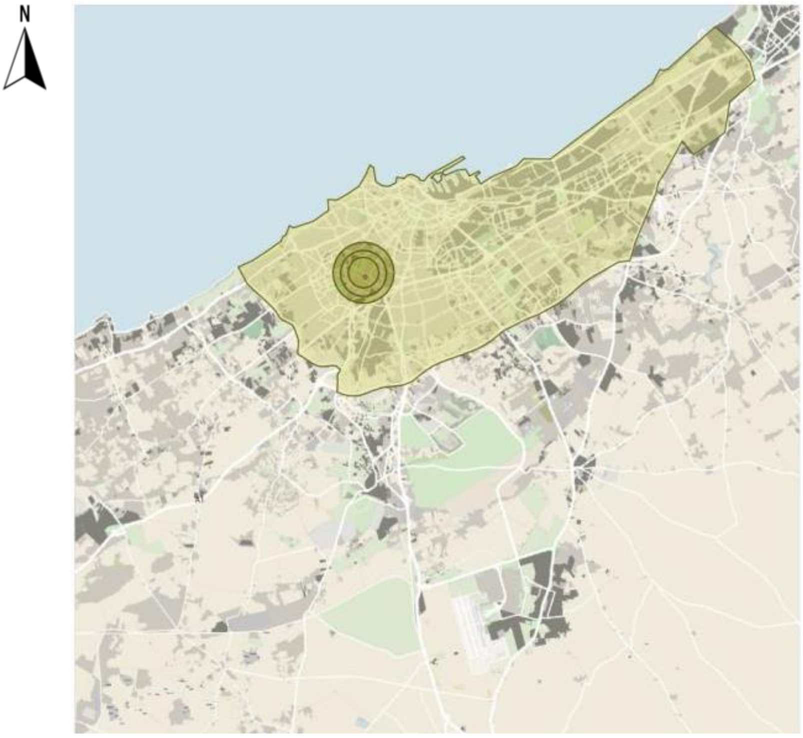


Figure 3.1. Location of design site in the city Casablanca

The project site is located in Casablanca Finance City (CFC), one of the most modern areas in Casablanca. The site is surrounded by office buildings, residential projects, sports spaces, green areas, and public spaces. The area has a modern urban character with contemporary architecture and open spaces. The location also has good accessibility because it is connected to the main roads and circulation networks of the city.

In the situation plan, the project site is shown in red to identify the boundaries and location of the proposed mixed-use building. The site has a strategic position inside CFC and benefits from good visibility and connection with the surrounding urban activities. Because of its modern environment and urban quality, the site has strong potential for the development of a sustainable mixed-use project that responds to the needs of the area and the city (Fig 3.2).

Figure 3.2. Scheme of situation plan

The project site in Casablanca Finance City has a strategic location with strong transport connections. As shown in the transport map, the site is connected to major roads, highways, secondary streets, and pedestrian paths, which makes movement easy around the area. The project area, highlighted in red, is located close to important circulation axes and roundabouts that improve accessibility and connection with different parts of Casablanca such as Ain Diab, the city center, Maarif, and Sidi Maârouf.

The area also benefits from different public transportation systems such as the Casablanca tramway and bus network. Tramway stations and bus stops are located near the site, providing easy access for users and visitors from different areas of the city. The tramway improves mobility between CFC and important districts of Casablanca, while the bus network strengthens daily transportation and accessibility around the project area. Pedestrian paths around the site also create safe and comfortable movement for people inside the district. Because of these transport connections, the site has strong accessibility and good potential for the development of a mixed-use building (Fig 3.3).

Figure 3.3. Scheme of transport and pedestrian connection

The selected area in Casablanca Finance City is located in a zone with different urban functions. As shown in the functional organization map, the area highlighted in red is surrounded by commercial and office zones, residential areas, sports facilities, landscape spaces, and public services. The area also contains administrative, educational, and medical functions that support daily urban activities.

This functional diversity creates an active and dynamic urban environment around the selected area. The presence of offices, housing, green spaces, and sports areas improves the quality of the district and encourages social and urban interaction. Because of this mix of functions, the area is suitable for the development of a sustainable mixed-use building that responds to the needs of the district (Fig 3.4).

Figure 3.4. Scheme of functional zoning

The project zone in Casablanca Finance City benefits from strong accessibility and good urban connection with the surrounding district. As shown in the compositional planning map, the area is connected to major roads, highways, secondary streets, and pedestrian paths, which allows easy movement for vehicles and people. The surrounding circulation network improves access to the project from different parts of Casablanca and creates smooth urban mobility around the site. The project zone also benefits from important visual axes and visibility from the nearby streets, which increases the urban value of the location.

The map also highlights important environmental factors that influence the architectural design of the project. The wind direction passing through the area helps improve natural ventilation and air circulation, creating better environmental comfort inside and outside the building. In addition, the solar movement provides good exposure to natural light during the day, which helps reduce energy consumption and supports sustainable design strategies. These environmental conditions make the project zone suitable for the development of a sustainable mixed-use building adapted to the climate and urban context of Casablanca (Fig 3.5).

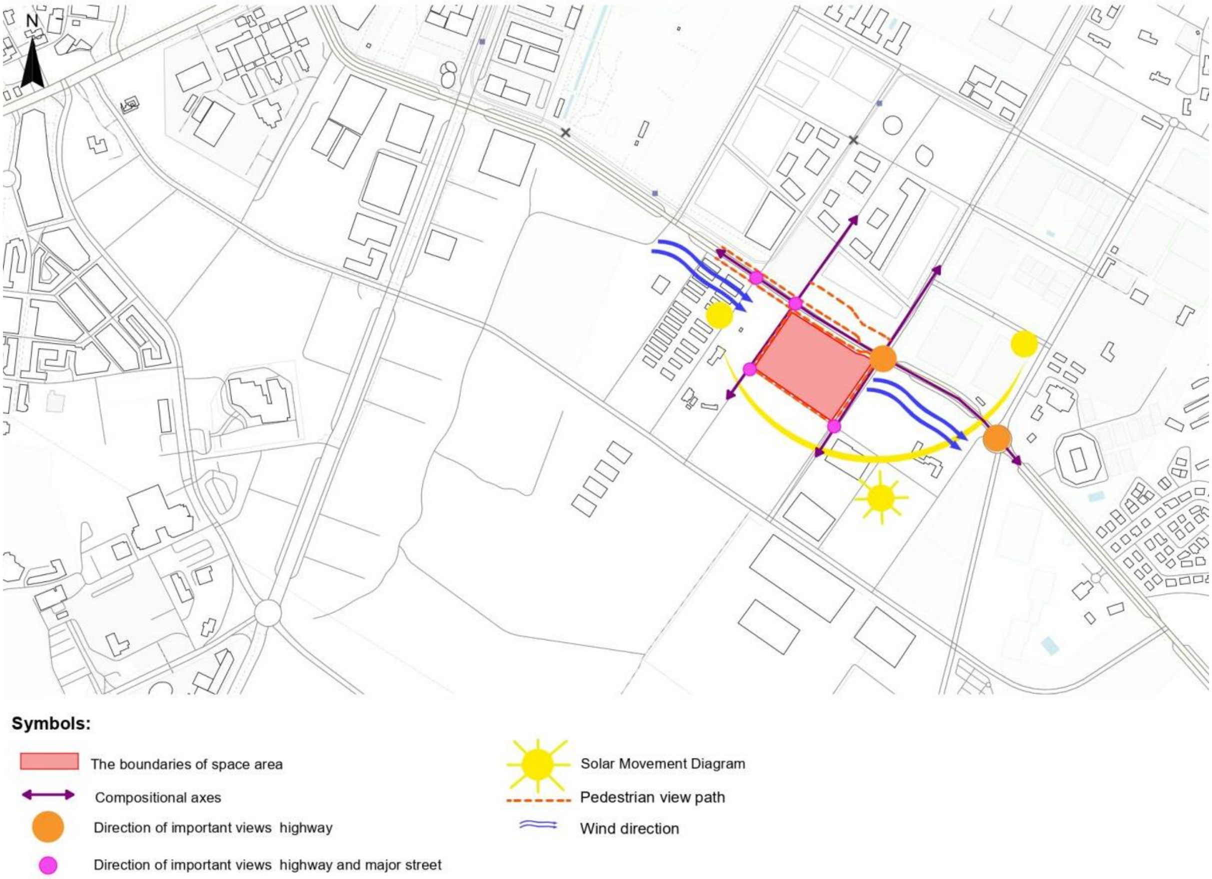


Figure 3.5. Scheme of compositional factors

The site organization was developed to create a balanced relationship between architecture, landscape, and circulation. The mixed-use building is positioned at the center of the territory as the main focal point, while the surrounding spaces are arranged to ensure functionality, accessibility, visibility and visual harmony. Green zones and pedestrian pathways are distributed around the building to provide comfortable outdoor spaces and improve environmental quality. Parking areas are integrated into the layout with clearly defined entrances and exits to ensure smooth vehicle circulation without disturbing the pedestrian movement. Water features and landscaped elements enhance the aesthetic character of the project and contribute to creating a pleasant urban atmosphere. In addition, the surrounding roadway network strengthens accessibility and connects the project effectively with the urban context. The overall composition reflects sustainable urban planning principles by combining functional efficiency, environmental comfort, and organized spatial planning within one coherent architectural environment (Fig 3.6).

Figure 3.6. Master Plan, S 1:500

3.2. Architectural planning and functional solution

The architectural planning of the project is based on the integration of multiple functions within one coherent and sustainable mixed-use building. The project combines commercial, administrative, office, residential, recreational, and service spaces in order to create a dynamic urban environment that responds to the needs of users while improving spatial efficiency and sustainability. The functional organization was carefully designed to ensure smooth circulation, clear zoning, and a strong relationship between interior and exterior spaces.

The underground parking levels (-1 and -2) are dedicated to vehicle circulation and technical services. These levels include parking spaces, ramps, storage areas, vertical circulation cores, security spaces, and car wash services, which help organize vehicle movement efficiently while reducing congestion at ground level. The parking system is connected directly to the upper floors through elevators and emergency stairs, ensuring easy accessibility and functional continuity throughout the project (Fig 3.7).

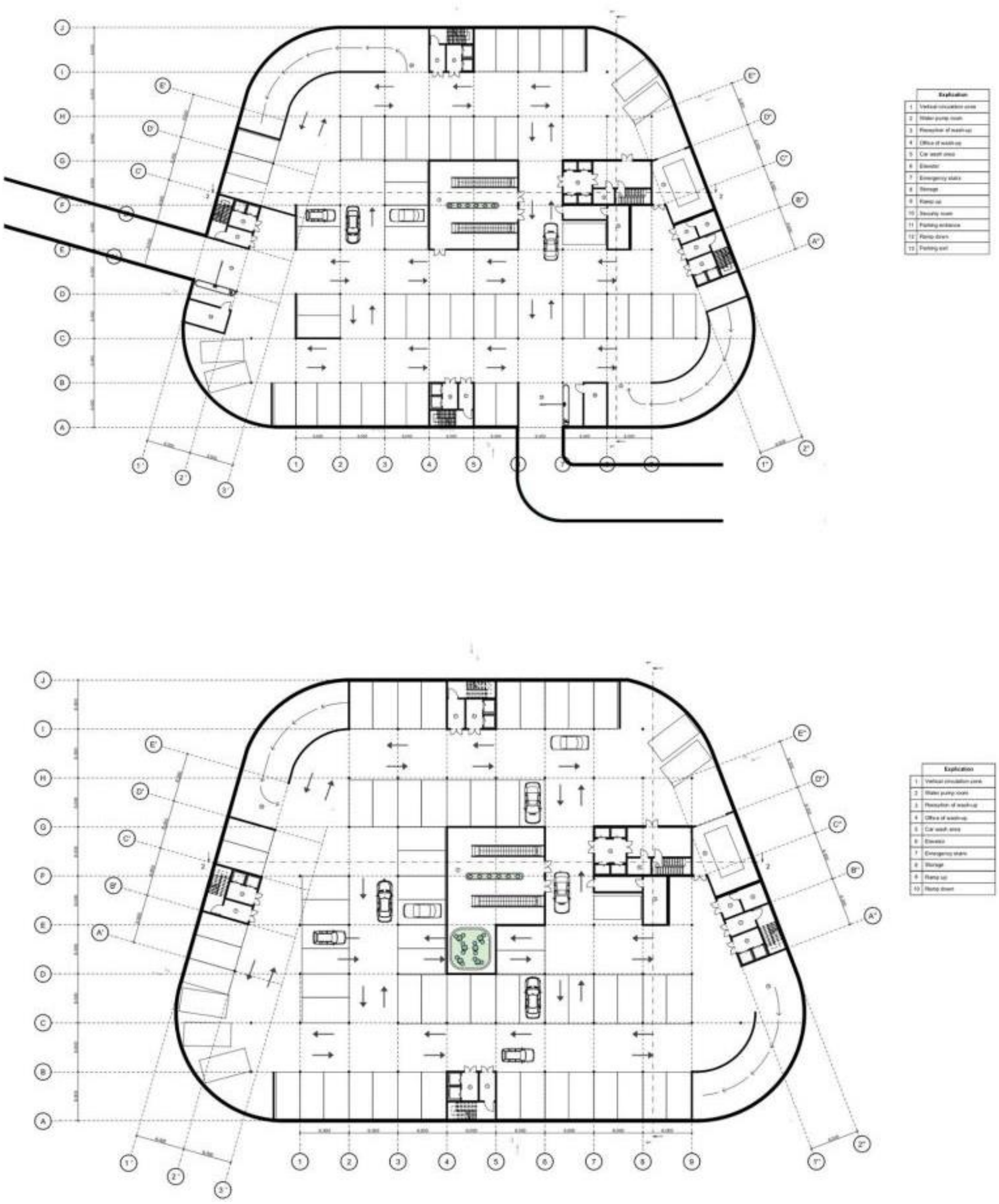


Figure 3.7. The underground parking levels (-1 and -2)

The ground floor was designed as an active public zone that strengthens the relationship between the building and the urban environment. It includes commercial shops, reception areas, meeting rooms, administrative offices, staff facilities, and seating areas organized around landscaped green spaces. The integration of public and semi-public functions at this level encourages social interaction and creates an accessible and welcoming atmosphere for visitors. The central circulation space improves movement and visual connectivity between different functional zones.

The second floor continues the administrative and commercial activities while introducing additional visual connections with green spaces and resting areas. Meeting rooms, offices, and shared circulation areas were organized to create flexible and comfortable working environments. Green terraces and visual openings contribute to natural lighting and environmental quality, while also improving the spatial experience inside the building.

The third floor is dedicated to recreational and wellness functions including a food court, cafe, fitness areas, yoga and cycling studios, spa spaces, saunas, massage rooms, and relaxation zones. This functional diversity enhances the mixed-use character of the project and creates a balanced environment that combines work, leisure, health, and social interaction within one architectural composition. The recreational spaces are organized around open circulation areas and seating zones to improve comfort, flexibility, and user experience (Fig 3.8).

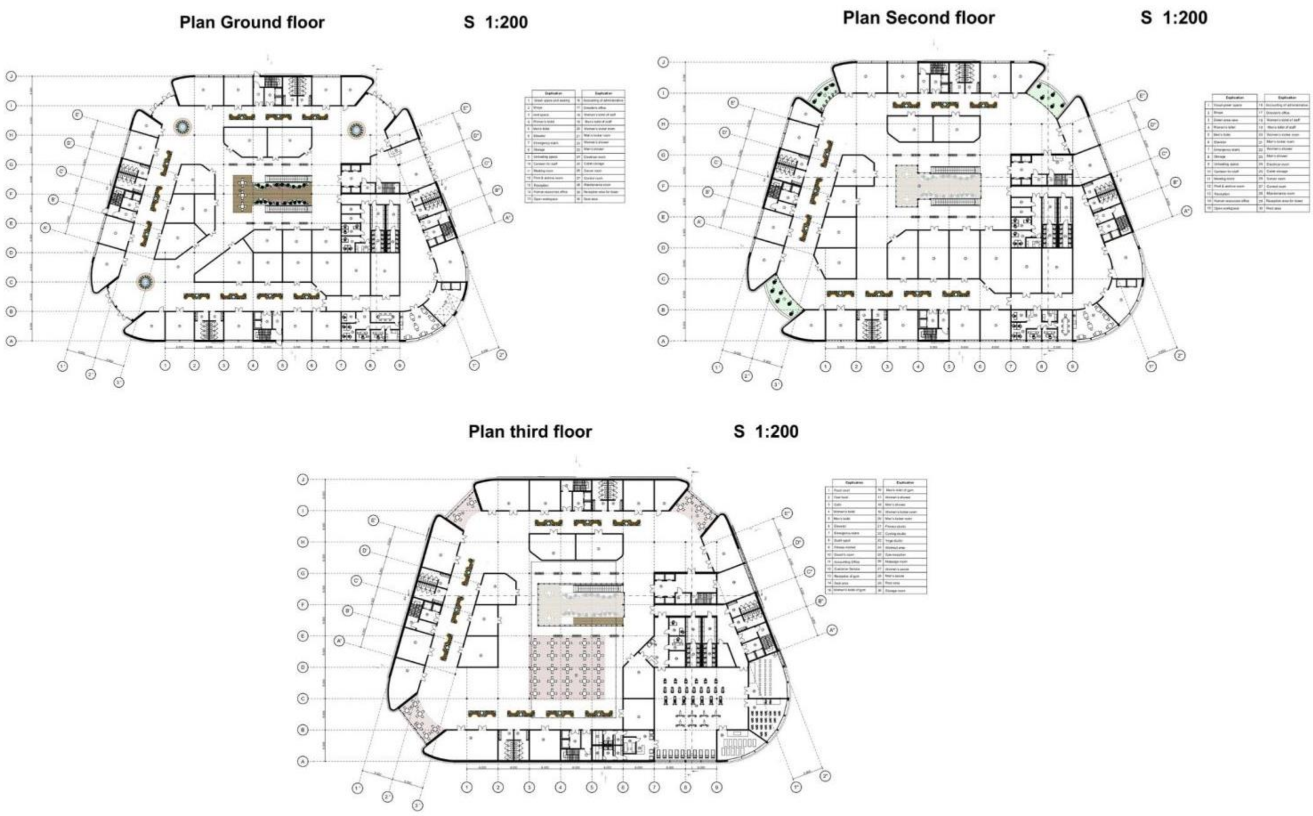


Figure 3.8. Floor Plans of the Shopping and Administrative Complex

The green roof spaces integrated within the office levels are directly connected to the shopping center located on the lower floors, creating visual and functional continuity between commercial and office activities. These landscaped terraces act as accessible semi-public spaces that encourage interaction, relaxation, and social activity for visitors, employees, and users of the mixed-use complex. The connection between the green roof and the shopping center enhances the spatial experience while improving environmental quality through vegetation, natural ventilation, and shaded outdoor areas. This design approach strengthens the integration between different functions and reinforces the sustainable and human-centered character of the project (Fig 3.9).

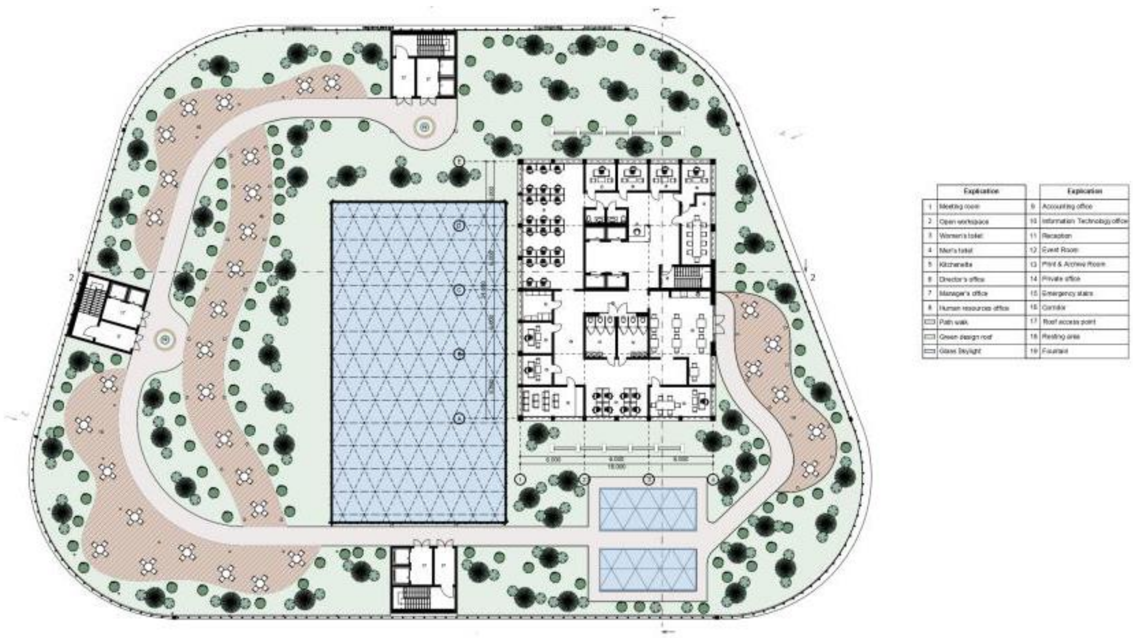


Figure 3.9. Office Floor Plan with Green Roof Space

Additional office levels were planned to accommodate two separate companies within the same floor through a flexible and efficient spatial organization. The planning solution ensures functional independence while maintaining clear circulation and shared service spaces. Open workspaces, meeting rooms, reception zones, and balconies create comfortable and productive environments adapted to contemporary office needs (Fig. 3.10).

Figure 3.10. Plan of an office floor with two companies

The residential tower levels, located from the 9th to the 17th floors, contain apartment units organized around central circulation cores. The apartments were designed to provide privacy, natural lighting, and functional comfort through carefully distributed living spaces including living rooms, kitchens, bedrooms, bathrooms, and balconies. The tower also incorporates green balconies that contribute to the sustainable identity of the project by improving thermal comfort, enhancing natural ventilation, and creating visual continuity with the surrounding landscape. These landscaped balconies soften the vertical mass of the tower and create a more environmentally responsive architectural expression (Fig 3.11).

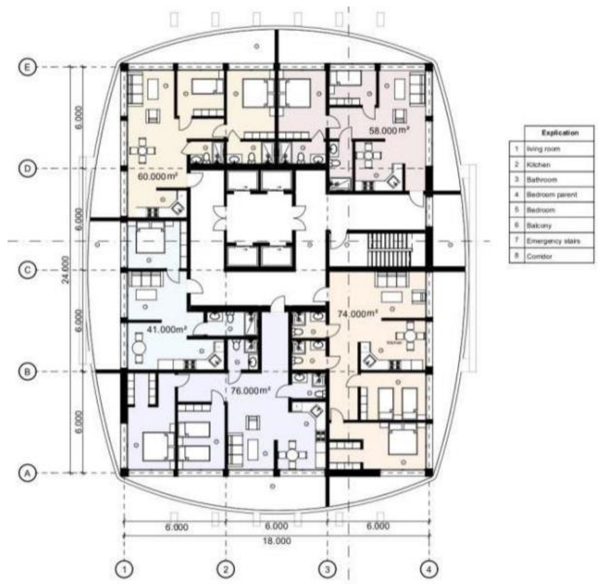


Figure 3.11. Plan of a typical apartment floor (9^{th} to 17^{th})

The upper levels of the tower contain duplex penthouse units designed to provide spacious and luxurious living environments with panoramic views and private outdoor spaces. The penthouse organization includes living areas, home offices, guest rooms, children’s rooms, terraces, and balconies distributed over two levels to create spatial flexibility and privacy. Large openings and landscaped balconies allow natural light and ventilation to penetrate deeply into the interior spaces while reinforcing the sustainable architectural character of the project (Fig 3.12).

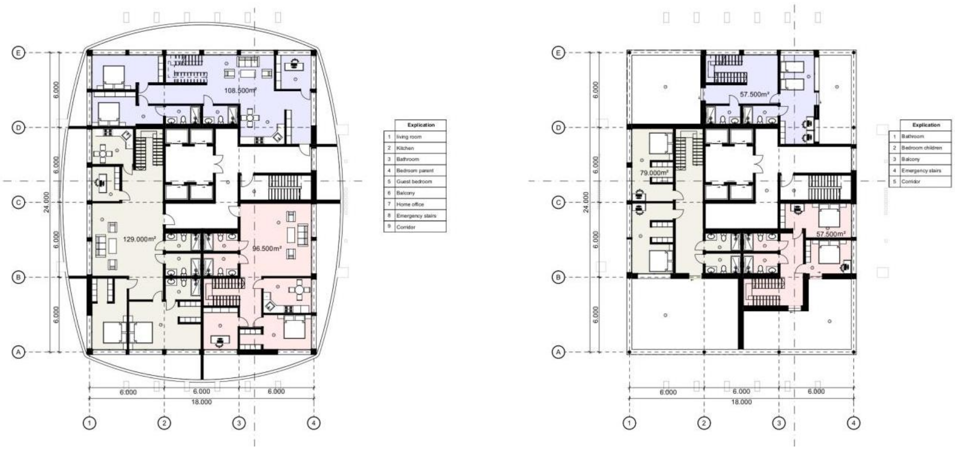


Figure 3.12. Duplex Penthouse Floor Plans (18th and 19th floors)

3.3. Architectural spatial solutions

The architectural spatial solution of the project is based on creating a contemporary and sustainable mixed-use composition that responds to the urban and environmental context of Casablanca. The project combines horizontal podium volume with a vertical tower element in order to create a balanced architectural composition that integrates commercial, office, residential, and recreational functions within one coherent spatial system. The organization of the different volumes establishes a clear hierarchy between public and private spaces while reinforcing the visual identity of the project.

The vertical tower acts as the dominant architectural element within the composition and contains office spaces, apartments, and duplex penthouse units organized vertically to optimize land use and improve urban density. The tower reaches approximately 74.50 meters in height and establishes a strong landmark within the urban skyline. The vertical composition emphasizes rhythm, repetition, and proportion through the arrangement of balconies, facade openings, and vertical architectural elements.

The architectural sections illustrate the relationship between the podium and tower volumes while demonstrating the integration of mixed-use functions throughout the building. The sections highlight the organization of underground parking levels, commercial spaces, office floors, residential apartments, and penthouse levels connected through vertical circulation systems including elevators and staircases. The spatial continuity between levels improves accessibility and functional efficiency while maintaining clear zoning between public and private areas (Fig 3.13).

Figure 3.13. Sections 1–1 (left) and 2–2 (right) of the Mixed-Use Building

Elevation 1'-2" highlights the relationship between the commercial podium and the residential tower through a balanced horizontal and vertical composition. The facade treatment emphasizes verticality through repetitive balconies and decorative perforated panels located in the center of the tower. Large openings and glazed surfaces improve natural lighting while reinforcing the contemporary architectural identity of the project.

Elevation 2"-1' illustrates the dynamic composition of the mixed-use complex by combining the horizontal podium volume with the vertical tower element. The repetitive rhythm of balconies and facade openings creates visual continuity and architectural harmony, while decorative vertical panels contribute to the visual identity of the tower and provide solar protection (Fig 3.14).

Figure 3.14. Elevations 1'-2" (left) and 2"-1' (right) of the Mixed-Use Building

Elevation A-J emphasizes the vertical character of the tower and its integration within the overall architectural composition. The facade organization creates a clear hierarchy between the residential tower and the commercial podium through the use of proportions, repetitive openings, and facade articulation. Vertical decorative elements improve the visual rhythm of the elevation while balconies create depth and shadow across the facade.

Elevation J-A demonstrates the contemporary architectural expression of the project through the combination of geometric facade patterns, glass openings, and modern materials. The podium facade creates visual interaction with public urban spaces through transparent commercial areas and architectural details inspired by contemporary interpretations of local architectural identity (Fig 3.15).

Figure 3.15. Elevations A-J (left) and J-A (right) of the Mixed-Use Building

Conclusions to Section 3

The development of the architectural project confirmed the importance of applying sustainable design principles in the formation of mixed-use buildings. The analysis of the design territory made it possible to understand the urban context, transportation connections, environmental conditions, and functional characteristics of the site. This analysis helped define the most suitable planning and spatial solutions for the project while ensuring integration with the surrounding urban environment.

The architectural planning and functional solution were developed to create an efficient organization of spaces that combines commercial, recreational, administrative, and public functions within one coherent structure. The project promotes functional diversity, improves accessibility, and creates active public spaces that encourage social interaction and urban vitality. The vertical and horizontal distribution of functions ensures clear circulation and effective separation between public and private zones.

The architectural spatial solutions were designed to achieve both aesthetic quality and environmental performance. The use of open spaces, landscaped areas, natural lighting, and sustainable architectural elements contributes to user comfort and environmental efficiency. In addition, the project emphasizes modern architectural expression while respecting the local urban identity and climatic conditions of Casablanca.

Overall, the project demonstrates how sustainable mixed-use buildings can respond to contemporary urban challenges by optimizing land use, improving environmental performance, and creating attractive and functional urban spaces. The application of sustainable architectural principles within the project contributes to the formation of a modern, flexible, and environmentally responsible urban environmen

SECTION 4. CALCULATION AND CONSTRUCTIONS

4.1 Location and climatic conditions of construction

The facility is located in Casablanca Finance City (CFC), Morocco, within a contemporary urban environment characterized by high-rise buildings and mixed-use developments. The site benefits from a strategic position within the city, with developed infrastructure and accessibility. The terrain is generally flat, which facilitates construction processes and the implementation of structural systems (Fig.4.1).

Figure 4.1. Casablanca Finance City

According to climatic data, Casablanca belongs to a Mediterranean climate zone influenced by the Atlantic Ocean, characterized by moderate temperatures, relatively high humidity, and significant wind exposure.

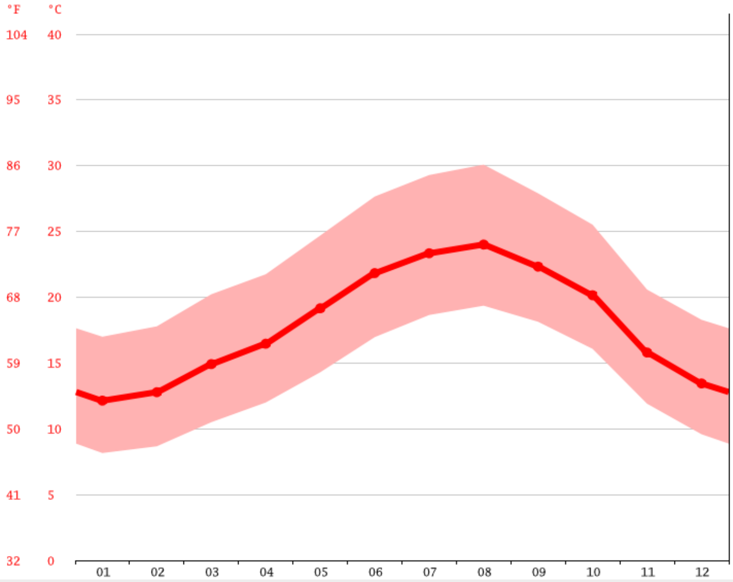
Average temperature in winter: 10–18°C

Average temperature in summer: 25–32°C

Average annual humidity: 60–80%

Dominant winds: north-west direction

The temperature conditions in Casablanca play a significant role in determining both architectural and construction solutions. During summer, increased temperatures combined with solar radiation can lead to overheating, especially in buildings with large glazed surfaces such as the tower in this project. Therefore, it is essential to integrate construction strategies that reduce heat gain, including shading devices and controlled glazing systems (Fig.4.2) [16].



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	12.1 °C (53.9) °F	12.8 °C (55) °F	14.9 °C (58.9) °F	16.5 °C (61.6) °F	19.2 °C (66.5) °F	21.8 °C (71.3) °F	23.3 °C (74) °F	24 °C (75.2) °F	22.3 °C (72.2) °F	20.2 °C (68.3) °F	15.8 °C (60.4) °F	13.4 °C (56.2) °F
Min. Temperature °C (°F)	8.2 °C (46.7) °F	8.7 °C (47.6) °F	10.5 °C (50.9) °F	12 °C (53.6) °F	14.3 °C (57.7) °F	17 °C (62.5) °F	18.7 °C (65.6) °F	19.4 °C (66.8) °F	18.1 °C (64.6) °F	16.1 °C (60.9) °F	11.9 °C (53.4) °F	9.6 °C (49.3) °F
Max. Temperature °C (°F)	17 °C (62.6) °F	17.8 °C (64) °F	20.2 °C (68.4) °F	21.7 °C (71.1) °F	24.7 °C (76.4) °F	27.7 °C (81.8) °F	29.3 °C (84.7) °F	30.1 °C (86.2) °F	27.9 °C (82.2) °F	25.5 °C (77.9) °F	20.6 °C (69.1) °F	18.3 °C (64.9) °F
Precipitation / Rainfall mm (in)	45 (1)	41 (1)	38 (1)	32 (1)	19 (0)	3 (0)	0 (0)	1 (0)	12 (0)	34 (1)	52 (2)	47 (1)
Humidity(%)	77%	75%	71%	69%	66%	66%	68%	69%	71%	73%	74%	75%
Rainy days (d)	5	5	5	5	3	1	0	0	2	4	5	5
avg. Sun hours (hours)	6.9	7.3	8.2	8.5	9.5	10.1	10.4	10.1	8.7	8.2	7.3	7.1

Figure 4.2. Average temperature by month in Casablanca

In winter, the relatively mild temperatures reduce the need for intensive heating systems. The use of reinforced concrete as the primary structural material contributes to thermal inertia, allowing the building to absorb heat during the day and release it gradually at night. This helps stabilize indoor temperatures and improves overall energy efficiency (Fig.4.3) [17].

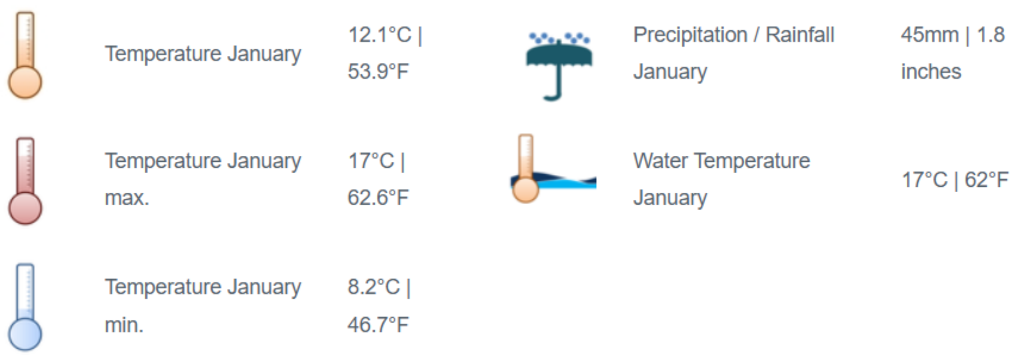


Figure 4.3. Casablanca weather in January

The proximity to the Atlantic Ocean introduces additional factors such as humidity and wind, which influence material selection and structural design. Construction materials must be resistant to moisture and environmental exposure, while the structural system must ensure stability against wind loads, particularly due to the building height (20 floors).

In response to these climatic conditions, the project incorporates sustainable construction solutions such as a green roof system, planted balconies, and skylights, which improve thermal performance, enhance natural lighting, and contribute to user comfort.

4.2. Architectural and structural construction

The project is a mixed-use building composed of a podium and a tower. The ground floor, first floor, and second floor are used for shops and administrative spaces. These floors are designed as open spaces to allow easy movement and flexibility.

Below the building, there is a basement used for parking and technical spaces. This level supports the structure and needs strong construction and waterproofing.

The upper part of the building is a 20-floor tower, which includes offices and residential spaces. This organization helps separate public areas (shops) from private areas (offices and housing).

The structure of the building is made of reinforced concrete, which is strong and durable. The system includes columns, slabs, and a vertical core with elevators and stairs.

The project also includes green roof and green balconies, which improve comfort and reduce heat. In addition, skylights are used to bring natural light into interior spaces such as the gym and dining area.

All these elements work together to create a functional, stable, and comfortable building.

Foundation

A raft foundation is adopted for the building due to the high loads generated by the tower and the need for uniform load distribution. This type of foundation consists of a large reinforced concrete slab that covers the entire footprint of the building.

The raft foundation is designed to:

- Distribute loads evenly to the soil
- Reduce differential settlement
- Support vertical loads from columns and structural elements
- Work together with basement retaining walls

The basement walls are constructed in reinforced concrete and act as retaining structures, resisting lateral earth pressure from the surrounding soil. The connection between the foundation slab and the basement walls ensures a rigid and stable system.

The foundation thickness and reinforcement are determined based on structural calculations and soil conditions, ensuring long-term performance and safety (Fig.4.4) [18].

Figure 4.4. Plates with Pedestals

Constructive system

The structural system of the building is based on a monolithic reinforced concrete frame, which is widely used for high-rise buildings due to its strength and durability.

The main structural components include:

Columns. Reinforced concrete columns arranged in a regular grid of 6 meters, which ensures efficient load transfer and allows flexible interior planning.

Slabs. Horizontal structural elements connecting columns and distributing loads.

Vertical core. A reinforced concrete core located on the west side, containing elevators and staircases. This core acts as the main stabilizing element of the building and resists horizontal loads such as wind.

The interaction between columns, slabs, and the core creates a rigid structural system, capable of supporting vertical and lateral forces. This system is particularly suitable for mixed-use buildings because it allows large open spaces in commercial areas and adaptable layouts in upper floors (Fig.4.5) [19].

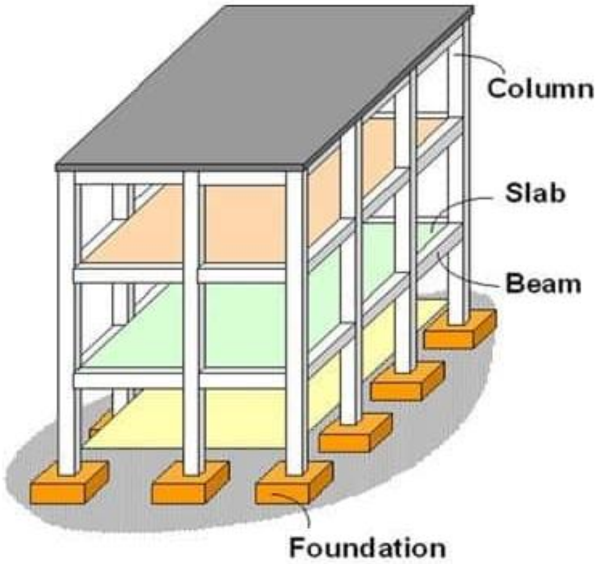


Figure 4.5. Typical RC framed building components

Floor slabs and roof structure

The floors are constructed using reinforced concrete slabs with a thickness of 200 mm. These slabs provide strength, rigidity, and good load distribution.

The building includes an operated green roof, used as a recreational space (Fig.4.6).

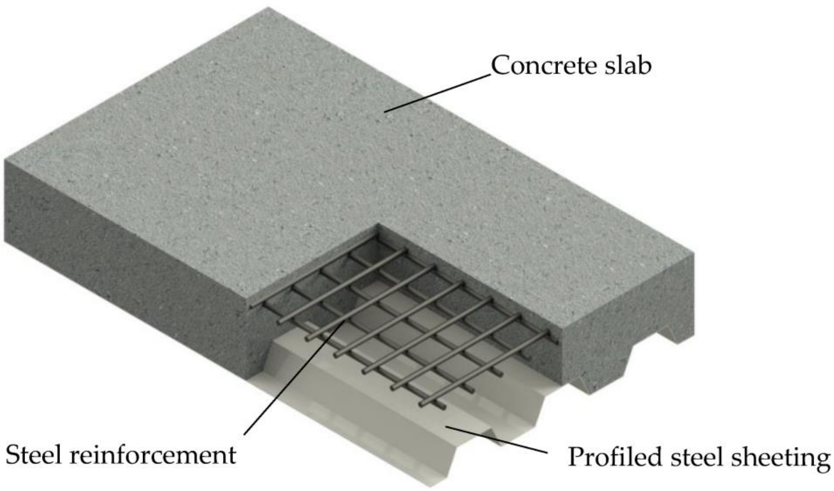


Figure 4.6. Concrete slabs

Green roof structure

Layer	Thickness	Description
Vegetation	150 mm	Green surface
Soil layer	150 mm	Supports plants
Filter layer	20mm	Protects drainage
Drainage layer	100mm	Removes water
Insulation	100mm	Thermal protection
Waterproofing	10mm	Prevents leakage
Structural slab	200mm	Concrete base

Green roof structure width – 700mm

The green roof improves thermal insulation, reduces heat gain, and increases comfort.

The roof also includes skylights, which allow natural light to enter interior spaces such as the gym and dining area (Fig.4.7) [20].

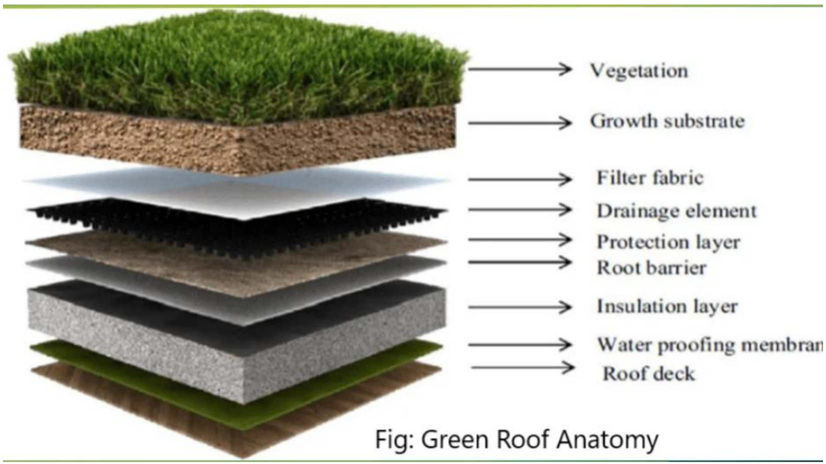


Figure 4.7. Green roof anatomy

Green balconies

The tower includes balconies with green spaces, designed as cantilever reinforced concrete slabs with a thickness of 300 mm. These slabs are fixed to the main structure and are designed to safely support additional loads from soil, plants, and water.

Each balcony is constructed with several **layers**, including waterproofing, drainage system, soil, and vegetation. The waterproofing layer protects the concrete slab from water infiltration, while the drainage system removes excess water and prevents damage.

The green balconies play an important role in improving the environmental performance of the building. They help reduce heat gain, provide natural shading for the façade, and improve air quality. In addition, they create comfortable outdoor spaces for users and enhance the visual appearance of the tower (Fig.4.8) [21].

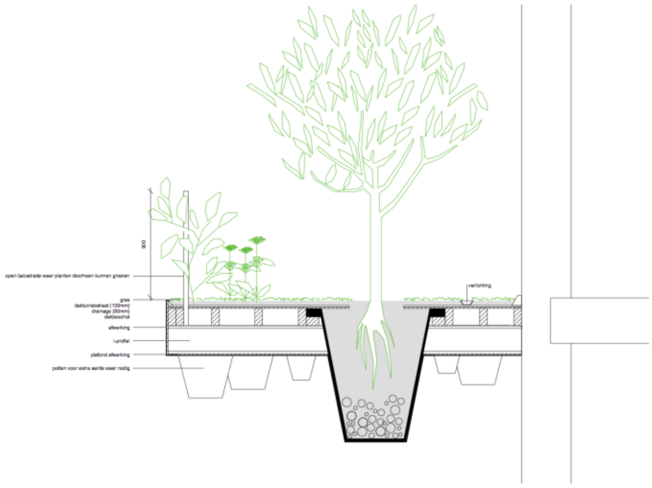


Figure 4.8. Green balcony system

Calculation of building loads

Element	**Density (kN/m³)**	**Thickness (m)**	**Load (kN/m²)**
Soil layer	18	0.15	2.70
Drainage layer	17	0.10	1.70
Insulation	0.6	0.10	0.06
Waterproofing	1	0.01	0.01
Concrete slab	25	0.20	5.00
Total permanent load			**9.47**
Live load (people)	-	-	200
Maintenance load	-	-	1.00
Total design load			**12.5 kN/m²**

Analysis of the structural solution of the facade

The facade of the building is mainly composed of large glass surfaces, especially in the commercial areas. This allows natural light to enter the building and creates a strong visual connection between the interior and exterior.

In some parts of the facade, a secondary layer of perforated geometric panels inspired by mashrabiya patterns is added. These panels are used only in selected areas, not on the entire facade.

This creates a partial double-skin facade system, where the glass is the main facade, and the perforated panels act as a shading and decorative layer.

From a structural point of view, the glass facade is fixed to the reinforced concrete structure using aluminum frames. The perforated panels are installed as lightweight elements supported by a secondary metal structure attached to the main frame.

This combination of glass and panels provides several advantages:

- good natural lighting inside the building;
- reduction of solar heat gain in exposed areas;
- better visual comfort by filtering sunlight;
- a strong and modern architectural identity.

The use of panels only in specific zones allows better control of sunlight while keeping transparency in commercial spaces.

Overall, the facade design creates a balance between openness and protection, combining functionality, comfort, and architectural expression (Fig. 4.9).

Conclusions to Section 4

The project is developed by carefully considering the climatic conditions of Casablanca, including moderate temperatures, high humidity, and strong winds. These environmental factors play an important role in shaping both the architectural design and the construction techniques. As a result, the building is adapted to its context and ensures better comfort for users throughout the year.

The structural system is based on reinforced concrete, which provides high strength, durability, and resistance to environmental conditions. The use of a raft foundation allows an even distribution of loads and helps reduce the risk of differential settlement. In addition, the combination of columns, slabs, and a central core ensures the stability of the building while allowing flexible interior layouts, especially important for a mixed-use project.

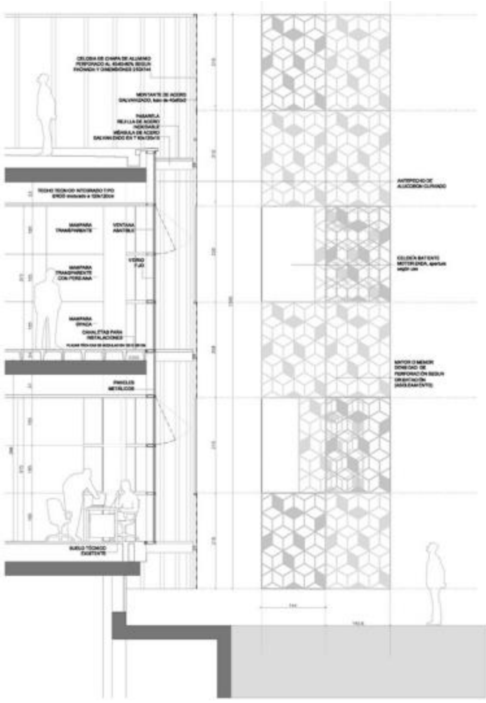


Figure 4.9. Facade detail showing glass facade and perforated geometric panels

Special attention is given to sustainable design strategies. The integration of a green roof and planted balconies contributes to improving thermal insulation, reducing heat gain, and enhancing air quality. Skylights are also used to bring natural light into interior spaces, reducing the need for artificial lighting and improving user comfort.

The facade design combines large glazed surfaces with perforated geometric panels. This solution allows good natural lighting while controlling solar radiation and providing shading. At the same time, it creates a modern architectural identity and improves the visual quality of the building.

The load calculations and construction details show that the project is technically well studied and can ensure safety and long-term performance. All structural elements are designed to support both permanent and variable loads efficiently.

Overall, the project reflects a balanced integration of structural logic, environmental strategies, and architectural expression. It results in a functional, stable, and comfortable mixed-use building that responds well to its urban and climatic context.

SECTION 5. OCCUPATIONAL HEALTH AND SAFETY

5.1. Regulation of Occupational Safety Issues at the Legislative Level

Mixed-use buildings — towers integrating commercial malls, residential apartments, offices, and shared amenities — require a robust regulatory framework to protect the diverse workforce operating within them. Workers in such complexes perform vastly different tasks: retail employees serve customers, maintenance technicians service elevators and HVAC systems, cleaning crews work across all floors, office employees sit at workstations for extended periods, and food court staff handle cooking equipment. Each activity generates distinct occupational hazards governed by both international and national legislation.

International Legislative Framework: The International Labour Organization (ILO) provides the foundational global standards for occupational safety. Three key conventions are directly relevant to mixed-use building operations:

ILO Convention No. 155 (1981) — Occupational Safety and Health: This convention requires ratifying states to develop national OHS policies, mandate employer risk assessments, establish safety committees with worker participation, and ensure adequate training. For mixed-use buildings, where multiple employers operate under one roof, this convention creates a coordination obligation that extends across all tenant organizations [22].

ILO Convention No. 187 (2006) — Promotional Framework for OHS: This instrument introduces continuous improvement into safety management, requiring dynamic systems with measurable objectives and regular audits rather than static compliance checklists. Building operators must adapt their safety programs as tenant mix, occupancy patterns, and technologies evolve.

ILO Convention No. 190 (2019) — Violence and Harassment: Particularly relevant to service-oriented environments, this convention requires policies against workplace violence and harassment, including training and confidential reporting mechanisms for retail staff, security personnel, and concierge employees who face interpersonal conflicts regularly.

The International Organization for Standardization (ISO) complements these conventions with voluntary management standards. ISO 45001:2018 provides a structured framework for hazard identification, risk control, and safety accountability — essential in multi-tenant buildings with diverse communication needs [23]. ISO 22000 establishes food safety protocols based on HACCP principles for food court kitchens, restaurants, and supermarkets within the commercial podium.

National Legislative Framework (Morocco): Morocco has developed a comprehensive domestic framework translating international OHS principles into enforceable law. The key instruments governing workplace safety in mixed-use buildings are:

The Moroccan Labour Code (Dahir No. 1-03-194, 2003): This is the primary legislation governing workplace safety in Morocco. It mandates safe working conditions across all sectors, including provisions for personal protective equipment (PPE), medical surveillance, working hour regulations, and ergonomic standards. For mixed-use towers, it imposes obligations regarding PPE for maintenance and cleaning staff, occupational health services, and working hour limits for employees in physically demanding environments such as underground parking and mechanical rooms [24].

Law No. 18-12 on Occupational Risk Prevention (2016): This legislation requires comprehensive workplace risk assessments and emergency preparedness tailored to specific environments. Building operators must conduct systematic hazard analyses, maintain safety signage in all areas, document workplace incidents, and develop emergency response plans accounting for the simultaneous presence of residents, shoppers, office workers, and service personnel.

Decree No. 2-12-431 on Workplace Hygiene and Safety Conditions: This decree specifies technical requirements for ventilation, lighting, noise levels, temperature control, and sanitary facilities in workplaces — all directly applicable to the diverse functional zones of a mixed-use tower.

Law No. 12-06 on Standardization and Certification: This law establishes the framework for adopting international standards (including ISO) within Moroccan industry, facilitating the integration of ISO 45001 safety management systems into building operations.

Together, these international and national instruments create a cohesive safety framework. Compliance ensures legal adherence while fostering environments that prioritize worker well-being and occupant confidence in mixed-use buildings.

5.2. Identification of Potential Hazards Related to the Object of the Thesis

A mixed-use tower is a complex environment where commercial, residential, office, and service functions coexist within a single vertical structure. Each zone generates specific occupational hazards shaped by workspace characteristics, task demands, and interactions between employees, residents, and visitors. The following analysis identifies the principal hazard categories affecting workers in this environment [25].

Employees in a mixed-use building perform diverse tasks. Retail staff stand for long hours at cash registers in artificially lit spaces. Food court workers operate cooking equipment in hot, humid kitchens. Office workers spend extended periods at computer workstations. Cleaning crews navigate corridors and service areas across multiple floors. Maintenance technicians service elevators, HVAC systems, and electrical panels — often in confined spaces or at height. Security personnel patrol all zones, managing access and responding to incidents throughout the complex.

Slips, Trips, and Falls. Wet mall floors, food court spills, rainy entrance areas, and freshly mopped corridors create slip hazards during peak hours. Loading docks present trip risks from packaging and uneven surfaces. In parking structures, oil stains and poor lighting increase fall risks. Maintenance workers on rooftops or elevated platforms face fall-from-height hazards with the most severe potential consequences.

Manual Handling and Musculoskeletal Injuries. Retail employees lift heavy merchandise during restocking. Kitchen staff carry supply crates and stand on hard floors for extended periods. Cleaning crews push heavy equipment and adopt awkward postures. Maintenance workers handle tools in constrained positions within elevator shafts and ductwork. Office workers face chronic neck and back pain from poorly configured workstations and prolonged sitting.

Psychosocial Hazards and Mental Strain. Retail and food service employees face stress from customer interactions, irregular shifts, and sales targets. Security staff experience chronic vigilance stress during extended shifts. Office workers contend with workload pressure, open-plan noise, and insufficient natural light. These invisible hazards contribute to burnout, absenteeism, and long-term mental health issues.

Insufficient Lighting and Poor Ergonomics. Underground parking, storage rooms, and service corridors often lack adequate illumination. Office floors may suffer from screen glare and limited daylight access. Workstations across all zones — cash registers, desks, kitchen counters — frequently fail to meet ergonomic standards, leading to visual fatigue, headaches, and chronic musculoskeletal discomfort.

Exposure to Hazardous Substances. Cleaning products containing ammonia and bleach cause respiratory and skin irritation in poorly ventilated spaces. Kitchens store flammable oils and gas cylinders. Maintenance teams handle refrigerants, solvents, and lubricants. Buildings undergoing renovation expose adjacent workers to construction dust and paint fumes. Improper labeling or chemical mixing creates additional dangers.

Noise and Vibration. HVAC plant rooms, generators, and elevator machinery produce sustained noise affecting maintenance staff. Commercial areas generate ambient noise from music, kitchen equipment, and crowds. Construction activities transmit noise through the structure. Prolonged exposure without hearing protection leads to progressive hearing damage and reduced concentration.

Confined Spaces. Elevator shafts, mechanical rooms, water tank chambers, fire pump rooms, and electrical closets present risks of oxygen deprivation, toxic fume exposure, and entrapment. The vertical complexity of a high-rise amplifies these hazards, with limited emergency egress from deep pits or rooftop enclosures.

Fire Hazards. Commercial kitchens, overloaded electrical panels, and high-combustible retail storage areas are primary ignition sources. The stack effect in tall buildings can rapidly propagate smoke through elevator shafts and stairwells. Simultaneous evacuation of thousands of occupants from different zones through shared stairwells presents an extraordinary logistical challenge.

Biological Hazards. Improper food handling in mall kitchens risks foodborne illness. Shared HVAC systems may spread airborne pathogens across zones. Waste management areas attract vermin and bacterial contamination. Cleaning staff handling waste without proper PPE face direct exposure to biological contaminants.

These diverse hazard categories highlight the need for a proactive, coordinated safety approach across all tenant organizations and building management entities within the mixed-use tower.

5.3. Study of the Risk of Implementation of Potential Hazards at the Thesis Object and Development of Measures for Their Prevention

Risk assessment is a structured process for evaluating workplace hazards based on their probability and potential severity. It transforms qualitative safety observations into quantitative scores that can be ranked and used to prioritize resource allocation. In mixed-use buildings with hazards spanning multiple functional zones, risk assessment provides the essential framework for deciding which threats require immediate action.

The importance of risk assessment lies in shifting from reactive incident management to proactive prevention. This approach reduces injury rates and associated costs, ensures regulatory compliance under Moroccan Law No. 18-12, strengthens organizational resilience, and creates environments where workers feel protected and valued.

The two-criteria risk matrix method evaluates each hazard along two dimensions: probability of occurrence (Pa), rated 1 to 10 (1 = rare, 10 = daily); and severity of consequences (Q), rated 1 to 10 (1 = minor injury, 10 = fatality). The risk rating is calculated as: $\boldsymbol{R = Pa \times Q}$

Scores range from 1 to 100. Higher scores indicate greater urgency. This method is transparent and easily communicated to diverse stakeholders — building management, tenants, and frontline workers. The results of the assessment are presented in Table 5.1.

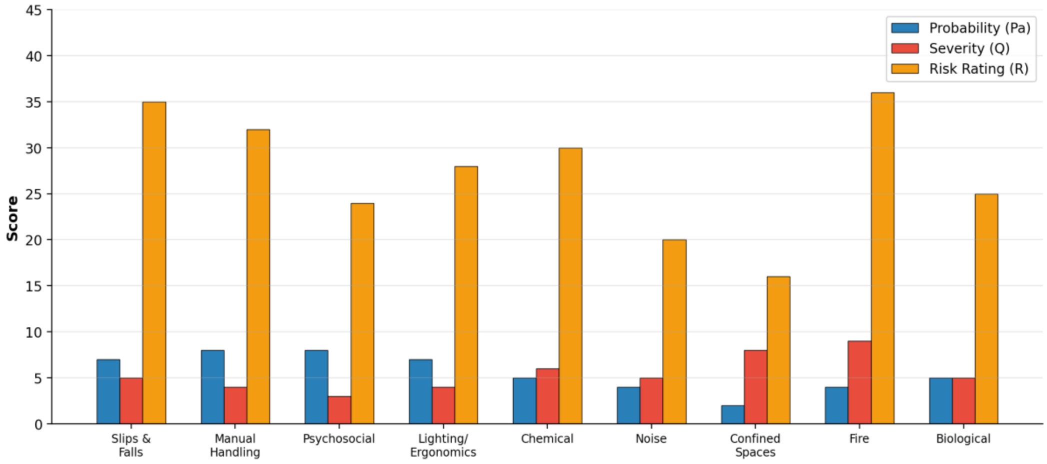


Figure 5.1. Risk Assessment Diagram

Table 5.1 — Risk Assessment of Occupational Hazards in a Mixed-Use Building

Hazard Category	Pa	Q	R
Slips, Trips, and Falls	7	5	35
Manual Handling Injuries	8	4	32
Psychosocial Hazards	8	3	24
Lighting / Ergonomics	7	4	28
Chemical Exposure	5	6	30
Noise and Vibrations	4	5	20
Confined Spaces	2	8	16
Fire Hazards	4	9	36
Biological Hazards	5	5	25

Fire hazards hold the highest risk rating (R = 36) due to extreme severity (Q = 9) in a high-rise context. Slips, trips, and falls (R = 35) and manual handling injuries (R = 32) follow, reflecting frequent occurrence. Chemical exposure (R = 30) and ergonomic/lighting deficiencies (R = 28) pose significant intermediate risks. Biological hazards (R = 25) and psychosocial stressors (R = 24) are notable for their high probability despite moderate severity. Noise (R = 20) and confined space hazards (R = 16) rank lower overall but demand attention due to potential severity.

Based on this analysis, the following preventive measures are recommended:

Slips, Trips, and Falls: Install anti-slip flooring in high-risk areas (entrances, food courts, bathrooms). Deploy wet-floor signage during cleaning. Ensure adequate lighting in parking, stairwells, and corridors. Keep loading docks clear with marked pedestrian pathways.

Manual Handling Injuries: Provide mandatory ergonomic training for all physical tasks. Supply mechanical lifting aids and adjustable trolleys. Ensure office workstations meet ergonomic standards with adjustable chairs and monitor stands. Introduce mandatory rest breaks for repetitive or strenuous work.

Psychosocial Hazards: Implement reasonable shift scheduling per the Moroccan Labour Code. Provide employee assistance programs. Install acoustic partitions in open-plan offices. Train customer-facing and security staff in conflict resolution and de-escalation.

Lighting and Ergonomics: Conduct a lighting audit per Decree No. 2-12-431 requirements. Maximize natural daylight on office floors. Add task lighting to reduce glare. Evaluate and retrofit all workstations against ergonomic standards.

Chemical Exposure: Replace toxic agents with low-VOC alternatives where possible. Store chemicals in ventilated, locked cabinets with GHS-compliant labeling. Train all staff in PPE usage and spill response. Isolate renovation zones from occupied areas with barriers and ventilation.

Noise and Vibrations: Provide hearing protection for maintenance staff near heavy machinery. Install acoustic enclosures around plant rooms and sound insulation between commercial and residential zones. Conduct regular noise monitoring.

Confined Spaces: Enforce strict entry protocols with atmospheric monitoring, buddy systems, and rescue equipment. Install mechanical ventilation in all elevator pits, plant rooms, and riser shafts. Use permit-to-work systems for all confined space activities.

Fire Hazards: Install interconnected fire alarms and automated sprinklers on all floors. Maintain fire-rated compartmentation between zones. Use pressurized stairwells for safe evacuation. Inspect electrical systems regularly. Conduct quarterly fire drills involving all tenants.

Biological Hazards: Enforce HACCP protocols in all food operations. Ensure HVAC systems have adequate filtration and fresh air intake. Maintain waste areas to high hygiene standards. Supply PPE for cleaning staff handling waste and contaminated materials.

Integrating these measures into daily operations, as required by Moroccan Law No. 18-12, represents the most effective strategy for reducing identified risk levels and creating a safer environment for all building occupants [26].

5.4 Safety in Emergency Situations

Mixed-use high-rise buildings face uniquely complex emergency scenarios. Thousands of people — shoppers, residents, office workers, and service staff — occupy the same vertical structure simultaneously, many unfamiliar with building layouts and evacuation routes. The vertical dimension extends evacuation times, while shared circulation cores must handle the simultaneous egress of diverse populations. These factors demand robust planning and rapid-response protocols.

Types of Emergency Situations

Fire Emergencies: The most consequential risk in high-rise buildings. Fires may originate in commercial kitchens, overloaded electrical systems, or residential units. The stack effect in tall structures rapidly draws smoke upward through shafts and risers. Primary threats include smoke inhalation, thermal injuries, and structural compromise. Simultaneous evacuation from multiple zones through shared stairwells is logistically challenging.

Natural Disasters: Earthquakes pose risks through lateral structural forces, falling non-structural elements (ceiling tiles, glass facades), and disrupted safety systems. Morocco, located along the Africa-Eurasia plate boundary, experienced the devastating Al Haouz earthquake in September 2023, underscoring the seismic vulnerability of the region. Flooding may affect underground levels and ground-floor retail, compromising electrical systems and egress routes. Moroccan construction standards (RPS 2000, revised 2011) establish seismic design requirements for buildings.

Medical Emergencies: High occupant density generates frequent medical events: cardiac arrests, fall injuries, allergic reactions in food areas, and heat-related illness. The vertical distribution of occupants may delay emergency medical response, making on-site first-aid capability essential.

Security Threats: Public commercial areas and high-traffic lobbies are vulnerable to unauthorized access, theft, and vandalism. Managing security across open retail zones and controlled residential entry requires integrated yet differentiated systems.

Structural Failures: Gas leaks, electrical outages, elevator malfunctions, and burst pipes can trigger evacuations. In mixed-use towers, failures cascade: a water main break on an upper floor may flood commercial spaces below; electrical failure may disable elevators, HVAC, and security simultaneously.

Human Behavior During Emergencies

Staff behavior is decisive during emergencies. Personnel must maintain composure, give clear instructions, and guide occupants to designated evacuation routes. Vulnerable populations — children in retail areas, elderly residents, and persons with disabilities — require prioritized assistance. Elevators must be avoided during fires (except firefighter elevators), with occupants directed to pressurized stairwells. Staff should report any signs of developing emergencies: smoke, gas odors, water leaks, or suspicious behavior.

Preventive Measures and Response Actions

Fire Prevention and Response: Install addressable fire alarm systems with zone-specific detection. Deploy automated sprinklers on all floors, with enhanced systems in kitchens. Maintain fire-rated walls and floors between functional zones. Pressurize stairwells to ensure tenable evacuation conditions. Conduct monthly fire drills simulating phased evacuation. Train staff in extinguisher use and mobility-impaired occupant assistance. These measures comply with Moroccan Law No. 18-12 and Decree No. 2-14-499 on fire safety in high-rise buildings [27].

Medical Emergency Preparedness: Position first-aid stations in the mall, on office floors, and in the residential lobby. Install AEDs at regular vertical intervals, especially near escalators, fitness areas, and food courts. Train designated staff per floor in CPR and first aid. Establish partnerships with local hospitals and pre-arrange emergency vehicle access protocols [28].

Natural Disaster Mitigation: Incorporate earthquake-resistant design per Moroccan

RPS 2000 seismic code. Install non-structural element restraints to prevent secondary injuries. Deploy weather monitoring systems for early warnings. Maintain emergency supply stockpiles (water, food, blankets, first-aid) at designated locations. Develop region-specific evacuation plans considering local hazard profiles.

Security Measures: Deploy CCTV surveillance across all public areas. Use keycard and biometric access systems differentiating commercial, office, and residential zones. Train staff in threat recognition and de-escalation. Establish communication systems enabling zone-specific lockdowns without disrupting other building sectors. Coordinate with local law enforcement (Surete Nationale, Gendarmerie Royale).

Structural Failure Prevention: Install automated gas leak detectors with emergency shutoffs. Provide backup generators with automatic transfer switches. Deploy building management systems (BMS) for real-time monitoring of all mechanical, electrical, and plumbing infrastructure. Conduct scheduled preventive maintenance on elevators, escalators, facades, and all building services.

Effectiveness of Preventive Measures

The effectiveness of these measures is well-documented. Addressable fire alarm systems reduce evacuation initiation time by approximately 50% and minimize property damage through early detection [29]. AEDs deployed within three minutes of cardiac arrest increase survival rates by up to 75% [30]. Integrated CCTV and access control systems serve as both deterrents and real-time monitoring tools, contributing to comprehensive security suited to mixed-use building access patterns.

Effective emergency preparedness in mixed-use towers requires integrating advanced technical systems, multi-stakeholder training, and documented response procedures. By maintaining capabilities across fire safety, medical response, disaster resilience, security, and structural monitoring, building operators protect occupants while preserving operational continuity and compliance with Moroccan regulatory requirements.

Conclusions to Section 5

This section has established that occupational health and safety, together with emergency preparedness, are indispensable pillars of responsible mixed-use building management. The regulatory framework operates at multiple levels: ILO conventions provide universal principles; ISO standards offer implementation frameworks; and Moroccan legislation — the Labour Code, Law No. 18-12, and related decrees — translates these into enforceable domestic obligations.

The hazard identification revealed a diverse landscape of occupational risks specific to multi-functional towers, including not only physical hazards but also psychosocial stressors, ergonomic deficiencies, and lighting inadequacies. The two-criteria risk assessment ranked fire hazards (R = 36), slips and falls (R = 35), and manual handling injuries (R = 32) as the highest-priority risks requiring immediate preventive intervention.

The emergency analysis confirmed that mixed-use high-rise buildings face uniquely complex scenarios shaped by vertical evacuation constraints, diverse occupant populations, and interdependent shared infrastructure. The preventive measures detailed — fire suppression, medical equipment, seismic resilience, security systems, and structural monitoring — provide a comprehensive framework for minimizing emergency impacts.

The safety of workers, residents, and visitors in mixed-use buildings is a core operational imperative. By embedding OHS practices into organizational culture and aligning with both international standards and Moroccan regulatory frameworks, building operators achieve the dual objectives of protecting human welfare and sustaining operational excellence.

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