

The Art of
Vertical Green Space Development
in the World

Mahdi Rahimi
Rouzbeh Kowsari



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In a world where cities are trapped amidst gray and lifeless structures, *The Art of Vertical Green Space Development* presents an innovative solution to bring life and beauty back to urban environments.

This book, focusing on green roofs, vertical gardens, and lush terraces, demonstrates how to transform barren, unused spaces into vibrant, beautiful, and sustainable environments.

Drawing on years of practical **experience** and **cutting-edge knowledge**, the authors provide practical solutions for optimizing urban spaces and designing sustainable architecture.

The Art of Vertical Green Space Development serves as a valuable guide for architects, engineers, and anyone passionate about creating greener cities and better lives. Every green roof, wall, and terrace is a step toward a more **sustainable future!**

www.greencheckco.com

www.chekadbam.com

www.chekadeno.com

www.chekadchoob.com

This book is the result of a collaborative effort between Mehdi Rahimi and Roozbeh Kowsari, who, drawing on their knowledge, experience, and passion, strive to reinvent cities and create greener, more sustainable, and smarter spaces. Their goal is to provide practical solutions for architects, engineers, and environmental enthusiasts to build a better future for cities and communities.

Foreword by Dr. Yaser Shahbazi

In 2017, the book *"The Art of Vertical Green Space Development in Iran"* was published by Engineer Mehdi Rahimi, the founder and CEO of Green Check (Chakadbam Sabz Shahr). It marked a milestone in the literature on green roofs and vertical green space development in Iran. This work, introducing key concepts of green roofs and vertical green spaces, became a valuable guide for engineers, students, and enthusiasts of sustainable architecture and urban green space development. Known among Iranian architects and builders as the "Father of Green Roofs in Iran," Mr. Rahimi has played a prominent role in advancing knowledge and culture of sustainable architecture in the country through the execution of hundreds of successful projects in this field.

Now, after several years, a new version of this book is presented with a different title and expanded content. This edition not only continues the path of its predecessor but also incorporates extensive experiences and recent advancements in this domain, offering a more comprehensive and up-to-date perspective on vertical green space topics. This version examines advanced technologies, modern design principles, and practical solutions with a global approach to addressing contemporary green architecture challenges. In this book, Mr. Rahimi strives to bridge theoretical knowledge and practical experience, offering a fresh vision for the transformation of urban green spaces.

The presence of Mr. Rouzbeh Kowsari, the production and technical manager of Green Check (Chakadbam Sabz Shahr) and co-author of this book, further enriches its value. His hands-on experience in designing and implementing vertical green spaces has allowed this book to convey the practical and operational aspects of green architecture with greater depth and precision. Mr. Kowsari's expertise in managing execution projects and optimizing technical processes makes this book a tangible and practical resource for professionals. In addition to its comprehensive scientific content, this book serves as an unparalleled practical guide for implementing vertical green space concepts in projects. Emphasizing engineering, economic, and environmental aspects, it stands as a unique and comprehensive work for all enthusiasts of creating more sustainable cities and better lives.

To all professionals, students, and enthusiasts of sustainable architecture and green space development, I recommend this book not only for reading but as a guide to action. This work can be an effective tool for addressing environmental challenges and improving urban life quality.

Dr. Yaser Shahbazi

Faculty Member, Tabriz Islamic Art University

Associate Professor of Intelligent Structures and Architectural Technology

Foreword by Dr. Mohammad Madhooshian

Faculty Member, Al-Zahra University, Tehran

The book "*The Art of Vertical Green Space Development*", first published in 2017 by Engineer Mahdi Rahimi, founder and CEO of Green Check (Chakadbam Sabz Shahr), introduced a revolutionary perspective on green roofs and vertical green spaces in Iran. By providing fundamental and practical concepts, it became a valuable reference for architects, engineers, and enthusiasts of sustainable architecture. With over two decades of hands-on experience in this field and numerous executed projects, Mr. Rahimi is rightly recognized as the "Father of Green Roofs in Iran."

Now, after several years, a new edition of this book is released with updated content and a refreshed title. Leveraging past experiences and the latest scientific and technological achievements, this edition offers a more thorough examination of the design and implementation of vertical green spaces. By blending theoretical knowledge and practical experience, Mr. Rahimi has proposed innovative solutions to contemporary green architecture challenges. The role of Mr. Rouzbeh Kowsari, production and technical manager of Green Check (Chakadbam Sabz Shahr) and co-author of this book, is also noteworthy. By sharing his practical and workshop experiences, he has enriched the content of the book, presenting the technical and operational dimensions of vertical green spaces with greater detail and accuracy.

This book, with a focus on technical, engineering, and environmental aspects, particularly in the intelligent use of sustainable wooden materials in designing green roofs and facades, is an invaluable resource for professionals, students, and enthusiasts of sustainable architecture. Studying and applying the recommendations of this work can take a significant step toward sustainable urban development and the reintegration of nature into urban environments.

Dr. Mohammad Madhooshian

Faculty Member, Al-Zahra University, Tehran

Specialist in Wood and Sustainable Architecture

Authors' Preface

In 2017, I published the book *"The Art of Vertical Green Space Development in Iran,"* a reflection of my knowledge and experience at the time in the fields of sustainable architecture and urban green spaces. The exceptional reception of that book highlighted society's need to revisit urban design and expand green spaces within the gray environments of cities. This response motivated me to continue this path with greater commitment and envision a brighter future for cities. Today, in a world facing environmental challenges, climate change, and rapid urbanization, utilizing modern technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Big Data analytics in architecture and urban design is an undeniable necessity. The new edition of this book reflects this global need, combining past experiences, advanced scientific knowledge, and emerging technologies to offer practical and intelligent solutions for creating more sustainable, beautiful, and human-centric cities. This book is not only a guide for designing and implementing vertical green spaces but also a roadmap for integrating nature and technology into urban life. From the application of AI tools in optimizing designs to exploring the impact of vertical green spaces on reducing pollution, enhancing life quality, and restoring nature to the heart of cities, this work provides a collection of practical and inspiring solutions for readers. I dedicate this book to all engineers, architects, students, and enthusiasts of sustainable architecture who strive to create a greener and smarter future. I hope this work inspires you and contributes to urban regeneration and a balanced coexistence between modern life and nature.

Mahdi Rahimi

The book *"The Art of Vertical Green Space Development in Iran,"* first published in 2017, inspired many enthusiasts of sustainable architecture and urban design. It introduced innovative concepts of smart utilization of urban spaces and laid the groundwork for new approaches in architecture and green roof development. This new edition focuses particularly on integrating green architecture with advanced technologies. Today, smart technologies such as environmental sensors, automated irrigation systems, and advanced data analysis algorithms enable us to design green spaces more efficiently and enhance their functionality. In addition to offering scientific and practical solutions, this book examines the cultural and historical use of flat roofs in Middle Eastern societies and redefines the cultural roots of this idea with a fresh perspective. I hope this work inspires a new generation of designers and engineers to create sustainable, smart, and more beautiful cities. This book, a blend of traditional knowledge, practical experiences, and technological advancements, can serve as a roadmap for urban regeneration and restoring nature to modern environments. I recommend utilizing this book not only as

a study reference but also as a practical guide for your future designs and projects.

Rouzbeh Kowsari

Acknowledgments

I extend my heartfelt gratitude to Dr. Yaser Shahbazi, esteemed Deputy of Research and Development (R&D) at Green Check, for his invaluable experience and numerous academic contributions in civil engineering and architecture, which played a pivotal role in enriching the content of this book. I am also deeply thankful to Dr. Mohammad Madhooshian, Director of Innovation and R&D at Green Check, whose extensive expertise in wood engineering and architecture greatly contributed to the preparation of this book's content.

Special thanks to Engineer Fatemeh Keshani for her remarkable collaboration and participation in drafting the chapters related to urban planning. Her distinguished background at the University of Tehran's Faculty of Arts and nearly two decades of practical experience at Green Check have significantly enhanced the scientific and practical quality of this work.

I am grateful to Engineers Saeed Azadi and Sina Abbasmirzayi for their essential roles in the sections on roof smart systems and editing the content related to sustainability. Their expertise and knowledge were fundamental to this book's development.

Special recognition goes to Mr. Mojtaba Rostami, who contributed his valuable practical experiences to assist in drafting the relevant chapters of this book.

My appreciation extends to Mr. Mohammad Sharif Fereidunnia for his consistent support and tireless efforts, which were instrumental in advancing this project.

I am sincerely thankful to Engineer Sahar Nargesi, esteemed Deputy of Education at Green Check, for her valuable cooperation in drafting the research sections and theoretical foundations of green roofs, which added substantial depth to this work.

Finally, I express my utmost respect and gratitude to my esteemed colleague, Mr. Rouzbeh Kowsari, who has been a loyal and supportive partner throughout all these years. From the inception of the ideas for developing vertical green spaces to their practical realization, his dedication, extensive research into the historical and cultural roots of these spaces in the Middle East, and his contributions to research and production have been invaluable in preparing and compiling this book.

Mahdi Rahimi

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Introduction:

**The Need
to Bring Nature Back to Cities**

The Philosophy of Returning Nature to Cities

Throughout history, cities have been recognized as centers of economic, cultural, and social activity. Humanity has always sought to construct structures that not only provide physical protection but also ensure psychological well-being and comfort. However, over time, with the growth of urbanization, the focus shifted more toward physical infrastructures and less on the environment and the need for nature in cities. This trend gradually led to the elimination of natural elements from urban spaces, transforming cities into industrial and artificial environments detached from nature.

Today, with the increasing population and urban density, environmental challenges such as air pollution, urban heat islands, and declining quality of life have emerged. However, scientific and technological advancements have introduced new methods to bring nature back to cities. One such method is the creation of vertical green spaces, allowing for the optimal use of limited urban spaces to reintroduce nature into the cityscape.

Vertical green spaces not only enhance the quality of urban life but also restore the lost balance between nature and modern life. This philosophy is grounded in the undeniable fact that humans need nature for their well-being and that cities must be designed to meet this fundamental requirement.

By implementing solutions such as vertical gardens, green walls, and rooftop gardens, the reintegration of nature into cities not only beautifies urban areas but also creates a healthier and more sustainable environment for future generations.



Urbanization Impacts and the Importance of Vertical Green Spaces

Rapid urbanization and uncontrolled city expansion in recent decades have led to a reduction in natural spaces and an increase in building density. This densification, coupled with the development of industrial and residential zones, has created numerous environmental and social problems. Some of the most significant challenges caused by urbanization include:

1. **Air Pollution:** The rise in vehicles and industrial activity has significantly increased air pollution, posing serious health risks.
2. **Urban Heat Islands:** The predominance of hard, impervious surfaces like concrete and asphalt has caused cities to retain heat, leading to higher temperatures in urban areas compared to surrounding rural regions.
3. **Declining Environmental Quality:** The lack of green spaces has diminished biodiversity and disrupted ecological balance.
4. **Public Health Issues:** The absence of nature in urban areas has led to increased stress and reduced overall mental and physical well-being of residents.

Vertical green spaces provide a novel and effective solution to mitigate these issues. Their benefits include:

- **Reducing Air Pollution:** Plants in vertical green spaces absorb carbon dioxide and release oxygen during photosynthesis, acting as natural air purifiers. Green walls and rooftop gardens can also capture fine particulate matter and harmful gases, improving air quality.
- **Combating Urban Heat Islands:** By introducing greenery to buildings and rooftops, vertical green spaces reduce surface temperatures and contribute to cooler urban environments. This effect also lowers the demand for air conditioning, saving energy.
- **Enhancing Mental and Physical Health:** Studies have shown that access to green spaces positively impacts mental health and physical well-being. Vertical green spaces bring accessible nature to densely populated areas, reducing stress and promoting a sense of calm.
- **Efficient Use of Urban Space:** With limited land availability in dense cities, vertical green spaces allow for the optimal use of walls and rooftops to incorporate greenery into urban design without additional land consumption.

In summary, vertical green spaces play a vital role in improving urban life. They preserve the environment, elevate residents' quality of life, and transform cities into healthier, more sustainable spaces.

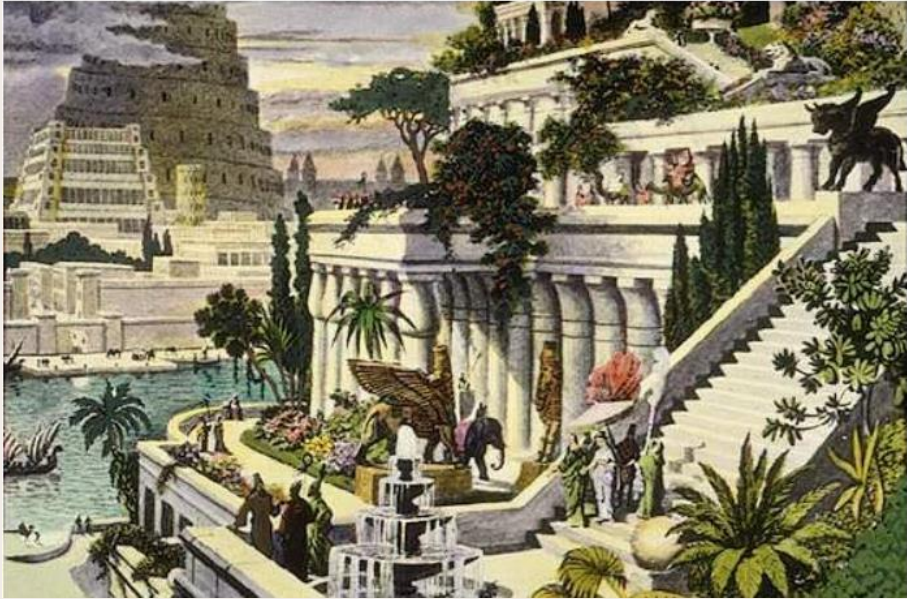
An Overview of Green Space Evolution in Architecture

From ancient times to the modern era, the concept of green spaces in architecture has undergone significant transformations. One of the earliest and most notable examples of integrating green spaces with architecture is the Hanging Gardens of Babylon, considered one of the Seven Wonders of the Ancient World. These gardens symbolized the union of nature and architecture in ancient civilizations, emphasizing the need for greenery in urban environments even then.

During the Middle Ages and the Renaissance, formal gardens—particularly in royal estates such as the Gardens of Versailles in France—showcased a blend of nature, art, and power. These meticulously designed gardens were examples of early efforts to incorporate greenery into architectural landscapes.



Hanging Gardens of Babylon Artist's re-creation of the Hanging Gardens of Babylon, constructed c. 8th–6th century bce.



A representation of the Hanging Gardens of Babylon, the fabled gardens which possibly adorned the capital of the Neo-Babylonian Empire, built by its greatest king Nebuchadnezzar II (r. 605-562 BCE). A 16th century CE engraving by Dutch artist Martin Heemskerck.



Assyrian Gardens



With the Industrial Revolution, cities became bustling industrial centers with little room for natural spaces. Public parks, such as Central Park in New York City, emerged as initiatives to bring nature back to urban settings, offering residents a refuge from industrialization's effects.



In the late 20th century, with rapid urbanization and a growing need to optimize space, attention shifted to vertical green spaces as a modern architectural solution. Green roofs, vertical gardens, and green terraces became effective ways to utilize building surfaces for greenery. These innovations addressed environmental challenges like air pollution, heat reduction, and biodiversity loss while enhancing the aesthetic appeal of urban structures.

Contemporary projects, such as the vertical gardens of the Bosphorus Tower in Turkey or the rooftop gardens of Marina Bay Sands in Singapore, illustrate how advanced technology and sustainable materials have made green spaces integral to urban architecture. These projects demonstrate how the fusion of technology and nature can result in functional, sustainable, and visually stunning urban environments.



Vertical green spaces are not just a response to environmental challenges—they represent a shift toward a harmonious relationship between modern life and nature. This approach can also address future challenges like climate change and urban population growth, creating a path toward a more sustainable and livable urban future.

Chapter 1:

Fundamentals and Concepts of Vertical Green Spaces

1.1 Definition of Vertical Green Spaces and Their Types (Green Roofs, Green Walls, Green Terraces)

Vertical green spaces refer to the use of vertical surfaces of buildings and structures to create gardens and vegetation coverage. This approach not only enhances the aesthetic appeal of buildings but also plays a crucial role in reducing air pollution, improving thermal insulation, and creating small-scale ecosystems.

- **Green Roof (Extensive and Intensive):** A green roof is a vegetative layer installed on building rooftops, incorporating layers of soil and plants. Green roofs can be categorized into two main types: **Extensive** and **Intensive**.

1.1.1 Extensive Green Roof

Extensive green roofs feature shallow layers of soil, making them lightweight and requiring minimal maintenance. These roofs are ideal for residential and urban commercial buildings. The vegetation used in extensive green roofs is typically drought-tolerant and low-maintenance, such as sedum and wild grasses.

Key Benefits:

- **Urban Air Quality Improvement:** Plants on extensive roofs filter pollutants and produce oxygen, contributing to cleaner air.
- **Reduction of Heat Island Effect:** The greenery minimizes heat absorption on building surfaces, mitigating urban heat islands.
- **Thermal Insulation:** These roofs improve energy efficiency by reducing heating and cooling costs.

Explanation:

- **Sedum:** A resilient, low-maintenance plant species commonly used in extensive green roofs due to its ability to thrive in harsh conditions with minimal water.
- **Urban Heat Island Effect:** A phenomenon where urban areas become significantly warmer than rural surroundings due to human activities and heat-retentive materials like asphalt and concrete.





Suitable Illustration: An extensive green roof with shallow and surface vegetation, showcasing the use of cost-effective and efficient technology to reduce energy consumption and improve the urban environment.

2. Intensive Green Roof

Intensive green roofs feature deeper layers of soil, allowing for the cultivation of larger plants, shrubs, and even small trees. These types of roofs are typically utilized for public spaces and rooftop gardens, offering the potential to create recreational areas such as walking paths and seating zones. However, they require more maintenance and are dependent on more complex irrigation systems.



Suitable Illustration: An intensive green roof with trees, colorful flowers, and walking paths, demonstrating the potential for creating larger green spaces and human use of these areas.

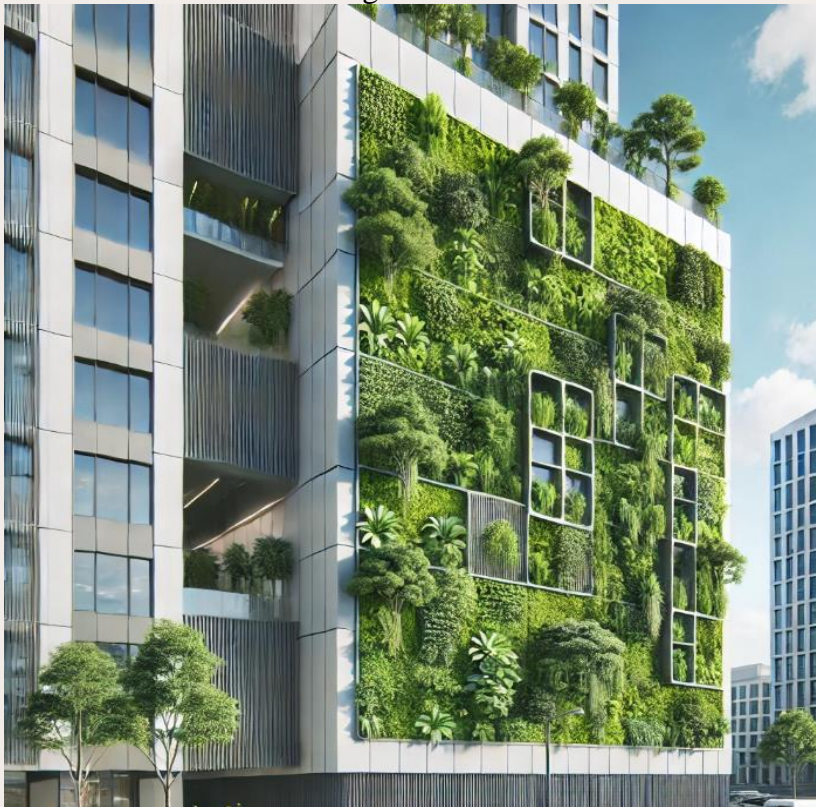


For an **intensive green roof** featuring the planting of large trees and diverse vegetation, the provided description effectively illustrates an intensive green roof with deep soil layers. This green roof is located atop a residential or commercial building and includes walking paths and seating areas, creating a tranquil space for residents.

Large trees and diverse shrubs planted on this green roof provide a lush, vibrant environment that contrasts starkly with the surrounding urban setting. These two types of green roofs, **extensive** and **intensive**, are designed to meet various urban needs, each with its unique applications and benefits.

A **Green Wall**, one of the modern technologies in vertical green space design, is installed on the interior or exterior walls of buildings. These walls use modular systems to hold plants and smart irrigation systems for efficient water distribution. Due to their natural insulation capabilities, green walls can regulate indoor temperatures, reduce energy costs, and improve the surrounding air quality.

Green walls are recognized as a key element of sustainable architecture and are employed in commercial, residential, and public projects to enhance environmental conditions and mitigate urban heat effects.



The provided illustration depicts a modern external green wall managed by smart irrigation systems, functioning as a natural insulation layer for the building.



These types of walls are utilized in work and commercial environments to not only enhance aesthetics but also transform interior spaces into greener and more dynamic settings.

The illustration showcases an example of an internal green wall, featuring lush plants and smart systems, creating a modern atmosphere within a workspace.

Green Terrace

A green terrace, as an innovative solution in urban green space design, transforms open spaces on terraces or balconies of residential and commercial buildings into natural environments. This type of green space is created through planting vegetation in pots, planter boxes, and portable modular structures. Green terraces can improve the quality of life for residents, create small green areas in densely populated urban zones, and even help reduce ambient temperatures.

These spaces are especially popular in bustling cities where access to large areas for green spaces is limited. Green terraces allow residents to enjoy their outdoor spaces while experiencing a relaxing and natural environment. They often include ornamental plants, small shrubs, and sometimes even edible plants like vegetables and aromatic herbs.

Benefits of Green Terraces

1. **Air Quality Improvement:** Plants on green terraces can purify the air and reduce pollution.
2. **Thermal Insulation:** Vegetation acts as an insulating layer for buildings, helping regulate ambient temperature.
3. **Urban Beautification:** Green terraces enhance the aesthetics of buildings and urban spaces, fostering a sense of connection with nature.
4. **Rest and Recreation:** These terraces serve as peaceful retreats for relaxation in daily urban life.



Designing a Green Terrace

When designing a green terrace, selecting the appropriate plants based on light, wind, and water conditions is crucial. A variety of pots and planter boxes are used to create diversity in planting. Adding benches, tables, and comfortable chairs can turn these spaces into multifunctional recreational areas.



Steps to Designing a Successful Green Terrace

1. Selecting plants resistant to specific climatic conditions.
2. Using pots and planter boxes with adequate depth for optimal plant growth.
3. Incorporating a suitable irrigation system for easier plant maintenance.
4. Creating seating areas with outdoor furniture that can withstand external conditions.

2.2 Differences Between Horizontal and Vertical Architecture in Urban Environments

In densely populated and large cities, designing and implementing green spaces is challenging due to spatial limitations and the increasing demand for residential, commercial, and office buildings. Horizontal and vertical architecture represent two distinct approaches to space utilization for urban development, each with its advantages and limitations.

Horizontal Architecture

Horizontal architecture refers to the use of ground-level space for construction and the creation of green areas. This type of architecture requires expansive open spaces and is suitable for regions with low to moderate population density. Horizontal green spaces, such as parks, gardens, and public open areas, are typically implemented in cities where land availability is higher.

- **Land Limitations:** In large and densely populated cities, open land is limited, making horizontal architecture less feasible for green space development.
- **Higher Density:** Horizontal architecture involves the horizontal expansion of buildings and green spaces, which is less applicable in high-density urban areas due to land scarcity.

Vertical Architecture

In contrast, vertical architecture leverages underutilized spaces in buildings by incorporating walls, roofs, and terraces to develop green areas. This approach includes features like green walls, green roofs, and green terraces, which contribute to improving urban air quality, reducing temperatures, and optimizing energy consumption.

- **Efficient Space Utilization:** Vertical architecture creates green spaces on walls and rooftops, offering more room for nature in cities without requiring additional land.
- **Reducing Heat Effects:** Vertical green spaces act as natural insulators, regulating indoor temperatures and reducing the need for energy-intensive cooling and heating systems.
- **Natural Insulation:** Plants on green roofs and walls provide thermal insulation, minimizing heat loss and improving energy efficiency.

Advantages of Vertical Architecture

- Creating more green spaces without occupying additional land.
- Improving urban air quality and reducing pollution.
- Optimizing energy consumption in buildings.

Vertical architecture, particularly in densely populated cities, is an effective solution for increasing green spaces and enhancing urban living conditions. It

represents a forward-thinking approach to addressing the challenges of modern urbanization.



The provided illustration effectively demonstrates two distinct approaches. On the left, horizontal architecture utilizes ground-level space for creating open areas and parks, which require more land. On the right, vertical architecture leverages walls and rooftops to develop green spaces without occupying additional land.

This image offers a suitable comparison of the two methods for green space development in densely populated cities, highlighting how vertical architecture can be a more efficient solution for making the most of limited urban spaces.

2.3 Overview of the History and Development of Vertical Green Spaces Worldwide

Vertical green spaces have undergone significant transformations from ancient times to the present. One of the earliest notable examples of utilizing vertical space for plant cultivation is the **Hanging Gardens of Babylon**. Considered one of the Seven Wonders of the Ancient World, these gardens represented a creative use of vertical space to create lush green areas within a large ancient city.

Over time, as urban populations grew, the need to develop green spaces without occupying limited urban land became more apparent. In the 20th century, with increasing urbanization, vertical green spaces gained attention as a solution to environmental preservation in cities. During this period, concepts like green roofs and green walls gradually emerged. Initially used primarily for aesthetic purposes, their role in improving urban air quality, reducing temperatures, and optimizing energy consumption became increasingly evident.



Modern Vertical Green Space Projects

In recent decades, numerous projects worldwide have become exemplary models of vertical green spaces. Two prominent examples include:

1. **Singapore's Rooftop Gardens:**

Singapore, a leader in sustainable architecture, has implemented major projects in green roofs and vertical green spaces. Iconic structures like **Marina Bay Sands** and **Gardens by the Bay** showcase a seamless integration of nature and technology. These projects play a vital role in mitigating heat effects and improving urban air quality.

2. **Green Walls of the Bosphorus Tower, Turkey:**

This project stands as one of the most successful examples of using green walls on a high-rise building. The green walls not only enhance air quality but also act as natural insulators, reducing temperatures and optimizing energy consumption.

These projects demonstrate how vertical green spaces can address environmental challenges in densely populated cities and improve the quality of urban living.



The created illustration depicts a visual timeline of the evolution of vertical green spaces from ancient times to the present. On the left, the Hanging Gardens of Babylon are shown as one of the earliest examples of vertical green spaces, featuring lush terraces. In the center, an image of 20th-century urban environments with early green roofs and green walls is displayed. On the right, modern projects like the rooftop gardens of Marina Bay Sands in Singapore and the green walls of the Bosphorus Tower in Turkey are showcased, highlighting the significant advancements in the use of vertical green spaces in architecture. This image effectively illustrates the transformations in green