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INSTITUTE OF GRADUATE SCIENCES

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IMPROVE URBAN SUSTAINABILITY SYSTEMS BY INCREASING GREEN AREAS: A CASE STUDY OF OLD RUSAFA IN BAGHDAD

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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ARCHITECTURE

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ABSTRACT

Green spaces in Baghdad are inadequate and fail to meet established standards. They are fragmented and disconnected, leading to neglect, environmental degradation, and increasing air pollution. This thesis explores the role of urban green spaces in Baghdad and investigates ways to expand green coverage to improve thermal comfort in a specific area. Using the Grasshopper simulation programme, factors such as average temperature, relative air temperature, humidity, and wind speed will be analysed. The study employs sustainable solutions and incorporates both quantitative and qualitative data to assess how changes in land use affect the urban environment, green spaces, and societal well-being.

The research also examines the impact of temperature variations on green urban spaces in Baghdad, providing recommendations to improve public spaces in slum areas and address deficiencies. The city's green spaces suffer from inadequate planning and management, resulting in a shortage of at least 4,800 hectares. To tackle this issue, regulations and procedures need to be established at the planning stage to integrate green spaces as part of a comprehensive system.

At the district level, sustainability focuses on maintaining a park hierarchy, rehabilitating damaged parks, and utilising roads and transport hubs to create shaded areas. For Old Rusafa, with its cultural and urban significance, the selected area should adopt standards for green spaces and consider them a cohesive entity during the planning process. Efforts such as reforesting green belt areas, reducing river and canal pollution, and improving ecosystem quality in major parks can help create substantial green spaces.

Locally, sustainability involves preserving park systems, restoring neglected green areas, and optimising roads and transit spaces for shading. The proposed strategy emphasises revitalising existing green spaces, developing an integrated urban green infrastructure, and restoring deteriorated green coverage. By integrating green and service infrastructures, the strategy assesses the area's sustainable performance while promoting comprehensive urban renewal.

KEYWORDS: **sustainability, human thermal comfort, building orientation, green cover, average temperature, air temperature, humidity, simulation programme**

KISA ÖZET

Bağdat’taki mevcut yeşil alanların yetersizliği, kentte ciddi çevresel sorunların ortaya çıkmasına neden olmaktadır. Bu bağlamda, bu tez çalışmasının amacı, Bağdat’taki yeşil alanların kentsel çevredeki ekosistem üzerindeki önemini araştırmak ve Eski Rusafa bölgesinin termal konforunu artırmaya yönelik gerekli uygulamaları belirlemektir. Çalıma sürecinde, arazi kullanımındaki değişikliklerin saptanması ve yeşil alanların, toplum refahı üzerindeki etkilerinin değerlendirilmesi amacıyla nicel ve nitel veri analizi yöntemlerinden faydalanılmıştır. Bu amaçla, öncelikle Grasshopper simülasyon programı kullanılarak ortalama sıcaklık, bağıl nem ve rüzgar hızı gibi faktörler incelenmiştir. Elde edilen veriler, yeşil alanların ortam sıcaklığı üzerindeki etkilerini ortaya koymuştur. Bu süreçte, Bağdat’taki yeşil alan miktarının kentsel alanlar üzerindeki etkileri detaylı bir şekilde incelenmiş ve bu etkilerin kamusal alanların iyileştirilmesine yönelik bir dizi öneri geliştirilmiştir.

Kentlerin yeşil alan miktarları, çevresel planlama ve yönetim açısından önemli bir gereklilik teşkil etmektedir. Bağdat’ın yeşil alan planlaması ve yönetimi, mevcut durumda oldukça zayıftır; bunun sonucunda yaklaşık 4.800 hektarlık bir yetersizlik söz konusudur. Bu sorunu aşabilmek için, yeşil alanların kapsamlı bir sistemin parçası olarak entegre edilebilmesi için planlama aşamasında düzenlemeler ve prosedürlerin geliştirilmesi gerekmektedir. İlçe düzeyinde sürdürülebilirlik ilkeleri, park hiyerarşisinin korunması, zarar görmüş parkların onarımı ve gölgeli alanlar yaratmak üzere yolların ve ulaşım merkezlerinin etkin kullanımı üzerine odaklanmaktadır. Eski Rusafa gibi kültürel ve kentsel öneme sahip bir bölge, yeşil alanlar için belirlenen standartları benimsemeli ve planlama sürecinde bu standartları tutarlı bir varlık olarak ele almalıdır.

Yeşil kuşak alanlarının yeniden ağaçlandırılması, nehir ve kanal kirliliğinin azaltılması ve büyük parklardaki ekosistem kalitesinin iyileştirilmesi; sürdürülebilir yeşil alanlar yaratma çabaları arasında yer almaktadır. Yerel sürdürülebilirlik, park sistemlerinin korunması, ihmal edilen yeşil alanların restorasyonu ve gölgeleme amaçlı yolların ve ulaşım alanlarının optimize edilmesini içermektedir. Önerilen strateji, mevcut yeşil alanların canlandırılmasını, bütünleşik bir kentsel yeşil altyapı geliştirilmesini ve bozulan yeşil kapsamın restorasyonunu vurgulamaktadır.

Bu strateji, yeşil ve hizmet altyapılarının entegrasyonu yoluyla kapsamlı bir kentsel yenilemeyi teşvik ederken, alanın sürdürülebilir performansını değerlendirmeye yönelik bir çerçeve sunmaktadır.

ANAHTAR KELİMELER: **sürdürülebilirlik, insan termal konforu, bina yönü, yeşil örtü, Ortalama sıcaklık, hava sıcaklığı, nem, simülasyon programı.**

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I would like to express my deepest gratitude to my family. Thank you for enduring this long journey with me, always offering love and encouragement, and for constantly being a shoulder to lean on. To **my mother**, who has been my inspiration and strength throughout my life. To my sister, **Noor Ahmed**, who has been my second shoulder and support—thank you for instilling in me the importance of hard work and dedication. Your sacrifices have not gone unnoticed, and I am here thanks to you.

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I would also like to take this opportunity to express my appreciation to myself. Completing this thesis was a significant personal challenge, and I am proud of the dedication and perseverance I have demonstrated throughout this process. This journey has taught me a great deal about myself and my abilities.

I am forever grateful to everyone who has directly or indirectly contributed to my academic journey. This thesis is not only a symbol of my academic achievements but also a tribute to the collective effort of all those who have walked beside me during this phase of my life.

This thesis stands as a testament to the collective support and encouragement of each and every one of you, for which I am deeply grateful.

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ABBREVIATIONS

CCDP	: Baghdad Comprehensive City Development Plan
CDP	: Comprehensive Development Plan
EIU	: Economist Intelligence Unit
ELC	: Environmental Literacy Council
GLCI	: Global Liveable Cities Index
ICDP	: Integrated Capital Development Plan
INGOS	: International Non-Governmental Organizations
SLM	: Sustainable Land Management
UNEP	: United Nations Environment Programme
URBACT	: Stands for URBAN and ACTION
USEPA	: United States Environmental Protection Agency
WHO	: World Health Organization

Blue Infrastructure : Water systems, rivers, and their branches.
Brownfield Service : Industrial sites, abandoned land, road sites, streets, and sanitation.
Green Network / Greenfield : Green infrastructure.
Social Infrastructure : Schools, hospitals, and community centres.

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I. INTRODUCTION

Green areas play a vital role in a city's existence by providing clean air and promoting good health. A city can also be seen as an environment that reflects the lifestyles of its people, integrating both natural and structural elements. Throughout history, the most pleasant urban spaces have not been defined solely by their architecture and planning but by the open spaces that facilitate social interactions, where residents engage in communal activities and events. However, urban growth and expansion have negatively impacted the natural ecosystem. Green spaces are essential for social interaction, communication, sports, and recreation. To address this issue, urban greening approaches are being promoted, including sustainable transport methods, urban intensification, land-use diversity, and biodiversity enhancement. This approach aims to compensate for the loss of green spaces and restore balance within urban systems.

Urban planning theories inspire the development of cities to support survival and societal advancement. While World Environment Day highlights the importance of green cities, the per capita share of green spaces remains below recommended levels. In Baghdad, land misuse, the spread of slums, and irregularities in green space planning have contributed to environmental changes and the erosion of essential planning criteria.

Baghdad has faced criticism for its lack of clarity and focus in lowering green standards without completely abolishing them. Planning challenges include conflicting visions, inconsistent standards, delayed development, and the absence of legislation to prevent the misuse of green spaces. Operational issues further contribute to the problem, such as inadequate planning, weak enforcement, poor management, and insufficient maintenance of green spaces.

The study area is a historic location with diverse land uses, but urban sprawl has resulted in low standards of green space. The current plan focuses on redeveloping existing green spaces, implementing an integrated urban green infrastructure plan, establishing sustainable management controls, and restoring degraded green cover. The city's ecology, along with other key considerations, aims to enhance green space as a fundamental objective. As a progressive step in urban development, it has become essential to prioritise these efforts and make them a primary requirement in city planning.

1.1. PROBLEM STATEMENT

Green open areas in Baghdad are rare, fragmented, and poorly connected, preventing the creation of an integrated system. As a result, their environmental quality deteriorates more each day. The lack of appropriate vegetation exacerbates these problems, which include soil erosion, loss of biodiversity, reduced air filtration, and further negative impacts on public health, as well as increased urban heat stress. Scattered and poorly distributed green spaces are unable to provide sufficient shade or cooling to protect residents from extreme heat, particularly during the summer months. This situation has been further aggravated by the unregulated expansion of urban areas, leading to the intrusion of residential, industrial, and commercial establishments into once-green spaces. Moreover, the city's urban planning policy has not prioritised the integration and preservation of green spaces in high-density areas. Improper zoning and the absence of a comprehensive master plan have fragmented green spaces, isolating them and significantly reducing their overall effectiveness.

1.1. PURPOSE AND OBJECTIVES

Main purpose: The aim is to create an integrated framework for the assessment, enhancement, and management of urban green spaces in Baghdad, with the goal of achieving environmental quality, promoting social welfare, and addressing the challenges of urbanisation and climate adaptation.

Objectives:

1. Assess the Distribution and Accessibility of Urban Green Spaces:

• Identify and prioritise underserved neighbourhoods for green space interventions to ensure equitable access for all residents.

2. Explore the Environmental and Social Benefits of Green Spaces:

• Environmental Benefits: Assess the role of green spaces in mitigating urban heat islands, lowering ambient temperatures, and improving air quality by absorbing pollutants.

• Social Impacts: Investigate how green spaces contribute to community well-being by fostering mental and physical health, as well as promoting social cohesion through communal and recreational opportunities.

• Economic Benefits: Examine the economic benefits of green spaces, including increased property values in areas near well-maintained parks and greenery

3. Develop Sustainable Urban Green Infrastructure Models:

• Design innovative and scalable solutions for green infrastructure that align with Baghdad's climatic and urban conditions, such as green roofs, which utilise vertical spaces to enhance building insulation and reduce urban heat.

1.1. RESEARCH METHODOLOGY

The study employs a mixed-methods approach, combining both qualitative and quantitative methods to assess the role of urban green spaces in Baghdad. This approach integrates theoretical and practical methodologies for a comprehensive analysis.

1. Theoretical Methodology

• Policy Analysis: A review of urban planning records and policies to evaluate the current distribution of green spaces and identify gaps in planning and implementation.

• Examination of successful urban green infrastructure projects in other cities to identify strategies that can be adapted to Baghdad's context.

2. Practical Methodology

• Simulation Analysis: Tools used include Grasshopper with the Ladybug and Honeybee plugins.

• Field Surveys: On-site assessment of green space distribution and accessibility in the study area.

Key Impacts Analysed:

1. Improvement of thermal comfort
2. Enhancements in urban design
3. Social benefits for residents

3. Purpose of Methodology

This framework combines policy insights, simulation-based analysis, and real-world surveys to:

• Identify gaps in green space coverage.

• Quantify the environmental and social benefits of new green infrastructure.

• Develop practical, data-driven recommendations for enhancing urban sustainability in Baghdad.

1.2. Research Hypothesis

1. Causal Hypothesis: Increasing the quantity and quality of green spaces in Baghdad will significantly improve local air quality and reduce ambient temperatures, effectively mitigating the urban heat island effect.

2. Comparative Hypothesis: Areas with enhanced green infrastructure will experience lower thermal stress and improved environmental quality compared to areas with minimal or no green spaces.

3. Descriptive Hypothesis: Planning and managing green spaces as a cohesive network can transform urban microclimates, improve urban resilience, and promote sustainable, liveable environments in high-density urban areas like Baghdad.

These hypotheses align with the research objectives and provide a clear framework for analysing the role of green infrastructure in enhancing urban sustainability and liveability.

CHAPTER 2 LITERATURE REVIEW

1.Urban Green Spaces in the City

2.Sustainability of Green Urban Spaces

2.1 Green Areas (Green Area Plan):

Green areas are considered the natural lungs of any urban fabric and are an indispensable element in urban life. They are part of the land use structure in cities and play a significant role in the visual formation of any urban agglomeration. The green areas network has a vital role in securing the biological diversity of nature in cities by compensating for its loss due to construction, development activities, or any other human intervention. The detailed green area plan addresses the relationship between these areas and land uses such as transport and housing and it includes: Open Spaces & Open Green Spaces (GIZ, BMZ, 2012, p139).
Green areas are considered the natural lungs of any urban environment and are an essential component of urban life. They are an integral part of the land use structure in cities, playing a significant role in the visual character of urban agglomerations. The network of green areas is crucial for maintaining biodiversity in cities, compensating for its loss due to construction, development activities, or other human interventions. A detailed green area plan examines the relationship between these areas and land uses such as transport and housing, and includes open spaces and green spaces (GIZ, BMZ, 2012, p.139).

1- Open Space:

The term ‘open space’ is used in land use planning to define areas that are free from urban development or undeveloped lands designated as low-density spaces. These include streets, squares, plazas, parks, gardens, playgrounds, and other green spaces. Open spaces also encompass rivers, water bodies, orchards, forests, and similar areas, which planners consider necessary to provide or preserve within the urban area to help reduce population density (GIZ, BMZ, 2012, p.139).

From this perspective, open spaces include everything around us, excluding built-up areas with enclosed spaces (Ali Nouri Hassan, 1986, p.7).

William Goodman defines open spaces as land areas free from construction, featuring greenery, water bodies, expansive lands, and clean air, and designated for recreational activities. As such, they encompass a variety of spaces (William Goodman,1968, p. 22).

According to Ashihara Yoshinobu, open spaces are land areas shaped by any means of framing, without a ceiling, which gives these spaces a new sense of security through their framing and the surrounding natural elements (Yoshinobu, Ashihara 1981, p. 11).

The degree of containment, defined by the relationship between the width of a space and the height of the surrounding elements, can define open spaces. When the open space area is large relative to the surrounding elevations, a weak ratio is generated, resulting in a sense of openness. What gives open space its sense of openness is the third dimension—how it meets the open sky above. This leads to the experience of the space as vast and free, elevated from its surroundings, particularly when the space is at ground level, which creates a sense of containment (Nan Fairbrother, 1974, p. 42).

Therefore, open spaces can be defined as areas and spaces surrounding us that remain connected to the atmosphere and the sky, excluding built-up areas. In other words, they refer to uncovered spaces.

If the ground is covered with vegetation and crops, these spaces are referred to as green open spaces. If the ground is paved or covered with other finishing materials, they are simply called open spaces. When located within the urban environment of cities, these spaces take on an urban character.

This means that the general characteristics of open spaces are:

a. They include all areas of land under open sky (excluding built-up areas), whether located inside or outside cities, and whether enclosed by walls or not.

b. They represent the origin of spaces, as construction is only carried out on open spaces, transforming them.

c. They vary in nature, ranging from deserts and mountainous areas to aquatic habitats like seas, and in appearance, including green spaces and forests, barren lands, and paved or concrete areas.

d. Open spaces can acquire additional characteristics, such as an urban character if located within a city's environment, or a green character if predominantly covered with plants.

2- Urban Open Space:

The term 'urban open space' refers to land areas that are neither developed nor built upon, and are not paved for use as roads. Instead, they are designated for recreational purposes, such as parks, green public spaces, plazas, or car parks, as well as natural areas with distinctive features (Alan Jay Christensen, 2008, p. 248).

It is also defined as the part of the city that provides spaces and facilities that serve the urban environment, either through visual relationships or by offering public services and amenities, such as educational, health, or environmental services. This definition encompasses all types of open spaces, as they offer visual relationships (such as green areas), provide urban services (like educational and health services), or serve as spaces designated for movement (such as roads and squares), as illustrated in Diagram 2-1 (John Handley, Stephan Pauliet, and Susannah Gill, 2006, p. 175).

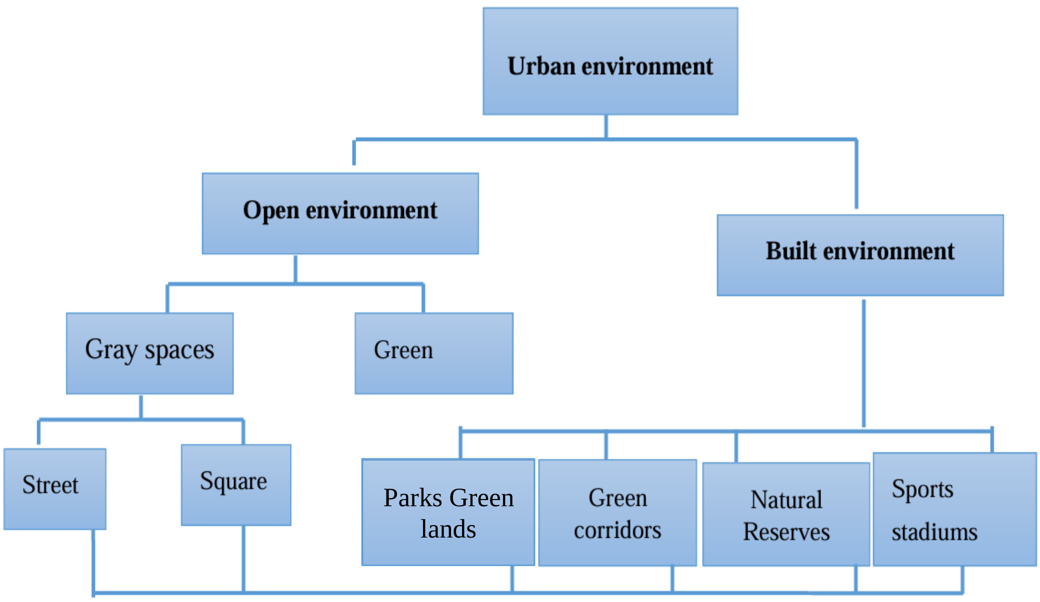


Figure 2-1: Green and Gray spaces in the city (John Handley, Stephan Pauliet, and Susannah Gill, 2006, p. 176).

Cliff Moughton suggests two architectural concepts for viewing the city: Firstly, the city is seen as a visible form of open land with three-dimensional structures representing positive elements, like sculptures placed amidst parks, as well as negative elements. Secondly, the city consists of open spaces such as streets, squares, and parks, separated by buildings and structures (Nan Fairbrother, 1974, p. 83).

Gray spaces, on the other hand, are those with hard surfaces like concrete or pavement, which can be further divided into functional grey spaces such as roads, walkways, car parks, squares, plazas, and gathering spaces (John Handley, Stephan Pauleit, and Susannah Gill, 2006, p. 176).

The Types of Urban Open Spaces Include: Urban open spaces in the city vary, encompassing any area directly exposed to the sky. They constitute most of the urban space in the city, excluding areas used for buildings and structures. Urban open spaces range from areas designated for movement and transport to green spaces, including spaces confined between buildings, which are considered open spaces, as well as vacant spaces. This represents a wide range of urban environments.

A. Gray Spaces:

These consist of areas within the urban space of the city, characterised by paved surfaces such as streets, alleys, transport routes, squares, paved gathering areas, and car parks, among others. The gray spaces can be listed as follows: (Alaa al-Din, Ahmed, 1995, p. 65).

1) Streets, Alleys, and Roads:

Streets are defined as paved passages designated for public use, connecting buildings within the urban environment. They allow residents to meet and interact, serving as axes of movement and pathways between different parts of the city (Elizabeth Burton and Lynn Mitchell, 2007, p. 47).

2) Pedestrian Streets:

They are one of the main means of community interaction, focusing not on their material benefits but on their social benefits, particularly social interaction (Dr. Muzaffar Al-Jabri, 1987, p. 82).

Some European countries have preserved certain alleys designated for pedestrians, expanding them to maintain their harmonious relationship with community life. Economically, reducing reliance on vehicles makes the conversion of streets into pedestrian streets impactful in the business sector. Supplementary elements such as street furniture, tree planting, lighting poles, water channels, benches, advertising boards, canopies, and sculptures play a fundamental role in giving character to the street, as shown in Figure 2-1 (Dr. Muzaffar Al-Jabri, 1987).

Figure 2-1: Types of pedestrian streets urban open spaces Bourke Street Mall on the Left (Melbourne) & Rambla del Poblenou on the Right (Barcelona)" .(Naya, Raimundo Bambó, et al., 2023).

3) Plazas and Squares:

Plazas are central spaces in cities that reflect the evolution of urban centres and neighbourhoods, transforming their planning into gathering places within the streets. Most plazas are intersections of streets, as they were in the past (Dr. Muzaffar Al-Jabri, 1987). Squares may undergo a long historical evolution before settling into their known architectural form and psychological associations. Squares are open urban spaces that represent part of the city’s history. St. Peter’s Square is an example of a public square in towns, as shown in Figure 2-2 (Eliel Saarinen, 1988, p. 83).

Figure 2-2: Plazas and Squares urban :St. Peter’s Square on the Left (Vatican City), Trafalgar Square on the Right (London) (Faragallah, R. N., 2018).

Here is a table of the types of open Gray spaces.

Table 2-1: Types of urban open Gray spaces (Dr. Muzaffar Al-Jabri, 1987).

Gray spaces		
Plazas and Squares		
	Type	Description
1	Squares and plazas	Open spaces resulting from the intersection of visual and movement axes within the city. They are part of the historical development of the city centre and may have been planned for the purpose of community gatherings and social activities, with access routes leading from adjacent streets.
2	Monuments and memorials	Public sites characterised by features related to individuals, events, or values associated with them.
3	Gathering squares (for events)	Open spaces or streets used as markets for agricultural products on specific days of the week or during certain times of the year. Streets, city centre parks, or car parks may be utilised as locations for their activities.
Streets		
4	Streets and roads	They are the arteries of movement and transport within the city. Streets vary in their usage and characteristics.
5	Pedestrian streets	They are designated for pedestrian movement and emergency vehicles. They are equipped with appropriate facilities.

B. Green Urban Open Spaces:

Green urban open spaces are defined as areas within the urban environment of the city that occupy vast green spaces, surpassing the non-open areas within it (Ali Nouri Hassan, 1986, p. 12). This definition sets a standard for the built-up area compared to the total open space, where this standard should be low initially, and the remaining areas should be planted subsequently, without interfering with their nature, uses, and benefits to the city.

They are also defined as lands that are not enclosed, permeable, with a smooth surface of soil, grass, shrubs, or trees (Alan Jay Christensen, 2008, p. 422).

Urban planning no longer views green urban spaces as separate entities but rather considers all green spaces in the city as part of an integrated whole, expressed through green infrastructure. It is not only about spatial extensions and local organisations but also about the interaction between them (Robert McFarlane, 2006, p. 156).

Green spaces vary according to the services they provide. Some are dedicated to sports purposes, others to environmental purposes, and others to scientific purposes, depending on their main function. Green infrastructure thus forms the environmental framework necessary to achieve long-term environmental, social, and economic benefits, taking into account its specific spatial conditions (Robert McFarlane, 2006, p. 156). These are urban spaces in the city that now encompass a wide range of green infrastructure as an expression of their cohesion and integration within a single system in the city. They are designated for mobility, enjoyment, recreation, or desired urban uses. They provide opportunities for games and, when possessing agricultural qualities, they acquire a green touch. Specifications of urban open spaces include:

• All areas within the urban environment of the city that are not designated for building or serving purposes such as transport, gathering, recreation, and sports.

• A small portion of urban open spaces can be built upon without affecting their overall area.

1) <u>River Channels and Water impoundment:</u>

These areas include the banks of rivers and waterways as open spaces. They provide opportunities for biodiversity conservation and contain ecological, recreational, and aesthetic values similar to those offered by open green spaces. Riverbanks and shores can be landscaped and utilised as part of the city's green environment, enhancing the visual relationship between the scenery and the water, and promoting interaction between them, as shown in Figure 2-3

Figure 2-3 Water bodies and river green urban spaces Cheonggyecheon Stream in the Center (Seoul, South Korea).

2) <u>Natural Environments within Urban Areas:</u>

These areas include natural features such as forests, orchards, or unique land formations within city limits. These areas are used for recreational purposes such as jogging, cycling, or walking with pets.

3) <u>Parks and Playgrounds:</u>

Parks are versatile spaces with undefined forms and multiple uses. They are utilised for recreational purposes, visual enjoyment, and free play: 5-10 hectares at the neighbourhood level, 10-15 hectares at the sector or district level, and national parks that extend to thousands of hectares (Garrett Eckbo, 1969).

Figure 2-4: School yards green urban spaces (A school in New York or Philadelphia)”

The hierarchical progression of these spaces can be outlined as follows:

It includes areas of land located within residential areas and consists of:

1. Children’s Playgrounds
2. Schoolyards, as shown in Figure 2-4
3. Parks and Recreation Areas (Chapin F. S. Jr., 1965, p. 300).

These are spaces within residential areas designated as parks and are required to meet two standards: Firstly is the distance from any residential unit, which is 400m or a walking distance of no more than 5 minutes. Secondly standard is the ratio of space allocated to inhabitants in the neighbourhood, determined by the housing density within it. This standard in some Australian cities is $10m^2$ per person (Design Standard for Urban Infrastructure, Australian 2010, p. 5), as shown in Figure 2-5.

The design standard for urban infrastructure is **14 m^2 per inhabitant, urban open spaces, Australian**, 2010, urban service, and **9 m^2 per inhabitant** according to the basic design of the city of **Baghdad** (Polservice Consulting Engineering, 1973, p. 174). As shown in Table 2-2, a comparison is made between the area of green spaces in the basic design standards and American standards for green spaces, as well as their relationship to the distance from residential units.

Figure 2-5 Parks with multiple shapes and areas green urban spaces: Abu Dhabi Corniche (Top Left), Shanghai Highway Greenery (Top Right), and a Modern Urban Park in Singapore (Bottom).

Table 2-2: Comparison of green space areas between basic design standards and American standards, and their relationship as to the distance from residential units. Source for American standards: Cliff Tandy, 1978, p. 100.

Space	**American standards for green spaces**		**Green space standard according to the basic design**	
	Minimum area (acre)*1	Distance from residential units (mile)	Minimum area (m2)	Distance from residential units (m)
Quarter Park	5-10	8/1-8/3	10000-20000 4M/2 inhabitants	400
Neighborhood park	10-15	1.5-1	6000-30000 3M/2 inhabitants	1200-2000
City Park	More than 15	Strategically located in the city	2M/2 inhabitants	Central Location

4. Green Belt

According to Eleanor Smith Morris (1997, p.175), the urban green belt is defined as areas of land near or surrounding urban areas, where construction is not permitted. Alternatively, it is described as a series of connected open spaces or cultivated lands surrounding urban environments or adjacent rural areas, forming a ribbon-like park around the urban area (Alan Jay Christensen, 2008, p. 163).

Ebenezer Howard proposed a green belt covering an area of 5,000 hectares surrounding the city, separating residential areas from industry to prevent unplanned urban sprawl (Eleanor Smith, 1997, p. 83). He was the first to conceive the idea of halting the endless expansion of cities, which would otherwise lead to their eventual merging.

Thus, the concept of utilising the green belt evolved, and by the 1980s, it had become one of the key spatial planning policies aimed at controlling urban sprawl. It was increasingly recognised for its aesthetic and recreational value. The proportion of land allocated to green spaces grew, with English urban development plans proposing that approximately 13.8% of a city's total urban area be designated as green belt space (Eleanor Smith, 1997, p. 83).

➢ The benefits of green belts can be outlined as follows:

- Controlling unwanted urban expansion of built-up areas.
- Defining the boundaries of urban areas to preserve natural spaces outside cities.
- Protecting agricultural land to support food production (Ali Nouri Hassan, 1986, p. 118).
- Enhancing urban revitalisation by reorganising land use and promoting environmental conservation (Eleanor Smith, 1997).
- Helping to preserve the unique historical character of certain cities by maintaining their distinctive features. Alternatively, green belts can be used to shape and protect significant landscapes near urban areas.
- Restricting industrial expansion beyond city limits (Stephan Handley John, Pauliet, and Susannah Gill, 2006, p. 171).

5. <u>Green Streets and Pathways:</u>

   Streets lined with vegetation and trees are considered green urban spaces, as the predominant green colour helps regulate temperature by reducing peak heat levels. Trees provide shade for pedestrians beneath their branches, enhancing both the aesthetic and visual appeal of the street (Fazia Ali & Helmut Mayor, 2006), as shown in Figure 2-6.

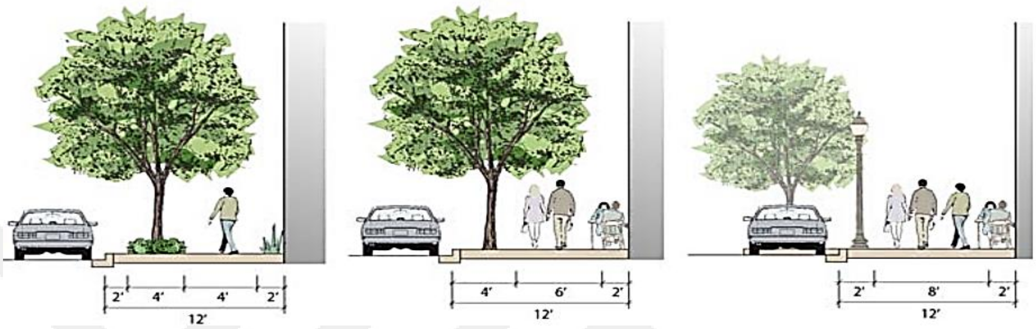


Figure 2-6: Planting plants and trees on streets and sidewalks.

6. <u>Specialised Sports Facilities</u>

Specialised sports facilities, such as football pitches, equestrian clubs, tennis courts, and other dedicated arenas, are considered green urban spaces. These areas form part of the urban environment and contribute to the overall green space within cities. Swimming pools are also classified as green urban spaces. The allocation of open space is calculated based on **Anon's recommended standard** of **1.62 hectares per 1,000 inhabitants** (Garrett & Eckbo, 1964, p. 344).

Rapid and concrete urban development not only signifies a hub of human activity but also highlights the role of cities as spaces for green amenities that enhance quality of life. Urban green spaces play a vital role in maintaining ecological balance, providing recreational opportunities, and preserving aesthetic continuity within urban systems. They contribute to environmental sustainability by promoting community well-being. Table 2-3 outlines various urban spaces categorised as green and typical areas, detailing their specific characteristics and contributions to creating a healthier and more liveable city.

Table 2-3: Types of Urban Open Green Spaces (Stephan Handley John, Pauliet, and Susannah Gill, 2006).

Urban Spaces		
Second Green Spaces		
	Type	Description
1	Green Belt	The agricultural area surrounding the urban area, despite being located outside of it, is considered part of the urban green spaces as it complements the overall green space system.
2	Natural Areas and Reserves	These spaces encompass areas characterised by specific natural features, such as forests and orchards, within the urban environment. In some cases, these areas may be designated as nature reserves to protect and conserve them from unauthorized logging or encroachment.
3	Riverbanks and Waterways	These spaces include rivers, water channels, waterfronts, beaches, riverbanks, and areas near lakes and marshes, which can be planted with vegetation and trees.
4	Green Pathways	These refer to streets where sidewalks and median strips are planted with vegetation, giving the street a green character due to the density of the plantings and interlocking foliage.
5	Central Park	Located within the central area of the city, it is characterised by its large size and the inclusion of various recreational and sports activities. Cities may have more than one central park.
6	Sector Park	This refers to green spaces planted with grass and trees, located in the central area of a residential sector. These spaces can be developed from either historical or newly designed parks. The size of these parks depends on the population density of the sector.
7	Neighbourhood Park	A large green space with public amenities for recreational and sports activities, located in the heart of a residential neighbourhood. There are certain criteria that must be met, including a maximum distance from residential units and a standard area allocated per person.
8	Quarter Park	A developed open space located in the middle of the residential area, including playgrounds for children and sports facilities. Specific criteria apply regarding its distance from residential units and the standard area allocated per person.
9	Children's Playgrounds	Small parks within residential neighbourhoods, surrounded by buildings. They may feature fountains, water features, or simple play equipment for children.

Table 2-4 below shows some green spaces in various Arab cities compared to international cities. In addition to open space, according to the WHO recommendation of 9–12 m² per person, it includes other indices such as city area, population, and the total area of green spaces. Furthermore, types of amenities, such as the number of parks, are also presented. Cities like Beijing have 66 m² per person and the USA 40 m² per person, both exceeding the WHO standards, while cities like Kuwait and Dubai have 1 m² per person and 2.18 m² per person, respectively, falling below the standards. This disparity in meeting WHO standards highlights the differing priorities of urban planning and the challenges faced in various regions of the world in providing equitable access to green spaces.

Table 2-4: Standards of Green Spaces in Arab and International Cities Compared to World Health Organization Standards. Source: **(data.unhabitat.org 2025)**

City	Total Area (km²)	Population in the Year	Standards of Open Spaces (m²/person)	Average Share of Open Spaces (m²/person)	Open Space Facilities (Amenities)
			Regional Park	Sectoral/Functional Park	Local Park/ Intermediate Islands
Baghdad	**890**	**7,879,000 * (2010)**	**-**	**-**	**-**
Barcelona	101.40	1,673,075 (2008)	-	18.1	-
Kuwait	200.00	2,380,000 (2005)	1.00	-	-
Singapore	710.20	4,117,700 (2000)	7.50	-	-
Hong Kong	1104.00	7,055,071 (2008)	2.50	-	-
Dubai	1287.40	2,262,000 (2008)	2.18	1.20	1.00
Istanbul	**1830.92**	**20,549,000(2008)**	**7.20**	**5.90**	**1.30**
Kuala Lumpur	243.65	1,809,699 (2009)	2.25	-	-
Japan	377,994.00	3,900,000 (2009)	4.52	-	-
Beijing, China	16,801.25	17,550,000 (2009)	66.00	-	-
Melbourne, Australia	8806.00	3,900,000 (2008)	6.30	-	-
UK (various cities)	-	-	24.30	-	-
USA (various cities)	-	-	40.00	-	1.3/1000
WHO	**-**	**-**	**9.00-12.00**	**9.00**	**-**

*Population of Baghdad in 202 as per (**(data.unhabitat.org 2025)**).
World Health Organization standards.

2.1.1 Classification of Green Spaces in the City

Green spaces occupy a significant portion of the area in every city. For example, in London, green spaces constitute 23% of the city's total urban area, while in Baghdad, literature suggests that green spaces make up 17% of the urban environment (Polservice, *Consulting Engineers*, 1973).

This large proportion of urban area in the city arises from the diversity of types and categories of green spaces, which can be classified in light of the following:

(A) Classification of green spaces according to their nature of use:

The types of green spaces vary according to the benefits, the nature of their use, or the purpose behind their existence. Some green urban spaces require specific sizes and dimensions to fulfil their intended purpose (Garrett Eckbo, 1964, p. 344).

According to the principle introduced by **Unwin** in 1929 and subsequently adopted by others, the estimated green space requirement per capita in urban environments is **2.83 hectares per 1,000 inhabitants**. This translates to a standard of **28.3 square metres of green space per person** (Eckbo Garrett, 1964, p. 344).

➢ **For example, in the city of Baghdad, with a population exceeding 6,000,000 inhabitants, this would necessitate a total green space area of 16,980 hectares, of which 7,260 hectares would be allocated for open spaces without specific purposes.**

(B) Classification of green spaces in the city according to their nature

Green spaces within urban areas can be classified based on the degree of human intervention in their creation as follows:

- Natural Urban Areas

These include spaces within the urban environment that possess natural characteristics, unaffected by human activity or intervention. While these areas may not always have recreational value, they serve other important purposes, such as preserving sensitive environmental systems like forests, orchards, rivers, wetlands, and nature reserves that happen to be within urban areas, as shown in Figure 2-7. Areas of green land untouched by human activity are referred to as natural green spaces (Garrett Eckbo, 1966, p. 91).

Figure 2-7: Natural urban green spaces: Great Wall of China (Left) and Sanjay Van Forest, New Delhi (Right) (Singh, V. S., Pandey, D. N., & Chaudhry, P. 2010).

- Developed Green Spaces

This category encompasses all land areas within the urban space of the city designated as green spaces, whether they are natural areas altered by human intervention or entirely human-made developments. It includes spaces such as residential gardens, neighbourhood parks, playgrounds, community and city parks, designated sports fields, gardens adjacent to places of worship, cemeteries, green corridors, riverbanks, wetlands, shallow water bodies, planted streets, and more, as shown in Figure 2-8 (Eckbo Garrett, 1964, p. 3).

Figure 2-8: Human intervention transforms green spaces into developed green spaces: Nhan Chinh Lake Park in Hanoi, Vietnam. (Eckbo Garrett, 1964, p. 3).

Here is the comparison in Table 2-5 format between the classifications of green spaces:

Aspect	(A) Classification by Nature of Use	(B) Classification by Nature
Criterion for Classification	Based on **function and use** of green spaces in the urban environment.	Based on the **level of human intervention** in the formation or preservation of green spaces.
Focus	Emphasizes **urban planning and social utility**.	Emphasizes **ecological and environmental integrity**.
Measurement	Uses a **quantitative approach** to determine the required green space per capita.	Uses a **qualitative approach** based on the natural or modified state of the green space.
Application	Applied in **urban policies and planning** to ensure proper distribution and accessibility of green spaces.	Applied in **environmental conservation and management** to assess human impact on ecosystems.

2.1.2 Green Infrastructure Planning Principles:

Integration: Green infrastructure integrates urban green areas with other infrastructures such as buildings, transport, and water management systems to establish physical and functional relationships.

1. Multi-Functionality: Combines ecological, environmental, social, economic, and cultural functions to provide benefits for both nature and society.
2. Connectivity: Establishes physical and functional links between green spaces across different levels to enhance their efficiency and ecological impact.
3. Multi-Scale Approach: Operates at various levels, from neighbourhoods to regional and national scales, ensuring comprehensive implementation.
4. Multi-Object Approach: Encompasses a variety of urban green and blue spaces, including natural areas, water bodies, and public/private green spaces, while respecting stakeholder needs.
5. Governance Process: Prioritises green infrastructure planning and protection before urban development occurs.

6. Strategic Approach: Aims for long-term sustainability while allowing for flexibility and adaptive management over time.
7. Social Inclusion: Promotes social planning and management to encourage community interaction through green spaces.
8. Transdisciplinary Approach: Relies on sound science and land-use planning theories for effective implementation (Rieke Hansen & Stephan Pauleit, 2014, p. 518), as shown in Figure 2-9.

Elements of Green Infrastructure Network: This includes interconnected green and blue spaces such as green roofs, urban forests, sustainable water designs, and peri-urban areas. These elements work together to enhance biodiversity, support urban ecological functions, and promote social systems within urban environments. (Cities Alive, 2014, p. 33)

Benefits of Green Infrastructure: Green infrastructure (GI) improves water management, mitigates floods, enhances air quality, reduces urban temperatures by 0.5–5°C, and bolsters food security. The connectivity and quality of green spaces are crucial for maximizing ecological services and supporting biodiversity conservation. (*Cities Alive*, 2014, p. 33; Hansen & Pauleit, 2014, p. 516). As shown in Figure 2-10, it illustrates the components of the green infrastructure network, its multiple dimensions, and its various applications, which include the following types: green walls; urban agriculture; main street trees in the city; suburban street planting; urban forests; public parks and recreational areas; sports stadiums; water-sensitive urban design with rainwater harvesting systems and roof gardens.

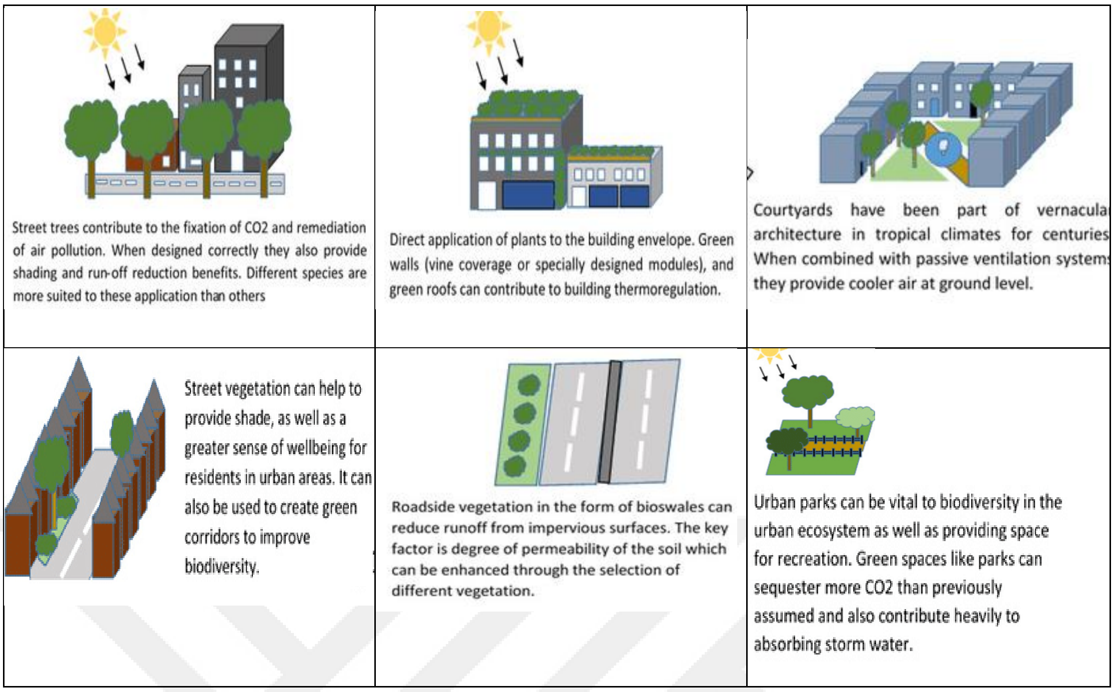


Figure 2-9: The elements of the green infrastructure network and they are functions. (Mydiagram-infrastructure-diagram-examples).

Figure 2-10: Illustrates the components of the green infrastructure network: in (Melbourne - Australia) (*Cities Alive*, 2014, p. 33; Hansen & Pauleit, 2014, p. 516).

<u>Role of Green Spaces in Urban Planning:</u> Green open spaces in urban planning serve as a cornerstone in light of changes in attitudes towards the utilisation of natural areas. The importance of green spaces is not only determined by their quality but also by their connectivity to other green spaces. This connectivity enhances the provision of various ecosystem services, including the maintenance of biodiversity. The ecological systems approach, popularised since the Millennium Ecosystem Assessment of 2005, has advanced the understanding and application of sustainability principles. This approach stresses the integration of ecological services into urban planning to ensure long-term sustainability. (Arup, 2014, *Cities Alive*, p. 33)

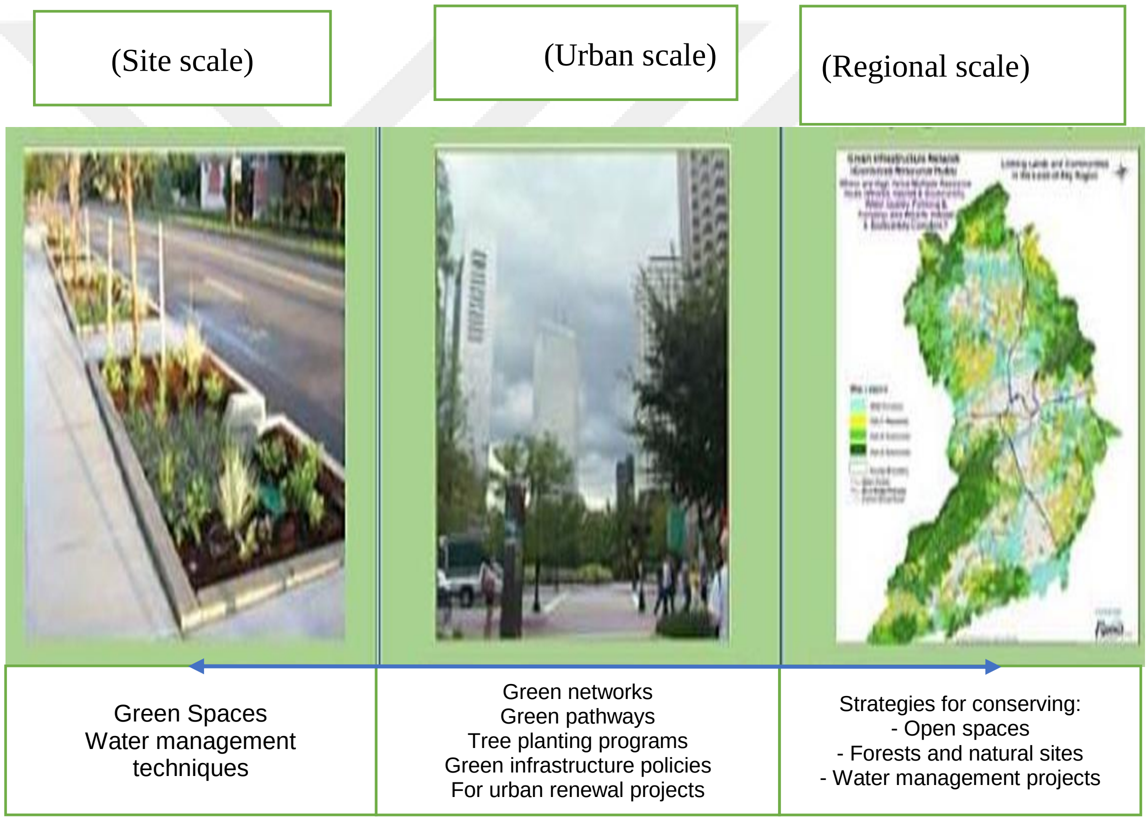


Figure 2-11: illustrates the three levels of the green network and its strategies (Houston, Texas) (Arup, 2014, *Cities Alive*, p. 33).

Although each level is integrated within itself, it cannot operate in isolation from the other levels, as the interaction between the levels is what green infrastructure expresses through connectivity and continuity. These features work in harmony and systematically to reduce the negative environmental impacts associated with urban development. (*Greening the Grey*, 2013, p. 15)

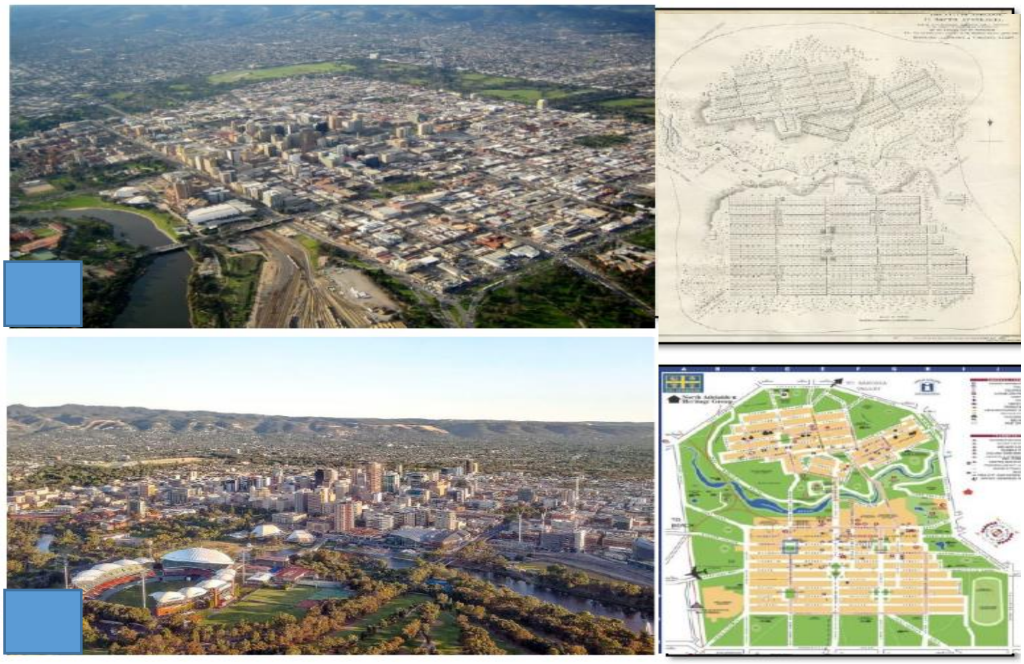


Figure 2-12: Creating gardens in Adelaide (South Australia) (Benjamin Charles Hedstrom, 2012, pp. 2-3).

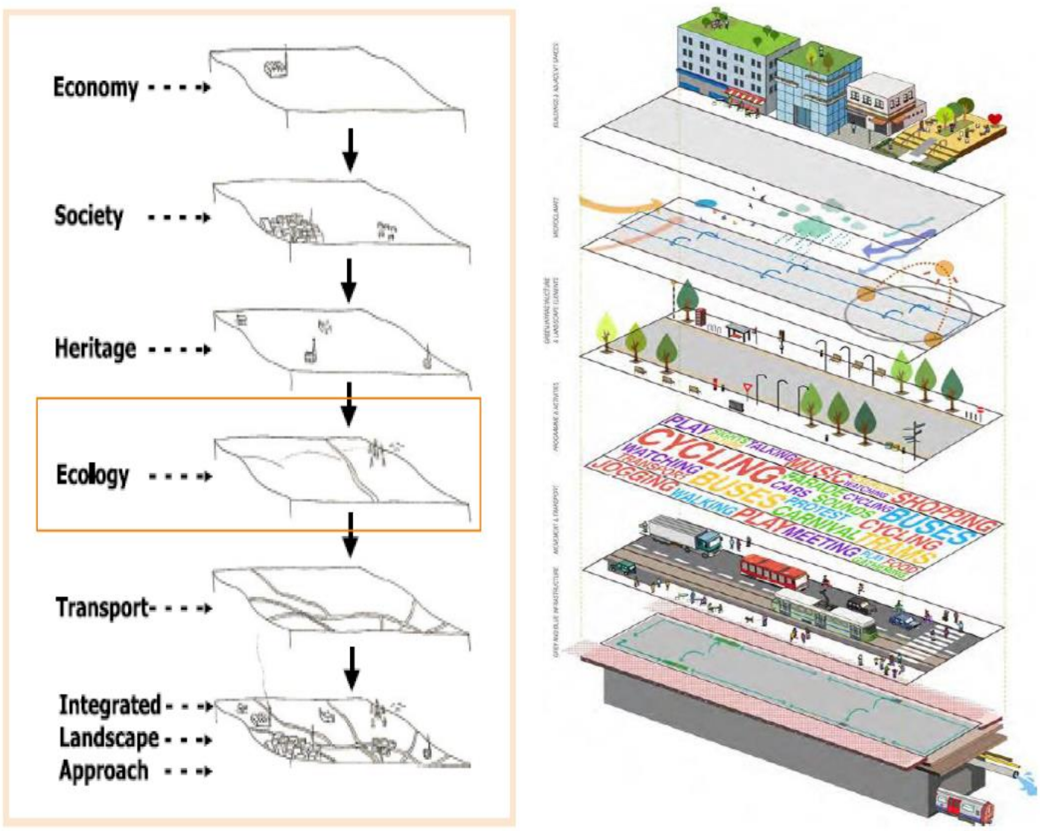


Figure 2-13: illustrates the multiple layers of the site in integrated landscape planning (Green city guidelines, 2008, p23).

2.2. Sustainability of Green Urban Spaces

The adoption of green space conservation as a conceptual and practical approach is essential for addressing the deteriorating state of urban green spaces, particularly in Baghdad. Sustainability, as a cornerstone of community development, focuses on long-term responsibility to preserve the Earth by balancing social, environmental, and economic dimensions. (Alan J. Christensen, *Sustainability*, 2008, p. 366)

Definition: Sustainability refers to the ability to persist and endure while supporting biodiversity and productivity over time. Derived from the Latin term meaning permanence, it gained significance in the 1980s, emphasising the need to pass the Earth on in good condition to future generations. There are two types of sources. (Alan J. Christensen, *Sustainability*, 2008, p. 366).

- **Renewable Resources:** These include wind power, solar energy, and forests. They require careful use to prevent depletion faster than replenishment.
- **Non-renewable Resources:** These include minerals and fossil fuels, where excessive use risks depleting them for future generations. Water management and pollution prevention are particularly critical. (Robert McFarlen, 2006, p. 149).

Babylon, one of the greatest cities of the ancient world, was known for its advanced architecture and sustainability. The Hanging Gardens, a wonder of the ancient world, showcased an innovative irrigation system that maintained lush greenery in the desert. This early example of sustainable design continues to inspire modern urban planning.

The Hanging Gardens of Babylon, one of the Seven Wonders of the Ancient World, are believed to have been an extraordinary series of tiered gardens featuring a diverse array of trees, shrubs, and vines, creating the appearance of a lush, green mountain constructed from mud bricks (*Hanging Gardens of Babylon* | Britannica).

These gardens are often considered an early example of sustainable design. The concept of integrating vegetation into urban structures, as exemplified by the Hanging Gardens, has influenced modern sustainable architecture, such as green roofs and vertical gardens (*blog.urbanscape-architecture.com*).

Figure 2-14: The Hanging Gardens of Babylon: An Ancient Marvel of Sustainability (Hanging Gardens of Babylon | Britannica).

Sustainable Development Goals: Balance social, environmental, and economic requirements to achieve long-term benefits. They emphasise preserving biodiversity, managing environmental changes, and transitioning to renewable resources while reducing material damage. (Alan J. Christensen, *Sustainability*, 2008, p. 366)

Human Impact and Solutions: The increase in population and human interventions in natural systems has accelerated resource depletion, disrupted natural cycles, and negatively impacted ecosystems. Returning to pre-established environmental boundaries and adopting sustainable practices (e.g. green architecture, sustainable agriculture) are necessary to improve human-environment integration. (Robert McFarlen, 2006, p. 149)

Benefits of Sustainable Green Spaces: They provide environmental, social, and economic advantages by maintaining biodiversity, improving urban environments, and ensuring resource availability for future generations.

Sustainability as a Social Practice: Sustainability, by nature, is a social practice entailing the fullest utilisation of the carrying capacity of the environmental support systems, checked through human-environmental systems. It calls for action and movement, as it reflects a planning process that gives continuity to political effort in terms of clear goals and instils responsibility. This approach follows the path of new means toward a lifestyle of sustainable living with the vision of a sustainable future. These include:

- Protection and Restoration: It addresses the security and rehabilitation of degraded environmental and green systems.
- Preservation of Biodiversity: Ensuring the continuity of life by maintaining ecological balance.
- Sustainable Production: Production methods should be adopted that protect resources and support ecological recovery. (Robert McFarlen, 2006, p. 149; Alan J. Christensen, *Sustainability*, 2008, p. 366)

Objective of Sustainability: This chapter explores the role of sustainability in preserving urban green spaces and creating sustainable environments, with a focus on Baghdad. It emphasises the importance of green spaces in providing ecosystem services, maintaining environmental balance, and addressing urban challenges. (Alan J. Christensen, *Sustainability*, 2008, p. 366; Robert McFarlen, 2006, p. 149)

2.2.1. Factors of Green Sustainability in the City

To benefit from resources without withholding the rights of future generations, it should be noted that the sustainability of green spaces in a city requires:

1. Taking care of the existing green spaces, preserving them, and making the most of them as a resource, as sustainability focuses on the controlled use of natural resources and the preservation of all existing life elements.
2. Adding new land formations in the areas designated as green spaces, taking into account the reduction of non-renewable resource consumption.
3. Adopting the idea of restoring the environment of degraded spaces and embracing the concept of reuse by converting existing facilities to new uses, thinking about

recycling materials, and taking advantage of the existing infrastructure and roads within the site.

4. New facilities intended to meet sustainability needs should be planned flexibly so that they can be repurposed, extending their lifespan and durability.
5. Taking advantage of green spaces for multiple uses and striving to maximise the services they provide. (John Handley, Stephan Pauliet, and Susannah Gill, 2006, p. 190).

- In the design process for open urban spaces, much consideration should be given to providing sunlight or shade, especially in a hot and dry region like Baghdad. The important factors to be considered are:

Solar Windows:

Tall buildings with narrow spacing admit limited direct solar radiation to the ground for a short period. These are necessary to ensure adequate light in the adjacent open spaces. (William Marsh, 1997, p. 292)

Shaded Green Corridors:

The sidewalks have been designed as green corridors with vegetation for maximum shading. These are flanked by high-rise buildings where direct rays of the sun do not reach, and the reflected light provides comfortable shaded areas for the movement of pedestrians and vehicles, as shown in Figure 2-17.

The length of the shadow corridor is calculated as: (William Marsh, 1997, p. 292)

Shadow corridor length = height of buildings / shadow angle of incidence.

Shading in Hot and Dry Climates:

Greenery needs to have continuous shading throughout the day. Low-light requirement vegetation may be considered in order for it to thrive under such conditions. Tall buildings can also facilitate urban shading by providing greater shadows that extend the benefit to the open green spaces and reduce exposure to strong sunlight. With such considerations, building heights can be increased to accommodate more floors with better shade coverage. (William Marsh, 1997, p. 292)

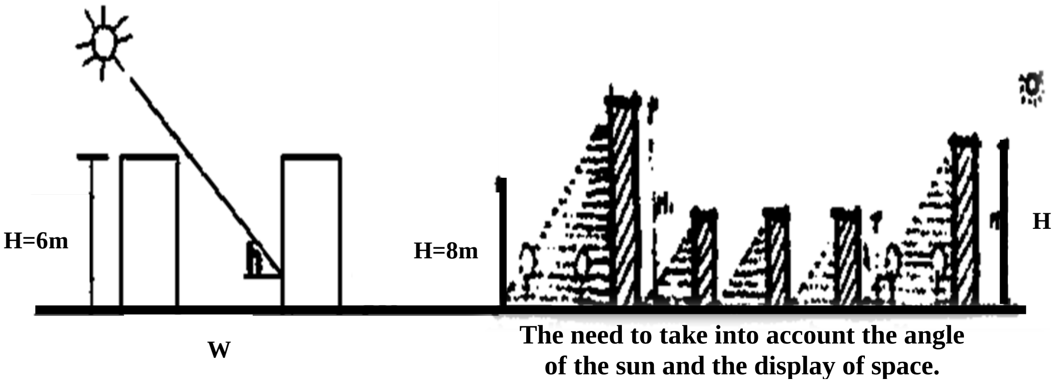


Figure 2-15: The relationship of building height with the angle of incidence of sunlight (Min, 2010).

2.2.2 The controlled systems for the sustainability of green spaces

Quality is a general principle representing indicators and standards governing the performance of green spaces, which can be summarised by the governing quality attributes. The intended meaning refers to the criteria that, if maintained or elevated, would classify a green space as sustainable. These criteria are outlined in:

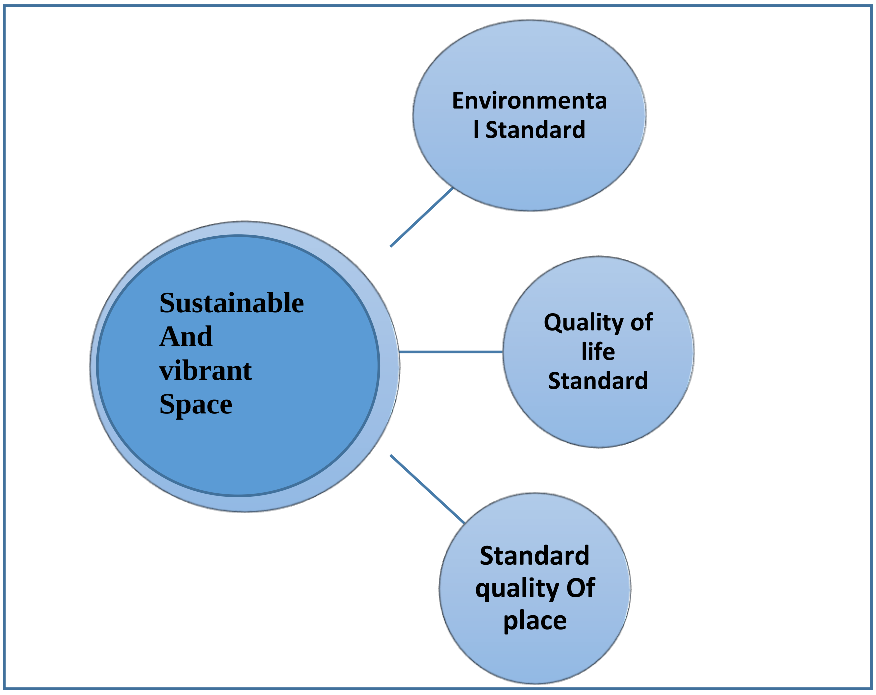


Figure 2-16: illustrating the relationship between the governing qualities attributes for sustainability (Robert Mc Farlen, 2006).

Environmental Quality: It stands for the changes in quality concerning water, air, and soil in green parks, planning for sustainability through reduced waste and energy savings. These indicators are guided by local and global parameters, as shown in Figure 2-16. (Robert McFarlen, 2006, p. 153).

Quality of Life: Land shaping, vegetation, and urban agriculture in the promotion of human and ecological well-being underline the quality of life. (Robert McFarlen, 2006, p. 153).

Quality of Place: Quality of place integrates natural, cultural, and architectural features that build aesthetically appealing, sustainable environments. (Robert McFarlen, 2006, p.153).

Pollution Control/Improvement of Air Quality**:** The trees act as a natural barrier, cleaning the air through the reduction of pollutant concentration and improving air quality in urban cities via barriers at source locations. (Nigel Dunnett & Andy Clayden, 2006, p. 198), as shown in Figure (2-16).

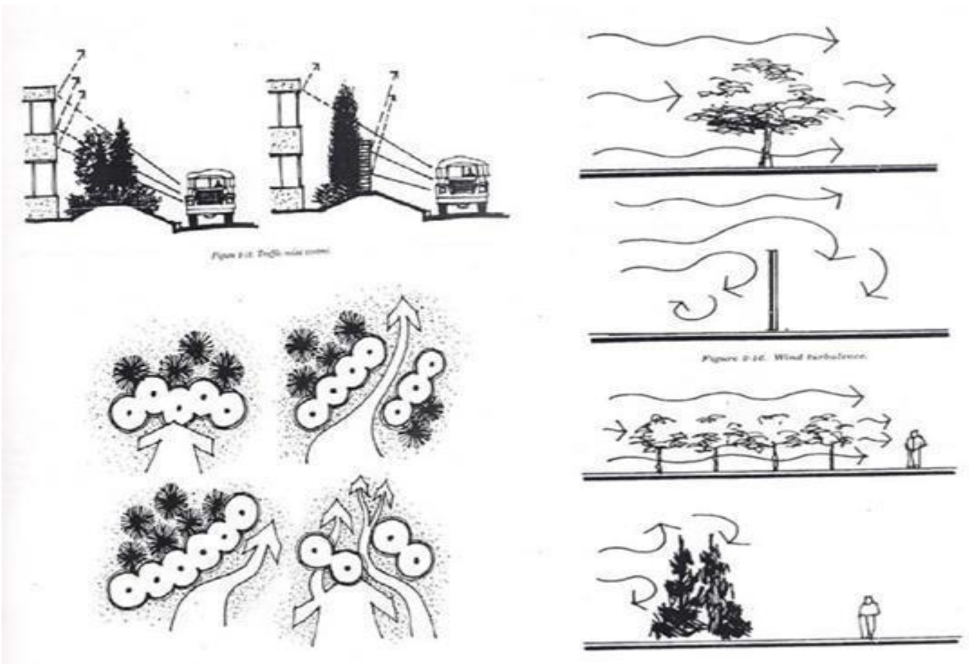


Figure 2-17: Using Plants as Barriers and Wind Direction Guides (Department Of The Army, 1988, p2-10)

Mitigating Climate**:** With plants, there are positive effects on the climate due to the process of evaporation, which increases humidity and draws the required heat for evaporation from the nearby air, thereby reducing its temperature. Therefore, with greenery, cooler air can be provided, with green areas contributing to this effect. Furthermore, with wider usage, trees are intended to contribute to temperature reduction by providing shade as well as enhancing aesthetics. Most trees used for aesthetic purposes reach heights between 4.5 and 7.5 metres. (Leroy Hannebaum, 2000, p. 133).

It is preferred to use trees with low branches at sufficient heights to prevent obstruction of movement and visibility. However, trees can be used in green belts since they provide good wind deflection, as observed in Figures 2-17 and 2-18. (Department of the Army, 1988, p. 2-5). Among other uses of plants in land shaping – aside from serving as a windbreak – plants provide comfort through their life functions and lower the ambient temperature. (John Handley and others, 2006, p. 192).

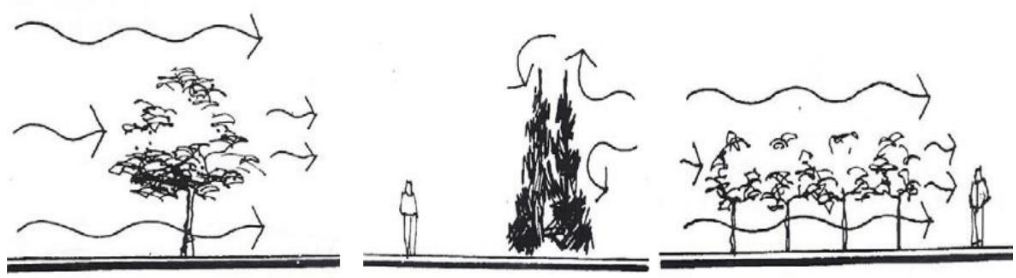


Figure 2-18: Role of Low-Branching Plants in Wind Deflection and Prevention (Department Of The Army, 1988, p2-10).

Protection from Dust Storms**:** the removal of vegetation increases the accumulation of dust in areas with heavy pedestrian and vehicular traffic. Vegetation serves as a natural barrier against dust storms, such as those occurring in Baghdad, which experiences over 25 dusty days annually. Strategic planting of vegetation can help reduce the dust effect and protect human health and environmental cleanliness. As shown in figure (2-19) (Ali Nouri, 1986, p. 33).

Figure 2-19: Baghdad City Experiences a Dust Storm.

Energy Balance: Trees around buildings reduce the need for air conditioning in summer and heating in winter, which conserves non-renewable energy. Vegetation provides thermal insulation when placed on walls and roofs, thereby decreasing energy demand. Climbing plants also reduce heat absorption and cool adjacent spaces, providing greater thermal comfort. (Mohammad Arif Kamal, 2010, p. 5; Nigel Dunnett & Andy Clayden, 2006, p. 199)

Productive Uses of Green Spaces**:** Urban green spaces are used productively

Forests: Sources of wood for industries.

Orchards: Providing fruits and vegetables for local consumption.

Green Belts: Helping reduce transport-related emissions and contributing to sustainability by producing local food. (Nigel Dunnett & Andy Clayden, 2006, p. 199)

Sustainability of Biodiversity: Biodiversity refers to the range of species in an ecosystem and is fundamental to ecological sustainability. Urban green areas enhance biodiversity by hosting diverse plant and animal species. To sustain ecological systems, planning must ensure connectivity, functionality, and sufficient scale. Green corridors play a significant role, performing multiple functions, including supporting biodiversity. (Nan Fairbrother, 1974, p. 27; William Marsh, 1974, p. 370)

Sustainable urban green spaces prioritise quality over quantity, integrating biodiversity into parks, gardens, rooftop greenery, and tree-lined streets, fostering a balanced coexistence between humans and nature. (McRobert Farlen, 2006, p. 150), as shown in Figure 2-20.

Figure 2-20: Plant diversity enhances the aesthetic value of land formations in Warsaw, Poland. (Melon, M., Sikorski, P., Archiciński, P., Łaszkiewicz, E., Hoppa, A., Zaniewski, 2024).

2.2.3. Green Sustainable City

Urban sustainability incorporates green space in its planning to overcome climate change and make the city more viable. Richard Rogers sees the sustainable city as clean, resourceful, and comfortable, with excellence in art, architecture, green spaces, and a balance between environmental impacts. Compact, polycentric designs ensure residential integration, diversity, and public engagement. Aspects include:

- Green Architecture: Incorporation of plants in urban areas for green belts, sidewalks, rooftops, and walls to balance the advantages between urban and rural settings.
- Green Corridors: Urban plantations connecting cities with agricultural and forest outskirts, exemplified by Stuttgart and New York’s Central Park. This concept merges natural aesthetic charm with functional urbanism.
- Sustainability Benefits: While economic and social gains are realised, the focus remains on environmental benefits, such as sustaining natural processes and biodiversity while minimising urban impacts.

o The following is incorporated within the concept of green infrastructure:

Social Connectivity: Parks and gardens should be interconnected to maximise benefits for residents.

Environmental Biodiversity: Connecting land formations to sustain diverse ecosystems and reduce habitat fragmentation.

The multifunctionality of a network of green spaces, serving both present and future generations in harmony with urban design and natural processes, is promoted by this approach.

1- Green Space Sustainability in Response to Climate Change

Green open spaces are essential in urban ecosystems for mitigating climate change, providing benefits such as shade, air purification, rainwater filtration, and cooling through evapotranspiration, thereby creating more comfortable microclimates.

Findings include:

- Impact of Vegetative Cover: A computer model of Manchester shows that surface temperatures are up to 12.8°C lower in forested areas compared to city centres. Vegetative cover, along with good soil quality and humidity, significantly mitigates climate extremes (Handley, Pauliet, Gill, 2006).
- Functional Diversity of Green Infrastructure:
  - Large green spaces exceeding 10,000 m² provide significant cooling effects.
  - Blue corridors, such as rivers, serve dual purposes, including flood storage and temperature regulation.
  - Recreational and sports green spaces contribute to temperature regulation.
- Urban Green Spaces: Parks, gardens, forests, green corridors, water bodies, roadside trees, and private gardens enhance urban vegetation cover and play a vital role in mitigating climate change (Handley, Pauliet, Gill, 2006, pp. 184–187).

By integrating green infrastructure into land shaping and urban planning, cities can effectively tackle climate challenges while enhancing environmental, social, and recreational benefits.

2- Principles of Sustainable Urban Green Space Management

These involve a predominant trend towards formations using ground cover plants, surrounded by shrub masses. Sustainable management relies on the use and cultivation of plant species with local characteristics, capable of withstanding natural environmental conditions, often requiring minimal maintenance.

These plants are spatially appropriate and contribute to broader ecological integration. Sustainable management is often dynamic, as the goal is to preserve plants' self-formation and nitrogen recycling (Nigel Dunnett and Andy Clayden, 2006, p. 201).
The foundation of a sustainable approach to green space management always involves selecting species compatible with the site. This reduces the need for excessive costs associated with skilful site use and minimises long-term maintenance issues by leveraging plant specifications that align with site conditions, which is a crucial aspect of sustainable management design (Nigel Dunnett and Andy Clayden, 2006, p. 201).
Plants intended to provide shade for spaces beneath, for movement and sitting, such as those planted in median strips, should have branches at a height of approximately 250 cm, which can evolve aesthetically through adaptation to environmental conditions (Nigel Dunnett and Andy Clayden, 2006, p. 201).
To adopt a sustainable approach to green spaces effectively, the following mechanisms must be implemented, representing the appropriate policy regarding green spaces in the city. There are three fundamental stages to maintaining the urban nature of green spaces:

a. Planning and designing existing green spaces in the city, which were previously identified based on the city's fundamental designs, enriches urban centres with open spaces that enhance and improve existing environmental conditions.
b. Identifying future factors influencing the sustainability of green spaces in the city and striving to transform urban green spaces into new habitat environments.
c. Reviving and revitalising existing urban green spaces and habitat environments that may have deteriorated.

The value of this approach lies in preserving the vegetative value of existing green spaces firstly, repairing the damaged environment of green spaces secondly, and heading towards developing existing green spaces within the urban environment by utilising the concept of environmental communication and connection to enhance functionality, the fundamental principle of land-shaping environment. (Forman RT., 1997, p.112)

3- Contemporary Trends in Sustainable Cities

A. Eco-cities

Eco-cities strive to balance urban and rural areas by incorporating natural landscapes, green rooftops, and parks to enhance biodiversity and mitigate urban heat islands. They focus on sustainable living, renewable energy, and reducing carbon emissions. Terms such as 'green cities', 'low-carbon cities', and 'zero-energy cities' share the same principles of minimizing environmental harm. (Jianguo Wu EL, 2013, p.18)

Influences of the Eco-System: **POET**

Population (P): The number of city inhabitants.

Organization (O): Social structures within the city.

Environment €: Urban infrastructure and natural systems.

Technology (T): Innovations affecting the urban environment. (David M. Hassenzah *et al.*, *Environment*, 2012, p. 88).

Urban ecosystems prioritise reducing greenhouse gas emissions, promoting renewable energy, and encouraging green transport. Key elements include efficient waste management, sustainable industries, increased per-capita green spaces, and cultural heritage preservation. Strategies involve rainwater harvesting, maintaining air and water quality, and promoting green lifestyles. (David M. Hassenzah *et al.*, *Environment*, 2012, p. 88).

Strategies for Planning an Eco-City:

Flow Management: Efficient use of energy, water, transport, and waste.

Area Management: Development of diverse urban and suburban areas with biological and social diversity.

Player Management: Active involvement of local residents in eco-city initiatives. (David M. Hassenzah *et al.*, *Environment*, 2012, p. 103).

Eco-cities utilise parks, urban agriculture, green roofs, and living walls to enhance biodiversity and cool urban areas. Planting trees and increasing carbon storage improve CO_2 absorption while aligning with urban densification. A truly sustainable city requires a comprehensive, multidimensional approach that integrates environmental enhancement, biodiversity, and site-specific urban design. Technology alone is insufficient; strategic and qualitative planning is essential for achieving carbon-neutral cities. (Steffen Lehmann, 2011)

B. Other Contemporary Trends and Terminologies for Sustainable Cities:

1. Green Cities: Cities that prioritise environmental conservation, resource efficiency, and green infrastructure to promote ecological balance.
2. Blue-Green Cities: Cities that integrate blue (water) and green (vegetation) infrastructure to manage water resources effectively, enhance biodiversity, and improve urban resilience to climate change.
3. Zero-Energy and Low-Carbon Cities: Cities striving to minimise energy consumption and greenhouse gas emissions, either through renewable energy sources, energy efficiency measures, or both.
4. Liveable Cities: Cities designed to provide a high quality of life for residents, focusing on factors such as access to green spaces, cultural amenities, affordable housing, and safe neighbourhoods.
5. Resilient Cities: Cities equipped to withstand and recover from shocks and stresses, including natural disasters, economic downturns, and social disruptions, through robust infrastructure, effective governance, and community engagement.
6. Smart Urban Growth: Cities employing technology and data-driven approaches to manage urbanisation sustainably, improve infrastructure efficiency, enhance public services, and foster innovation.

Whether termed sustainable cities, eco-cities, low-carbon cities, or smart cities, they all strive for a healthy and safe environment for all residents. They share core characteristics of sustainable development, including reduced energy consumption, minimal encroachment on environmental and natural landscapes, and increased use of eco-friendly building materials and waste management systems.

C. Key Elements of Different Trends in Sustainable Cities:

Although each city must tailor its approach according to local and cultural specificities, there are common elements that underpin various trends in sustainable urban development. The fundamental elements include:

1. Low Environmental Impact and Climate Change Mitigation: Developing cities in a way that minimises environmental degradation and mitigates climate change

effects. This involves innovative waste recycling and management techniques, as well as utilising renewable energy resources.

2. Inclusive Development for Residents: Urban planning should encompass all residents, including mechanisms to uplift the poor and marginalised.
3. Resilience Building: Cities must anticipate and prepare for shocks and hazards, including natural disasters. Building resilience helps ensure the safety and well-being of people and maintains robust infrastructure.
4. Cultural and Historical Preservation: Recognising the cultural and historical value of cities and incorporating them into planning and development strategies. Examples like Melaka in Malaysia demonstrate the importance of preserving historical neighbourhoods, as shown in Figures 2-24 (A, B), and 2-25. (UNCTAD 2015, p. 7)

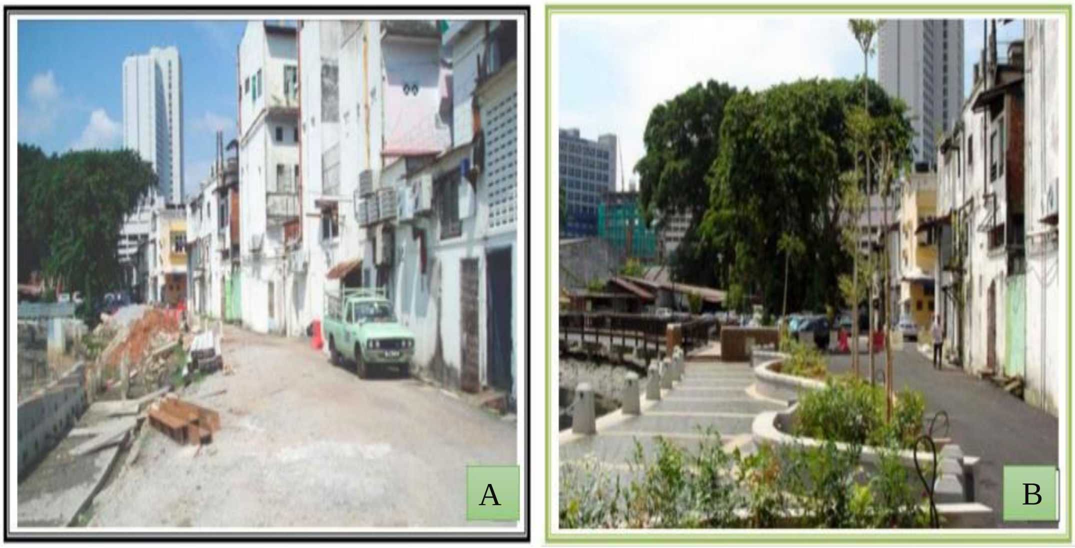


Figure (2-21 A, B): Melaka City in Malaysia before and after area development, transforming it into a vibrant city. (Source: The researcher relied on the Asian Development Bank (ADB).

5. Green Spaces and Walkability: Designing cities to include ample green spaces and prioritising pedestrian-friendly infrastructure. This entails moving away from car-centric urban layouts, which are common in developing cities. Singapore, as shown in Figure 2-22, serves as a prime example of a city effectively addressing environmental issues. Considered the greenest and most tree-covered city in Asia, Singapore’s significant shift towards public transport earned it the title of a green

city. In addition, it boasts the lowest water consumption among Asian countries. This green shift is complemented by a green lifestyle adopted by both the government and its citizens, contributing to the preservation of a healthier environment.

Figure 2-22: Singapore city in Asia, serves as a good example of a city effectively (http://www.gardensbythebay.com.sg/en.html).

2.2.4. Principles of Designing an Integrated System of Green Spaces with Environmental Landscapes

Designing a network for a cluster of adjacent and repetitive ecological systems in a similar format over an area of miles with clearly recognised boundaries from the land. Examples of environmental landscapes include desert landscapes, wetland landscapes, marshland landscapes, cultivated landscapes, and suburban landscapes, connected by buffer zones of natural or aquatic areas with recreational, cultural, or natural attributes linking various open areas and containing a density of greenery contributing to the visual perception of the city.

A. <u>Principles of Designing a Landscape Network</u>

The principles of designing a landscape network, as outlined in Landscape Ecology Principles, organise design ideas into four key components:

• **Patches:** Homogeneous areas with similar ecological conditions or land cover.

• **Edges and Boundaries:** Transitional zones between patches**.**

• **Corridors and Connectivity:** Linear features enabling movement and ecological interactions between patches.

These principles ensure effective connectivity, mitigate development impacts like traffic noise and habitat disruption, and enhance the quality of green environments in urban areas. (Landscape Ecology Principles in Landscape Architecture and Land-Use Planning, 2010).

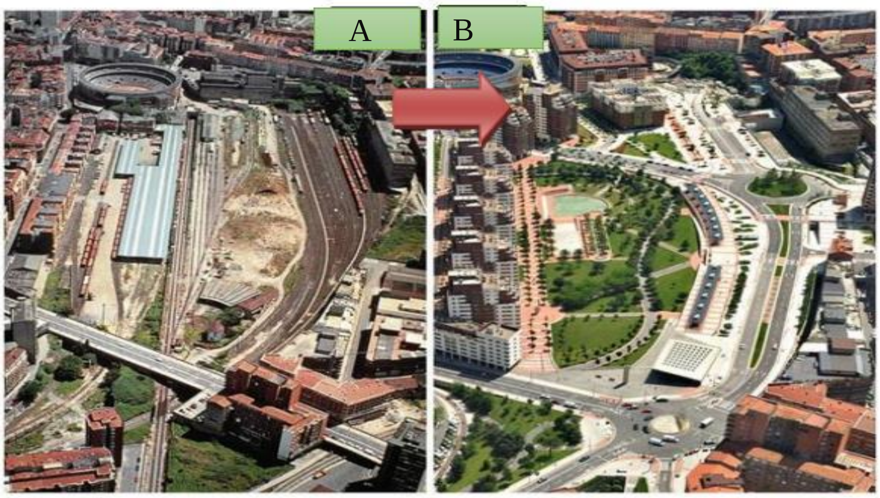
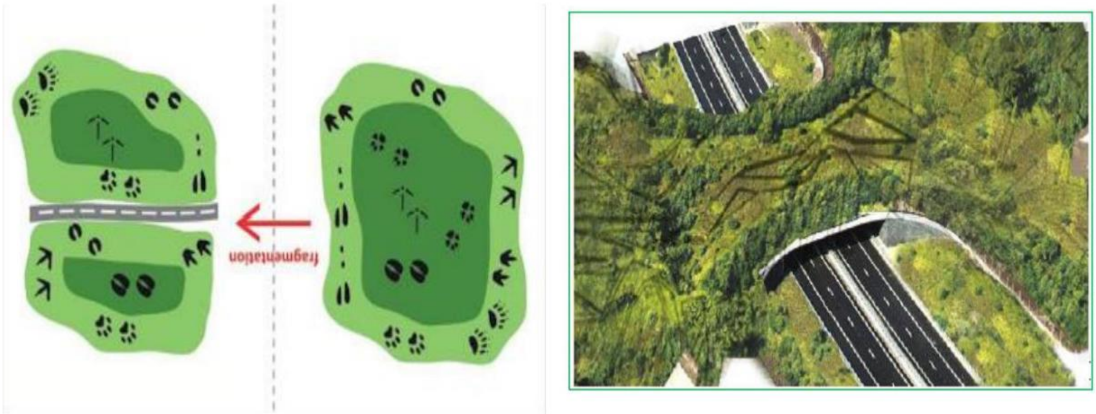


Figure 2-23: Green infrastructure projects for urban renewal at the urban level in Zaragoza, Spain. Source: (Greening the Grey, Green Hubs and Corridor, December 2013, p.13).

In Figure 2-23, the constituent elements of the green infrastructure network and the connectivity that is fundamental to its design are illustrated, while Figure 2-24 depicts the strategy of environmental corridors implemented in significant ecological areas to mitigate the negative impacts of development, such as traffic noise and disruption of wildlife habitats.

Maintaining tranquillity and serenity is crucial in green environments, providing psychological benefits and enhancing the overall quality of urban areas. Therefore, measures are taken to minimise the visual and auditory impacts of urbanisation by planting more trees and greenery. (Source: *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning*, 2010)



Figures 2-24: illustrate the constituent elements of the green infrastructure network and the connectivity that is fundamental to its design (Wildlife Overpasses in Banff National Park, Canada).

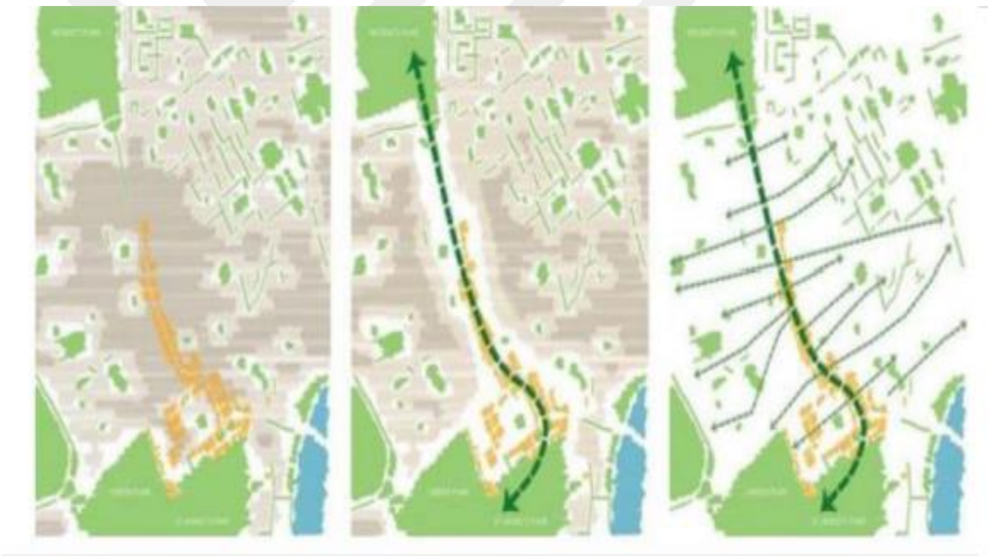


Figure 2-25: illustrates the implementation of environmental corridors in important ecological areas (Source: "Greening the Grey, Green Hubs and Corridors," December 2013, p. 13).

In Figures 2-26 (A, B), the application of landscape ecology principles across a wide range of scales is demonstrated, from large regional areas to small-scale site levels. These principles are applied and influenced according to the scale of the project as follows:

1. Regional Scale (Macro or Regional Scale):

- National parks and regional conservation areas

- New suburban development projects

2. Landscape Scale (Meso or Landscape Scale):

- New highways
- Urban parks

3. Site Scale (Micro or Site Scale):

- Group of gardens, backyards
- Wildlife corridors and movement pathways.

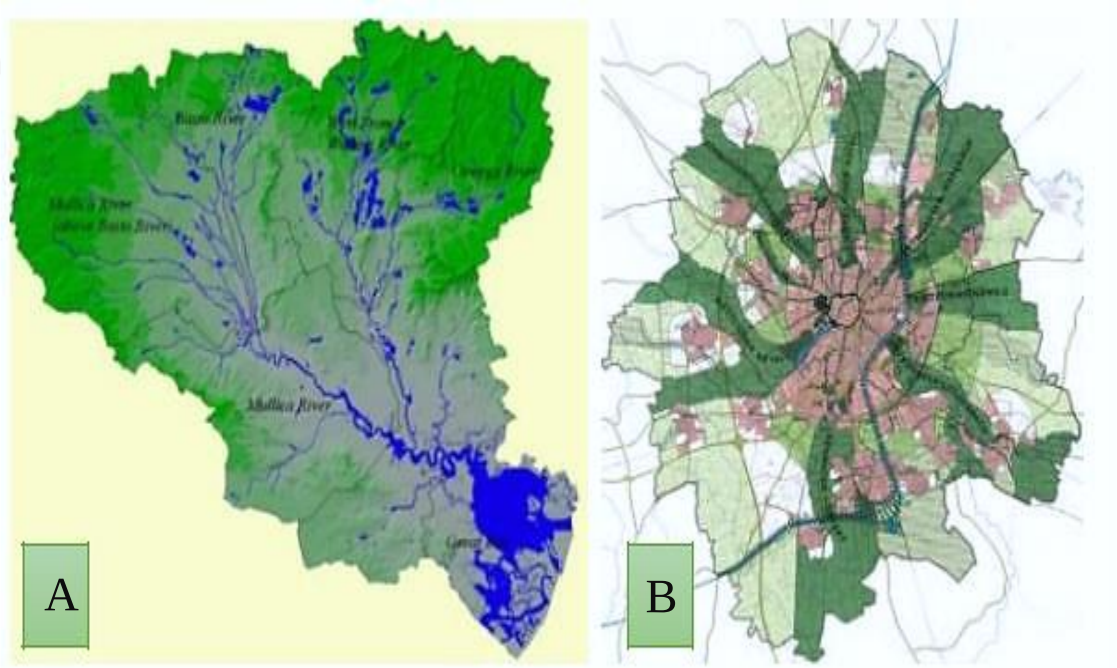


Figure 2-26: applies the principles of ecological landscape design at multiple levels. A wide range of scales (Mallika River Basin Map) Source: (Greening the Grey, December 2013, p.15).

1. Local Development Plan for the City of Aberdeen: Inclusion of One of the Prominent Applied Examples of the Green Network

This strategic network connects various habitats, species, and urban and rural green spaces to each other and to surrounding communities, benefiting biodiversity and providing a wide range of advantages. Aberdeen’s Green Space Network consists of three main components:

1. Cores: Large or primary green spaces.

2. Links: Existing or desired corridors connecting green spaces, such as main pathways, water bodies, and wildlife corridors.
3. The Stepping Stones are isolated green spaces that may be challenging or unsuitable to connect to the rest of the network and continuous green corridors.
However, they still offer opportunities to provide the benefits of the green network and infrastructure. Aberdeen’s open space strategy sets a new vision aimed at enhancing the quality of open spaces. It is based on the results of a comprehensive audit of open spaces conducted by the city in 2010.
This initiative has made Aberdeen a better place for current and future generations to live, work, invest, and study. Please refer to Figure 2-30 for further details: [*https://www.aberdeencity.gov.uk/*].

Figure 2-27: presents Aberdeen City's Green Spaces Network Strategy. For more Information.

B. Strategies for Enhancing and Increasing Green Spaces in Cities

The growth of urban populations places a strain on green spaces, necessitating strategies to promote and expand them.

1. The Concept of Urban Greening

Urban greening focuses on preserving urban vegetation while creating artificial ecosystems around water bodies and embankments alongside natural landscapes in cities. The concept incorporates urban forests, street tree plantations, living walls, green roofs, and small green spaces in dense urban areas. It emphasises introducing greenery even in limited spaces. (Yusof Mohd, Johari Mohd, 2012, p. 21)

- Benefits of Urban Greening:

1. Cooling and Energy Efficiency: Living walls and shade trees reduce energy needs for cooling and heating. A 10% increase in tree cover can reduce energy consumption for these purposes by 5–10%.
2. Climate Mitigation: Green landscapes help moderate temperatures, manage heavy rainfall, and prevent flooding, especially in coastal areas.
3. Environmental Benefits: Public parks and green areas function as ‘green lungs’, purifying air and water, providing habitats for wildlife, and offering recreational spaces.
4. Innovative Solutions: Materials like ‘green concrete’ absorb atmospheric carbon, contributing to resource-efficient urban environments.

By integrating these approaches, cities can promote ecological balance, reduce urban heat, and enhance quality of life (Mohd. Johari Mohd Yusof, 2012), as show in Figures 2-28, 2-29, and 2-30.

Figure 2-28: The Verdant Skyline: Bosco Vertical (Vertical Forest) by Stefano Boeri in Milan, Italy, 2009. Two high-rise residential buildings covered with as much vegetation as possible. Source: (Cities Alive, Arup, 2014, P.7).

Figure 2-29 Vertical/Ecological System in Spain: Providing habitat in dense urban environments using creative space design adds value to urban wildlife.

Figure 2-30 Urban Greening in Bilbao, Spain: Greening of the railway track. https://www.trackopedia.com/en/encyclopedia/infrastructure/superstructure/track-greening

2. Greening Previously Developed Brownfield Land:

Enhancing sustainable development and improving the quality of life in urban areas have been issues that have gained widespread political support for the clean-up and redevelopment of underutilised sites in urban areas, known as brownfield land. However, there has been increasing recognition among local communities and environmental organisations of the immense potential to 'green' polluted sites to enhance urban environments by implementing parks, playgrounds, pathways, and other open spaces. (Andreas Schulze Baing, REAL CORP, 2011, p. 4)
The redevelopment of previously developed and vacant brownfield lands helps curb urban sprawl and address the shortage and housing deficit in new residential units. (*100 Facts about Urban Nature*, 2012, p. 4).

3. Rooftop and Terrace Gardening

Sustainable urban areas are not necessarily those with the largest open spaces. This can be achieved through streets, parks, terrace gardens, window boxes, and even rooftop gardens.
Green roofs provide significant benefits, such as stormwater management, carbon sequestration, thermal insulation, and pollution reduction. Studies in Berlin reveal that green roofs absorb 75% of rainfall. Additionally, they offer various benefits including UV protection, thermal insulation, and enhanced comfort for residents. (Hamin, E. M. & Gurran, N., 2009, p. 230)
Green roofs and green walls are integrated into building designs. Figure 2-36 illustrates concepts for utilising rooftops in the city of Beirut. (Hamin, E. M. & Gurran, N., 2009, p. 230)
By utilising brownfields and rooftops, cities can maximise opportunities for urban greening, thereby enhancing environmental sustainability and urban liveability.

Figure 2-31: Addresses the problem of the shortage of green spaces in the city of Beirut from the previous source.

A. Madrid has embraced nature-based solutions to tackle urban challenges such as pollution, heat islands, and biodiversity loss, particularly addressing the constraints of limited horizontal space through vertical and innovative approaches.

- Vertical Green Landscapes: Madrid repurposes unused solid façades into green walls that purify air and sound, regulate temperatures, and protect buildings from harsh weather. While maintenance can be costly, strategic plant selection and reuse of existing structures help reduce expenses. (Figure 2-39)
- Sustainable Roofing Solutions: Green roofs with plants and trees offer multiple benefits, including temperature reduction, insulation, stormwater management, and support for biodiversity. Rooftops are utilised for urban farming, beekeeping, or solar panel installations, contributing to sustainability and energy efficiency. Reflective white rooftop coatings provide a cost-effective solution for mitigating summer heat.
- Biotope Area Factor (BAF): The BAF index combines urban planning with natural environments, ensuring a minimum percentage of vegetated spaces. This approach balances green infrastructure with high urban density, supporting development while conserving natural resources.
- Community and Biodiversity Enhancements: Green bridges and tree-lined streets improve living standards, foster community connections, and reduce pollution. Initiatives such as river restoration, permeable sidewalks, pocket parks, and urban farming enhance water absorption, limit runoff, and create spaces that support recreation and biodiversity.

Madrid effectively addresses urban environmental challenges by integrating vertical solutions, sustainable roofing, and community-driven green projects (Arup’s Vision of the Spanish Capital: Painting Madrid Green).

Figures 2-32 depict the development project for the capital of Spain, Madrid Natural, which consists of a series of guidelines on how to address the issue of global climate change from a local perspective. Source: (Arup's Vision of the Spanish Capital: Painting Madrid Green).

B. Project banks of the Huang River in Shanghai Sustainability study Development

The Albnand region in the city of Shanghai, established in 2007 with a global colonial basis and spanning 1500m, called for a global design competition to develop the defining features for this part of the city. The award was won by the design of Chinese architect Zhan Greves Cinevigs.

Figure 2-33 the use of trees in the project to develop the banks of the Hawa River NG for shading purposes in Shanghai

Figure 2-34 increasing the width of the platform and reducing the number of car lanes it gives a sense of security in Shanghai

Project features:

- <u>Narrowing the Road and Widening the Bank:</u> Reducing road widths and expanding banks prioritise pedestrian safety and create open public spaces, fostering a welcoming, secure, and accessible environment for everyone. (Xin Min, 2011).

- <u>Cultural Integration:</u> Incorporating cultural elements enhances the unique identity of the site. This includes modifying traditional structures, such as compounds, to reduce their dominance and harmonise them with the surrounding landscape. (Xin Min, 2011).

- <u>Expanding Open Space:</u> Increasing open areas enhances safety and accessibility, offering opportunities for social interaction and recreational activities. Public roads are narrowed, and intersections are designed with pedestrian safety in mind. (Xin Min, 2011)

Figure 2-35 Using plants for aesthetic and environmental purposes and to provide shade in Shanghai.

- <u>Elevated Pathways for River Interaction</u>: Separating pedestrian pathways from road levels enables safe and interactive engagement with the riverfront, offering visual and physical experiences. (Xin Min, 2011).
- <u>Linking Visual and Movement Axes:</u> Aligning visual connections with movement paths creates focal points and adds aesthetic diversity to different sections of the project. (Xin Min, 2011).

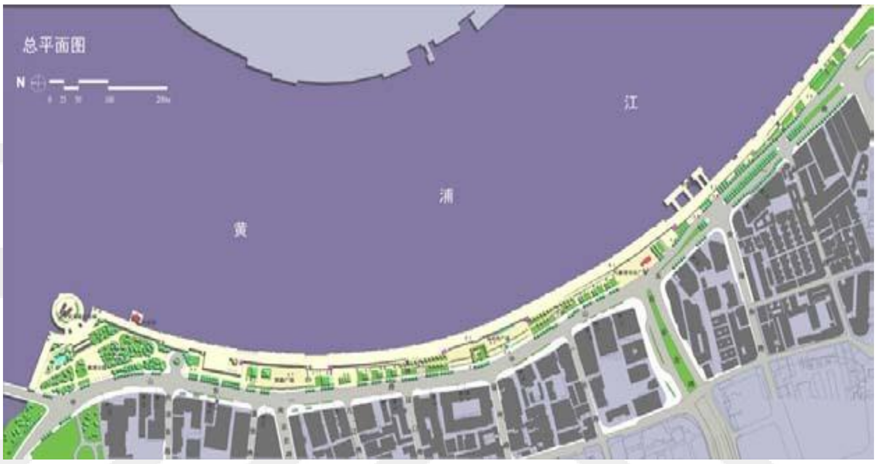


Figure 2-36 of the relationship between visual axes and movement axes to create focal points Focus mast in Shanghai.

- <u>Utilising Riverfront Spaces:</u> Platforms and walkways are designed to integrate with the riverfront, facilitating continuous interaction between land and water across various levels. (Xin Min, 2011).

- <u>Spatial Identity and Aesthetic Enhancement:</u> Local environmental elements are used to give spaces a distinct identity. Vegetative barriers and landscaped areas mask unsightly features and create natural separations between pedestrian and vehicular zones. (Xin Min, 2011).

Figure 2-37 an aerial view of the project area in Shanghai.

Figure 2-38: the meeting point of the city’s two rivers, where a mural was created the project icon represents in Shanghai.

Figure 2-39: Expanding the platform space by flying over the river without cross his path in Shanghai.

2.2.5 Strategies for Developing and Expanding Green Spaces Adopted in This Research

1. **Urban Planning Level**

A. Urban Greening Concept: Parks and green areas improve air and water quality, support biodiversity, and provide recreational spaces.

- Cooling and Energy Efficiency: Living walls and trees reduce energy needs for heating and cooling by up to 10%.
- Innovative Solutions: Materials such as 'green concrete' absorb carbon, promoting resource-efficient urban environments.
- Climate Mitigation

B. Rooftop and Terrace Gardening: Rooftop gardens and green walls provide environmental benefits, including stormwater management, carbon sequestration, UV protection, and thermal insulation.

- Utilising rooftops and terraces maximises the potential for urban greening, particularly in densely populated cities.

C. Greening Previously Developed Brownfield Land:

- Brownfield sites – underutilised or polluted urban areas – can be transformed into green spaces, such as parks, playgrounds, and pathways.

2. **City Level**

- Establish hierarchical systems for green spaces and connect them through green infrastructure networks.
- Establish green belts, restore degraded areas, and plant trees along streets.
- Reduce urban sprawl and encourage vertical development to provide shading and cooling.

3. **Neighbourhood Level**

- Use local, climate-appropriate vegetation to reflect the city's identity.

4. **Individual Household Level**

- Make use of vacant spaces, rooftops, and exterior walls for planting.
- Use sustainable, locally sourced materials to reduce resource consumption.

2.2.6. Conclusion and Insights from Chapter 2

This chapter examined existing literature and highlighted the growing recognition of the importance of green spaces within urban environments to enhance residents' quality of life. A significant body of empirical research was presented, demonstrating that green spaces contribute not only to the city's economy and social prosperity but also to general well-being. These spaces have proven benefits for improving both physical and mental health, alleviating pollution, and enhancing air quality. Additionally, the data underscores that green areas play a crucial role in preserving urban biodiversity, offering ecological services that support the city's environmental health. As the global movement towards sustainable urban development grows, green spaces are increasingly being viewed as vital infrastructure—on par with essential services like transport. This shift underscores the importance of integrating green infrastructure into urban planning to provide long-term benefits for cities and their residents.

Open spaces can be defined as all non-built areas that are open to the sky, meaning they are not enclosed or covered by any roofs. If these spaces are planted with vegetation, they are referred to as green open spaces; if the ground is paved or covered with other finishing materials, they are simply called open spaces. When these areas are located within an urban environment, they take on urban characteristics. Based on the above, the following conclusions can be drawn:

1- General Specifications of Open Spaces:

a) They include all non-built land areas, whether inside or outside cities, whether surrounded by fences or not.

b) They represent the initial state of spaces because construction arises from open spaces.

c) They vary in nature, ranging from deserts, mountains, and Waterways like seas, and also vary in appearance from green spaces to barren lands and paved or cemented areas.

d) Open spaces acquire urban characteristics if they are within cities or green characteristics if they are planted with vegetation.

2- Urban Open Spaces can be defined as:

All areas within cities except those designated for building construction. When agricultural characteristics predominate in this space, it is given the green attribute.

Specifications of Urban Open Spaces are:

a) All urban areas with low building densities.

b) Open spaces serve purposes such as transport, gathering, recreation, etc., that are needed by city residents for daily life.

c) They are characterised by grey for transport-related areas like streets and squares, and green for recreational areas and riverbanks.

3- One of the reasons for the imbalance in urban environmental equilibrium is the scarcity of green spaces, as well as the inadequate allocation per capita at the neighbourhood and city levels. This exacerbates issues such as high summer temperatures, dust, and winter floods globally. Furthermore, the degradation of green cover and the significant reduction in genetic diversity and distribution of living species lead to the instability of green areas and zones within cities.

4- Green belts around cities represent natural areas that serve as protection against pollution, in addition to contributing to biodiversity compensation for built-up areas. The fundamental concept of the green infrastructure network lies in connecting public parks, urban forests, and other green spaces through a hierarchical gradient of tree-lined streets and squares, starting from residential neighbourhoods and extending to the city's green belt. This network also includes waterways and riverbanks, creating a cohesive urban green infrastructure system.

5- Green Urban Open Spaces can be defined as:

All land areas in the city with agricultural characteristics that have not been designated for building construction, intended for sports facilities, waterways, and water bodies. Thus, we can specify the general characteristics of green urban spaces as follows:

a) They include all areas that can be cultivated and turned green.

b) They are accessible safely.

c) They are capable of achieving visual communication when passing nearby.

d) They include water feature spaces such as riverbanks that can be cultivated.

Green Spaces	Specification
Small Park	It refers to small-sized parks within residential neighbourhoods surrounded by buildings. These parks may feature fountains and water features.
Neighbourhood Park	It refers to a park located centrally within a residential area. Its size depends on the population of the neighbourhood and the maximum distance from residential units. It may also include recreational activities and sports facilities.
Quarter Park	It refers to a park designed to serve the residents of a specific residential area. It includes large green spaces for various recreational and sports activities. Its size is determined by the number of residents in the neighbourhood, and its distance from residential units does not exceed 2 kilometres.
Sector Park	It is located within an important area of the residential sector. It is characterised by its spaciousness and the variety of recreational and sports activities it offers. These parks may be developed from historical, traditional, or newly developed parks.
Central Park	It is a large open space area developed and managed by public authorities. It contains the most recreational activities and occupies a strategic location within the city.
Watercourses and Waterways	They include waterfronts, riverbanks, lake shores, and wetlands that can be planted with vegetation and trees.
Green Corridors	They refer to streets where sidewalks and median strips are planted with vegetation, giving the street a green character due to the density of tree foliage.
Cemeteries	Cemeteries are places for burying human remains and are considered urban open green spaces due to the limited built-up areas within them and their potential for planting vegetation.
Botanical and Zoological Gardens	They include nurseries, agricultural research centres, plant propagation areas, and are characterised by their agricultural nature. They also encompass animal breeding enclosures, pathways for movement, and are characterised by a lower ratio of built-up areas and an increased ratio of cultivated and open spaces.
Green Belt	It includes cultivated areas surrounding the city.

Types of Green Urban Spaces: refer to Table 2-6 for the types of green spaces in the city **(Researcher's work).**

6- Providing a well-distributed network of open public spaces, attractive pedestrian pathways, and natural areas within neighbourhoods, along with community units offering a variety of recreational and sports activities, and playgrounds, is challenging in rapidly growing urban capitals. High population densities and poor planning and management often lead to encroachment on public spaces, rendering them severely limited and unplanned.

7- One of the reasons for urban environmental imbalance is the lack of green spaces, as well as the decline in per capita allocation at the neighbourhood and city levels, or the unequal distribution of these spaces. This exacerbates global issues such as high heat and dust in the summer, and floods in the winter. Additionally, the degradation of green cover and the significant decline in the diversity and genetic distribution of biological species lead to the impermanence of green spaces and areas in cities.

8- Green belts around cities serve as natural areas that provide protection from pollution while also supporting biodiversity. They contribute to enhancing the quality of the environment, which in turn positively impacts people's quality of life. The fundamental concept of a green infrastructure network lies in the integration of public parks, urban forests, and other green spaces across all hierarchical levels, from small residential parks and neighbourhood green spaces to the city's green belt. Additionally, waterways and riverbanks play a crucial role in establishing and connecting the urban green infrastructure network.

9- Providing a well-distributed network of public open spaces, attractive pedestrian walkways, and natural areas within neighbourhoods, along with neighbourhood units that offer a variety of recreational activities, sports facilities, and play areas where social life can thrive, is particularly challenging in rapidly growing urban capitals. High population densities, coupled with poor planning and management, often result in the encroachment on public spaces, making them scarce and inadequately planned.

10- The change in land use and land cover due to urban expansion has significant environmental repercussions and presents a major challenge to achieving environmental sustainability at both local and global levels. It is a key driver of global environmental change, impacting Earth's systems. Prevailing global changes are closely linked to deforestation, desertification, biodiversity loss, food insecurity, climate change, carbon emissions, and other consequences of unsustainable land use and practices.

11- The presence of green areas has become a necessity and a key strategy for promoting healthy lifestyles by providing accessible recreational and green spaces. It is also a standard of well-being for city residents. The aim is to foster social capital and create a sustainable, vibrant green city that supports environmental compatibility and resilience. The green system plays a crucial role in balancing and stabilising urban ecosystems while addressing economic demands and preserving the spirit of the place.

CHAPTER 3. GREEN URBAN SPACES IN BAGHDAD: A PRACTICAL STUDY – ANALYSIS OF ABU NAWAS STREET, BAGHDAD (OLD RUSAFA), THE SELECTED LOCATION

This chapter discusses the impact of temperature changes before and after the addition of green cover using sustainable solutions, as mentioned in the previous chapter, leading to thermal comfort in the selected study area, Al-Rusafa, which is affiliated with the First Municipality of Al-Rusafa, for the period from 2003 to 2024. In the context of applying theoretical framework indicators to elucidate the impact of changes in land use and their effects on the urban and natural environment, green spaces, and society, the study utilises both quantitative and qualitative data. It also considers key indicators for analysing and identifying response mechanisms and policies that directly or indirectly contribute—positively or negatively—to changes in the urban environment.

Furthermore, the research proposes a set of strategies aimed at achieving two main objectives:

A. Applied Study: This involves testing research indicators within the study area, defined by the historical boundaries of Al-Rusafa Municipality in Baghdad, from 2003 to 2024. It explores the restructuring of green spaces and their impact on design, management, and long-term sustainability. The study emphasises design improvements aimed at fostering inclusivity and cultural relevance for local communities.

B. Impact on Micro-Urban Climates: This section analyses how urban spaces in Baghdad influence local microclimates and urban heat islands. It focuses on assessing temperature variations, air quality improvements, and differences in energy consumption between areas with high and low green cover.

The study proposes strategies to address these objectives, enhancing the sustainability and effectiveness of green urban spaces in Baghdad.

3.1. Baghdad and the Historically Chosen Area

1- Historically

Baghdad is distinguished as one of the world’s cities with a prominent presence in literary and human history. Even before the Islamic conquest, it held a unique position across various historical epochs. Initially, it comprised small settlements and scattered villages within a vast agricultural landscape. The city of Baghdad, incorporating several of these settlements, was chosen by Abu Ja’far al-Mansur for its strategic location within the region of Al-Karkh, amid a cluster of flourishing villages at the time (Dr. Mustafa Jawad *et al.*, 1969).

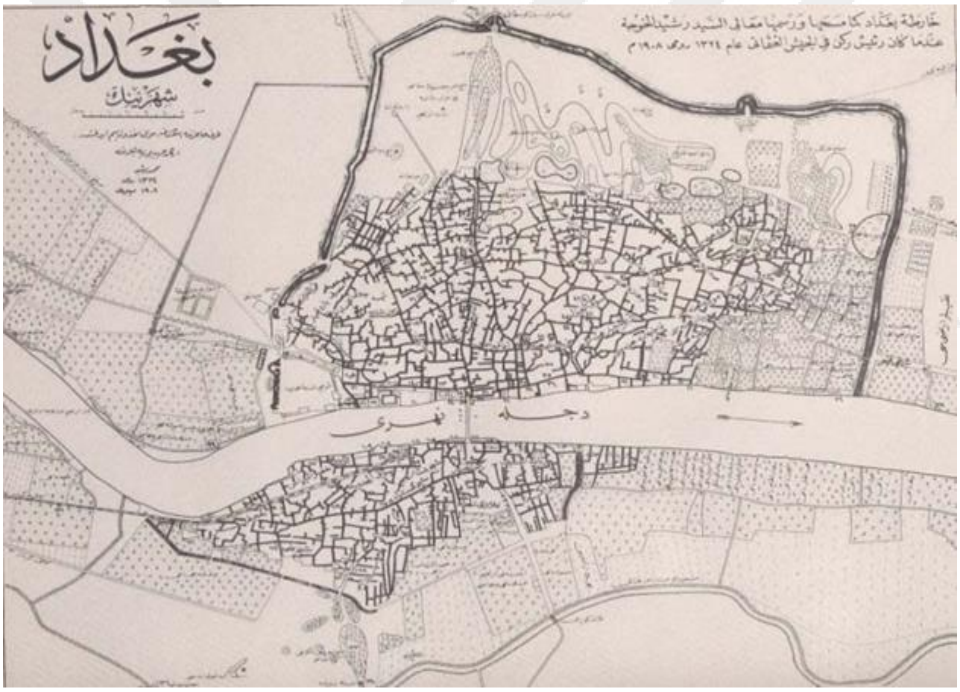


Figure 3-1: Survey map prepared by Rashid Khooja in 1908, showing the open spaces between the populated area and the walls of Al-Rusafa.

This suggests that Baghdad initially emerged within an agricultural environment surrounded by open green spaces. As the city expanded, the eastern side, known as Al-Rusafa, was developed and eventually became the historical centre of Baghdad. Due to the migration of caliphs to this area and its gradual development, Al-Rusafa was eventually enclosed from the east, restricting its urban environment and separating it from the surrounding green open spaces.

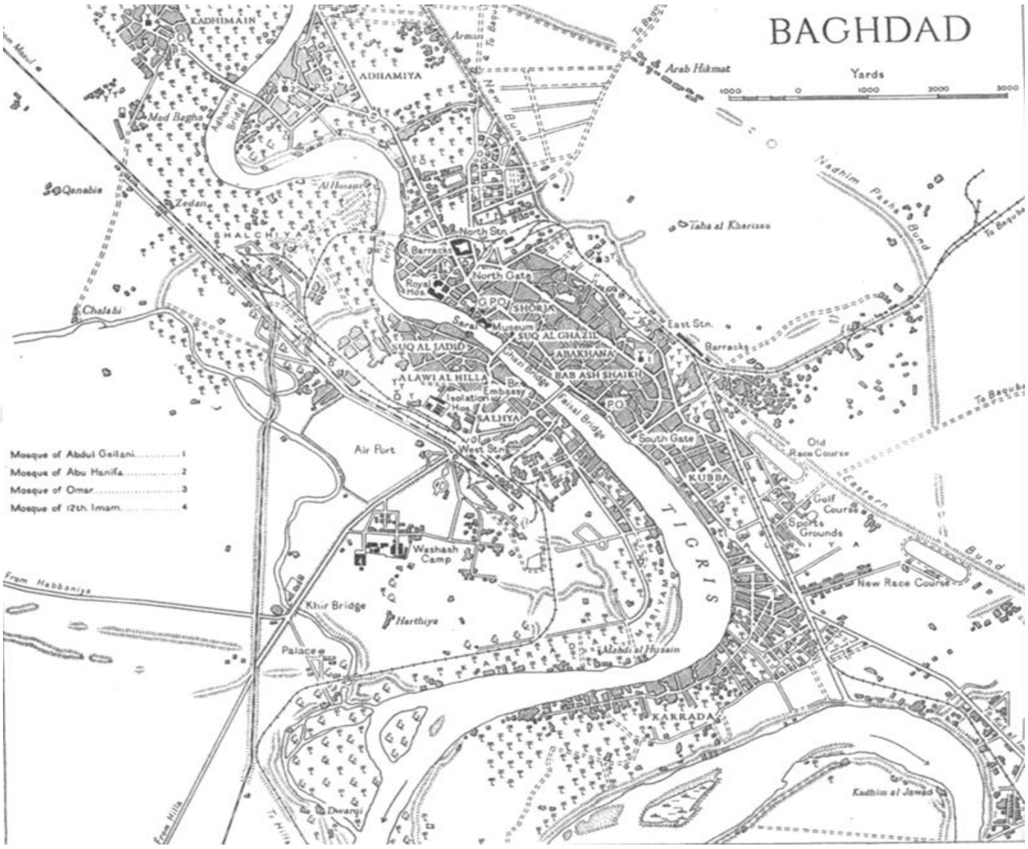


Figure 3-2: Baghdad city in the forties, showing the connection between the cities parts (Al-Rusafa and Al-Karkh) through a series of thoroughfares while agricultural uses remained between them (Ali Nouri, 1986, p. 66).

2-The development of green urban spaces in the city of Baghdad during the Twentieth century

A. Master Plans for Baghdad City

The city of Baghdad has undergone the development of several master plans, beginning with the initial design formulated by the Mino Bureau in 1956. However, these designs faced criticism, rejection, or identification of shortcomings in certain aspects, necessitating the creation of revised plans to address previous errors, fulfil emerging requirements, and better accommodate the city and its inhabitants. These plans include:

1. Mino Bureau and Associates' Basic Design for Baghdad City (1956).
2. The Basic Design by the Doxiadis Foundation (1959).
3. The Basic Design by the Nonservice Foundation (1967).
4. The Comprehensive Development Plan for Baghdad City 2000 by the Polservice Foundation (1973).
5. The Integrated Development Plan for Baghdad 2001 by the Japanese JCCF Foundation (1987).
6. Baghdad Urban Development Project 2015 by the College of Engineering, University of Baghdad (1998).
7. The Comprehensive Development Plan for Baghdad City 2030 by the Khateeb & Alami Office (2009-2010).

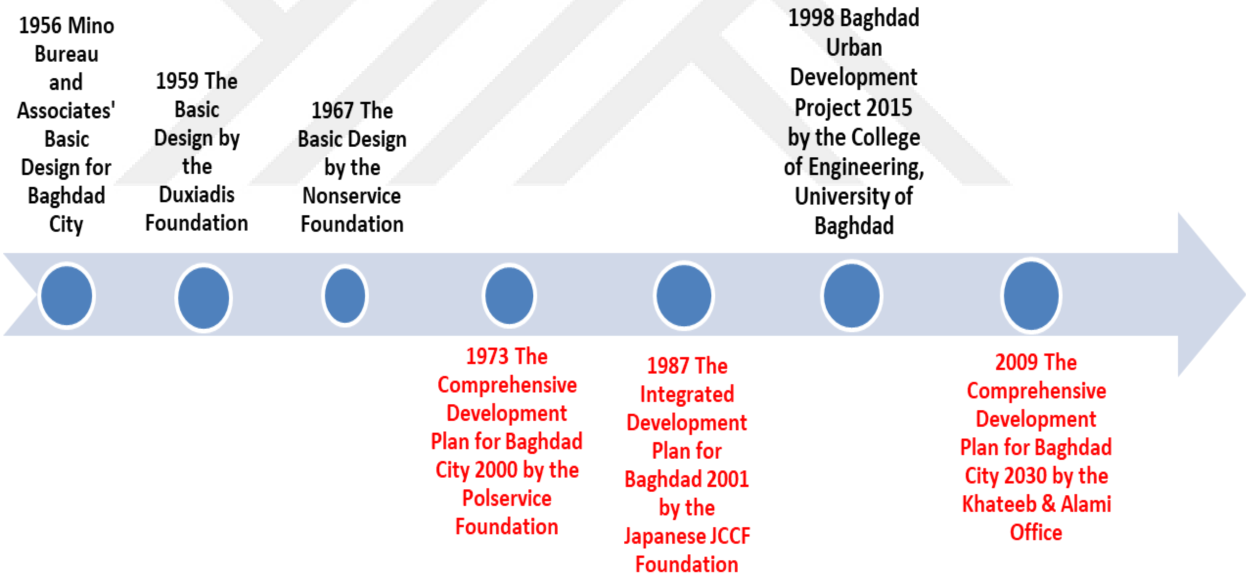
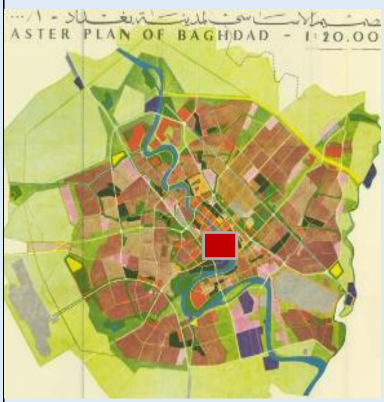


Figure 3-3: Timeline of Studies

By analysing the growth and development of green spaces in the city through the lens of all design trends, it becomes evident that the basic designs prepared for Baghdad city have varied in their approach to incorporating green spaces. The designs have evolved based on the needs and development objectives of each era. To explore how these plans addressed green spaces, three key studies were selected, which contributed significantly to the changes in the urban landscape of Baghdad. These studies are summarised in Table 3.1.

Plan	Proposed Standards	Key Directions	
Comprehensive Development Plan and Urban Landscaping Prepared By : **Polservice Consulting Engineers 1973**	1. Hierarchical park system: - Neighborhood Park: 4.00 m²/person - District and Sector Park: 8.00 m²/person - City Park: 28 m²/person (12 m² private gardens) 2. City-Level Park: 2.00 m²/person 3. Green belt: Depth of 10 km (density standard: 1.21–0.81 m²) 4. Establishment of a botanical garden and zoo 5. Construction of a cemetery outside urban areas	- Utilize existing green spaces - Proposal for extensive green belts and public parks - Focus on creating hierarchical green spaces	■ Study Area 
Integrated Urban Development Plan Prepared By: **Japanese Company (JCCF) 1987**	1. Reduce park standards: - Neighborhood Park: 3.00 m²/person - District and Sector Park: 6.00 m²/person - City Park: 2.00 m²/person 2. Reduction of green space standards outside the city by 20% 3. Actual green space standard (excluding private gardens): 16 m²/person (total of 10.2% of urban area) 4. Connect city edges to its center with green corridors 5. Strengthen green space axes through large green spaces	- Reduce green space standards - Enhance connectivity of green spaces - Green corridors to integrate urban and suburban areas	■ Study Area  
Comprehensive Urban Development Plan for 2030 Prepared By: **Khateeb & Alami Office 2012**	1. Redevelopment of existing green spaces 2. Integrated urban green infrastructure plan 3. Regulations for sustainable management and maintenance of green spaces 4. Restoration of degraded green cover, urban forest canopy, and streetscape 5. Transformation of green spaces into multifunctional infrastructure to evaluate sustainable performance	- Redevelop green spaces - Enhance biodiversity and mitigate urban heat island effect - Focus on sustainability and ecological integration	■ Study Area  

B. Proposed Strategies to Enhance Green Spaces in Baghdad According to Future Studies by Khatib and Alami 2010–2030

1. Exploiting vacant and abandoned lands for parks and recreational spaces, including reusing areas expected to become vacant, such as Al-Muthanna Airport and Al-Shalajiya railway lines.
2. Rerouting the circular railway and reallocating Green Belt areas westward, outside the boundaries of the 1971 Master Plan, to create green open spaces.
3. Protecting green spaces and existing agricultural lands within the city limits.
4. Moving the green belt to the west of Baghdad Airport and proposing a segmented green belt east of the Diyala River.
5. Exploiting the Tigris River and its banks for recreational and transport purposes.
6. Promoting projects such as floating restaurants and interconnected green spaces along the river and canals, including the Army Canal.
7. Developing distinctive entertainment projects on Baghdad Island and Wedding Island.
8. Transforming Al-Rashid camp into a sports city, as shown in Figures **3-4** and **3-5**.

These strategies aim to transform Baghdad into a modern, sustainable, and green city, balancing urban growth with environmental preservation.

Figure 3-4: a proposal to change the location of the green edge of the city of Baghdad outside Green belt areas (Al-Khatib and Alami’s Office, 2012, p. 19).

Figure 3-5: the design proposed by the Khatib and Alami Office (Al-Khatib and Alami's Office, 2012, p. 19).

- Study Area

Table 3.2 presents another indicator of the standard of green spaces in the study area, considering the diversity and population growth.

Source	Approved standard according to development studies and urban development planning	Standard actually achieved according to the actual situation	Population growth	Population	Year
Basic design of the city of Baghdad, developed by the Polservice Foundation / JCCF	14.0	----	2.7	----	**1978**
Implementation Report of Residential Studies (MOL)	12	5.10	3.1	113	**1990**
Dr. Mohammed al-Badri - 2013	12	3.04	3.2	220	**2013**
Results of the field survey on the reality of the situation by the researcher	9-16 Suggested	2.3	----	350	**2022**

3- Analysis of the Factors Contributing to the Deterioration of the Reality of Green Spaces in Baghdad

1. **Legislative Issues**:
    - Before 2003: Policies prioritised residential and commercial construction over preserving green spaces.
    - After 2003: No new laws or regulations were introduced to protect or expand green spaces, leading to continued neglect.
2. **Administrative Challenges**:
    - There are no effective laws to prevent damage or misuse of green spaces.
    - Projects to expand green spaces have not been implemented, with plans only discussed for the future.

3. **Urban Planning Issues**:
   - <u>Incomplete Plans</u>: Urban designs lacked continuity, as each plan failed to build upon the previous one.
   - <u>Conflicting Standards</u>: International green space standards vary by region, but Baghdad lacks localised standards to address its specific social, recreational, and environmental needs.
   - <u>Misuse of Land:</u> Green spaces were often converted to commercial or industrial use, reducing their availability.
4. **Home Gardens**:
   - In **1971**, the planned green space was **12 m² per person**, but this standard was not achieved.
   - In **1987**, residential plot sizes were reduced from **400–600 m²** to **200 m²**, significantly shrinking garden areas. This reduced green space per person from **12 m²** to **4 m²**.
   - After **2003**, private gardens largely disappeared due to insecurity and lack of regulations. In some areas, green space per person fell to **0–1 m²**, and many gardens were replaced by parking lots or shops.
   - **Riverbanks and Tigris River**: The decline in water levels increased desertification and dust storms throughout the year. A **2000 regulation** prohibited construction within 15 metres of riverbanks, but enforcement has been weak.
   - **Loss of the Green Belt**: Baghdad's green belt, intended to protect the city's environment, has been neglected for years without restoration. A proposal in the 2010–2030 plan to develop a larger green belt remains unimplemented.

   These factors highlight the urgent need for better laws, effective administration, and comprehensive urban planning to restore and expand green spaces in Baghdad, as shown in Figures 3-6, 3-7, and 3-8 (*Methods of Creating Green Belts,* Ali Nuri Hassan, 1986, p. 22).

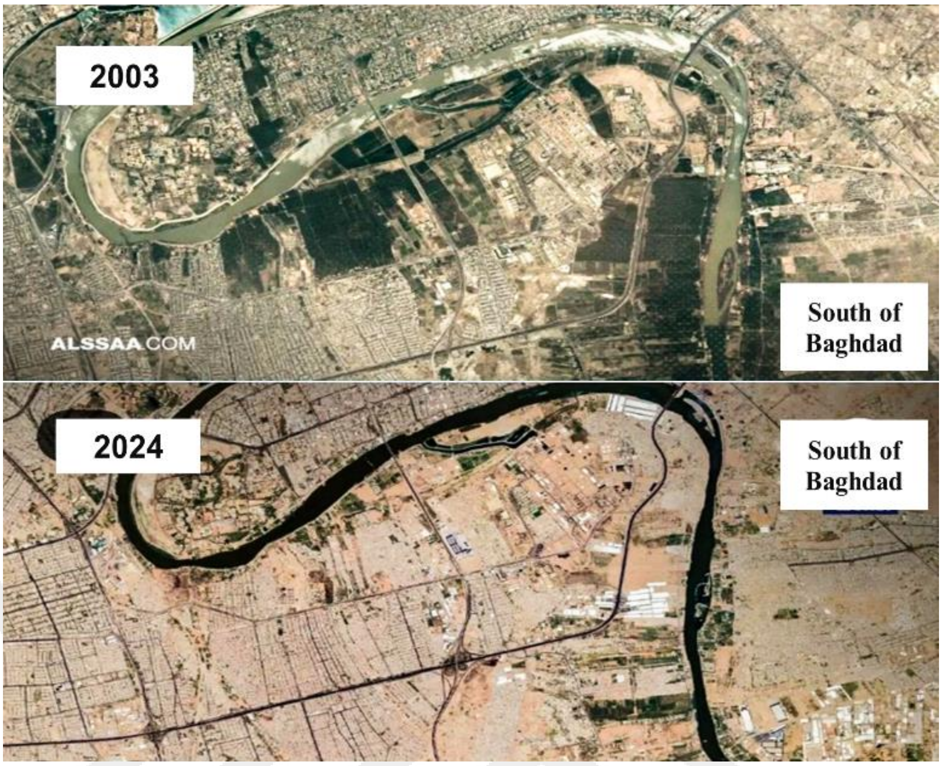


Figure (3.6) Google Maps images during the period 2003-2024

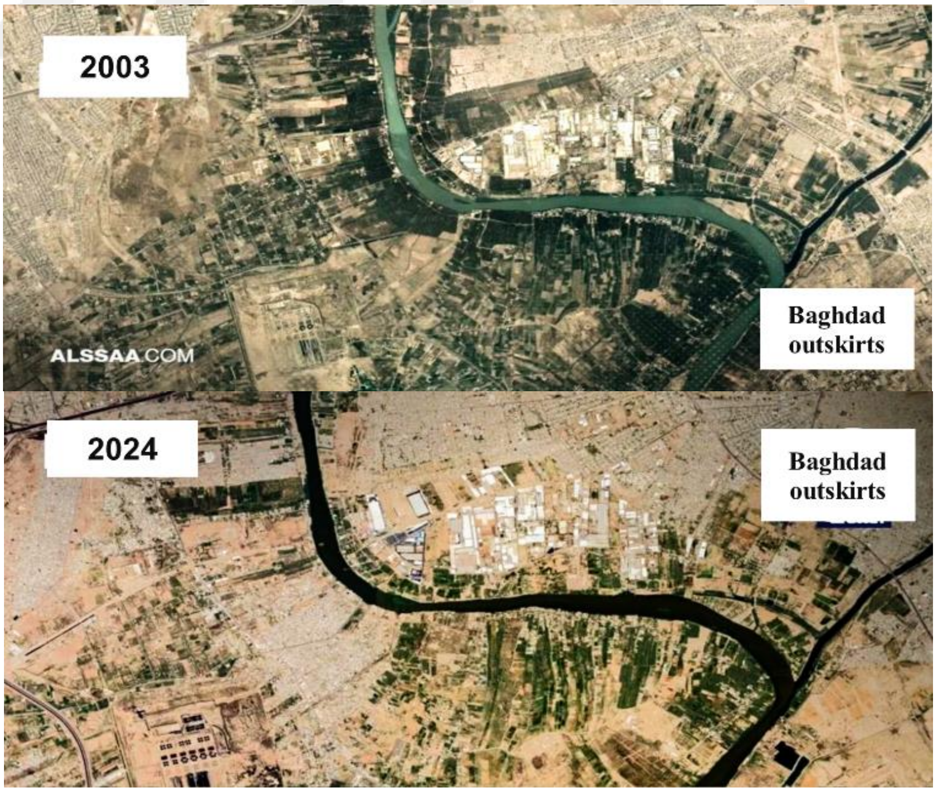


Figure 3-7: Google Maps images during the period 2003-2024

Figure 3-8: Facebook.com/Baghdad Projects images during the period 2003-2024

4- Sustainability of green spaces of the city of Baghdad according to studies and prepared proposals

To address Baghdad's lack of green spaces, sustainability principles can be applied across various planning levels, focusing on integrated solutions that enhance environmental, social, and urban outcomes.

Integrated Green Space System:

1. Treat green spaces as an interconnected system, with measurable standards and clear implementation mechanisms.
2. The research recommends adopting the 12 m² per person standard, aligning with the Anwin Standard.
3. Green Infrastructure:

4. Incorporate a green belt around the city for agricultural and environmental services.
5. Design a hierarchical network of green spaces offering recreational and sports services.
6. Develop corridors and urban axes that link the green belt to city parks, acting as ‘Green Police’.
7. Establish the green belt by scientifically planting trees to combat climate extremes, reduce dust storms, and achieve environmental goals.
8. Protect the rivers from pollution (e.g., chemicals, untreated sewage).
9. Create continuous green strips along riverbanks to enhance kinetic and visual access.
10. Utilise rivers for transport, sports (rowing, swimming), and multi-functional activities.
11. Restore degraded parks, such as Baghdad Forest, by planting local, climate-resilient trees.
12. Maintain diverse parks with rehabilitated damaged spaces.
13. Enhance roads and streets by planting sidewalks and medians with shade-providing plants and trees.
14. Optimise shading by aligning building heights with street widths to increase thermal comfort for pedestrians and vehicles.
15. Reduce cooling energy consumption by using external shading techniques and planting trees near buildings.
16. Implement green roofs to shade rooftops and reduce heat absorption.
17. Use climbing plants and screens to minimise solar radiation on walls, lowering temperatures around and inside buildings.
18. These strategies integrate sustainable practices across different urban scales, contributing to an improved quality of life and enhanced urban resilience in Baghdad

3.2. Study Area and Justifications for Selection

3.2.1. General Description of the Study Area

1. Urban Fabrics and Urban Axes

I. Al-Saadoun Street:

Al-Saadoun Street is the main commercial artery and transport axis, where the Baghdad Municipality has proposed a metro line. It showcases architecture from the first half of the twentieth century with an eclectic style, as well as modernist architecture from the 1950s. However, it suffers from poor street facilities and unregulated parking. Beautification efforts for this street are necessary to preserve its architectural character, as shown in Figure 3-9.

II. Abu Nuwas Street

Abu Nuwas Street was opened in the 1930s, serving as a shared boundary between residential neighbourhoods and the open space along the corniche. It embodies the character of garden cities, particularly towards the Al-Karrada direction.

III. Landmarks, Sites, and Buildings of Historical and Architectural Importance

The proposed historical area does not include archaeological sites but only buildings, among which is the ‘Al-Rahibat School’, the oldest school. It is important to preserve the residential neighbourhoods from the 1930s architecture, which, despite their deterioration, still constitute a cohesive entity on both sides of Sadoun Street. Currently, many of these houses are in an advanced stage of deterioration, and a large number of them are structurally unsound, as shown in Figure 3-9.

IV. Houses that cannot be salvaged should be replaced with urban development while simulating the same architectural style of the replaced building to maintain the homogeneity of the block. A survey should be conducted to assess the current condition of 1930s-era houses, identifying those to be documented, as well as those at risk and in need of replacement, as shown in Figure 3-9.

2- Social and Economic Characteristics

Residents of Old Al-Rusafa are predominantly from lower socioeconomic backgrounds and engaged in various commercial and industrial trades. They also tend to adhere strongly to social customs, religious practices, and traditional norms.

The neighbourhood experiences a high and increasing population density. Due to a sense of insecurity in the area, it has become a destination for displaced and migrant populations from other regions, leading to dense urbanisation.

The buildings in the neighbourhood are subject to the control of Baghdad Municipality, which prohibits construction, renovation, or sale due to its status as a heritage area.

Most of its streets are characterised by narrow alleyways. As a result of population migration, many buildings have become abandoned and filled with waste.

The scene suggests that living in this area is nearly impossible, contributing to its gradual transformation into a mini-state controlled by drug traffickers. During periods of sectarian tension, the area faced severe restrictions from armed groups, leading some residents to migrate outside Iraq. Economically, the area is generally below average, with decent purchasing power due to its predominantly commercial-industrial nature, as shown in Figure 3-12: Map illustrating the construction status of the area in 2016.

3- Reasons for Choosing the Study Area

I. Geographic, Cultural, and Urban Significance:

The selection of the Al-Rusafa area for applying theoretical frameworks is primarily due to its geographic, cultural, and urban importance. Situated close to the centre of Baghdad, it holds a strategic location in the heart of the city. It is a vital part of its fabric and bordered by the river on its eastern side, providing clear natural boundaries. This area has witnessed clear encroachments on green spaces in favour of industrial, commercial, and other uses. This environmental issue takes precedence, especially given its possession of globally significant heritage buildings and proximity to the urban boundary. Therefore, it presents the greatest opportunity to secure green infrastructure. The focus on its functionality was intended for both environmental and economic benefits, as shown in Figure 3-8: Location of the Selected Area.

II. Diverse Land Use:

The selected area represents a miniature version of the city in terms of diverse and integrated land uses, including residential, commercial, industrial, educational, cultural, health, administrative, service, and religious functions shown in Figure (3-10).

II. Urban Sprawl and Green Space Consumption:

Al-Rusafa was chosen for the practical study due to the numerous instances of urban sprawl encroaching on green spaces, leading to a significant decline in green space standards. Consequently, it has become a fertile environment that embodies the research problem and is suitable for studying the various conditions presented by the research. As designated land for construction gets consumed, urban sprawl begins to emerge, consuming green cover instead of redirecting towards other areas for development projects, as shown in Figure 3-12.

4- Strengths and Weaknesses of the Site

A. Strengths:

- Green Spaces: Green areas, covering 15.6% of the site, dominate the southern side, benefiting from the presence of the Tigris River.
- River Bend: The river bend defines the southern edge of Al-Rusafa, imparting a distinctive character, especially with landmarks like the Abu Nuwas Corniche Gardens.

B. Weaknesses:

- Continued Deterioration: Heritage residential areas continue to deteriorate, especially on state-owned lands, with many buildings being demolished or repurposed for non-residential uses such as warehouses, small workshops, and various commercial activities, further impacting their already deteriorating structural condition.
- Urban Landscape Destruction: The destruction of the existing urban and traditional fabric of Baghdad, along with the unnatural pressure on existing public services and infrastructure facilities.
- Unauthorized Development: The unauthorized creation of spaces and residential areas contrary to established standards and allowable ratios.

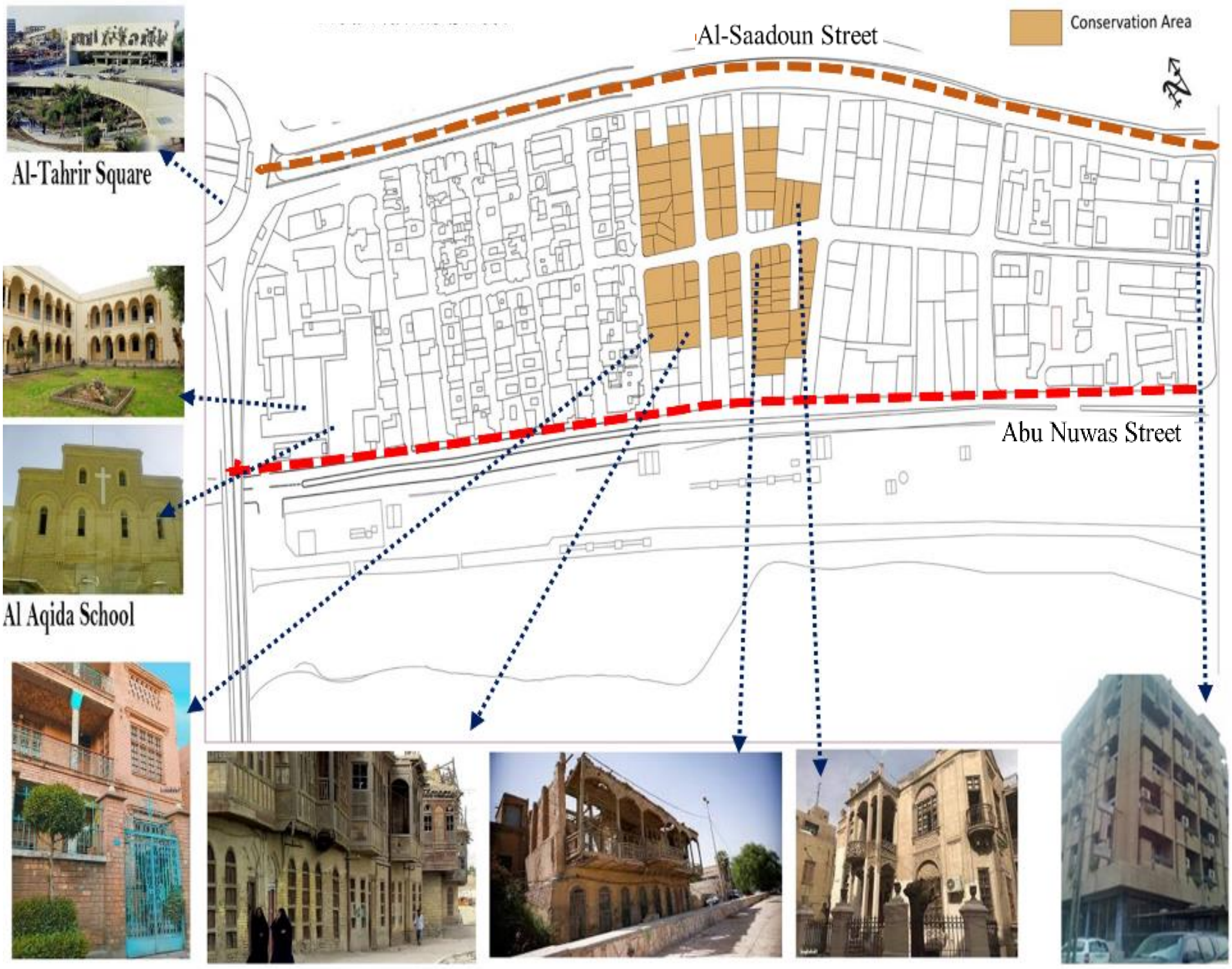


Figure 3-9**:** Urban Axes Landmarks, Buildings Historical & Architectural Importance (Source: Researcher's work).

Figure 3-10: Location of the Selected Area in 2016 / Source: Baghdad Municipality, GIS Department/ (Source: Researcher's work).

Figure 3-11: Map Illustrating Land Uses in 2016 / Source: Baghdad Municipality, GIS Department/ (Source: Researcher's work).

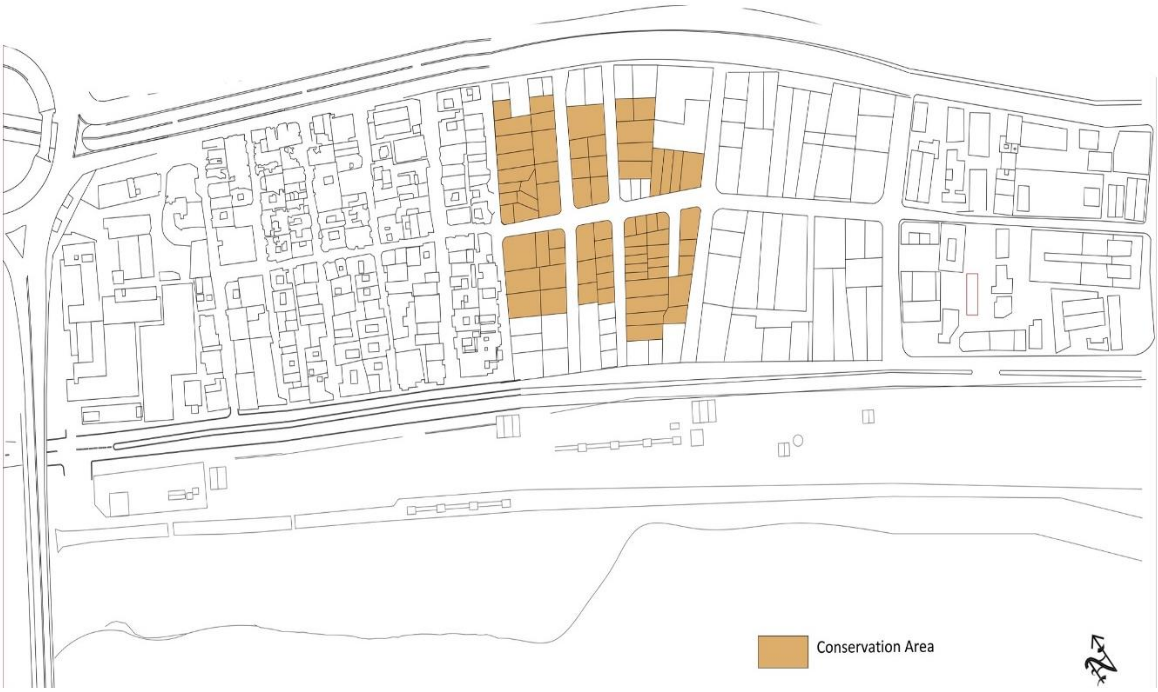


Figure 3-12: Map Showing Conservation Areas with Green Spaces in 2016.

Figure 3-13: Map Illustrating the Construction Status of the Area in 2016 / Source: Baghdad Municipality, GIS Department/ (Source: Researcher's work).

Figure 3-14: Map Illustrating Building Heights in the Area in 2016 / Source: Baghdad Municipality, GIS Department/ (Source: Researcher's work).

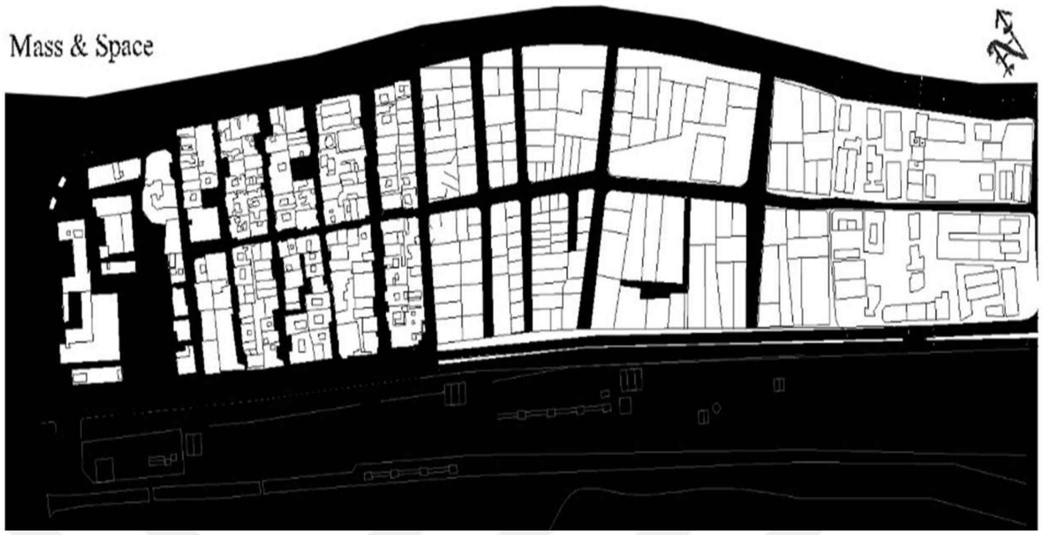
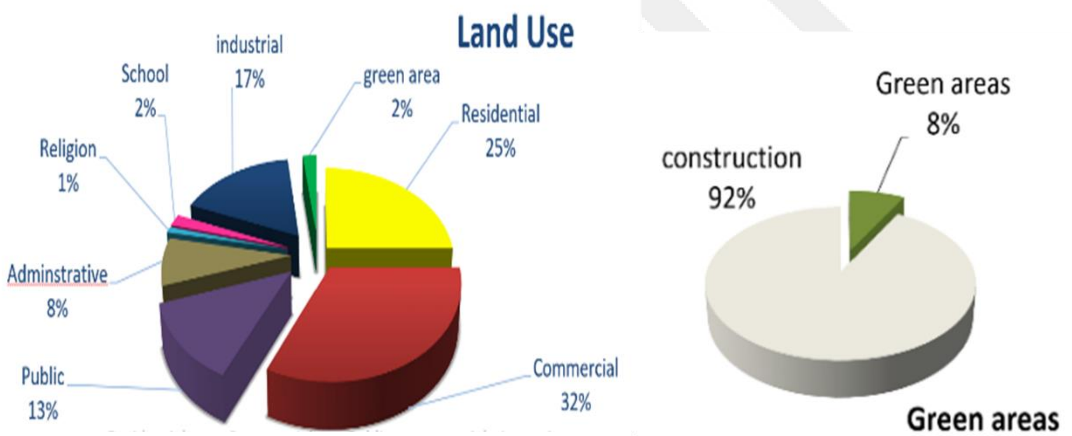


Figure 3-15: Map Illustrating the Ratio of Open Space to Building Blocks in 2016 / Source: Baghdad Municipality, GIS Department/ (Source: Researcher's work).



Shows the percentage of **green areas** as part of all land use categories	Shows the percentage of **green areas** compared specifically to constructed areas (all areas).

Figure 3-16: Analysis of The percentage for Land Use Distribution and Green Space Proportion in the Region (2023) (Source: Researcher's work).

3.3. Methodology for Environmental Performance Assessment

The paper discusses the role of green urban areas in Baghdad by analysing temperature variability, air quality improvement, and energy consumption in highly vegetated versus less vegetated areas. It presents a comparative study using simulations in Al-Rusafa, Baghdad, from 2003 to 2024, employing tools like Grasshopper, Rhinoceros, and their plugins, Ladybug/Honeybee.

- **Phase One:** Observe prevailing environmental conditions without green-cover indicators.
- **Phase Two:** Evaluate conditions after implementing green-cover indicators through modifications.

Simulation Tools: Grasshopper with Rhinoceros and Ladybug/Honeybee plugins for parametric analysis.

The simulation spans the year (January 1st to December 31st) for 2024, using hourly climate data to evaluate conditions before and after green cover implementation. It also evaluates solar radiation, thermal comfort, and environmental performance. The aim of this method is to demonstrate the effectiveness of green spaces in mitigating urban heat and improving environmental conditions in Baghdad.

Climate Data: Extracted from Baghdad International Airport using EPW files (Energy Plus format).

Modelling: Includes a 2D AutoCAD model and a 3D model in 3ds Max of the study area.

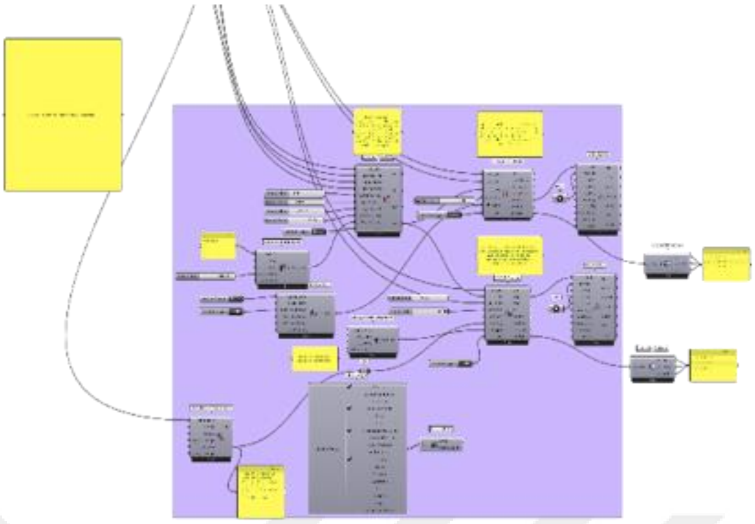


Figure 3_17: data as the input in the 3D Grasshopper simulation program (Source: Researcher's work).

Figure 3_18: the selected area in AutoCAD and a 3D model using 3d max (Source: Researcher's work).

3.3.1. Initial area Analysis Based on Energy plus (EPW) Data

The simulation spans the year (January 1st to December 31st), for the year 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

A. Sun path and temperature variation analysis:

Baghdad experiences large seasonal and daily temperature fluctuations, with temperatures reaching 55°C. This highlights the need for effective cooling strategies in summer and heating solutions during winter.

B. Urban heat island effect:

Inland areas, especially in the eastern and south-eastern regions, experience higher temperatures due to dense urbanisation and prolonged exposure to sunlight, which intensifies the urban heat island effect.

C. Sun path effect:

South-eastern regions, with prolonged exposure to sunlight, experience higher temperatures, which underscores the importance of shading and solar control measures.

- Recommendations:

- Implement urban green infrastructure, including green roofs and tree canopies.
- Use reflective materials to reduce heat absorption.
- Focus on reducing the urban heat island effect and enhancing thermal comfort.
- Utilize the river edge and the cooling effect of the area through the river.

3.3.2. Wind Speed Analysis for Abu Nawas Street, Baghdad

The simulation spans the year (January 1st to December 31st), for the year 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

A. Wind Profile by Height:

Wind speed increases with height, ranging from 2.73 m/s at 4 m to 4.96 m/s at 28 m, with surface friction decreasing at higher elevations, as shown in Figure 3.18.

B. Wind Direction and Frequency:

Winds mostly come from the northwest (NW) and west-northwest (WNW) at speeds of up to 12 m/s, with calm conditions occurring only 5.5% of the time, as shown in Figure 3.19.

C. Building Orientation:

Buildings and openings aligned with NW, WNW, and WNW winds can maximise natural ventilation.

D. Green Infrastructure:

Plants along southeast and northwest corridors can enhance airflow and act as a wind barrier.

E. Cooling Potential:

Using prevailing winds in parks and open spaces can significantly reduce urban temperatures.

- <u>Recommendations:</u>
- Orient buildings to optimise natural ventilation.
- Integrate green infrastructure strategically.
- Use wind management to leverage local patterns to improve comfort.

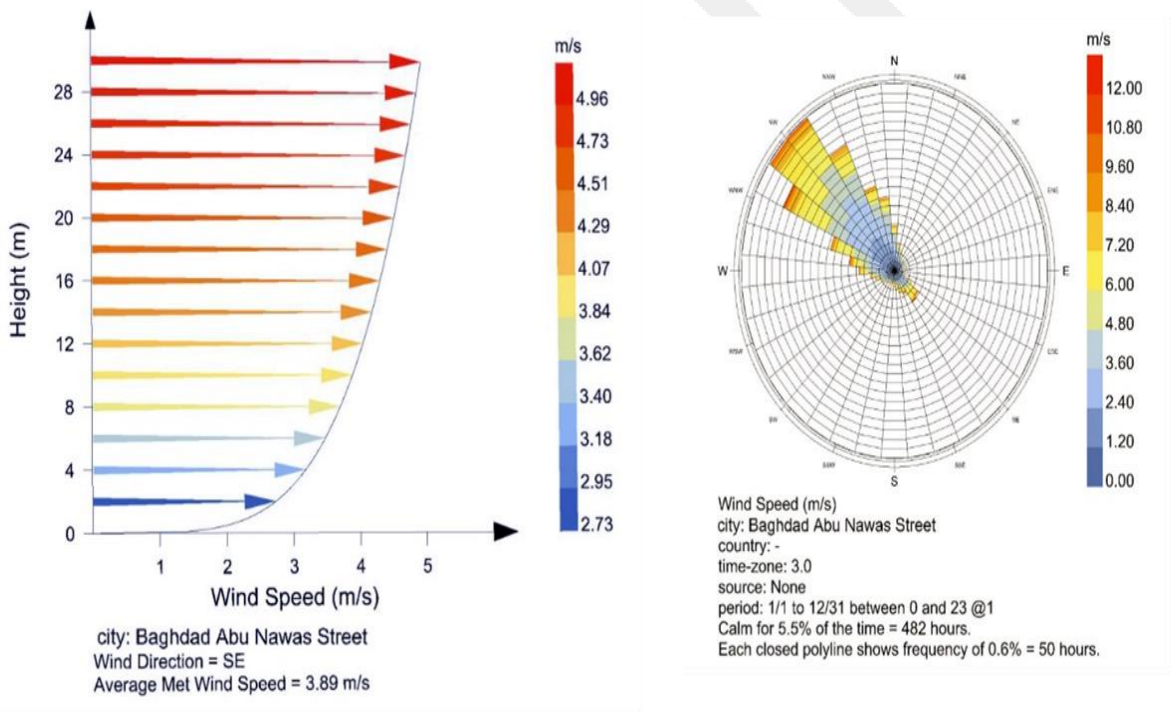


Figure 3-19: A Wind Speed Profile with Height above Ground Level, B Wind Rose Diagram Showing Wind Speed and Direction Distribution.

3.3.3. Dry bulb temperature and sun path analysis

The simulation spans the year (January 1st to December 31st), for the year 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

A. Temperature changes:

Temperatures range from -1.7°C in cold areas to 55°C in hot areas. Areas near the Tigris River, especially to the northwest and west, experience cooler conditions due to evaporative cooling, while areas to the east and southeast are hotter due to prolonged sunshine and dense urbanisation.

B. Sun path effect:

The sun path leads to hotter areas, concentrated in regions exposed to direct sunlight for long periods, as shown in Figure 3.20.

- <u>Recommendations:</u>
- Expand green spaces to provide shade and reduce heat absorption.
- Use reflective roofing materials to reduce heat retention.
- Increase tree cover to mitigate solar heat absorption and improve thermal comfort, particularly in areas away from the river.

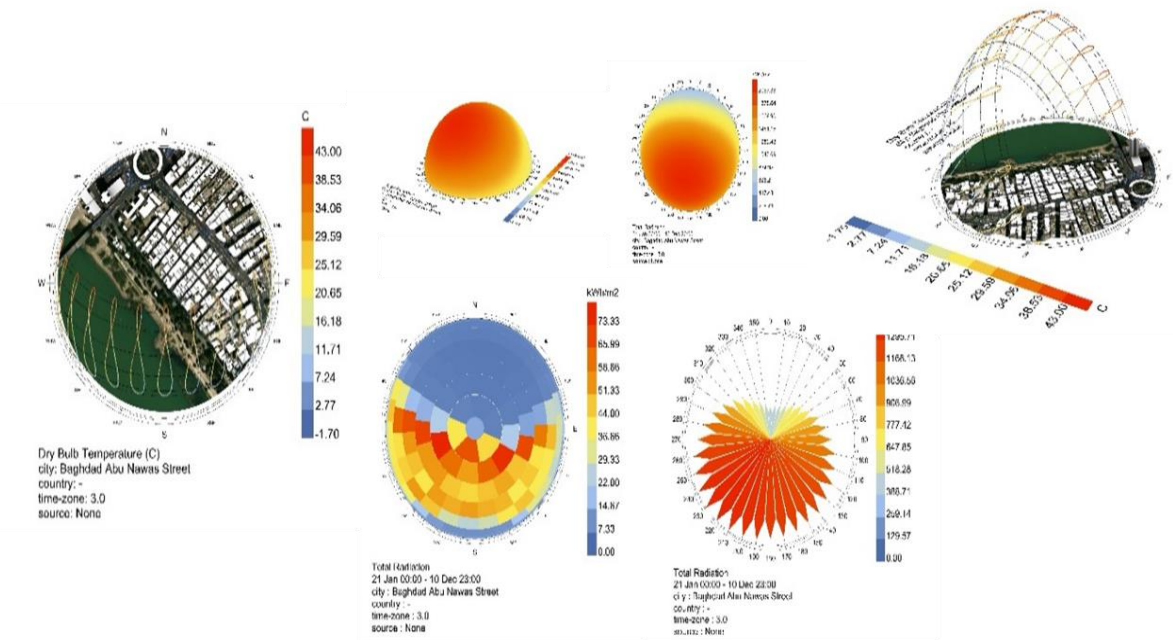


Figure 3-20: Sun Path and Dry Bulb Temperature Distribution (Source: Researcher's work).

3.3.4. Physiological Equivalent Temperature (PET) Analysis on Abu Nawas Street, Baghdad

The PET analysis for Abu Nawas Street, derived from the EnergyPlus Weather File (EPW) data, evaluates outdoor thermal comfort by combining air temperature, humidity, solar radiation, and wind speed into a single metric expressed in °C.
The simulation spans the year (January 1st to December 31st), for the year 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

Seasonal Thermal Comfort:

• Summer (June–September): PET values can reach up to 52°C during midday, indicating extreme heat stress. To improve outdoor comfort, shading, green infrastructure, and cooling strategies are essential.

• Winter (December–February): PET values range between 0–15°C, reflecting much cooler and more comfortable conditions.

Daily Heat Stress:

• Midday (12 PM – 6 PM): PET peaks during these hours due to intense solar radiation, making outdoor conditions uncomfortable.

• Nighttime (6 PM – 6 AM): PET values drop significantly, but in summer, nighttime cooling is inadequate, highlighting the urban heat island effect (as shown in Figure 3.21).

Urban Planning Implications:

• Summer Heat Mitigation: Strategies should focus on increasing vegetation, incorporating water features, and using reflective materials to reduce heat absorption.

• Cooling from the Tigris River: While the river offers some natural cooling, additional measures are needed to fully alleviate heat stress during the peak summer months.

• Green Spaces: Expanding vegetation can significantly lower PET, provide shade, and reduce heat stress, especially in areas with high solar exposure.

• Roof Surfaces: Roofs are critical for temperature control, necessitating the use of cool roofing materials or green roof systems to minimise heat absorption.

The PET analysis underscores the importance of sustainable urban design strategies to combat heat stress in Baghdad, particularly during summer. Expanding green spaces and leveraging natural cooling resources, such as the Tigris River, can enhance thermal comfort and contribute to a more liveable urban environment.

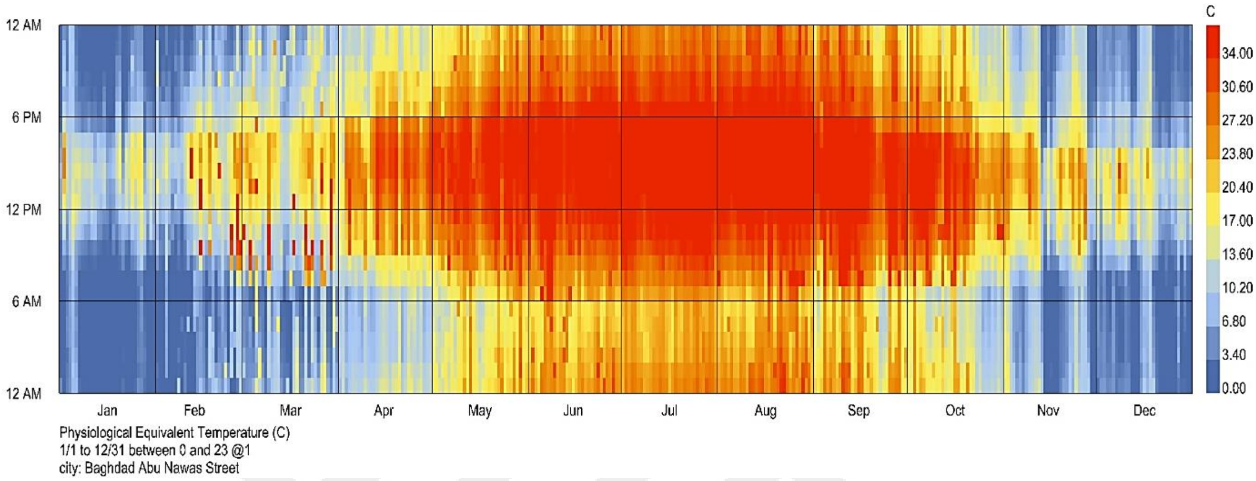


Figure 3-21: Annual Variation of Relative Humidity, (Source: Researcher's work)

3.3.5. Thermal Comfort Analysis for Abu Nawas Street, Baghdad

The thermal comfort analysis for Abu Nawas Street, situated along the western bank of the Tigris River in the Rusafa district, offers valuable insights into the area's environmental performance prior to any urban design interventions. This analysis is based on simulations conducted using Energy Plus with data derived from an Energy Plus Weather File (EPW).

The simulation spans the year (January 1st to December 31st), for the year 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

1. Distribution of Comfort Levels:

- A significant portion of the year is characterised by 'uncomfortable' conditions (in blue), especially during the peak summer months of June to September. During these months, extreme heat is prevalent, with discomfort peaking between 12 PM and 6 PM due to high outdoor temperatures and limited shading.

- Comfortable conditions are restricted to early morning and late evening, particularly during the cooler months.
- Comfortable hours (in red) are mainly observed in the early morning and late evening, even in summer. However, these periods are limited, especially during the hottest months (as shown in Figure 3.22).

2. Seasonal Variation:

- Winter (December–February): These months exhibit relatively better thermal comfort, though discomfort around midday persists due to solar radiation.
- Summer Transition Months (March, April, October, and November): These months show a mixed thermal comfort profile, with midday hours consistently reflecting peak discomfort due to direct sunlight exposure.

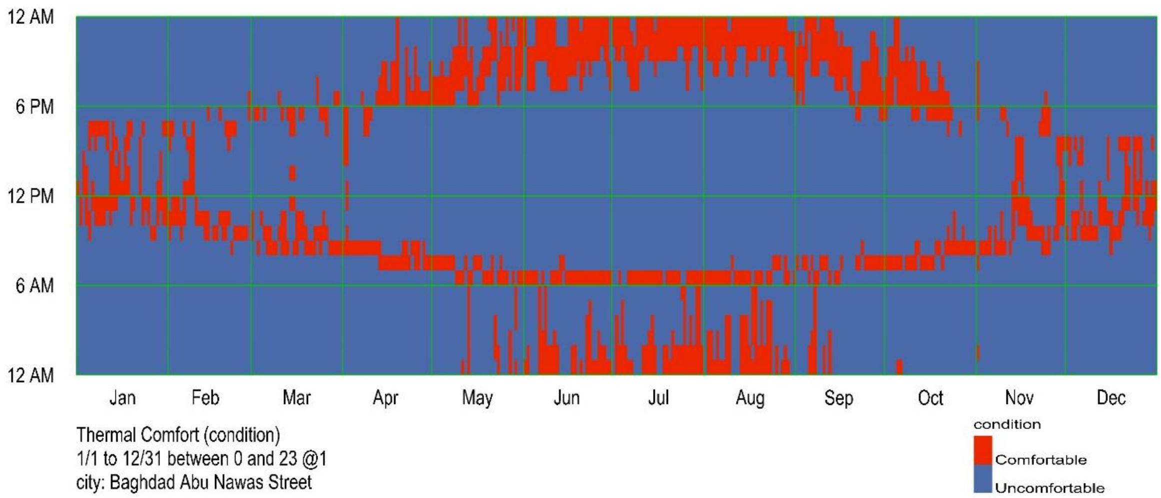


Figure 3-22: Annual Thermal Comfort Conditions (Source: Researcher's work).

Challenges Identified:

- High Thermal Stress: Persistent uncomfortable conditions, caused by intense solar radiation and insufficient shading, result in high thermal stress. This significantly impacts the usability and liveability of public spaces along Abu Nawas Street.
- Insufficient Vegetation and Shading: The lack of vegetation and shade leads to direct sun exposure in open areas, contributing to thermal discomfort. This emphasises the need for urban heat mitigation strategies.

- Recommendations:
  - Vegetative Cover: Increase vegetative cover to provide essential shading and reduce solar exposure.
  - Shading Devices: Install shading devices to minimise direct sun exposure and enhance comfort levels.
  - Cool Materials: Use cool surface materials to lower heat absorption and improve the thermal environment.
  - Roof Solutions: Employ cool roofing materials or implement green roof systems to reduce roof-level heat absorption.

These findings establish a baseline for evaluating the impact of future urban design interventions aimed at enhancing thermal comfort and improving the overall liveability of Abu Nawas Street throughout the year.

3.4. Proposed Solutions to Address the Green Space Shortage in the Selected Area

1. Design Interventions:

- 3D Modelling: Visualisation tools were used to depict the area before and after retrofitting.
- Regional Scale Modifications: Adjustments were made based on the specific needs of different parts of the area, including renovation, rehabilitation, or minor upgrades, particularly in conservation zones.
- Building-Level Improvements: Green walls constructed with locally sourced materials such as wood and iron were introduced. Shading devices, including vertically dynamic louvers, were installed on southern, western, and south-eastern façades to modernise and enhance thermal performance.

2. Zoning and Land Use Strategies: The area was divided into four zones, with tailored solutions proposed to increase green coverage, as depicted in Figure 3.23.

- Preservation Zone: This zone includes historical and archaeological buildings that must remain untouched to preserve their heritage.

- Residential Areas: These predominantly feature buildings and dilapidated houses converted into workshops and factories, which have heavily impacted green coverage. These areas require strategic green interventions.
- Mixed-Use Zone: A combination of commercial, industrial, and residential buildings, many in disrepair. Public facilities in this zone should be refurbished, and suitable areas repurposed for improved functionality.
- Riverfront Zone: Previously a landfill and currently underutilised, this zone should be reclaimed and developed into green spaces along the riverbanks.

3. Recommendations for Green Coverage Expansion: Each zone will adopt specific strategies to enhance green spaces and improve overall thermal comfort. These include:

- Improving Public Health Conditions: Introducing green areas to enhance environmental quality and livability.
- Reviving Local Architecture: Incorporating sustainable designs that align with the area's heritage.
- Enhancing Street Facilities: Improving urban design and landscaping to create more inviting public spaces.
- Establishing Heritage Nodes: Highlighting and preserving key cultural and historical landmarks.
- Creating a Tourist Trail: Developing recreational and cultural nodes along the Tigris River.
- Beautifying the Riverbanks: Transforming the Tigris River's banks into open spaces with cultural and recreational amenities, particularly around Abu Nuwas Street and adjacent green areas.
- Improving Public Transport: Reducing motorised vehicle congestion in the central business district by establishing pedestrian zones in historic areas and creating multimodal transport hubs that connect urban centres without compromising historical integrity, as shown in Figure 3.24.

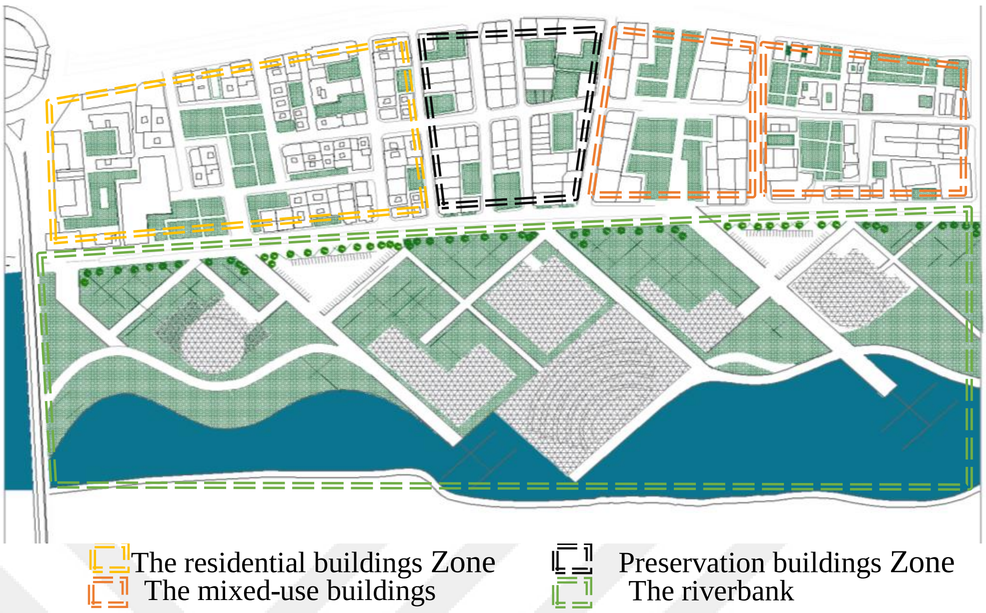


Figure 3-23: Division of the selected area into 4 zones (Researcher).

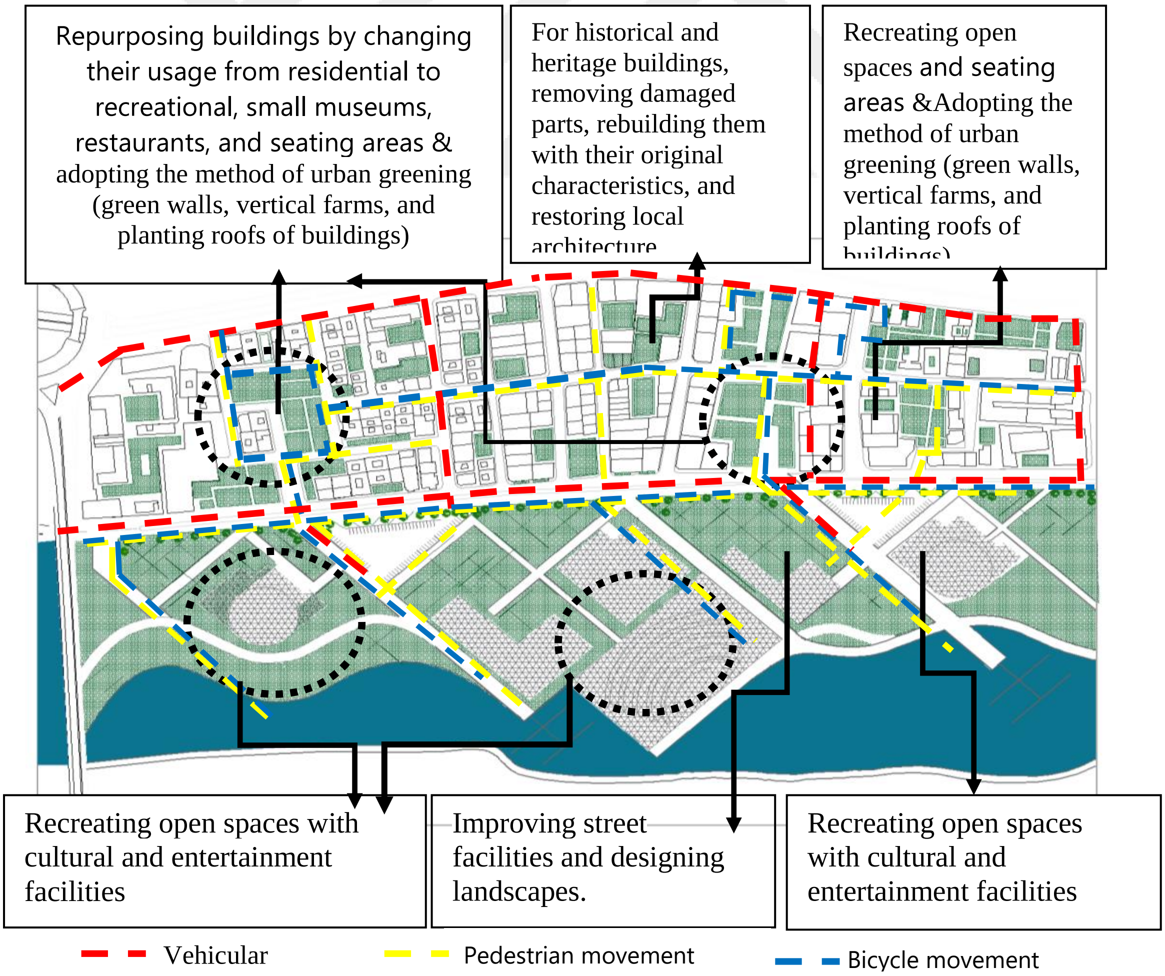


Figure 3-24: Solutions for the issue of green space shortage in the selected area Types of New Movement in the Region (Researcher).

3.4.1. The areas have been divided according to development needs

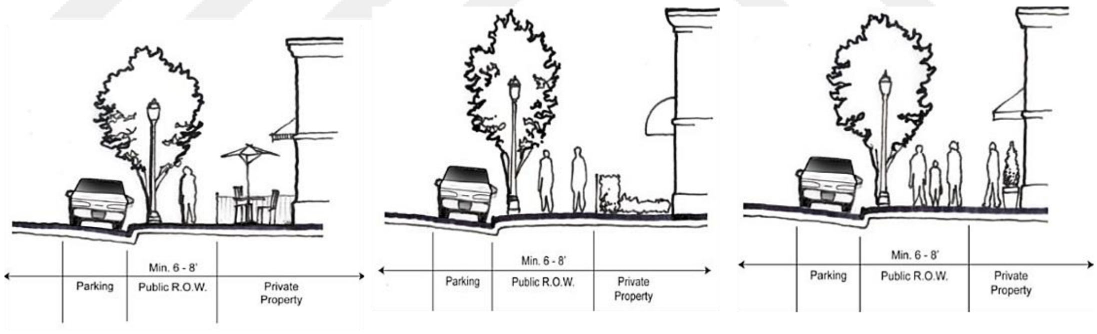
1- Conservation Area:

- An area that contains conservation buildings, as it includes historical and archaeological structures that must not be tampered with. Therefore, it is necessary to preserve the buildings with distinctive architectural features, remove dilapidated buildings or damaged parts of heritage buildings, reconstruct them with their original characteristics, and restore local architecture by adopting urban greening techniques like green walls.
- Improve poor health conditions by enhancing street facilities through urban design and landscape design.
- Establish a heritage cluster for settlements and utilise heritage buildings by changing the type of use from mixed-use or neglected to recreational, such as transforming them into small museums as shown in Figure 3.25.

Figure 3-25: A (Preservation buildings) in 2023, B plans for new development incorporating green cover (Researcher).

2- Mixed-use area

- The area has a mixed use of dilapidated commercial, industrial, and residential buildings, as well as public facilities, some of which are still usable, while most are demolished buildings and houses that have been converted into factories and warehouses. This has greatly impacted the area and green cover, leaving heritage buildings without use, maintenance, or restoration, making it a landfill and distorting the aesthetics of the city. Therefore, the damaged, dilapidated buildings must be removed and rebuilt, adopting the urban greening method, such as: a) green walls, b) rooftop gardening.
- Creating a node for gatherings and repurposing buildings by changing their use from residential or neglected to entertainment, such as small museums or restaurants. This includes creating pedestrian areas in historical zones and improving public transport, as shown in Figure 3.26 and 3.27.



Method of treatment outside restaurants and cafeterias | Method of treatment | Method of treatment outside shops and public services

Figure 3-27: Method of treatment of walkways and sidewalks in the main streets and central areas (researcher).

Figure 3-27: A (Residential buildings) in 2023, B plans for new development incorporating green cover (Researcher).

3- Residential Areas

- Residential areas are mostly characterised by dilapidated buildings and abandoned houses that have been converted into workshops and factories, significantly impacting the region and green spaces. Neglecting traditional buildings without maintenance or restoration has turned them into dumping grounds, detracting from the city’s aesthetics. Therefore, it is essential to remove deteriorating and damaged buildings and reconstruct them using urban greening techniques such as: a) green walls, b) vertical farms, c) rooftop gardening.

- Improving poor health conditions by enhancing street facilities through urban design and landscape architecture.

  Creating hubs for gatherings and repurposing buildings by changing their use from residential or neglected to recreational, such as small museums or restaurants. The central business district will include stations and seating areas, connecting it to urban centres without compromising historical areas and the urban identity in general. Additionally, pedestrian zones will be established in historical areas, and public transport will be improved, as shown in Figure 3.28.

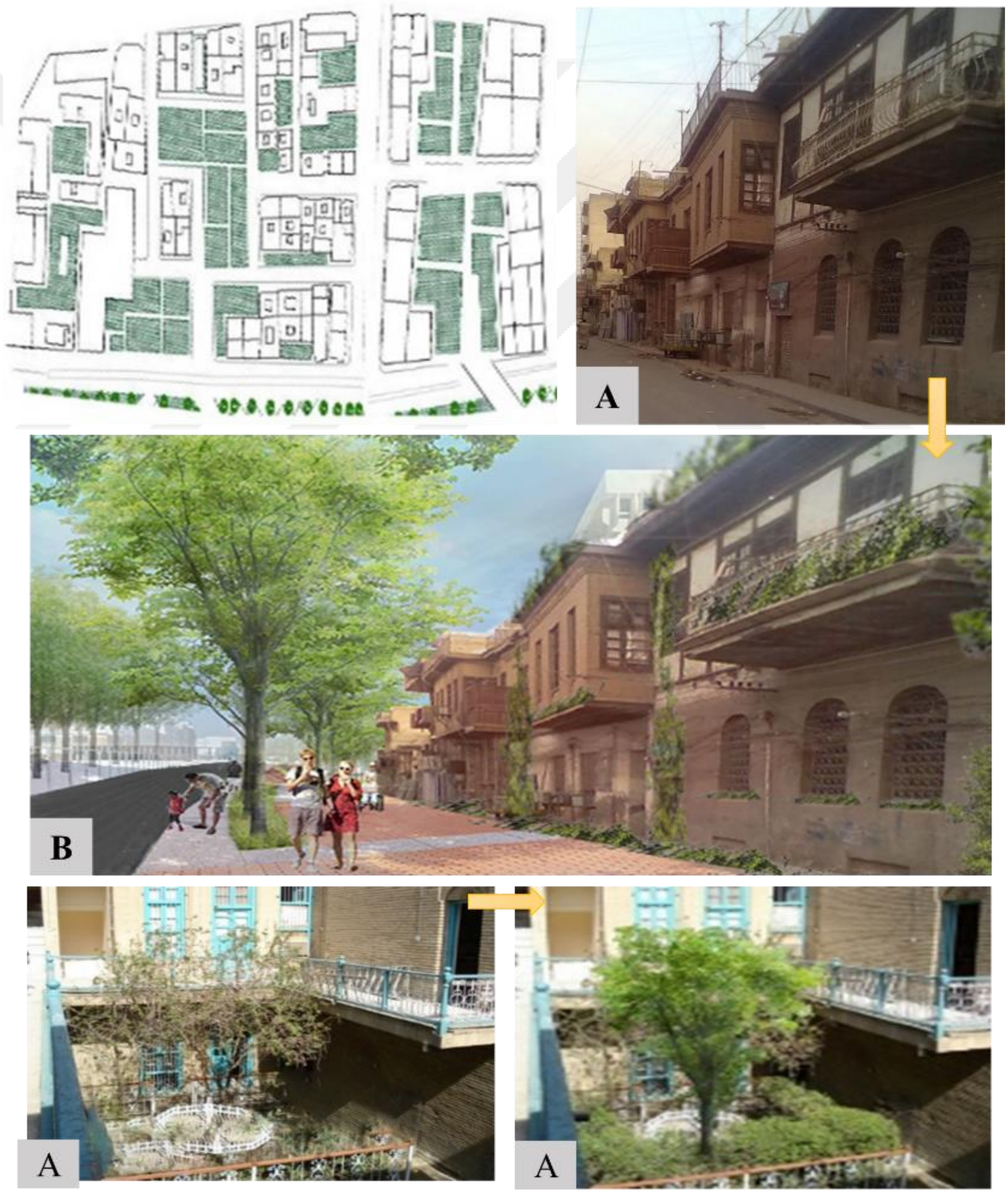


Figure 3-28: A (The mixed-use buildings) in 2023, B plans for new development incorporating green cover (Researcher).

4- River Edge area

Fourth, the area along the river's edge, which was once a landfill and remains underutilised, with the river being polluted with waste and other debris, where the urban greening method is adopted in its reconstruction:

1. Prevent pollution of riverbeds and develop and improve green spaces near the river.
2. Restore natural river courses and rehabilitate the environment along the riverbanks.
3. Promote the multifunctionality of the river for sports, recreation, and climate treatment.
4. Improve poor health conditions through urban design and landscape architecture.
5. Create a node for gatherings and repurpose buildings by changing their use from residential or neglected to entertainment, such as small museums or restaurants, with stations and seating areas connecting them to urban centres without compromising historical areas and urban identity. Pedestrian areas will be created in historical zones, and public transport will be improved, as shown in Figure 3.29.

Figure (3.29) A (The riverbank Zone) in 2023, B plans for new development incorporating green cover **(Researcher).**

3.4.2. Analysis of Retrofitting Modifications Based on Theoretical Framework Indicators

1. Design Scope: A 3D Grasshopper simulation programme was used to visualise the area both before and after retrofitting, providing an insightful comparison of the modifications.

- Regional Scale Adjustments: Modifications were tailored to meet the specific needs of different parts of the region, ranging from renovation and rehabilitation to simpler interventions, especially in conservation zones.
- Building-Level Improvements:
  - Green walls were incorporated using locally sourced materials, such as wood and iron, to enhance environmental performance.
  - Shading devices, including vertically dynamic louvres, were added to the southern, western, and south-eastern façades. These not only improve shading but also complement a modernised façade design.

2. Occupant Comfort and Wellbeing:

- Improved Ventilation: Ventilation was enhanced through the use of open windows and interior courtyards, promoting better air circulation.
- Enhanced Thermal Comfort: Thermal insulation was added to external walls, and the building envelope for the southern, western, and southeastern façades was redesigned. These measures aimed to reduce heat transfer and improve indoor comfort.
- Sustainable Solution: The retrofit assessment aligns with a solid theoretical framework, offering a sustainable design approach that optimises energy efficiency while prioritising the comfort and well-being of occupants.

This analysis highlights a comprehensive approach to urban and architectural retrofitting, ensuring sustainable and practical solutions that enhance liveability and environmental performance.

1- Analysis of Direct Sun Exposure: Before and After Redesign of Abu Nawas Street

❖ This analysis highlights the impact of redesigning Abu Nawas Street, located adjacent to the Rusafa area in Baghdad, focusing on annual solar radiation exposure expressed in hours per year. The goal was to optimise the urban landscape, reduce heat stress, and improve thermal comfort.

The simulation spans the year (1st January to 31st December), for the year 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

Before Redesign:

High Sun Exposure:

- The area was characterised by widespread, intense solar radiation. Most areas were shown in dark yellow to red shades, reflecting exposure levels of up to 4,026 hours/year.
- Extended direct sunlight, particularly on building rooftops and open public spaces, resulted from the absence of trees, vegetation, and shading elements.

After Redesign:

A. Significant Reduction in Sun Exposure:

- A marked decrease in sun exposure was observed, with many areas now depicted in blue, indicating exposure levels of 0–800 hours/year.
- Improvements were achieved through increased vegetation and structural modifications.

B. Improved Shading: The redesign incorporated additional vegetation cover, shading structures, and canopy installations. This effectively reduced sun exposure in high-use areas, such as pedestrian pathways and public gathering spaces.

C. Enhanced Thermal Comfort: Reduced direct sun exposure significantly improved thermal comfort, particularly during the peak summer months.

D. Percentage Reduction in Sun Exposure:

Before Average Sun Hours: The areas in the ‘before’ scenario predominantly range from 1,200 to 4,000 hours/year, with many areas averaging around 3,000 hours/year.

After Average Sun Hours: In the ‘after’ scenario, the majority of the areas are shown in shades of blue to light yellow, indicating a significant decrease, with many areas averaging around 800 to 1,600 hours/year.

Using an estimated average:

Before Average = 3000 hours/year

After Average = 1200 hours/year

The redesign resulted in a 60% reduction in direct sun exposure, primarily through the addition of green infrastructure, shading elements, and improved building orientations

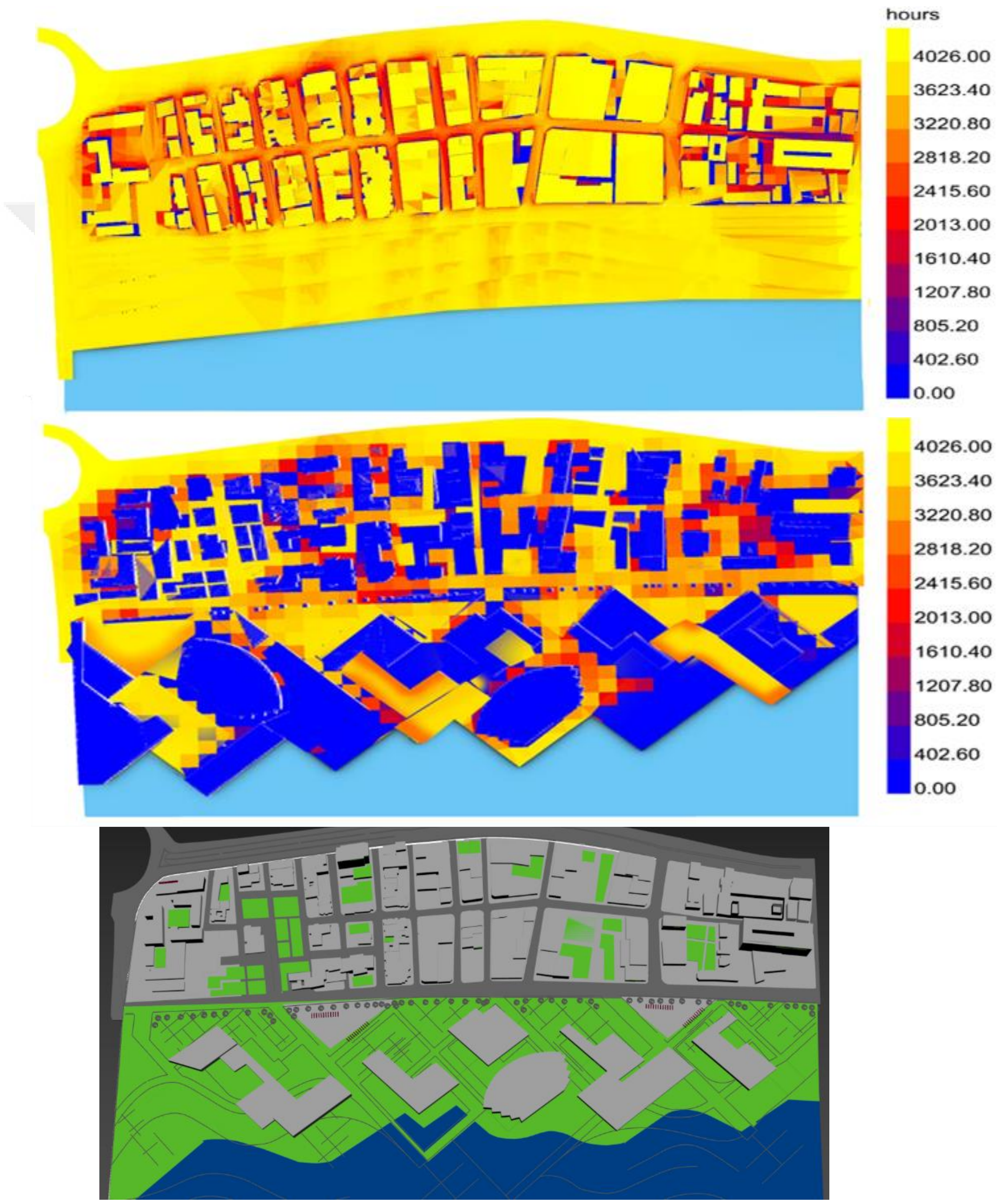


Figure 3-30: analysis of old Rusafa before and after the redesign in terms of direct sun exposure hours, for the entire selected area from the simulation programs used data location, (Researcher).

Benefits of Redesign:

1. Reduced Heat Stress: Decreased sun exposure lowers surface temperatures, enhancing comfort in hot weather.
2. Improved Thermal Comfort: Increased shaded areas make outdoor spaces more usable and reduce the urban heat island effect.
3. Additional Vegetation: Planting more trees, especially dense-canopy species, further enhances shading.
4. Material Optimisation: Using high-albedo or reflective materials for roads and rooftops reduces heat accumulation.
5. Community Engagement: Involving the local community in maintaining green spaces ensures sustainable and long-term success.

Column Bar Chart: Direct Sun Hours Before and After Redesign:

This comprehensive analysis demonstrates that thoughtful urban redesign, emphasising strategic shading and vegetation, can significantly improve the thermal comfort and overall liveability of public spaces like Abu Nawas Street. This is illustrated in Figure 3.31, where bar and column charts compare the direct sun exposure before and after the redesign

Before Redesign (in red): ~3,000 hours/year.

After Redesign (in blue): ~1,200 hours/year.

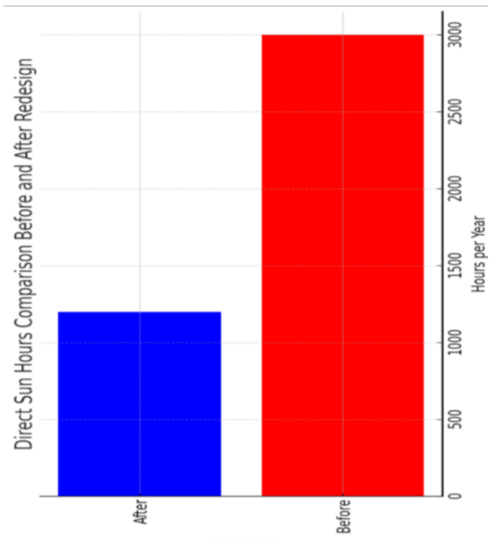


Figure 3-31: “Comparison of Annual Direct Sun Exposure: Before and After Redesign of old Rusafa" data for the entire selected area, (Researcher's work by using https://matplotlib.org/).

2- Analysis of hours of direct sun exposure shows the “before” and “after” conditions of Abu Nawas Street adjacent to the Rusafa area in Baghdad, with emphasis on solar radiation exposure, as expressed in hours per year for a specific small area.

- ❖ The simulation spans the year (January 1st to December 31st) for 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

<u>Before Redesign:</u>

- High Solar Radiation Exposure:
- Most of the area experienced high levels of solar radiation, represented by yellow to red shades on the exposure map, with values ranging from 2,000 to over 4,000 hours/year.
- This indicates extensive sunlight exposure, resulting in higher temperatures, limited shade, and discomfort for pedestrians, especially during the peak summer months.

<u>After Redesign:</u>

- Significant Reduction in Sun Exposure:
- The ‘after’ scenario shows a marked reduction in solar radiation exposure. The map highlights increased blue-shaded regions, representing areas with lower solar exposure values (ranging from 0 to 805 hours/year).
- This reduction was achieved through the introduction of green spaces, shading structures, and tree canopies, which provide more shaded areas and reduce radiation absorption.

<u>Quantitative Analysis:</u>

- **Before Redesign:** Approximately 60% of the area had high solar exposure levels (above 3,000 hours/year).
- **After Redesign:** Only 20% of the area now experiences high exposure, while the remaining areas show significantly reduced exposure.
- This indicates that the redesign resulted in a 40% reduction in areas exposed to high levels of solar radiation, significantly improving thermal comfort and environmental sustainability.

Before Redesign (Before Area): The high solar exposure rate 60%.

After Redesign (After Area): The high solar exposure rate 20%.

- Reduction in Solar Exposure: A 66.67% improvement highlights the effectiveness of urban planning measures.
- Enhanced Thermal Comfort: Less direct sun exposure creates cooler, more liveable spaces for residents and visitors.
- Sustainable Design: The use of green infrastructure and shading elements has proven to be a critical factor in achieving a sustainable urban environment.

These changes are pivotal in transforming Abu Nawas Street into a model for thermal comfort and urban sustainability in high-temperature regions such as Baghdad.

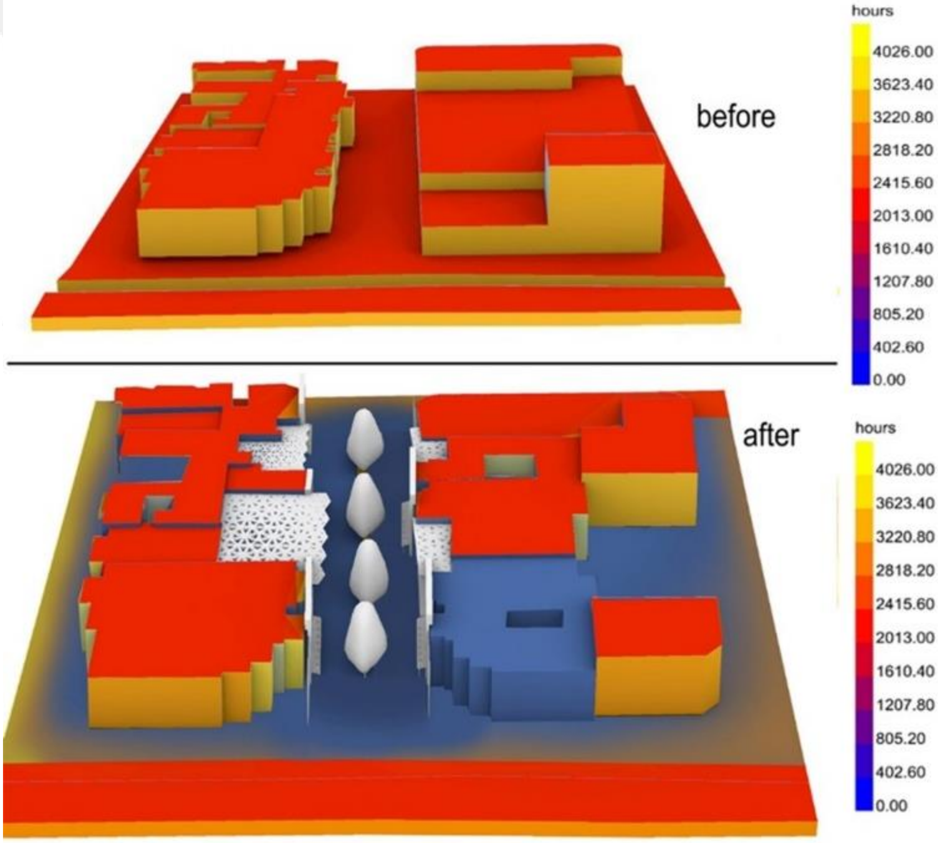


Figure 3-32: shows a comparative analysis of old Rusafa for a specific small area. Researcher's work

Column Bar Chart: Before and After Redesign:

The chart compares the direct sun hours in the 'Before' and 'After' scenarios:

• Before Redesign (in red): Represents high sun exposure, with most areas experiencing prolonged direct sunlight.

• After Redesign (in blue): Illustrates a significant reduction in direct sun hours, with areas now benefiting from enhanced shading and reduced solar radiation.

This visual representation, Figure 3.33, clearly shows the substantial improvement in thermal comfort conditions due to the redesign.

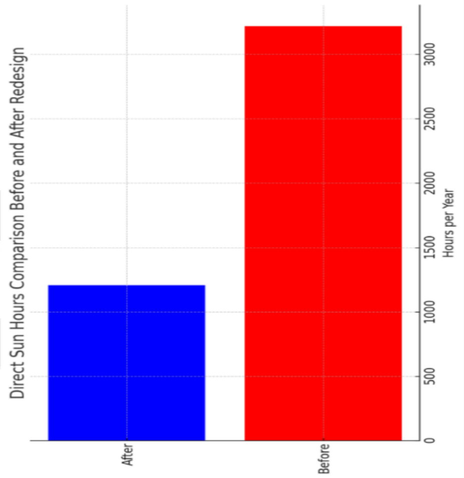


Figure 3-33: "Comparison of Annual Direct Sun Exposure: Before and After Redesign of old Rusafa" data for the entire selected area, (Source: Researcher's work by using https://matplotlib.org/).

3- Physiological Equivalent Temperature (PET) Analysis for Abu Nawas Street, Baghdad: Before and After Adding Green Cover

- ❖ The PET analysis for Abu Nawas Street assesses thermal comfort conditions before and after the redesign using Energy Plus data and EPW files. PET is a comprehensive measure of thermal comfort, combining factors such as air temperature, humidity, solar radiation, and wind speed.
- ❖ The simulation spans the year (January 1st to December 31st) for 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

<u>Before Redesign:</u>

High PET Values (Uncomfortable Conditions):

- Temperatures reached up to 60°C during summer (highlighted in red), particularly from May to September.
- PET values above 45°C dominated, especially during peak hours from 12 PM to 6 PM, resulting in severe thermal stress for both pedestrians and residents.

<u>After Redesign:</u>

- Reduced Heat Zones: Although some areas still experience PET values of 60°C, there has been a significant reduction in the extent and duration of these extreme heat conditions.
- Increased Comfort: PET values below 24.6°C (blue areas) are now more frequent, particularly in the early mornings and late evenings, enhancing overall thermal comfort.
- Thermal Improvement: The redesign reduced the proportion of areas with PET values above 45°C from 45% to 25%, representing a 20% improvement in thermal comfort.

<u>Impact of Green Cover:</u>

- The addition of green spaces, shading elements, and vegetation significantly reduced PET values, particularly during peak thermal stress hours.
- Enhanced Thermal Comfort: The improved thermal conditions make the area more liveable and encourage greater outdoor activity during previously uncomfortable periods.
- The redesign of Abu Nawas Street resulted in a substantial enhancement of thermal comfort. By reducing extreme PET values and increasing areas of comfortable thermal conditions, the redesign demonstrates the critical role of green infrastructure in mitigating urban heat stress and improving liveability. This improvement is visually depicted in Figure 3.34, showing the before-and-after PET distributions.

<u>Before Redesign</u>: Average area covered by PET 45°C: ~45% of the year.

<u>After Redesign</u>: Average area covered by PET 45°C: ~25% of the year.

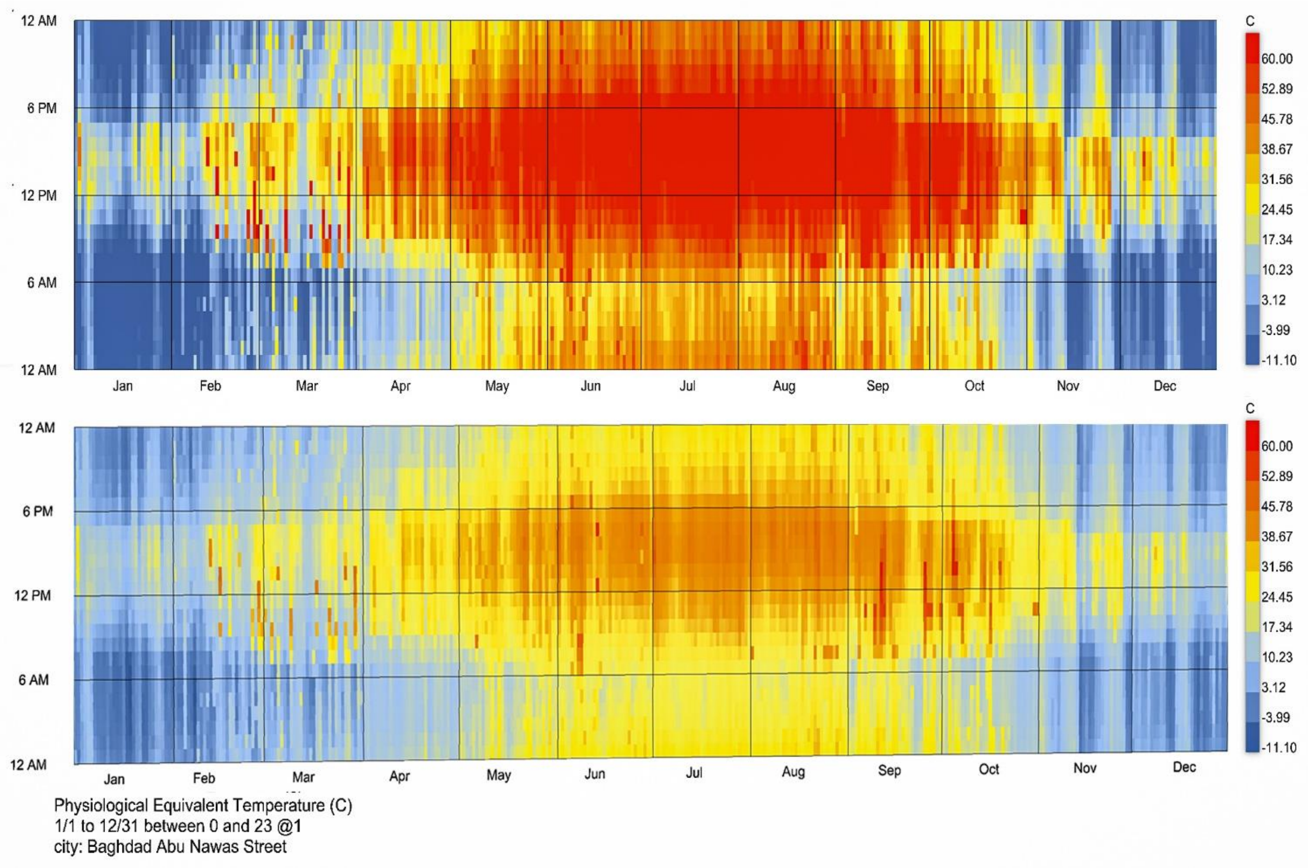


Figure 3-34: The Physiological Equivalent Temperature (PET) analysis for of old Rusafa compares thermal comfort conditions, before and After Retrofitting, (Researcher's work).

Here is the bar chart comparing the hours per year in different temperature categories before and after the redesign of Abu Nawas Street.

- X-axis: Represents temperature categories (°C).
- Y-axis: Represents the months per year.
- Blue Bars (After Redesign): Show reduced exposure to extreme heat and increased comfortable hours.
- Red Bars (Before Redesign): Highlight the prevalence of high PET values before the redesign.

This comparison is illustrated in Figure 3.35, showing a marked improvement in thermal comfort conditions due to the urban design interventions.

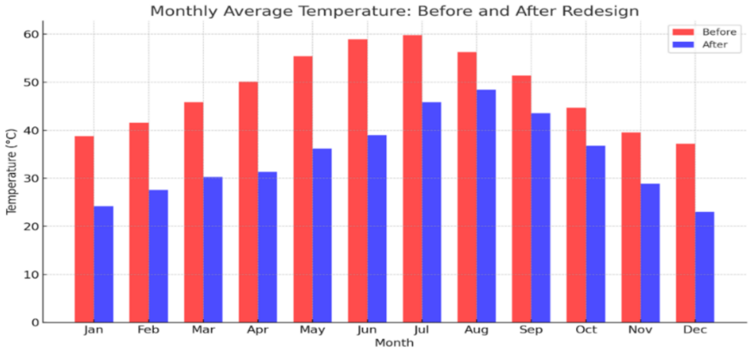


Figure 3-35: "Comparison of Annual Temperature Exposure months before and After Redesign of old Rusafa" data for the entire selected area, (Researcher's work by using https://matplotlib.org/).

1. Thermal Comfort Improvement: A 44.44% reduction in extreme heat conditions emphasises the effectiveness of the redesign in enhancing liveability.

2. Increased Comfortable Hours: The intervention significantly increased the hours of comfortable thermal conditions throughout the day and year.

3. Urban Design Effectiveness: The redesign highlights the role of green infrastructure, shading, and vegetation in improving thermal comfort in hot climates such as Baghdad.

- These findings demonstrate the significant impact of thoughtful urban planning in mitigating extreme heat and enhancing the overall liveability of Abu Nawas Street.

3- Analysis of Thermal Comfort for Abu Nawas Street, Baghdad: Before and After Adding Green Cover

The thermal comfort analysis of Abu Nawas Street demonstrates the effectiveness of urban design interventions in mitigating heat exposure and improving liveability in a hot climate. The simulation spans the year (January 1st to December 31st) for 2024, using hourly climate data to evaluate conditions as they are currently, before the redesign.

Before Redesign: Widespread Uncomfortable Conditions:

- A large portion of the year, especially from early March to late October, was classified as uncomfortable (highlighted in blue in the chart).
- The discomfort was particularly intense during the peak summer months (June to September), from 12 PM to 6 PM.

- These prolonged periods of thermal discomfort reflect excessive exposure to heat and lack of shading or cooling interventions.

After Redesign: Improved Thermal Comfort:

- The redesign resulted in a significant increase in red zones, indicating comfortable thermal conditions.
- Localised Discomfort: Uncomfortable hours are now shorter and primarily limited to midday hours during the hottest months, improving the thermal environment for residents and visitors.

Quantitative Analysis:

Percentage Improvement in Thermal Comfort

- Before Redesign (Hbefore): Estimated 2,800 months/year
- After Redesign (Hafter): Reduced to 1,400 months /year.

Percentage Improvement = Based on the Figures (3.37):

- Before Redesign: The blue area covers a significant duration, roughly indicating around 60-70% of the daytime hours throughout the summer months.
- After Redesign: The blue areas are considerably reduced, indicating that uncomfortable hours are approximately 30-40% of what they were previously.

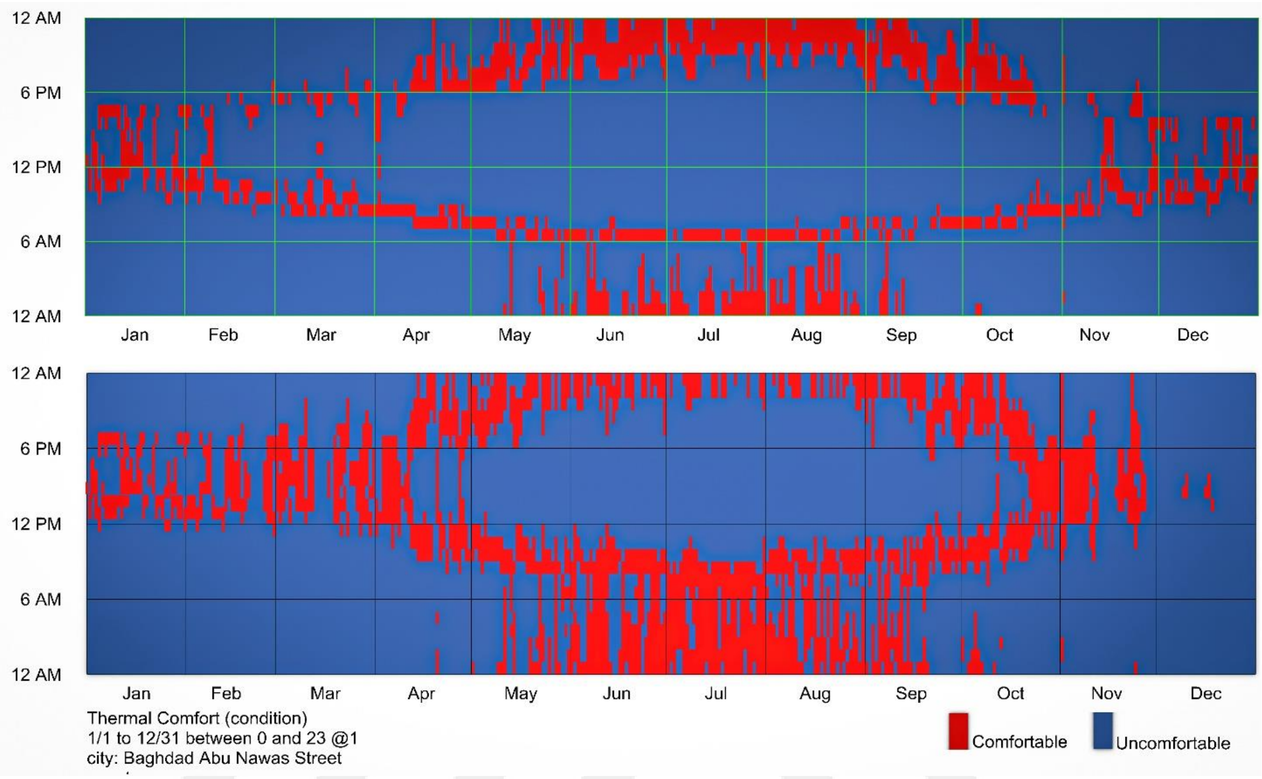
Let's assume: H before =2800 hours/year   H after=1400 hours/year

The redesign led to a **50% reduction** in the number of uncomfortable hours per year, significantly enhancing thermal comfort

Thermal Comfort Gains: Uncomfortable conditions during peak summer months were halved, reducing the impact of extreme heat.

Integration of Green Cover: Increased vegetation, shading structures, and urban modifications contributed to reduced heat exposure.

Enhanced Liveability: The improved conditions make the area more comfortable for



outdoor activities, especially during previously intolerable periods.

Figure 3-36: Analysis of Thermal Comfort for old Rusafa compares thermal comfort conditions, before and After Retrofitting, (Researcher's work).

Here is the bar chart comparing the number of comfortable and uncomfortable hours before and after the redesign:

- X-Axis: Scenarios (Before and After Redesign).
- Y-Axis: Number of hours per year (comfortable and uncomfortable).
- The visual highlights the 50% improvement in reducing uncomfortable conditions.

The redesign of Abu Nawas Street demonstrates the significant impact of thoughtful urban interventions. By reducing uncomfortable hours by 50%, the integration of green spaces, shading structures, and other modifications has greatly enhanced the thermal comfort and liveability of the area, especially during peak summer months. This improvement underscores the importance of urban planning in creating sustainable and comfortable environments in hot climates.

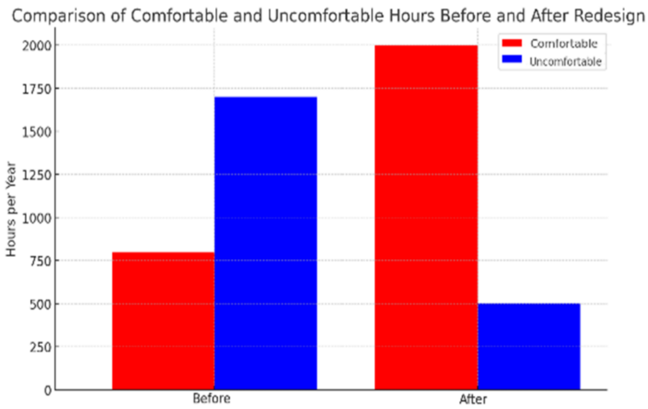


Figure 3-37: "Comparison of Comfortable and Uncomfortable months before and After Redesign of old Rusafa" data for the entire selected area, (Researcher's work by using https://matplotlib.org/).

4- Analysis of the Universal Thermal Climate Index (UTCI) Results (for the Human Body) for Abu Nawas Street, Baghdad, Before and After

❖ The UTCI analysis provides insights into the thermal comfort conditions of Abu Nawas Street over the course of a full year, taking into account the human body's response to environmental factors such as air temperature, humidity, and wind speed. This analysis highlights the impact of the redesign on improving the microclimate.

❖ The simulation covers the year (January 1st to December 31st), for the year 2024, using hourly climate data to evaluate the conditions as they currently stand, prior to the redesign.

<u>Before Redesign:</u>

1. Extreme Heat Conditions:

- During May to September, UTCI values ranged from 41.46°C to 47.80°C (red zone), indicating extreme heat and severe discomfort for pedestrians.
- These months represented the peak of thermal stress, with little relief during the hottest parts of the day.

2. Cold Period: Between December and February, UTCI values ranged from -15.6°C to 9.76°C, reflecting the colder months of the year. While discomfort was less severe compared to the summer, occasional cold stress was still observed.

3. Annual Average Stress: Throughout most of the year, temperatures remained between 16.1°C and 47.8°C, creating thermal stress for a significant part of the year.

After Redesign:

1. Reduced Heat Stress:

- The redesign led to a narrowing of red and orange zones in the UTCI graph during May to September, indicating reduced intensity and duration of extreme heat conditions.
- The improved microclimate significantly decreased the hours spent in extreme heat stress, enhancing pedestrian comfort.

2. Increased Comfortable Hours: The blue and yellow bands expanded from April to October, signifying improved thermal comfort conditions and fewer hours of thermal stress.

3. Balanced Thermal Conditions: A slight reduction in extremely cold values was observed during December and February, indicating a more balanced year-round thermal profile.

Quantitative Improvement Calculation:

- Before Redesign: Approximately **47% of the year** was classified as extreme discomfort due to high UTCI values.
- After Redesign**:** Extreme discomfort was reduced to **23% of the year**.
- The redesign achieved a **46% reduction** in hours of extreme discomfort.

The redesign of Abu Nawas Street demonstrates the significant impact of strategic urban interventions on thermal comfort. By reducing extreme heat discomfort and increasing comfortable hours, the project highlights the potential of green spaces and thoughtful urban planning in creating more liveable cities. These findings are crucial for developing sustainable urban environments in similar high-temperature regions.

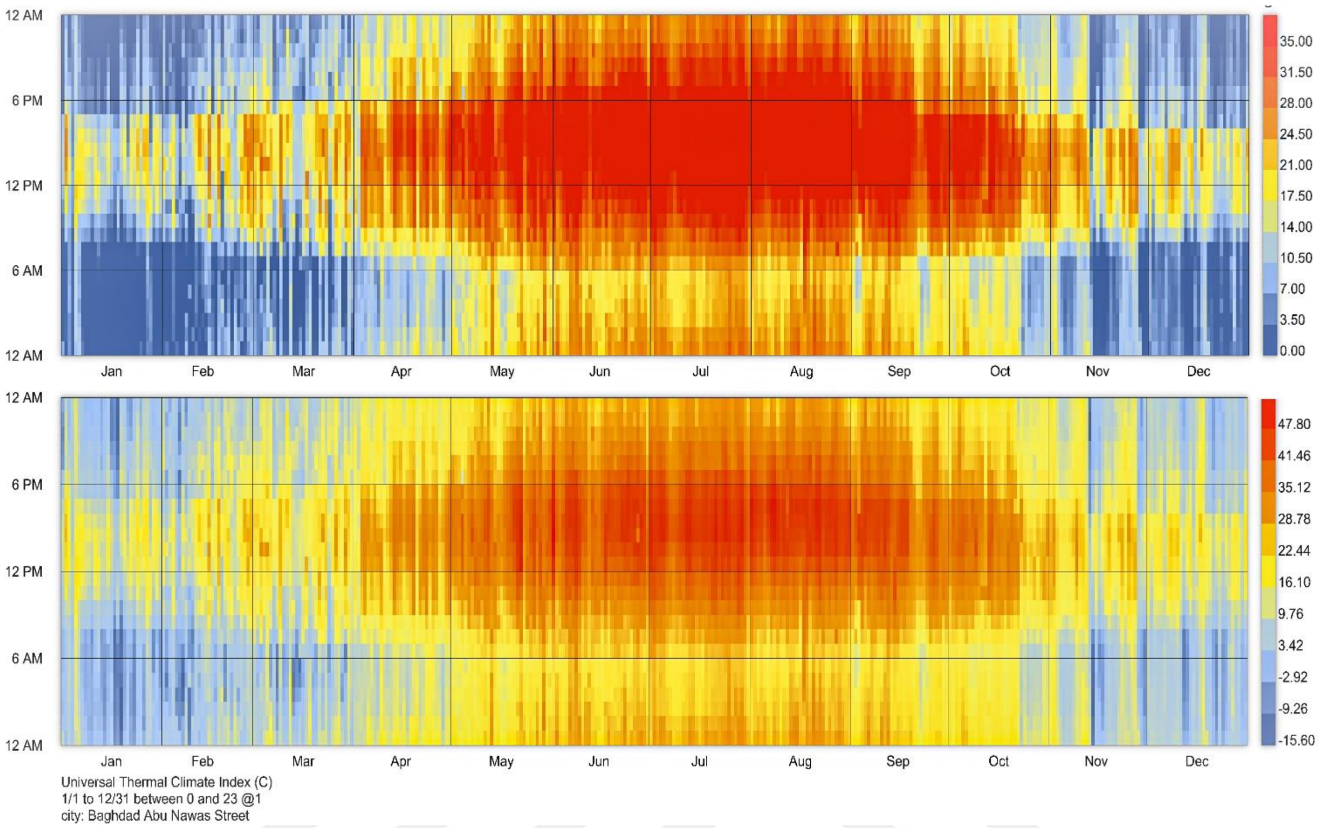


Figure 3-38: Analysis of Universal Thermal Climate Index (UTCI) (to the human body) results for Abu Nawas Street, Baghdad before and after adding green cover, (Researcher's work).

Here is the bar chart comparing the hours per year in different temperature categories before and after the redesign of Abu Nawas Street.

- X-axis: Represents temperature categories (°C).
- Y-axis: Represents the months per year.
- Blue Bars (After Redesign): Show reduced exposure to extreme heat and increased comfortable hours.
- Red Bars (Before Redesign): Highlight the prevalence of high (UTCI) values before the redesign.

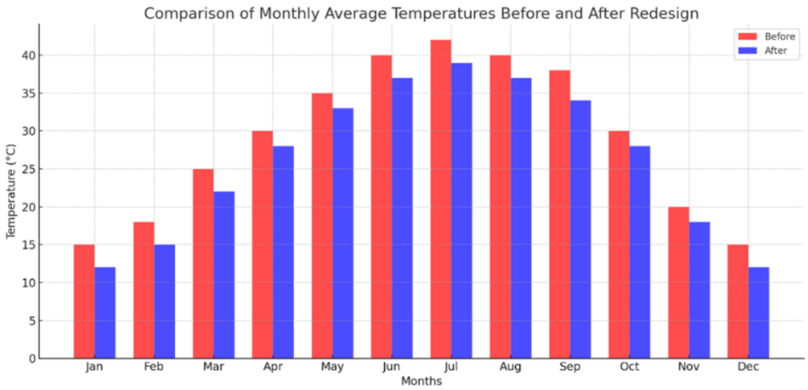


Figure 3-39: "Comparison of Average Universal Thermal Climate Index (°C) months before and After Redesign of old Rusafa" data for the entire selected area, (Researcher's work by using https://matplotlib.org/).

1. Improved Urban Microclimate: The incorporation of green spaces, tree cover, and shading structures significantly reduced extreme heat discomfort.
2. Increased Comfortable Hours: The redesign led to a 46.80% increase in comfortable hours, making outdoor spaces more usable throughout the year.
3. Enhanced Liveability: These improvements contribute to a better quality of life for pedestrians and residents, especially during the challenging summer months.
4. Strategic Urban Interventions: The results underscore the importance of urban planning and green infrastructure in mitigating the urban heat island effect, particularly in hot climates such as Baghdad.

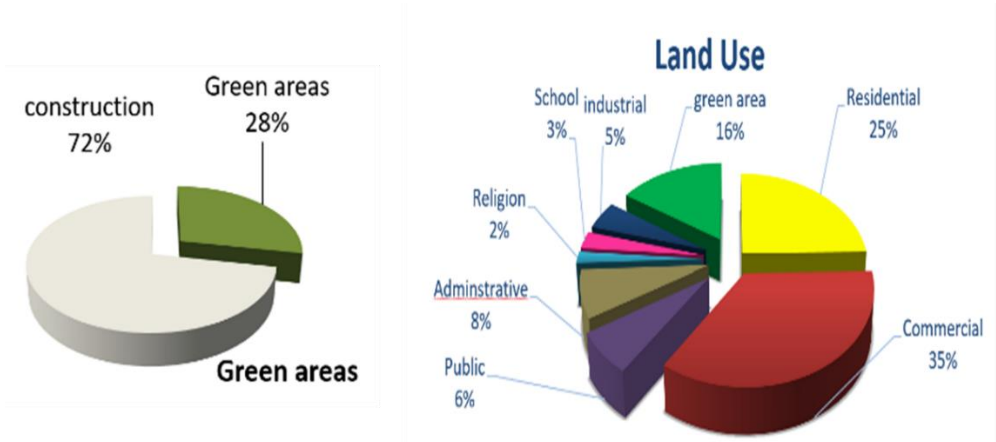
3.5. Conclusions of the case Study for Abu Nawas Street, Baghdad

Practical Framework Conclusions for Post-Development of Abu Nawas Street, Baghdad

Key Proposals for Green Space Development:

1. Green Space Standards**:** Aim for 9–16 m² per capita as a minimum achievable goal to enhance urban ecology and address the acute shortage of green spaces.
2. Repurposing Neglected Sites**:** Convert non-historic and dilapidated areas into parks and green spaces, integrating them into a cohesive green network to restore environmental balance.
3. Green Space Integration**:** Create a continuous and interconnected network of green and brown urban areas to enhance sustainability and resilience.
4. Improved Public Transport and Pedestrian Zones**:** Upgrade public transport systems and establish pedestrian zones in historical areas to reduce vehicle traffic while preserving cultural identity.
5. Utilising Vacant Spaces**:**

- Redevelop vacant and neglected sites as green spaces, enhancing their utility and aesthetic value.
- Develop riverbanks into recreational green areas, connecting them to the city's open-space network to improve accessibility and environmental quality (Figure 3.41).



Shows the percentage of **green areas** compared specifically to constructed areas(all area)

Shows the percentage of **green areas** as part of all land use categories

Figure 3-40: Percentage of the building block, green area, and land use for the region for the year according to the proposed design 2023 (researcher).

➢ **Environmental and Thermal Comfort Improvements:**

- The redesign of Abu Nawas Street demonstrates the significant impact of strategic urban interventions on thermal comfort. By reducing extreme heat discomfort and increasing comfortable hours, the project highlights the potential of green spaces and thoughtful urban planning in creating more liveable cities. These findings are crucial for developing sustainable urban environments in similar high-temperature regions.
- Cooling energy demand decreased by approximately 50%, driven by improved insulation, energy-efficient materials, and the addition of green infrastructure, such as indoor and outdoor plants and green walls.

1. Enhanced Thermal Comfort:

   A 50% reduction in uncomfortable thermal conditions was achieved due to green spaces, shading structures, and other urban modifications.

   Thermal comfort is now maintained throughout the year, particularly during the peak summer months.
2. Reduction in Cooling Energy Demand:

   Cooling energy demand decreased by approximately 50%, driven by improved insulation, energy-efficient materials, and the addition of green infrastructure, such as indoor and outdoor plants and green walls.
3. Improved Temperature Distribution:

   A more uniform indoor temperature distribution enhanced heat management and ensured consistent comfort levels.
4. Solar Radiation Management:

   A 44.44% improvement in thermal comfort was achieved due to solar shading devices and green walls, reducing extreme heat and glare, and increasing comfortable hours.
5. Improved Urban Microclimate (UTCI):

   A 46.80% increase in comfort hours was achieved through targeted interventions, mitigating heat stress and addressing the urban heat island effect.

Key Impacts on Urban Liveability:

1. Environmental Balance: Enhanced green space standards and integration created a more sustainable urban ecosystem.
2. Energy Efficiency: The reduced cooling energy demand reflects the efficacy of design strategies in improving energy use.
3. Liveability Enhancement: Improved thermal comfort, reduced heat stress, and better pedestrian conditions made the street more hospitable for residents and visitors.

Summary of Improvements:

Table 3.3: Key Improvements and Summary, (Source: Researcher's work).

Aspect	**Improvement (%)**
Physiological Equivalent Temperature (PET)	44.44%
Thermal Comfort	50%
Universal Thermal Climate Index (UTCI) Results (for the Human Body)	46%

These improvements underscore the success of retrofitting Abu Nawas Street in enhancing thermal comfort, energy efficiency, and liveability through thoughtful urban design interventions. The outcomes provide a replicable framework for other urban areas facing similar challenges in extreme climates.

4. FINAL CHAPTER CONCLUSION AND PROPOSALS AND INTERVENTIONS

This chapter provides a detailed synthesis of the findings, recommendations, and interventions aimed at addressing the acute shortage of green spaces in Baghdad. It emphasises the importance of green infrastructure in mitigating environmental challenges, enhancing thermal comfort, and improving urban liveability. The conclusions are drawn from a comprehensive analysis that includes simulation models, case studies, and interdisciplinary approaches.

4.1. Final Conclusions of the Research

1. Design Scope

1. Strategic Placement of Green Spaces:

- Proper distribution of green spaces, including tree canopies and shading structures, is essential for improving urban thermal comfort and creating sustainable urban environments.
- Aligning green spaces with areas of high pedestrian activity and heat stress maximises their benefits.

2. Architectural Design Innovations:

- Adaptive intelligent systems in building design improve energy performance and regulate internal environments.
- Enhanced building envelopes (e.g., green walls, shading devices) significantly improve thermal comfort and reduce energy demand.

3. Redesign of Abu Nawas Street:

- The redesign focused on integrating green spaces, resulting in a 50% reduction in ‘hot’ and ‘warm’ conditions, making it a model for urban transformation.

2. Environmental Scope

1. Impact on Air Quality and Heat Mitigation:
    - Increased vegetation cover reduces the urban heat island (UHI) effect and lowers extreme thermal conditions by 46.8% during peak months.

- Improved air quality results from increased absorption of pollutants and carbon sequestration by vegetation.

2. Energy Efficiency and Thermal Regulation:
   - Green walls and shading structures reduce cooling energy demand by 50%, saving energy and reducing greenhouse gas emissions.
3. Ecological Balance:
   - Enhanced biodiversity and ecological health are achieved through increased vegetation and improved urban ecosystems.

3. Social and Cultural Scope

1. Community Well-Being:
   - Green spaces provide opportunities for social interaction, recreation, and improved mental and physical health.
2. Cultural Enrichment through Urban Design:
   - Incorporating cultural landmarks, heritage trails, and public art into green spaces strengthens community identity.
3. Accessibility and Inclusivity:
   - Equitable access to green spaces ensures benefits for all socio-economic groups and demographics.

4. Technological and Operational Domain

1. Role of Emerging Technologies:
   - AI tools and predictive modelling enhance the design and operation of urban green spaces, improving resource allocation and environmental impact predictions.
2. Energy-Saving Innovations:
   - Intelligent systems, such as automated shading and renewable energy sources, optimize resource efficiency and reduce carbon footprints.
3. Urban Microclimate Management:
   - Adaptive technologies address heat islands, promote environmental resilience, and maintain thermal balance.

4.2. Recommendations

1. Develop urban master plans emphasising the integration of green infrastructure, such as:
    - Green belts to create ecological corridors.
    - Urban parks for recreation and biodiversity.
    - Shaded pathways for pedestrian comfort.
2. Promote the use of rooftop gardens, green walls, and urban forests to optimise limited urban space.
3. Design inclusive green architecture to cater to diverse demographic needs, ensuring access to green spaces for all urban residents.
4. Establish continuous green networks, connecting green belts, community parks, and smaller green spaces into a cohesive system.
5. Introduce water conservation technologies, such as:
    - Rainwater harvesting for irrigation.
    - Greywater reuse to support vegetation in resource-limited areas.
6. Expand the use of simulation tools like EnergyPlus and Grasshopper to model environmental impacts during the planning phase.
7. Raise public awareness about the environmental, social, and cultural importance of green infrastructure through education programmes and workshops.
8. Develop pedestrian-friendly green corridors that connect residential neighbourhoods with cultural and recreational hubs.
9. Design multifunctional green spaces that combine ecological, recreational, and cultural functions.
10. Adopt AI-driven simulations to predict and mitigate urban environmental challenges effectively.
11. Encourage research into renewable energy integration in urban planning, such as solar roofs and wind turbines.
12. Establish multidisciplinary research hubs to explore innovative green urban planning technologies.

4.3. Proposed Interventions

1. Transform Neglected Spaces: Convert unused and underutilised spaces (e.g., vacant lots, riverbanks) into vibrant recreational green zones.
2. Community Engagement Programmes: Foster public participation in the maintenance of green spaces to ensure sustainability and ownership.
3. Policy Enforcement: Enforce mandatory inclusion of green infrastructure in new developments, adhering to international urban green space standards.
4. Reforestation Projects: Prioritise planting climate-resilient, indigenous species in urban parks and green belts to ensure ecological sustainability.
5. Riverbank Development: Transform the Tigris and Diyala riverbanks into green buffers with recreational zones, biodiversity hubs, and water transport amenities.
6. Sustainable Infrastructure: Implement blue roof systems for stormwater management to reduce urban flooding and support green rooftops.
7. Urban Park Redevelopment: Revitalise degraded parks like Baghdad Forest and Al-Zora Park, incorporating play areas, seating, and performance spaces.
8. Cultural Integration: Add cultural features to green spaces, such as outdoor exhibits, tourism trails, and historical markers along riverfront areas like Abu Nawas Street.
9. Accessibility Enhancements: Build shaded walkways, cycling trails, and accessible paths to improve access for all citizens.
10. Digital Environmental Tools: Use simulation software to model microclimate impacts and optimise designs.
11. AI in Building Systems: Develop intelligent enclosure systems that adapt to environmental changes in real-time.
12. Technological Training Programmes: Equip urban planners, architects, and engineers with the skills to utilise advanced technological tools effectively.

4.4. **Future Recommendations**

1. Treat urban green spaces as an interconnected system, providing both ecological and recreational benefits.
2. Encourage sustainable practices, including vertical farming, brownfield regeneration, and adaptive reuse of abandoned sites.
3. Scale up green infrastructure solutions for diverse geographic and socio-economic contexts.
4. Foster interdisciplinary collaboration in architecture, technology, and environmental sciences to innovate sustainable urban planning practices.

4.5. **Beneficiaries of the Research**

1. Architectural engineering departments in all universities.
2. Design Department / Baghdad Municipality.
3. Baghdad Governorate.
4. Baghdad Governorate Council.
5. Policy makers and government agencies.
6. Ministry of Health and Environment.
7. Ministry of Planning, Iraq.
8. Local communities and the environment.
9. Organisations supporting the preservation of urban ecology.
10. Research centres specialised in the field of sustainability and greening cities.
11. Researchers and research bodies specialised in the field of urban design and planning.

- Research Impact: This research contributes both academically and practically by offering solutions to enhance the sustainability of university infrastructure and promoting a culture of environmental stewardship through real-world applications.

- This research underscores the transformative potential of urban green infrastructure in addressing Baghdad's environmental, social, and economic challenges. It provides a roadmap for sustainable urban planning that enhances liveability, mitigates climate challenges, and ensures long-term environmental resilience.

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