T.C.
ISTANBUL GEDIK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

ADOPTING THE REQUIREMENT OF A PROPOSED SUSTAINABLE BUILDING DESIGN IN BAGHDAD CITY

MASTER'S THESIS

Ausaid Atheer Sabah AL-RAWI

Civil Engineering Department

Civil Engineering Master in English Program

DECEMBER 2023
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Second Advisor: Assist. Prof. Dr. Suaad RIDHA

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DECLARATION

I, Ausaid Atheer Sabah, declare that this thesis titled “Adopting The Requirement of A Proposed Sustainable Building Design In Baghdad City” is original work I completed this to receive my master's in civil engineering. I further declare that neither this thesis nor any part of it has ever been submitted to or presented for a research paper or other degree at any other university or institution. (29 /12/2023)

Ausaid Atheer Sabah AL-RAWI

DEDICATION

To my beloved country, Iraq, the source of my heritage and inspiration. Despite being miles away, your spirit and history have echoed in every word penned in this thesis. As I defend this work beyond our borders, I carry the essence of "My Iraq" with pride and gratitude.

To my family, the steadfast anchor in the tempest of academic pursuits. Your unwavering support, encouragement, and understanding have been the bedrock upon which I built this thesis.

To my friends, the companions on this intellectual journey. Your camaraderie, discussions, and shared moments of triumph and challenge have made this endeavor richer and more fulfilling.

PREFACE

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December 2023 Ausaid Atheer Sabah AL-RAWI

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ABBREVIATIONS

ASCE	: The American Society of Civil Engineers
CFD	: Computational Fluid Dynamics
EMLI	: The Environmental Management Leadership Initiative
EVI	: The Global Environmental Vulnerability Index
GHGs	: Greenhouse Gases
IPCC	: Intergovernmental Panel on Climate Change
MDGs	: Millennium Development Goals
OTC	: Outdoor Thermal Comfort
OUT_SET	: Outdoor Standard Effective Temperature
PET	: Physiological equivalent temperature
PMV	: Predictive Mean Vote
RAYMAN	: Radiation and Advective-Convective Model
SDGs	: Sustainable Development Goals
SOLWEIG	: Solar and Long Wave Environmental Irradiance Geometry
SVF	: Sky view factor
Tmrt	: Mean Radiant Temperature
UN	: United Nation
UNFCCC	: United Nations Framework Convention on Climate Change
VOC	: Volatile Organic Compound

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ADOPTING THE REQUIREMENT OF A PROPOSED SUSTAINABLE BUILDING DESIGN IN BAGHDAD CITY

ABSTRACT

The climate has recently undergone significant changes, including an unexpected temperature increase. This temperature rise has had a significant impact on human life and has exacerbated global warming. The urgent need to rethink city design, particularly in hot and dry climates, emerged now. One of the main focuses for the researcher's right nowadays is achieving sustainability in cities, especially in hot and dry climates The inadequate and inevitably limited studies on developing sustainability and improving human thermal comfort in the arid local weather may also be caused by a lack of planning for healthy environments or a plan to increase environmental comprehension and keep up with contemporary advancements in urban architecture. The study proposes an arid climate area design based on structural and application criteria to improve pedestrian thermal comfort requirements, as well as how urban factors like sky view factor, building orientation, vegetation, and shadings influence pedestrian thermal comfort. In this study, a city with a hot, dry, and long summer, such as Baghdad, where the temperature regularly exceeds 50°C, will be proposed. ENVI-met will investigate and accurately analyses a number of factors related to improving thermal comfort, including predicted mean vote PMV and mean radiant temperature Tmrt. The air temperature, relative humidity, and wind speed will all be considered. The study's findings and recommendations will be incorporated into the requirements for designing and implementing sustainable cities in hot, dry climate regions.

We suggest considering a district in Baghdad due to its sophisticated urban fabric, which includes conventional and traditional residences and modern buildings. The Baghdad region has a semiarid and dry climate, with warm summers and cold winters. In the summer of 2010, the highest recorded temperature was 50 °C, which included the hottest days of summer in Iraq's hottest year.

Prof. Michael Bruse of the University of Mainz, Germany, and his team developed ENVI-met in 1994, starting with the design of the microclimate model and continuing to improve it. Since that time. ENVI-met is a software program that simulates the interactions between urban surfaces. At the microscale, vegetation and the atmosphere are studied. ENVI-met enables the investigation of the effects of small-scale changes in urban design (trees, backyard greening, new infrastructure).on microclimate under different mesoscale conditions. The building model is evaluated by ENVI-met in close connection with the outdoor fluid dynamics model, which offers precise wind data for every minute of the day for every wall and façade section of the structure.

Keywords: *Global Warming, Sustainability, Hot and Dry climate, Human thermal comfort, Sky View Factor, Building Orientation, Vegetation, ENVI-met, Mean radiant temperature, Predicted Mean Vote, Air Temperature, Humidity.*

BAĞDAT ŞEHRİNDE ÖNERİLEN SÜRDÜRÜLEBİLİR BİNA TASARIMI GEREKSİNİMLERİNİN KABUL EDİLMESİ

ÖZET

İklim, son zamanlarda beklenmeyen bir sıcaklık artışı da dahil olmak üzere önemli değişikliklere uğramıştır. Bu sıcaklık artışının insan yaşamı üzerinde önemli bir etkisi olmuş ve küresel ısınmayı daha da kötüleştirmiştir. Özellikle sıcak ve kuru iklimlerde şehir tasarımını yeniden düşünme ihtiyacı şimdi ortaya çıkmıştır. Araştırmacıların şu anda odaklandığı ana konulardan biri, özellikle sıcak ve kuru iklimlerde şehirlerde sürdürülebilirliği sağlamaktır. Arid iklimde sürdürülebilirliği geliştirmeye ve insanların termal konforunu artırmaya yönelik yetersiz ve kaçınılmaz olarak sınırlı çalışmalar, sağlıklı çevreler için plan eksikliği veya çevresel anlayışın artırılması ve kentsel mimarideki çağdaş gelişmelere ayak uydurmak için bir plan eksikliği tarafından da kaynaklanabilir. Çalışma, yaya termal konfor gereksinimlerini iyileştirmeye yönelik yapısal ve uygulama kriterlerine dayalı olarak kurak iklim alanı tasarımı önermektedir. Ayrıca, gökyüzü görüş faktörü, bina yönelimi, bitki örtüsü ve gölgeleme gibi kentsel faktörlerin yaya termal konforunu nasıl etkilediğini de incelemektedir. Bu çalışmada, sıcak, kuru ve uzun yazları olan Bağdat gibi bir şehir önerilecektir, burada sıcaklık düzenli olarak 50°C'nin üzerine çıkmaktadır. ENVI-met, termal konforu artırmaya yönelik bir dizi faktörü, tahmini ortalama oy (PMV) ve ortalama radyant sıcaklık (Tmrt) dahil olmak üzere, doğru bir şekilde inceleyecek ve analiz edecektir. Hava sıcaklığı, bağıl nem ve rüzgar hızı da dikkate alınacaktır. Çalışmanın bulguları ve önerileri, sıcak, kuru iklim bölgelerinde sürdürülebilir şehirlerin tasarımı ve uygulanması için gereksinimlere dahil edilecektir.

Bağdat'ta bir bölge düşünmenizi öneriyoruz, çünkü bu bölge sofistike bir kentsel dokuya sahiptir ve geleneksel konutları, modern binaları içermektedir. Bağdat bölgesi, yarı kurak ve kuru bir iklime sahip olup, sıcak yazlar ve soğuk kışlarla karakterizedir. 2010 yazında kaydedilen en yüksek sıcaklık 50 °C idi ve bu, Irak'ın en sıcak yılında yazın en sıcak günlerini içermekteydi. Almanya Mainz Üniversitesi'nden Prof. Michael Bruse ve ekibi, 1994 yılında mikro iklim modelinin tasarımıyla başlayıp onu geliştirmeye devam ederek ENVI-met'i geliştirdi. O zamandan beri, ENVI-met, kentsel yüzeyler arasındaki etkileşimleri simüle eden bir yazılım programıdır. Mikro ölçekte bitki örtüsü ve atmosfer incelenmektedir. ENVI-met, ağaçlar, arka bahçe yeşillendirmesi, yeni altyapı gibi küçük ölçekli değişikliklerin mikro iklim üzerindeki etkilerini farklı mezoskal koşullar altında araştırmayı mümkün kılar. Bina modeli, ENVI-met tarafından, yapıların her duvarı ve cephe bölümü için günün her saati için ayrıntılı rüzgar verilerini sağlayan dış ortam akışkanlar dinamiği modeli ile yakından bağlantılı olarak değerlendirilir.

Anahtar Kelimeler: *Küresel Isınma, Sürdürülebilirlik, Sıcak ve Kuru İklim, İnsan Termal Konforu, Gökyüzü Görüş Faktörü, Bina Yönelimi, Bitki Örtüsü, ENVI-met, Ortalama Radyant Sıcaklık, Tahmini Ortalama Oy, Hava Sıcaklığı, Nem.*

1. INTRODUCTION

1.1 General Background

In recent years, the globe's all-time high temperature occurred so early, which was immediately followed by a variety of climate-related natural disasters such as floods, droughts, and wildfires all over the world. This reminds us of the world's most crucial sustainability objective, which is to keep global warming to 1.5 °C over pre-industrial levels. Despite the fact that human activity has resulted in a 1.25°C increase in global temperatures, the current emissions trajectory suggests the world's current efforts to keep warming to 1.5°C are inadequate. Integrating sustainability with broader development needs is critical for reaching this limit, making scientists' and sustainability professionals' missions more important than ever. More than half of the world's population must be accommodated on only 3% of the Earth's land surface area. They are to blame for human-caused climate change in urbanized areas and contribute to global climate change, which is currently a major challenge. According to the Intergovernmental Panel on Climate Change (IPCC) report, global warming has been recognized as a serious global problem in the last decade. As a result, more intense urban heating is being observed in urbanized areas around the world, affecting people's health and well-being. Rapid urbanization and its consequences, together with increased human activity, have posed significant challenges to urban management and development. Controlling urban problems is extremely difficult, if not impossible, because of the numerous factors that influence urban development. Globalization makes it more difficult for urban planners and designers to take into account all of the variables involved in urban management. Cities face unique challenges as economic engines and innovation hubs. The basis causes of urban problems are ineffective government and management, rather than inherent characteristics of cities. Scheduling for development and urban design are widely acknowledged to have a significant part in managing urban development. The form and structure of the city are influenced by planning and urban design, which in turn influences the uses of land that are carried out there. Traditionally, when designing a development, all of these factors are taken into account. The concept of sustainable development has accelerated the planning process's consideration of all three elements (social, economic, and environmental). To follow the principles of sustainable development, development efforts must consider everything of their social, economic, and environmental consequences.

1.2 The Significance of the Research

First and foremost, this study aims to emphasize the significance of managing sustainable city design, particularly in hot and dry environments. The study's second and most important goal is to identify the most important design criteria for the implementation and management of sustainable construction in hot, dry climates. The researcher was motivated to conduct this research due to the recent rise in the desertification of hot, dry regions, especially Baghdad, and a lack of interest in designing cities in a way that best mimics their natural environments and enhances pedestrian thermal comfort. Secondly, Baghdad has chosen a city with one of the longest summers in the world, lasting more than seven months of the year and characterized by hot temperatures when compared to neighboring cities. The most important and fundamental goal is to propose a set of design changes to a significant Baghdad structure, as well as to manage all aspects and advancements required to achieve thermal comfort and sustainable construction for this building.

1.3 The Objectives of the Study

The study seeks to propose more than just designing cities in hot, dry climates, but also to investigate all of the engineering factors and requirements needed to meet the specifications of sustainable cities. In this study, a city with a hot, dry, and long summer, such as Baghdad, where temperatures exceed 50° C on most summer days, will be proposed. This study looked into several factors that could influence the design of sustainable cities in the study area, such as the sky view factor, aspect ratio, street orientation, materials albedo factor, and vegetation effect.

1.4 Methodology

- Study Area

Baghdad is located to the right of the Iraqi capital, at latitude 33 18' N and longitude 44 21' E, and is 39 m above sea level. The Tigris River, which flows from north to south through the city, divides it in half. Baghdad is one of the world's hottest cities, with temperatures reaching nearly 50 °C on hot days. Figure 1 depicts the location of Baghdad in relation to Iraq.

Figure 1.1: The location of Baghdad in relation to Iraq

Source: (https://www.getamap.net/maps/iraq/).

- Numerical Modeling ENVI-met

Michael Bruse at the University of Mainz and his group in Germany created ENVI-met in 1994, beginning with the design of the microclimate model and evolving since then. ENVI-met replicates the micro-scale interactions between vegetation, urban surfaces, and the atmosphere. Scientists can investigate how various meso-scale conditions, such as backyard greening, trees, and new construction, impact microclimate on a small scale by using ENVI-met. Figure 2 displays the architecture of the ENVI-met model. ENVI-met analyzes the external microclimate as well as the energy performance of every building in the model domain. The building model is directly coupled to the outdoor fluid dynamics model, which provides detailed wind data for every second of the day for each wall and façade segment of the building, because wind and sun are the primary factors controlling a surface's thermodynamics and heat distribution. A 3D tool for modeling urban climates, ENVI-met is used in real estate development and urban design to mimic the microclimatic effects of vegetation, buildings, and other objects.

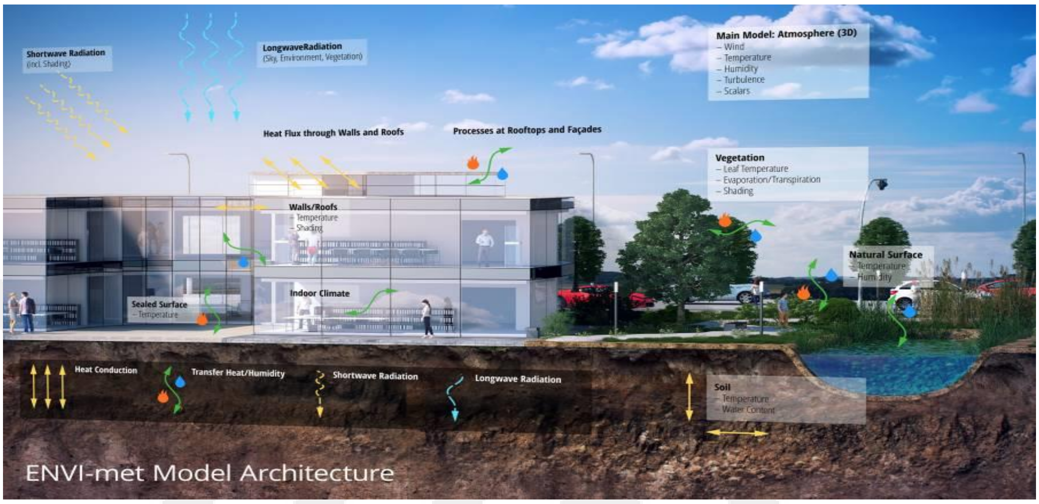

Figure 1.2: Model Architecture for ENVI-met

Source: (https://doku.php?id=intro:modelconcept; envi-met.info).

1.5 The Organization of the Study

There are five chapters in the dissertation. In the second chapter, terms and concepts related to sustainability are briefly reviewed, principles of sustainability, the concept of sustainable management, and the impact of climate change. Chapter three discusses the requirements of sustainable urban design, which include aspects such as aspect ratio, sky view factor, orientation, the effect of the albedo factor, and the role of vegetation in enhancing outdoor thermal comfort. In the fourth chapter, a design for a sustainable city in Baghdad is proposed according to the requirements outlined in the third chapter. The results of the simulation process are also discussed in the ENVI-met software in this chapter. Chapter Five presents the insightful results derived from the simulation models. It offers ideas and suggestions for further study as well.

2. THE CLIMATE CHANGE AND THE DEVELOPMENT OF THE CONCEPT OF SUSTAINABILITY

2.1 Introduction

Climate change has a significant impact on our environment, societies, and economy, making it a pressing worldwide concern. The concentrations of greenhouse gases in the atmosphere, primarily caused by human activity, are the main cause of it. The vulnerability of the environment to global climate change is a critical concern, as changing weather patterns and rising temperatures pose significant risks to ecosystems, biodiversity, and natural resources. Furthermore, climate change has specific regional impacts, such as in Iraq, where its effects are already being felt. These include extreme weather events, water scarcity, and ecosystem disruptions, which have profound socio-economic consequences.

Globally, efforts to address climate change have accelerated as a result of awareness of how urgent the issue is. The aforementioned endeavors encompass reducing greenhouse gas emissions, adjusting to the evolving climate, and advocating for sustainable development methodologies. A resilient and prosperous future is largely dependent on sustainability, which places a strong emphasis on striking a balance between social, environmental, and economic factors. By incorporating sustainable practices into our plans, we can reduce the adverse effects of climate change and build a more just and sustainable world.

This study looks at how vulnerable the environment is to climate change, how greenhouse gas emissions affect the environment, how the situation in Iraq is particularly examined, and how current efforts to address climate change while promoting sustainability in various areas such as development goals and sustainable building practices are being evaluated. Emphasizing the role of sustainability in reducing climate change and building resilience, the researcher hopes to add to the global dialogue and motivate constructive action toward a sustainable future.

2.2 Climate Change

According to earlier research, the term "climate change" refers to long-term variations in temperature and weather patterns. Significant volcanic eruptions or variations in the sun's activity may cause such fluctuations. However, since the 1800s, human activity has been the main contributor to climate change, particularly the burning of fossil fuels like coal, oil, and gas. Greenhouse gas emissions from the burning of fossil fuels cover the earth like a blanket, trapping solar heat and raising temperatures. The main greenhouse gases that cause climate change are carbon dioxide and methane. For instance, when coal or gasoline is burned to heat a building, these are produced. Clearing land and trees can also release carbon dioxide into the atmosphere. Agriculture and the production of gas and oil are the primary sources of methane emissions. Energy, industry, transportation, buildings, agriculture, and land use are the main industries that produce greenhouse gases (United Nations, 2023).

Furthermore, climate scientists have shown that nearly all of the global warming that has occurred during the past 200 years is due to human activity. Greenhouse gases from human activities such as the ones mentioned above are causing the earth to warm more quickly than it has in the last two millennia. The surface of the Earth is currently, on average, 1.1 °C warmer than it was before the industrial revolution in the late 1800s and warmer than it has ever been in the preceding 100,000 years. The most recent decade (2011–2020) is the warmest on record, with temperatures rising over the last four decades to levels not seen since 1850. A common belief is that the primary impact of climate change is an increase in temperature. However, the temperature rise is not where the story begins. Because the Earth is a system in which everything is interconnected, changes in one area may have an effect on changes in all other areas. Climate change is currently causing extreme droughts, water scarcity, destructive fires, flooding, melting polar ice, catastrophic storms, and a decline in biodiversity (IPCC, 2021).

Climate change, however, might affect our jobs, homes, security, and capacity to cultivate food. Certain people like those who live in developing countries and small island states, are already more vulnerable to the effects of climate change. While conditions like sea level rise and saltwater intrusion have advanced to the point where entire communities have been forced to evacuate, long-lasting droughts are putting people at risk of starvation. It is projected that there will be more "climate refugees" in the future.

2.2.1 The environmental vulnerability and global climate change

According to Maplecroft (2021), a global risk consultancy, the Global Environmental Vulnerability Index (EVI) is determined and released by the company. The world's largest and fastest-growing economies including India present serious risks to their citizens, ecosystems, businesses, and environment, according to a new global rating that evaluates their susceptibility, according to Edmonds et al (2020). To evaluate country vulnerabilities in three main categories, the worldwide Environment Vulnerabilities Index examines 42 social, economic, and environmental elements on a worldwide scale.

Wagdi and Hasaneen (2019) stated that the extent to which cities and nations will be impacted by climate change depends on several additional non-climatic elements. Estimating the future effects of climate change can be very challenging since there are many variables that affect it, such as rising temperatures, changes in precipitation and snow cover, and the effects of extreme weather events. Scientists' predictions of climate change are also not always accurate. To determine if a country is ready for something, it also seems necessary to consider the political and social developments in a region. Several developing countries are particularly vulnerable because they rely on natural resources for their economic development.

Overall, a country or region's level of environmental vulnerability is represented by the EVI, a numerical index. Since then, the emphasis has shifted to encompass human environmental management, such as the utilization of fossil fuels, deforestation, and modifications to land use, human health, and pollution, as well as environmental hazards resulting from the improper use of natural resources like land, water, and soil. Additionally, it was determined that the vulnerability index should be simple to create and based on metrics that are help compare countries and indicate each nation's relative risk. For instance, the Atlantic and the Mediterranean, as well as other areas, are related to the Mediterranean basin. Leduc et al. (2017) concluded It is a very diverse region where complex interactions between human activity and natural phenomena affect the variability of the climate.

2.2.2 Greenhouse gas emissions

According to Somerville et al. (2007), gases that absorb and release radiant energy at thermal infrared wavelengths are known as greenhouse gases (GHGs), and they are responsible for the greenhouse effect. The primary greenhouse gases found in Earth's atmosphere are water vapor (H2O), carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and ozone (O3). Without greenhouse gases, the average surface temperature of the Earth would be approximately 18 °C (0 °F), as opposed to the current average of 15 °C (59 °F).

Since the start of the Industrial Revolution (about 1750), human activity has caused the atmospheric concentrations of carbon dioxide and methane to rise by more than 50% and 150%, respectively (National Oceanic and Atmospheric Administration, 2022). The industry continued to be the largest polluting sector in 2020, the latest year for which there is enough information to offer sectoral-level detail, producing 31% of global emissions as shown in Figure 1. 28% of the world's emissions come from the electric power industry, a large portion of those emissions coming from the burning of coal. Land use, agriculture, and waste production together produced emissions that made up 18% of all emissions worldwide, followed by transportation at 16% and buildings at 7%.

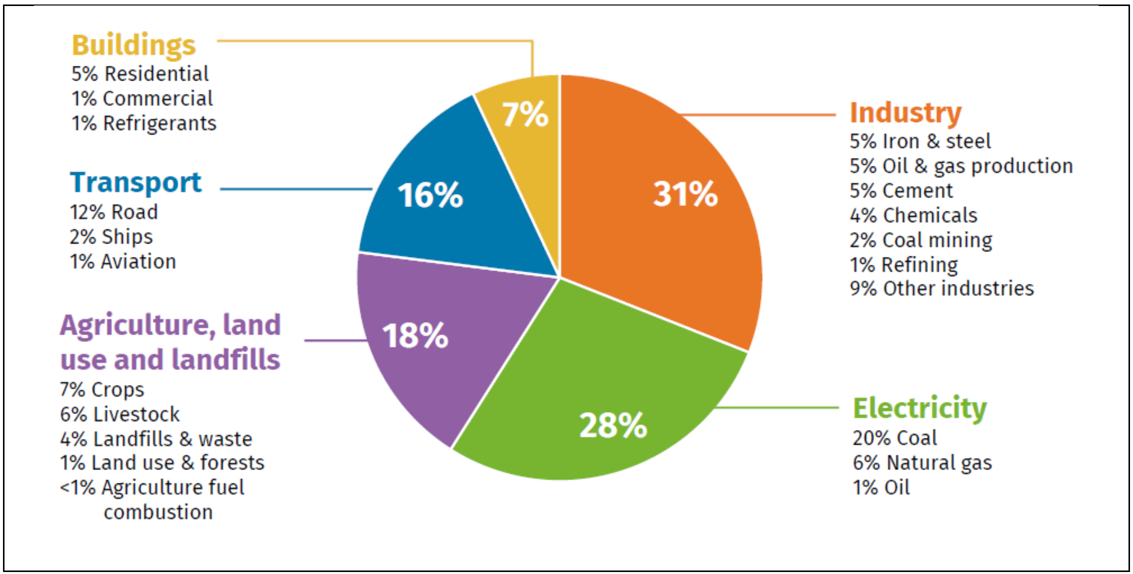

Figure 2.1: Global Emission By Sector

Source: (Rhodium Group, 2021).

2.2.3 The impacts of climate change in Iraq

The following are the major climate change issues in Iraq:

- Desertification.
- Water Scarcity and Drought.
- Declining Precipitation.
- Extremely High Temperatures.
- Dust and Sand Storms.
- Soil Erosion and Salinization.
- Increased Energy Consumption.

Desertification: There are numerous reasons why Iraq is becoming increasingly desertified. High temperatures, a lack of water, and soil erosion are a few of the climate factors contributing to the problem. Human-caused factors such as population growth, which accelerates the loss of natural resources, and unrestricted tree-cutting, which contributes significantly to deforestation, inadequate water management, and ineffective farming techniques exacerbate the problem. These factors combined have put the nation's agriculture sector on the verge of collapse. The agricultural industry is obviously in decline and is still in decline with an annual loss of 100 square kilometers of fertile land owing to desertification and more than 40% of the country already being a desert (Republic of Iraq: Ministry of Agriculture, 2017).

Al-Saidi and Al-Jumaili (2013) found that between 1970 and 2010, estimated cultivated lands decreased from 12.2% to 8.3% of the country’s total area.

Extremely High Temperatures: Global warming is caused by "greenhouse gases," such as carbon dioxide and other air pollutants, accumulating in the atmosphere and absorbing solar radiation and light reflected off the earth over time. As a result of their efforts to keep heat from escaping into space, the planet's temperature rises (The Natural Resources Defense Council [NRDC], 2021).

Also, during the last century in Iraq, the advancements in the consumption of fossil fuels have further triggered this phenomenon. Consequently, and in recent years, the temperature is breaking records or coming very close to it, as it soars above 50°C. Basra province, in 2016, broke the record for the hottest temperature in Iraq at 53.8°C. In 2020, Baghdad experienced a 51.8°C breaking its former highest temperature record of 51°C set in 2015 (The Weather Network, 2020). the government declared its first-ever heat holiday back in 2011 and advised citizens to stay at home, a matter that has become more frequent throughout the last decade, displaying the extent of this extreme heat in shutting down the entire public sector (The Washington Post, 2011). On the other hand, workers in the private sector with outdoor jobs such as in agriculture, construction, Industry, services, transport, and tourism are at higher risk of health issues and lower productivity which negatively affects their daily or monthly income.

Increased Energy Consumption: One of the industries affected by climate change is the energy sector. The annual energy consumption has increased from just 20 trillion watt hours (TWh) in 1965 to 610 TWh in 2019, which was then slightly reduced to 573 TWh in 2020 (British Petroleum BP, 2021). Although the country's growth is the primary cause of this increase, climate effects are also a significant factor. According to the graph below, fossil fuels account for 99% of all energy use, making them the primary source of energy. Additionally, the primary source of greenhouse gas (GHG) emissions is those fuels. Only the last two decades (2000-2020) saw a 194% growth in annual CO_2 emissions (the major gas that makes up GHGs), accounting for 0.61% of the total global CO_2 emissions that are the main cause of global warming (Global Carbon Project, 2021). In contrast, compared to the 1990s, when low carbon sources had the greatest representation and made up 27% of the electricity supply in 1995 in particular, the share of primary energy from low carbon sources, primarily hydropower, has gradually decreased to its lowest percentile in recent years, contributing to only about 1% of total energy use and 2% of electricity (Our World in Data, 2022).

2.2.4 Efforts to address climate change

1. Mitigation Efforts:

- Renewable Energy Transition: nvesting in and promoting renewable energy sources, such as hydroelectric, wind, and solar power, to lessen emissions and reliance on fossil fuels.

- Energy Efficiency: Reducing energy consumption and emissions in buildings, transportation, and industry by implementing energy-efficient technologies and practices.

- Carbon pricing: Putting a price on carbon emissions and encouraging emission reductions through the use of mechanisms like carbon taxes or emissions trading systems.

- Sustainable Transportation: Promoting the use of electric cars, bicycles, walking, and public transportation to lower greenhouse gas emissions from the transportation sector.

- Sustainable Land Use: Implementing sustainable agricultural practices, reducing deforestation, promoting afforestation, and managing land use to minimize emissions.

2. Adaptation Efforts:

- Climate Resilient Infrastructure: Designing infrastructure that can withstand climate impacts, such as sea-level rise, extreme weather events, and changing precipitation patterns.

- Water Management: Implementing measures to conserve water resources, improve water efficiency, and manage water scarcity caused by climate change.

- Ecosystem-based Adaptation: Conserving and restoring ecosystems like forests, wetlands, and coastal areas that provide natural resilience to climate change impacts.

- Climate Risk Assessment and Planning: Conduct risk assessments to understand vulnerabilities and develop strategies for climate change adaptation in various sectors.

3. Agreements and International Cooperation:

- Paris Agreement: Taking part in and carrying out the obligations stated in the Paris Agreement, such as establishing carbon reduction goals, reporting development, and offering financial assistance to developing nations.

- United Nations Framework Convention on Climate Change (UNFCCC): Participating in global climate negotiations and partnerships.

2.3 Sustainability

Morelli And John (2011) described the atmosphere when first observing our planet from orbit in the middle of the 20th century, it appeared to be a little, delicate ball that was dominated by patterns of clouds, oceans, vegetation, and soils rather than human activity or man-made structures. The failure of humanity to integrate its actions into that pattern is radically altering planetary systems. Hazards that could endanger life are present with several of these developments. It is necessary to acknowledge and manage this new reality, from which there is no way out (From One Earth).

Development can be made sustainable by humanity so that it satisfies present needs without endangering the capacity of future generations to satiate their own. Though not strict limits, the concept of sustainable development does refer to constraints placed on environmental resources by the state of technology and social structure at the moment, as well as by the biosphere's ability to absorb the effects of human activity. However, it is possible to better manage technology and social structure to clear the path for a new period of economic growth. The committee asserts that widespread poverty is no longer a given. While poverty is a bad thing in and of itself, sustainable development calls for providing for everyone's basic needs and expanding opportunities for people to realize their dreams of a better life. Ecological and other disasters will always be a possibility in a world where poverty is pervasive (Strategic Imperatives, 1987).

As seen in Figure 2, Baker and Barbara (1997) demonstrated the connection between the definitional and normative aspects of sustainable development and the development of language. On the normative front, the WCED report is acknowledged to have its roots in two early political documents of the global environmental debate: the documents produced following the 1972 Stockholm United Nations (UN) environmental conference and the Ramsar Convention of 1971 on the conservation of wetlands (cf. Wolters 1995). These documents for the second UN conference on the environment, held in Rio de Janeiro in 1992, spoke of environmentally sound strategies and the wise use of natural resources, respectively.

These were far more normative terms than sustainable development as the overall paradigm.

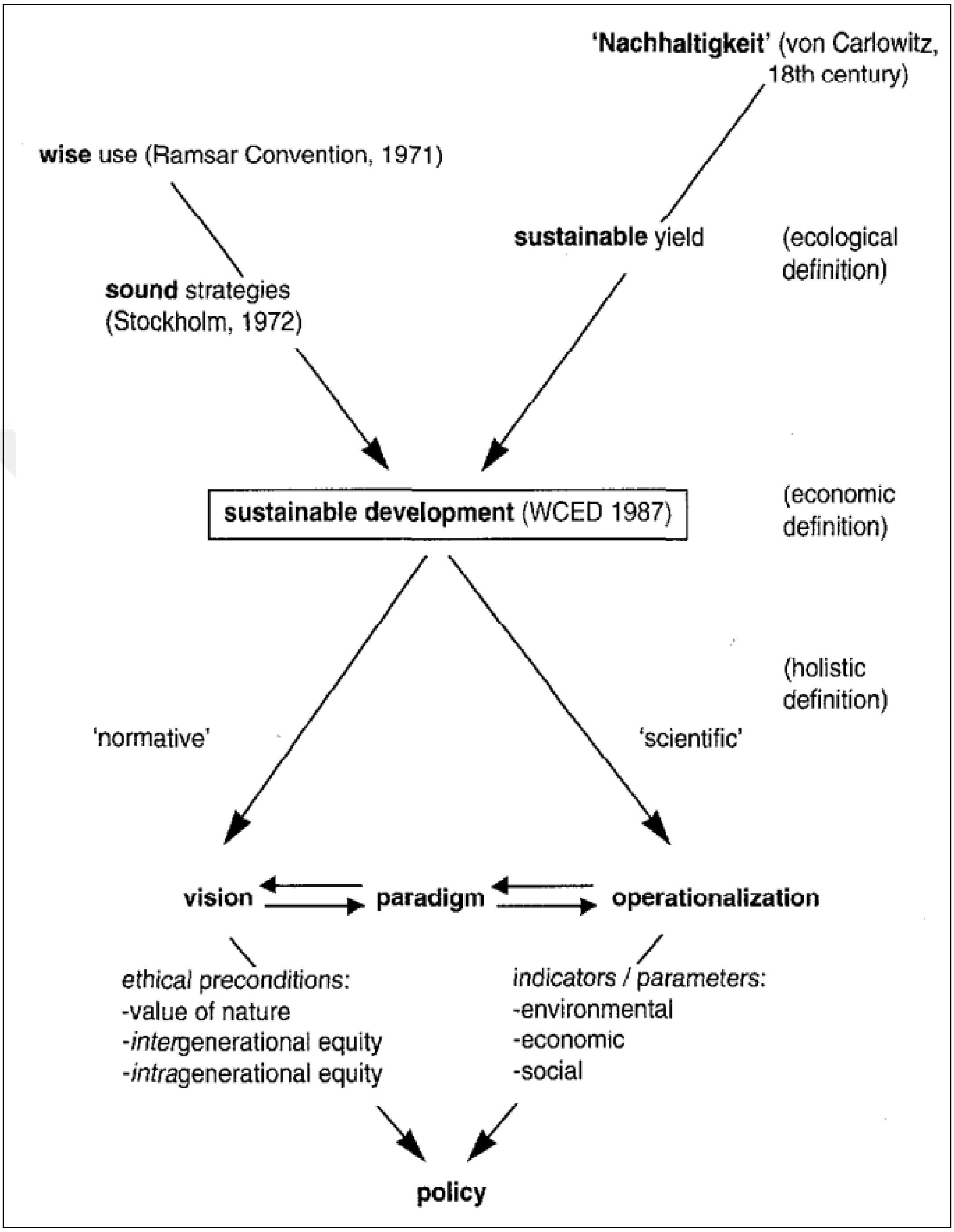

Figure 2.2: The Scientific and Normative Facets of Sustainability
Source: (Becker & CGIAR Secretariat, 1997).

2.3.1 Achieving balance between the environment, equity, and economy

Callicott et al. (1997) demonstrated that even though the idea of sustainability is losing its usefulness as a standalone term, it seems to be doing something when preceded by a defining modifier like "ecological," "agricultural," or "economic." As shown in Figure 3. Members of numerous professions have made an effort to define the term in the context of their fields. In "Ecological Sustainability as a Conservation Concept," Callicott and Mumford introduce an ecological definition of sustainability that connects human needs and ecosystem services: "meeting human needs without compromising the health of ecosystems." This definition clarifies the meaning of the term "ecological sustainability" as a concept that conservation biologists can use. They suggest using this idea as a compass for regions where people do activities.

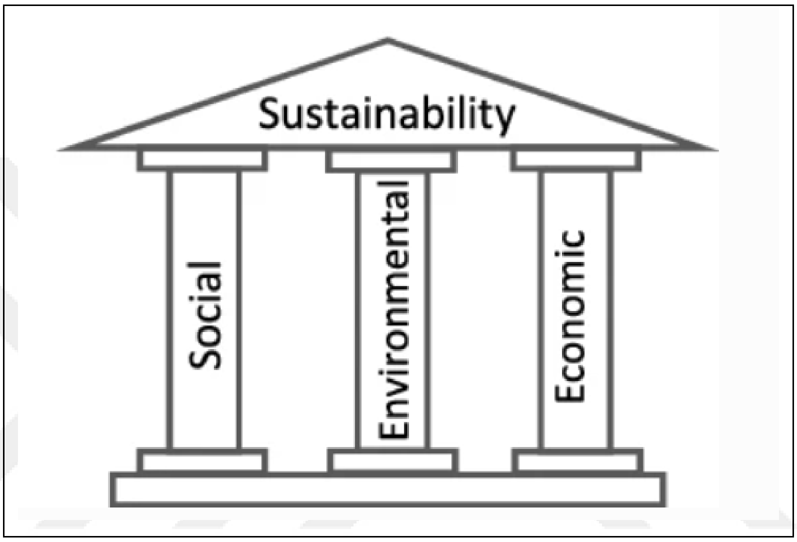

Figure 2.3: Pillars of Sustainability

Source: (Callicott & Mumford, 1997).

Per Foy's (1990) elucidation in "Economic Sustainability and the Preservation of Environmental Assets," economic sustainability requires that present economic activities do not unnecessarily burden future generations. According to economists, environmental assets comprise only a small portion of the value of natural and man-made capital, and their preservation necessitates a thorough financial analysis. In contrast, an ecologist will work to protect the bare minimum of physical environmental assets. To assure sustainability, he contends that since an ecological perspective will better capture the current situation, it should be used to constrain traditional economic thinking. Economic sustainability analysis should focus on reducing social costs associated with upholding environmental asset protection requirements, not on establishing what those standards should be.

In "Social Sustainability: towards some definitions," McKenzie and Stephen (2004) noted several definitions that have been made, and she comes to the broad conclusion that social sustainability is "a positive condition within communities and a process within communities that can achieve that condition." A list of similar principles is provided as an addition to this definition, including:

- Fairness in obtaining essential services.
- Equitable treatment among generations.
- A social structure that honors different cultural traditions.
- Citizen participation in politics, especially locally.
- A sense of belonging to the community.
- A method by which one can teach others about social sustainability.
- Ways in which a community can, when feasible, meet its own needs.
- Advocating politically to address issues that community action is unable to resolve.

Butler concluded that environmental managers do share a shared professional aim that is distinct from but related to that of those goals was tentatively identified by him as "ecological balance" and the industries that employ them. The Rochester Institute of Technology's Environmental Management Leadership Initiative (EMLI), a cooperative worldwide research program, funded his work. According to the program's Statement of Purpose, the goal of EMLI is "to define and develop the evolving role of the professional environmental manager in moving our social and economic systems toward a more sustainable future."

Over the past four years, Butler and Brian (2009) have provided support and continued this work to further refine this goal and validate the evolving results through presentations and corresponding workshops at a series of EMLI symposia hosted by Budapest, Hungary's Corvinus University, the American College of Management and Technology in Dubrovnik, Croatia, Milan, Italy's Bocconi University, Luneburg, Germany's Leuphana University, and Rochester, New York's Rochester Institute of Technology. The process's conclusion was that the establishment of "environmental sustainability" as the environmental manager's career goal has garnered strong support from other professionals in the field.

2.3.2 Sustainable development goals (SDGs)

The 2030 Agenda of Goals for Sustainable Development, which was endorsed by all UN members in 2015, offers a unifying framework for peace and prosperity for people and the planet both now and in the future. At the core of them are the seventeen Sustainable Development Goals (SDGs), which represent an invitation to action for all countries—developed and developing—to participate in a global partnership. They are aware that eradicating poverty and other forms of deprivation calls for policies that support economic growth, improve health and education, reduce inequality, thwart climate change, and defend our forests and oceans (United Nations, 2015). The Sustainable Development Goals have been the focus of decades of work by the UN Department of Social and Economic Affairs and other UN agencies.

- More than 178 countries ratified Agenda 21, a comprehensive action plan to foster international cooperation for sustainable development that will enhance human well-being and protect the environment, during the Rio de Janeiro Earth Summit in June 1992.At the United Nations Headquarters in New York in September 2000, member states unanimously ratified the Millennium Declaration. As illustrated in Figure 4, eight of the Millennium Development Goals, or MDGs, were created in response to the summit with the aim of eradicating extreme poverty by 2015.

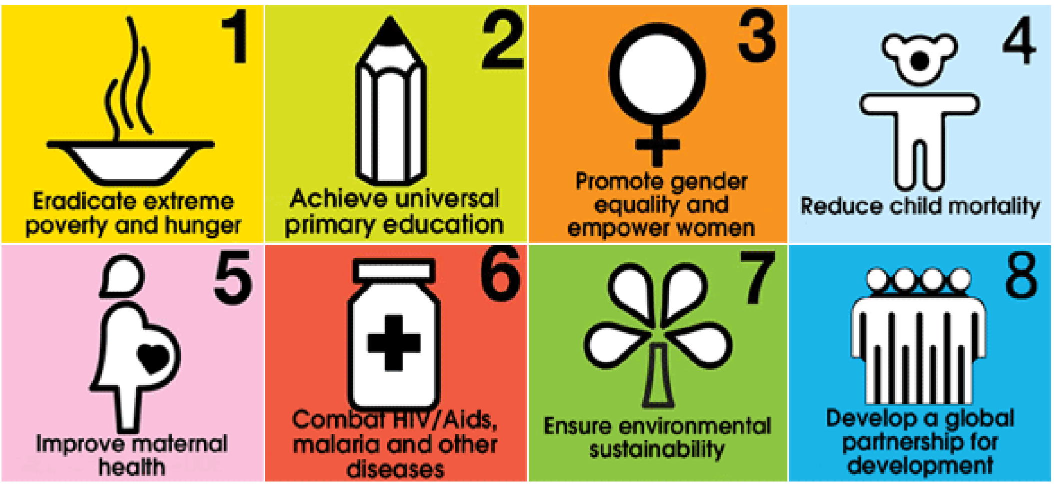

Figure 2.4: Millennium Development Goals (MDGs)

Source: (United Nations, 2015).

- The Declaration of Johannesburg on Sustainable Development and the Plan for its Implementation, which was adopted at the 2002 World Summit on the

Environment and Development in South Africa, built on the principles of Agenda 21 and the Declaration of the Millennium by emphasizing international partnerships and restated the international community's commitment to the environment and the eradication of poverty (United Nations, 2002).

- The member states adopted the final report, "The Future We Want," at the Rio+20 United Nations Summit on Sustainable Development in June 2012, in Rio de Janeiro, Brazil. Among other decisions, they resolved to establish the United Nations High-Level Political Forum on Sustainable Development and to begin the process of developing a set of SDGs to build upon the MDGs. The Rio + 20 agreement included guidelines for future work programs in development funding, small island developing nations, and other areas in addition to these additional measures to implement sustainable development (United Nations, 2012).
- In 2013, the General Assembly formed a thirty- member Open Working Committee to draft a proposal for the SDGs.
- In January 2015, the General Assembly began negotiations on the development plan for the post-2015 era. The process culminated in the adoption of the 2030 Agenda of Goals for Sustainable Development, which has 17 SDGs at its core, during the United Nations Summit on Sustainable Development in September 2015.
- 2015 was a historic year for international policy formation and multilateralis m, as numerous significant agreements were ratified.

The most significant is changing the world. The 2030 Agenda for Sustainable Development and its 17 SDGs were adopted at the September 2015 United Nations Sustainable Development Summit in New York City, as depicted in Figure 5.

Presently, the primary UN forum for the monitoring and evaluation of the SDGs is the yearly High-Level Political Forum on Sustainable Development.

Figure 2.5: Goals for Sustainable Development (SDGs)

Source: (United Nations, 2015).

2.3.3 Achieving sustainable development goals in Iraq

By combining and balancing the three elements of sustainable development, Iraq defined a new collective policy and institutional vision for the future of the nation with the adoption of the 2030 Agenda and the 17 Sustainable Development Goals (SDGs) and associated objectives in 2015. In order to facilitate the implementation of the SDGs, a comprehensive consultation process with a variety of important stakeholders and experts resulted in the formulation of the national strategic framework for sustainable development for the period from 2019 to 2030, "The Future We Want" (Iraq 2030 Vision). The 17 SDGs were mapped out in order to determine which ones are most pertinent to the situation in Iraq as part of the process of creating the 2030 Vision framework. This was followed by the contextualization of the global targets into national priorities to address a wide scope of critical issues, grouped into five interlinked building blocks for people, prosperity, planet, peace, and partnership (the “5Ps”): (Government of Iraq- Ministry of Planning [Iraq], 2022).

- People: End informal settlements, offer good housing, establish a high-quality and inclusive healthcare system, encourage decent employment for all unemployed people, and reduce poverty. This directly enables the achievement of priority targets under SDG 1; SDG 3; SDG 4; SDG 8; and SDG 11.

- Planet: reduce environmental pollution and greenhouse emissions; support the efficient use of water resources; ensure environment conservation; promote environmentally sustainable consumption and production patterns; and protect biodiversity - enabling the implementation of relevant targets under SDG 6; SDG 12; SDG 13; and SDG 15.
- Prosperity: promote sustainable economic growth; increase oil sector efficiency; strengthen private sector contributions for sustainable development; develop the agricultural sector and food security; develop infrastructure; and achieve well-governed financial sector contributing to priority targets under SDG 2; SDG 7; SDG 9; and SDG 10.
- Peace: a) building responsible, accountable, and inclusive governance, including the rule of law, access to justice, improving administrative decentralization, transparency, integrity, and public involvement in decision-making; combating corruption; reforming public financial administration and achieving financial sustainability; ; and b) safe society, including enhance a culture of tolerance and dialogue, development of families, women, and vulnerable groups, enhance values of citizenship and reduce inequalities, support the values of community achievement and voluntary work, provide sustainable solutions for the displaced populations and internal and external migrants- providing an enabling environment for the achievement of relevant targets for SDG 5; and SDG 16.
- Partnerships: facilitating multi-level, multi-sectoral, and multi-stakeholder national partnerships for sustainable development in line with key elements of SDG 17.

2.3.4 Sustainable building development

Researchers, 2020 examined the 2030 Agenda's implementation at engineering schools all across the world five years after its launch. They came to the conclusion that curricula, results, teaching-learning methodologies, and the evaluation of engineering degrees should all be aligned with the SDGs. The students of today will be the professionals of tomorrow, and society needs engineers who are socially conscious and who have properly integrated sustainability principles into their decision-making.

The best tool available to society to reshape and alter the world is engineering. As they develop new sustainable technologies, aspiring engineers must be equipped to tackle challenging, multidisciplinary problems. Civil engineering in particular carries a heavy burden as a catalyst for changing the built environment. The American Society of Civil Engineers in the United States has defined "civil engineer" in a clear and inspiring way. Upkeep of the drinking water, energy, roads, bridges, and other infrastructure is necessary to support modern society and promote environmental sustainability. The SDGs must therefore be included in the curriculum for aspiring civil engineers.

The United Nations Sustainable Development Goals (SDGs) have been endorsed by the American Society of Civil Engineers (ASCE, 2017). The organization also created "The Vision for Civil Engineering in 2025," a global blueprint that was derived from a summit on the future of civil engineering that took place in June 2006. Goals for civil engineering in the twenty-first century: a vision In line with the document. According to the American Society of Civil Engineers (2017), in 2025, civil engineers will play a key role in managing risk and uncertainty brought on by accidents, natural disasters, and other factors. They will also be responsible for constructing, designing, and operating society's built environment, which serves as its economic and social engine. All of these roles will require civil engineers to act competently, cooperatively, and ethically.

Helen (1992) stated it is necessary to revert a significant portion of developed and contaminated areas to their natural form to construct sustainable cities. However, due to the expansion of urban areas and populations, the normal recovery of land may be difficult or even impossible.

Also, it is yet possible to replace this recuperation with sustainable building practices and greening metropolitan areas, which would enable the development of brand-new biopositive facilities that are connected to, accepted by, and integrated into natural ecosystems. In order to achieve sustainability, correct the imbalance, and stop human-caused damage to nature, nature will eventually accept biopositive artifacts (buildings, structures, towns, and nations) as natural objects (Dempsey, 2009).

In terms of the design and development of neighborhoods and residential areas, creating a desirable urban environment is a significant challenge. The challenge is based on the concept of developing a comprehensive strategy to meet a variety of demands, including social, architectural, artistic, economic, sanitary, and hygienic requirements. Building networks and fostering community are social demands. Buildings are positioned to produce the best circumstances for their practical use. The single spatial composition of a space with its surroundings is the goal of architectural-artistic solutions. Rational use of local territory is a requirement of the economy (Guidebook for Assessment and Regulation of the Wind Regime of Residential Areas, 1986).

Designing a sustainable building that achieves two important goals of sustainable development:

- **Goal 11 Sustainable Cities and Communities.**
- **Goal 13 Climate Action.**

11 Sustainable Cities and Communities: Developing resilient societies and economies, safe and reasonably priced housing, and employment and business opportunities are all necessary to make a city sustainable. It entails making investments in public transportation, developing green public areas, and enhancing inclusive and participatory urban planning and management. By 2050, two thirds of humanity 6.5 billion people will reside in cities, accounting for more than half of all people on Earth. Sustainable development cannot be accomplished without a fundamental shift in the way our cities are planned and maintained. Because of the rapid urbanization brought on by growing populations and increased migration, particularly in emerging nations, slums are increasingly becoming an integral part of urban life. The objectives are as follows (United Nations, 2023).

- By 2030, guarantee that everyone has access to basic services and decent, safe, and affordable housing. Slums should be upgraded.

- By 2030, increase worldwide capacity for integrated, participatory, and sustainable human settlement planning and management, as well as inclusive and sustainable urbanization.
- Intend to protect and safeguard the natural and cultural heritage of the world.
- By 2030, lessen the negative effects of cities on the environment per person, especially by focusing on air quality and the management of municipal and other waste.
- By 2030, ensure that everyone has access to green, public, and safe spaces, especially women and children, the elderly, and people with disabilities.
- Through improving national and regional development planning, promote constructive economic, social, and environmental ties amongst urban, peri-urban, and rural communities.
- In accordance with the Sendai Framework for Disaster Risk Reduction 2015–2030, develop and implement holistic disaster risk management at all levels. By 2020, significantly increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters.
- Assistance in the form of financial and technical support should be extended to the least developed nations so that they can construct resilient and sustainable structures using locally available materials.

13 Climate Actions: The dangerous effects of climate change can be seen in every country in the world. The amount of greenhouse gas emissions has increased by over 50% since 1990. Global warming will continue to change our climate system if we take no action, which could have disastrous effects. Each year, climate change-related disasters result in economic losses worth hundreds of billions of dollars. Not to mention the human costs of geophysical disasters, which produced 4.4 billion injuries and 1.3 million fatalities between 1998 and 2017 and are 91% linked to climate change.

By 2020, it is intended to generate $100 billion a year to support poor nations' requirements for climate change adaptation and investments in low-carbon development. Target 13 and the other SDGs will both be directly supported by helping in disadvantaged areas. These activities must be carried out in tandem with efforts to incorporate disaster risk reduction strategies, sustainable resource management, and human security into national development plans. Maintaining the global mean temperature rise to two degrees Celsius over pre-industrial levels, with a 1.5°C target, is still feasible with strong political will, increased investment, and the application of current technology; however, this will require quick and decisive collective action. And the goal targets: Boost global adaptability and resistance to climate-related dangers and natural disasters. Include climate change mitigation measures in national planning, strategy, and policies (Rosa, 2017).

3. THE REQUIREMENTS OF SUSTAINABLE BUILDING DESIGN

3.1 Introduction

Since 1930, discussions on thermal comfort have existed (Taleghani et al., 2012).The canopy layer climate in dry climates is greatly influenced by three key factors: cooling techniques, ventilation, evaporation, and solar sheltering. As stated by Shishegar N. (2013) Solar access is a necessary condition for solar heating's effect on structures. The direction of solar radiation exposure is one of the major factors that influence the microclimate in urban planning. Compared to partially enclosed spaces and roads, parks and other open areas are typically more exposed to solar radiation.

Access to the sun for structures and access to the sun for pedestrians are the two main categories that make managing access to the sun's energy. The amount of solar radiation may have a direct effect on sun access. As a result, it affects the thermal comfort outside. The impact of solar access in urban design canyons is necessary to improve urban microclimate.

According to Erell E et al. (2011) Pedestrians are shielded from the direct impact of sunlight by trees and other plants, as well as by architectural features like arcades, overhangs, canopies, or frames. One strategy for providing shade is to restrict the width of the road. Other strategies include using pedestrian arcades that are connected to the nearby buildings at street level or planting trees along the sidewalks.

Numerous studies have shown how environmental benefits play a significant part in the development of human thermal comfort, energy conservation, and sustainable urban cooling methods. In Cairo, a study was carried out by Fahmy and Sharples (2009). Due to the urban area's clustered form with cool green islands and the wind flow through the main canyons, there were adequate comfort levels and cooling in some orientations.

In accordance with Rosheidat (2014) shading surfaces assist in reducing temperature and mean radiant temperature, which helps to improve thermal comfort at any given time. The energy that is stored at night can be released by shading surfaces to help create thermal comfort for pedestrians the following day.

3.2 The Requirements of Urban And Buildings Sustainable Design

There are certain criteria that must be met in order to effectively design sustainable cities in hot, dry regions in order to address the difficulties that high temperatures in these areas present. Among these conditions are:

1. Aspect ratio.
2. Sky view factor (SVF).
3. Orientation of building.
4. Vegetation.
5. Building Materials.
6. Geometric Design of The Buildings.

3.2.1 Aspect ratio

The aspect ratio was defined by Sravanti and Jareemit (2020) as the proportion relating the height of a building to the street's width. According to figure1, one of the fundamental design criteria for thermal comfort-based urban planning includes aspect ratio.

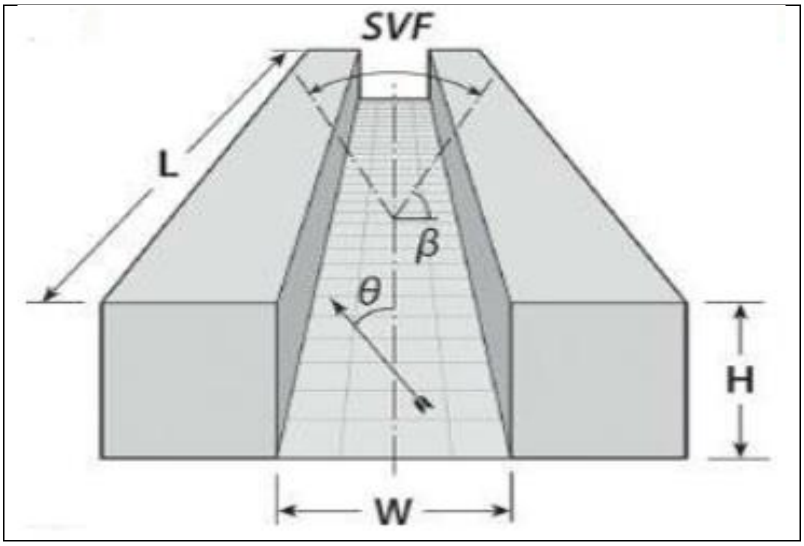

Figure 3.1: A Symmetrical Canyon Pattern's Cross-Section

Source: (Srivanit & Jareemit, 2020).

The H/W ratio, as stated by Kouklis and Yiannakou (2021) directly affects the urban microclimate because it alters how solar radiation enters the city through urban canyons, wind fluxes, and material absorption. The volumes, shading, and aperture design of the building also affect the microclimate's composition. Different environmental measures are affected differently by various H/W ratios.

For the purpose of clarity, a high H/W ratio can be indicative of low to moderately available areas for tree planting, low to average winter solar benefits, average to high summer sun exposure, high air circulation obstruction, and high sunlight reflection. Having said that, a little represents appreciable solar advantages, limited summer sun exposure, a minimal to average amount of sunlight reflection, a minimal to very minimal amount of airflow obstruction, and a sizeable area suitable for planting trees. Consequently, it is difficult to find an ideal H/W rate that correlates with each of the case-by-case domains (Muniz-Gäal et al., 2020).

Muniz-Gäal et al. (2020) looked for to ascertain whether the geometric features of urban street canyons affected the pedestrians' thermal comfort and microclimates. Achieving sustainability requires an understanding of how these factors influence the microclimate that affects urban street canyons in terms of both urban occupancy and thermal comfort.

The findings demonstrated that a canyon's higher H/W aspect ratio optimizes wind speed and building shading, enhancing pedestrian thermal comfort, particularly in the summer. However, the increase in the H/W ratio had a similar effect to what would happen if the space between the buildings had not been considered as far as the perception of thermal comfort at the pedestrian level.

3.2.2 Sky view factor (SVF)

Johnson and Watson (1984) defined the sky view factor (SVF) as one of those parameters that support current understanding and knowledge about urban-climate relationships. This definition was reached through a comprehensive and varied set of studies that looked at SVF and its relationship with urban heat island (UHI), thermal comfort, energy budget, air temperature, and day lighting. The term SVF refers to the ratio of radiation received at a given location to the total amount of radiation that would be received from the surrounding hemispheric radiant environment.

According to Steyn (1980) surface properties and their geometrical relationships, including the distances between surfaces and their orientations, may have an effect on this ratio's effect on the radiant energy flux density in an urban area.

Consequently, SVF can be conceptualized as the ratio of the visible sky to the total sky dome, which includes both the visible and obstructed sky, as viewed from a location within the urban space.

The limits of this ratio, in accordance with Lin et al. (2012) are between 0, which denotes a completely obscured sky, and a value of 1, which denotes a completely clear sky.

Numerous methods can be used to determine the SVF value. Using simple geometric compositions, Oke (1981) proposed the mathematical method of computing SVF, but in reality, urban buildings have asymmetrical geometry and constrained dimensions. In 1984, Johnson and Watson introduced the SVF value for more realistic situations and revised Oke's theory and equations to take this constraint into account.

The definition of the sky view factor (SVF), one of RayMan's key features, was clarified by Matzarakis et al. in 2007. The software generates it from an obstacle dataset, a topography raster, a user-drawn horizon limit, a Fish eye image, or another data source.

The sky view factor (SVF) is a measurement of the percentage of the sky that is visible from a particular point. . It has no dimensions and has a range of 0 to 1, with 0 denoting a sky that is entirely obscured by land or other obstructions and 1 denoting an open sky. Since the values of radiation fluxes are weighted on the SVF, it plays a significant role in the calculation of the indices. The SVF can be computed while accounting for the aspect ratio (Erell et al., 2011).

The relationship between aspect ratio and sky view factor (SVF) was discovered by Erell et al. (2011) and is depicted in Figure2.

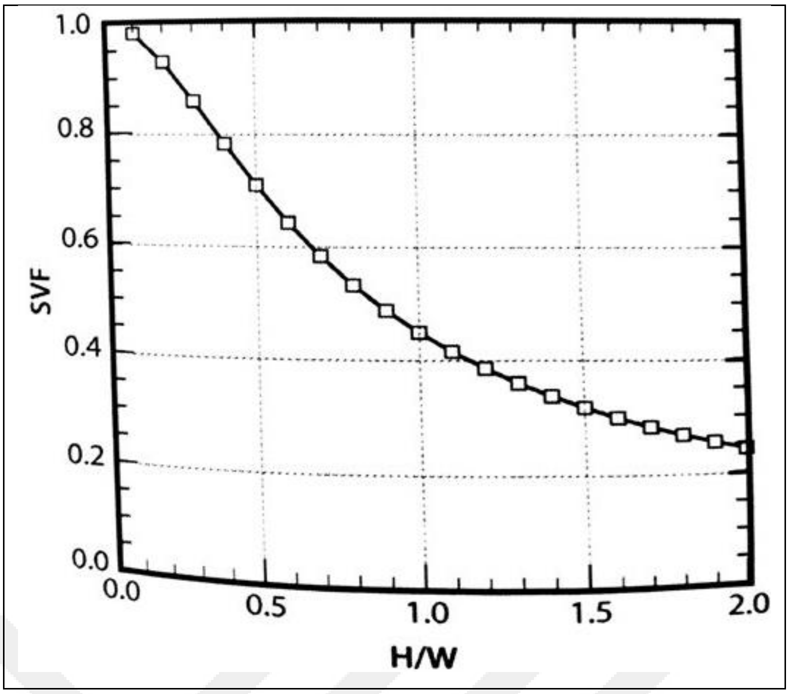

Figure 3.2: The Relationship between Canyon Aspect Ratio (H/W) and Sky View Factor (SVF)

Source: (Erell et al., 2011)

The sky view factor, which, as shown in Figure 3, is significantly influenced by the presence of vegetation and the distance between buildings, has a significant impact on how much sunlight reaches the ground and the surfaces of buildings due to the importance of the aspect ratio's influence.

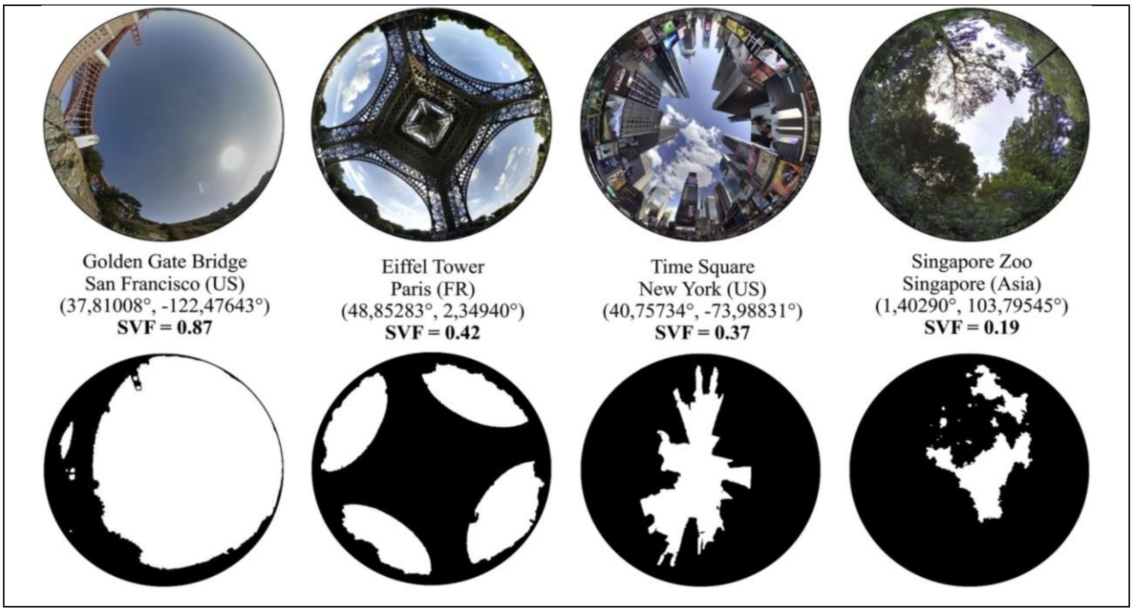

Figure 3.3: Fisheye Photos Produced Using Google Street View (Top), Identified Horizon Limits (Bottom), And Corresponding Sky View Factors (Bold Text) For Four Global Sites.

Source: (Middel et al., 2018).

3.2.3 Orientation of building

One of the most significant design elements influencing outdoor-thermal-comfort (OTC) traffic has been identified in numerous recent studies as the orientation of blocks and streets. For instance, Faroughi et al. (2020) used ENVI-met software to simulate a portion of the Netherlands' east-west and north-south streets on the hottest day of the year.

The findings showed how important the mean radiant temperature is for thermal comfort. The highest level of outdoor comfort is offered by north-south streets, in contrast to east-west streets, which can be less pleasant for pedestrians. East and west-facing streets get the most sunlight and have the highest mean radiant temperatures (Kuo-Tsang et al., 2009).

According to certain studies, the ideal direction for roadways in urban planning is northeast-southwest. Airflow at the pedestrian level is significantly influenced by street orientation as well. The maximum rate of wind speed, which might accelerate due to a low height/width ratio, is experienced on streets that face the same direction as the predominant winds.

East-west streets receive direct radiation in the mornings and afternoons of summer days, but not during the winter months, according to a study conducted on streets with different widths (10, 15, 20, and 25 meters) in both north-south and east-west orientations.

The study also showed that even the shortest north-south routes only have moderate exposure to radiation on the shortest day of the year, but they have significant exposure in the morning and evening (Ruger et al., 2011). In a study conducted in Brazil, the effect of street orientation on wind speed and spatial turbulence was investigated, and it was found that this orientation had a significant impact on people's thermal comfort (Berkovic et al., 2012). A further investigation using shading software on urban open spaces found that the best orientation for cooling is a north-south rectangular yard with the larger side facing either east or west. It also found that access to direct sunlight can be obtained in a short amount of time at the center of the yard (Andreou, 2013).In general, street orientation significantly affects physiological equivalent temperature (PET) in response to wind direction and speed (Watson & Johnson, 1987).

One of the most important design elements in outdoor thermal comfort-based urban planning is the way streets and alleys are oriented. As a result, four modes winter (February) and summer (August) were used to individually simulate the microclimatic conditions and thermal comfort of the streets of the residential blocks in the chosen site.

The roadways are shaded until noon and then get full radiation until sunset, as seen in the NE-SW direction in Figure 4(a). Figure 4(b)'s W-E direction demonstrates that streets receive less radiation and spend the majority of the day in the shade. As seen by Figure 4(c), the streets receive radiation early in the day but are shaded for the majority of it due to their NW-SE orientation. Figure 4(d), which displays the N-S orientation, demonstrates that during most hours of the day, the streets receive the maximum radiation (Delpak et al., 2021).

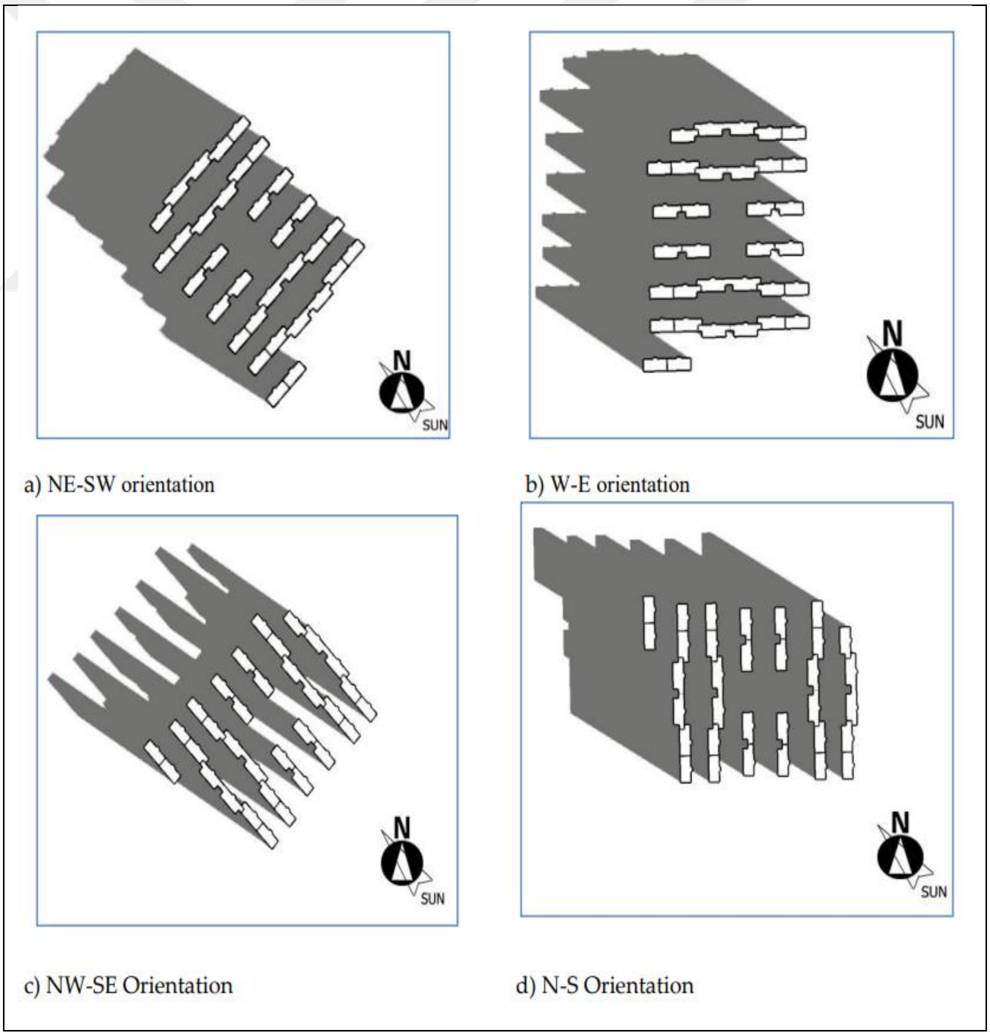

Figure 3.4: Different Block Orientations and Their Shading at 8:00 a.m. On The Winter Day

Source: (Delpak et al., 2021).

3.2.4 Vegetation

Through landscaping, the outside temperature can be significantly reduced. When used significantly, according to McPherson et al. (1994), it may even be able to lessen the impact of the urban heat island.

Nevertheless, the quantification of urban vegetation's function led to variable findings through studies. There aren't many studies on how vegetation affects outdoor thermal comfort, especially in urban areas (Shashua-Bar & Hoffman, 2000).

According to McPherson et al. (1994), vegetation primarily regulates the urban climate in 24 by providing shade, evapotranspiration, and wind direction, which it provides by acting as a wind funnel or a windbreak.

The tree's potential to provide shade is its most significant characteristic. Its volume, shape, and leaf density are the key features in this regard.

Numerous studies looked at how traffic was moderated by trees in planted urban streets at different locations in a hot, dry urban environment. They discovered that the impact of tempered urban roadways ranges from 1 to 3 K (1.8 to 5.4 of). Their findings, which are corroborated by other studies of a similar nature, suggest that the capacity of the vegetation is what mainly causes the local cooling effect to shade the environment rather than evapotranspiration.

Shashua-Bar and Hoffman (2000) investigated how shade trees at small urban vegetated sites could act as a moderator. They came to the conclusion that, in contrast to other factors, the shading effect of the tree was primarily responsible for 80% of the cooling effect. They found that the shade that vegetation provides, which reduces direct solar radiation incident on the high heat capacity materials of the street, is the most efficient use of vegetation in hot climates. Nevertheless, individual trees placed widely apart, as is typically the case in an urban street, have little to no impact. Consequently, it is advised that multiple smaller, densely planted areas provide a greater cooling effect than a single, expansive green area.

Trees may be found in a densely populated area in a number of places, including rows beside sidewalks, parking lots, and street intersections. In studies conducted in Chicago, McPherson et al. (1994) discovered that substantial financial gains in the form of energy savings were obtained from the green cover, of which the planting of trees along streets made up a third. The largest energy savings (between 50 and 65 percent) were attributed to residential areas with planted vegetation.

Radhi et al. (2015) looked into how artificial islands affected climate variables in Bahrain using a computational fluid dynamics (CFD) study. The findings demonstrated that there was a mean radiative temperature difference between concrete surfaces and a vegetated area of up to 5 °C. In Alexandria, Egypt, Barakat et al. (2017) employed ENVI-met to examine three different microclimates (a hot and dry region). They proposed that paving areas could be decreased while vegetation surfaces, water features, and tree populations could be increased in order to improve thermal conditions. It is generally agreed upon that these changes result in a decrease in air temperature and average radiation temperature, but an increase in humidity.

Georgi and Dimitriou (2010) investigated the ways in which vegetation could improve the island of Crete's (Mediterranean climate) thermal conditions in Chania. On a 100 m2 area, they assessed three distinct vegetation management techniques: planting eight trees, using four cooling fans, and using a cladding canopy. It was concluded that planting trees was the most cost-effective way to improve the thermal conditions.

Jeong et al. (2016) conducted research and comparisons on the degree of contentment among residents of a forest-urban area in the city center of Seoul. In the forest-urban area, 79.3% of residents reported feeling comfortable, in contrast to the core of the city, where this percentage was 31.1%.

Klemm et al. (2015) assessed the psychological and physiological impacts of green spaces on thermal comfort by analyzing nine streets in Utrecht with similar geometry. The average radiative temperature was 39% lower in streets with trees than in streets without them, according to the results. In a study by Salata et al. (2015), using ENVI-met to analyze the thermal environment of a historic site in Rome, researchers discovered that vegetation enhanced overall thermal conditions while lowering the PMV index by 1.5 °C in the middle of a hot summer day.

The best kind common of trees in Iraq (Yahya, 1977):

Acacia (Acacia spp.): Acacia trees are well-suited to arid climates and are commonly used for afforestation and soil conservation efforts.

Olive (Olea europaea): Olive trees thrive in the Mediterranean-like climates of northern Iraq and produce olives for oil and consumption.

Sophora japonica.

Date Palm (Phoenix dactylifera): Date palms are one of the most iconic and culturally significant trees in Iraq. They provide valuable shade and produce dates, which are a staple food in the area depicted in figure 3.5.

Figure 3.5: Palm trees in Baghdad

Eucalyptus (Eucalyptus spp.): Eucalyptus trees are known for their rapid growth and adaptability to arid conditions. They are often planted for shade and windbreaks as shown in figure 3.6.

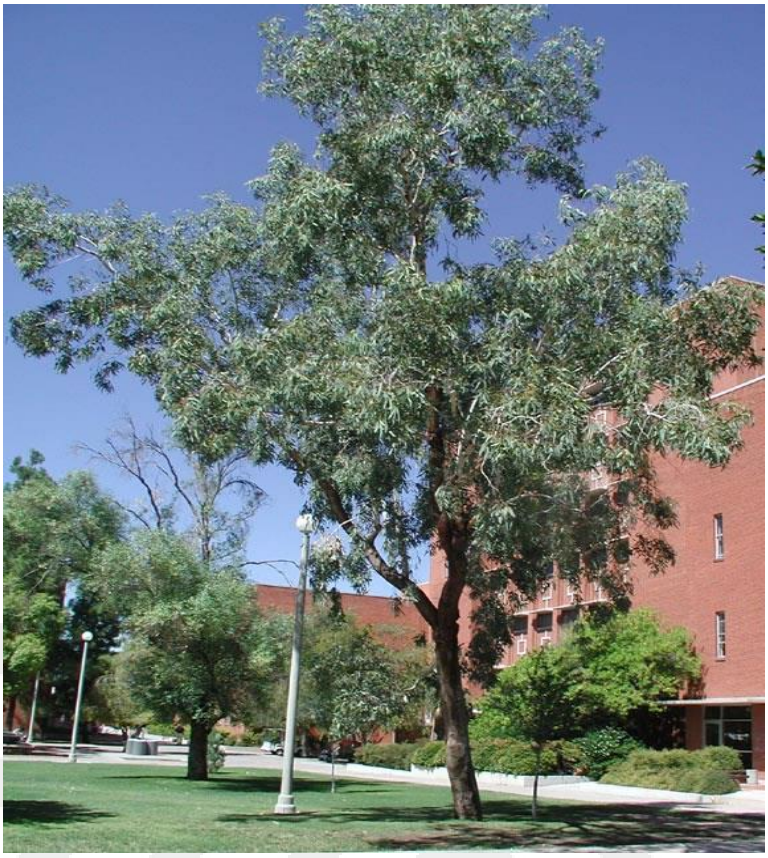

Figure 3.6: Eucalyptus Microtheca

3.2.5 Building materials

Around 60% of the surface area in cities is made up of pavement and roofs. More than 80% of the solar radiation is typically absorbed by these dark surfaces. Turning it into heat, which harms the environment and drives up energy costs. By changing the pavement with more reflective materials and enhancing pedestrian comfort, urban heat islands may be lessened (SKAT, 1993). Summertime temperatures of up to 65°C for paving materials contribute to warming the air above them. Global Cool Cities Alliance (2012) suggests that lighter paving materials may result in more reflective surfaces.

Li (2012) concluded that a pavement's increased evaporation lowers its temperature, mean radiant temperature, and PET. As a result, it improves thermal comfort in heated spaces. Peak temperatures for paving materials can reach 50 to 65°C in the summer, which warms the air above them. Lighter pavement materials may produce more reflecting surfaces.

According to UN-Habitat (2015) the following general suggestions for choosing products and materials while considering sustainability and the climate:

- As shown in Figure.7, employ a local workforce, and make use of materials and technologies that are readily available nearby.
- Make use of easily accessible, naturallyoccurring materials, especially regenerative organic materials (straw, grass, bamboo, trees, etc.) from sustainably managed forestry. Makeuse of reusable and recycled non-renewable inorganic materials, such asstone and clay.
- To enable long term use and lower maintenance, renovation, and refurbishment costs over a building's lifetime, use durable materials and components.
- Swap out steel frames for low-energy building techniques and materials, such as load-bearing masonry.
- Choose materials with a greater potential for reuse and recycling; pure materials such as bricks, dirt blocks, wood, concrete, stone, and metal sheets are the best choices in this regard. Composite materials, like prefabricated solid foam-metal or foam-plaster parts, are difficult to separate and recycle.
- Reduce the amount of resources used (fewer materials, more breathing space) and make efficient use of the materials during construction.
  Make decisions that will guarantee less scrap material is used (this is importa nt, especially for materials with a high embodied energy).
- Recycle or reuse construction waste.
- For paints, use clay- or water-based acrylics.
- When using adhesives indoors, choose ones with minimal or no volatile orga nic compound (VOC) emissions.
- Products containing CFCs and asbestos should not be used as they are carcino genic
- Reduce the amount of metallic fittings, pipes, and surfaces that are used.

Figure 3.7: Creative Application of Locally Accessible Building Materials and Technologies

Source: (UN-Habitat, 2015).

1. The building envelope and thermal comfort:

Since the beginning of time, man has continuously improved his living conditions to make sure that his defense against the elements and other harmful elements of the outside world is always more effective. However, the thermal behavior of a building's envelope has the biggest impact on its thermal comfort (Figure 8).

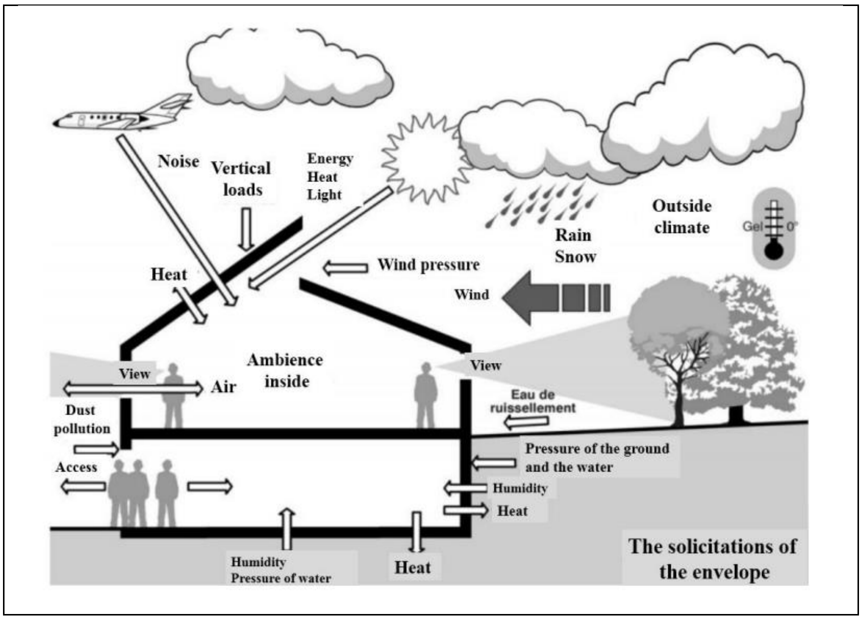

Figure 3.8: The External Envelope Experiences Multiple Assaults From The Surrounding Climate And Surroundings.

Source: (Hauglustaine, 2006).

More precisely, a building's capacity to adjust to shifting weather conditions is determined by the building materials used as well as the architectural and constructive characteristics of the structural elements (wall thickness, compositions, arrangement, etc.).

According to Necib, H. (2016) the building's exterior is its first line of defense and is composed of two different types of walls: transparent walls (windows) and opaque walls (walls and roof). The roof transmits 70.62% of the gains, the four facades transmit 27.11%, and the windows transmit 2.27% of the gains..

If the walls of the building envelope are carefully treated in accordance with the warm and arid climatic conditions (e.g., by reducing the dimensions of windows and solar protections, choosing construction materials with high thermal inertia for walls and roofing, etc.), maximum comfort within the building can be guaranteed even in unfavorable external conditions (Izard, 1979).

2. External and Internal Finish:

The amount of daylight in rooms and the thermal performance of a structure are both impacted by the choice of exterior and interior treatments. Light-colored/highly reflecting wall and roofing materials are preferred to reflect undesired solar radiation and lower solar heat gain.

Through evapotranspiration, the integration of green and living walls, green roofs, and vertical gardens featuring vegetation growing on the façades can effectively reduce the temperature of the corresponding building surfaces.

Figure 9 illustrates how to specify light-colored interior finishes for the walls, floors, and ceilings to increase daylighting.

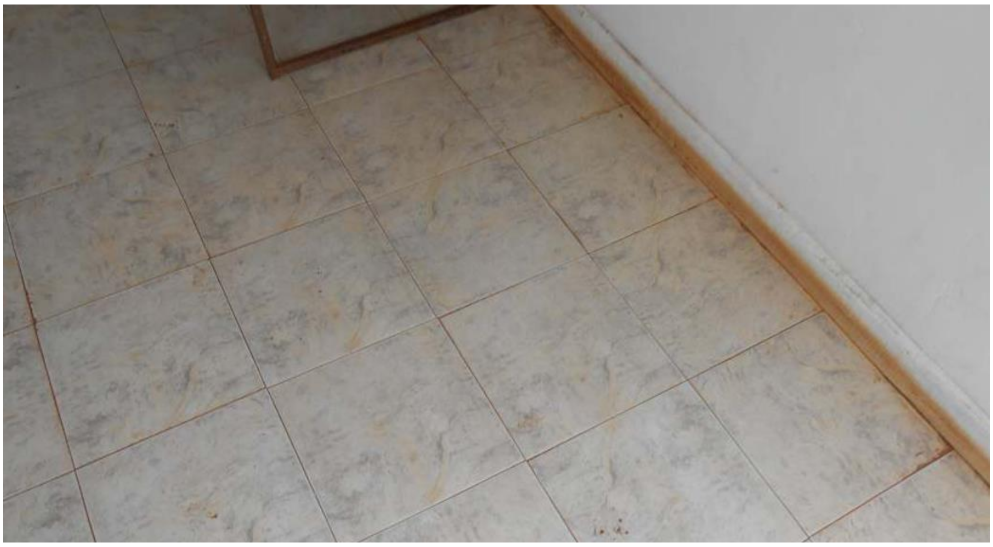

Figure 3.9: Light-Colored Internal Wall and Floor Finishes

3.2.6 Geometric design of the buildings

The thermal comfort that building occupants experience is largely determined by the shape and design of the building. Mental state is referred to as thermal comfort, where individuals feel satisfied with the surrounding thermal environment, with neither feeling too hot nor too cold. Achieving thermal comfort is essential for creating a healthy and productive indoor environment for occupants.

Buildings are subjected to various external climate conditions, such as temperature, humidity, and wind, which can influence the indoor thermal environment. The shape of a building can significantly impact its ability to manage and control these external factors, affecting the energy efficiency and comfort levels within the structure.

It is advised to use the following design tactics (UN-Habitat, 2015):

- Low surface-to- volume ratio buildings are favored because they reduce the amount of space exposed to solar radiation, which reduces solar heat gains.
- Courtyard forms provide shade from the sun, glare, and hot, dusty breezes.
- Forms with a single bank encourage cross-ventilation.
  To stop hot air from entering the building during hot weather, natural ventilati on should be avoided during the day.

To cool the building during this time, night ventilation is recommended.
A courtyard building could effectively address these opposing needs.

- Narrow building forms (with rooms not exceeding 7 m) are preferred to facilitate natural ventilation and allow day lighting when side lighting from one wall.In residential buildings, ceiling heights should not be lower than 2.7 meters in order to allow for proper airflow. In commercial buildings, 3.6 meters is the minimum ceiling height. Higher values, such as 4.2–4.5 m, are preferred.

The following guidelines for the building layout should also be followed (Gut & Ackerknecht, 1993):

- The building that is advised to be constructed along the east- west axis will minimize solar exposure to the main façades, which face north and south. These façades should have the main entrances to the livable areas.
- To mitigate solar heat gain, it is recommended that non-living areas such as restrooms, lobbies, stores, lifts, and kitchens be situated on west-facing elevations.
- Living rooms and other habitable areas should be on the north or south side of the building, with bedrooms ideally on the east side, which is cooler at night.
- To facilitate easy heat extraction through high-level windows or vents, spaces with high internal heat loads, such as mechanical rooms, kitchens, etc., should ideally be placed on external walls or separated from the main spaces.
- Because they need less sun protection, spaces like offices, classrooms, and the like should be situated on facades that face north or south for optimal daylight conditions.

In a courtyard, as illustrated in Figure 10, because the cool night air is heavier than the surrounding warm air, it can be held in place. Breezes won't disturb these pockets of cool air if the courtyard is small (width not greater than height). The tiny courtyard works wonders for controlling the temperature. Large portions of the interior surfaces and floor are shaded during the day, preventing excessive heating; additionally, the earth beneath the courtyard absorbs heat. High walls block out the sun, save for around midday. The heat that has accumulated during the day is released by reradiation during the night. Sufficient ventilation should be provided at night to prevent heat dissipation through the interior surfaces. Therefore, two criteria should be used to guide the design of openings: The holes should be small enough to allow proper ventilation to disperse the heat produced by the courtyard's walls and floor during the day and large enough to offer adequate ventilation at night (UN-Habitat, 2015).

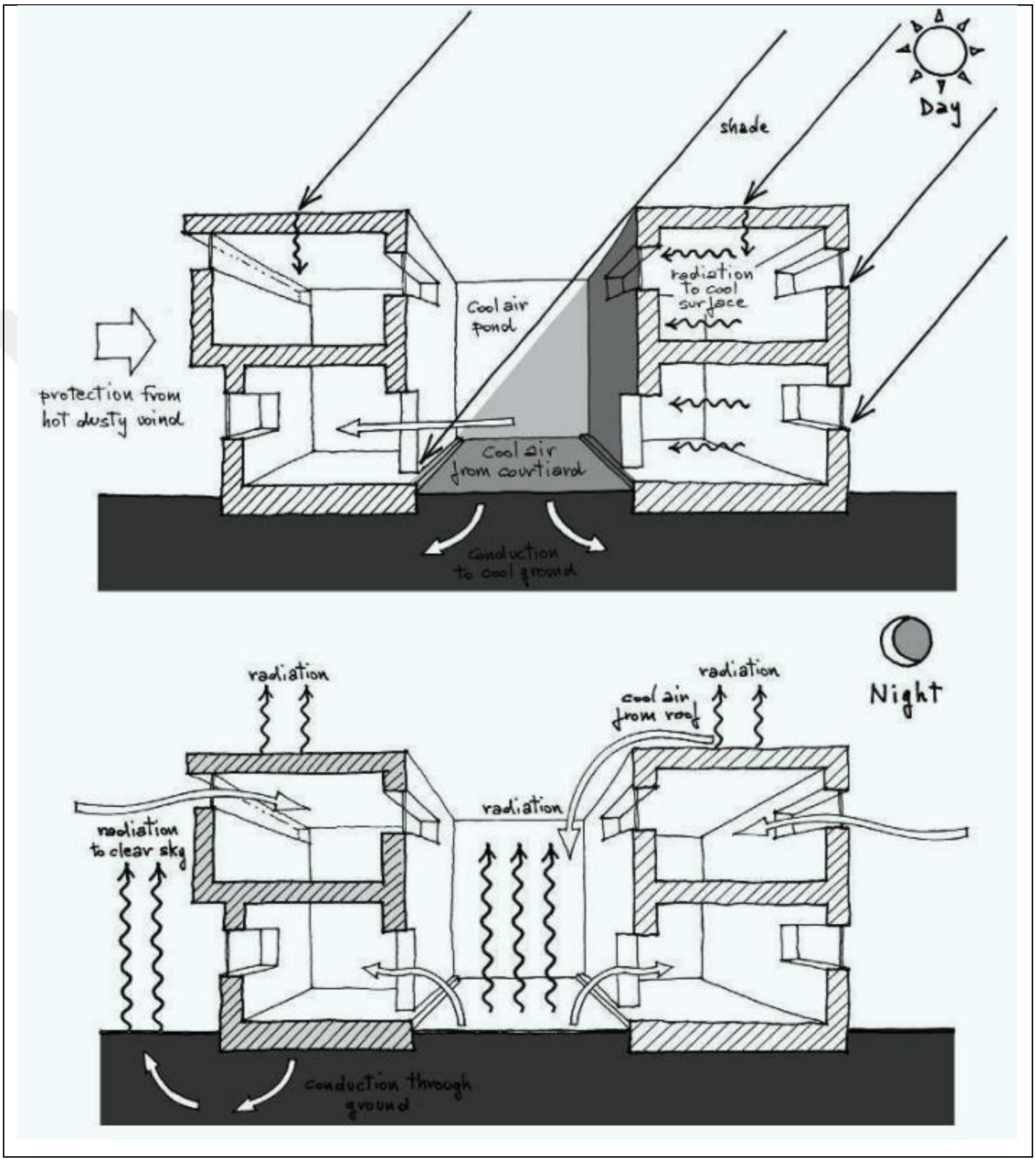

Figure 3.10: The Concept for the Courtyards' Work

Source: (UN-Habitat, 2015).

A courtyard serves as the focal point and a private open space in traditional homes. Even during the hottest part of the summer, some floor sections are shaded by the courtyard's dimensions in terms of length, width, and height (Al-Ali, 1984). Common courtyards are adorned with a variety of trees and flowers to improve comfort and ventilation by transforming the surroundings of the buildings. Iranian research indicates that courtyards improve natural lighting, heating, cooling, and ventilation (Zamani et al., 2012).

The courtyard layout offers greater comfort than a pavilion, according to Ratti et al. (2003) (see Figure 11). All throughout Iraq, one can find the typical courtyard houses of Baghdad. It looks like they satisfied the needs of their occupants in terms of internal thermal performance and functional requirements. A central courtyard serves as the focal point of the traditional courtyard house, which is surrounded by every room.

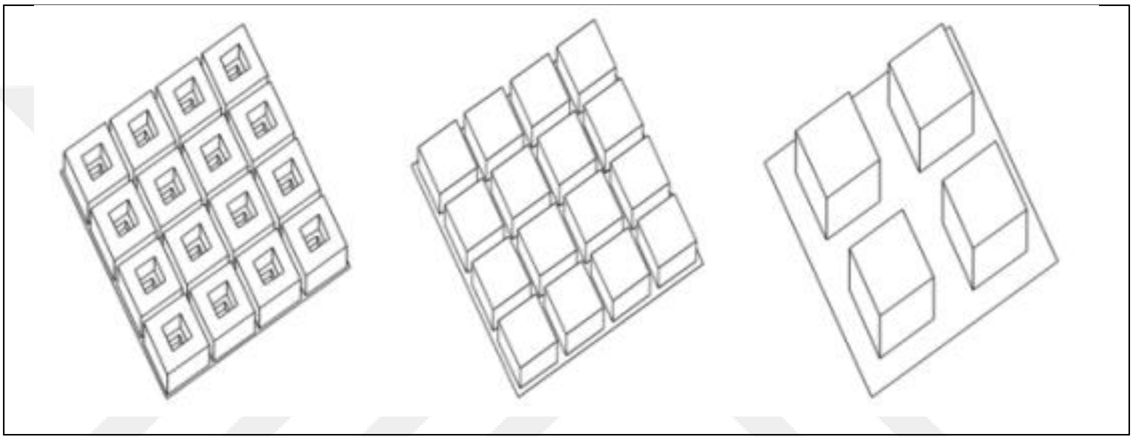

Figure 3.11: Traditional Courtyard

Source: (Ratti et al., 2003).

4. DEVELOPING A PROPOSED DESIGN FOR THE CITY OF BAGHDAD USING ENVI-met SOFTWARE

4.1 Introduction

In the scorching heat of Baghdad's summer months, providing relief from high temperatures for pedestrians becomes a paramount concern. As climate change continues to manifest with temperature increases and a rise in the frequency of heat waves urban environments like Baghdad face the dual challenge of reducing energy consumption and creating comfortable spaces for their inhabitants. In response to these challenges, this chapter delves into the development and implementation of a sustainable building design model tailored to the unique climate of Baghdad. The primary aim of this model is to lessen the negative effects of intense heat, eventually improving the standard of living for residents and passengers.

Baghdad's climate is characterized by its arid, desert-like conditions, with summertime temperatures often surpassing 40°C (104°F). The relentless heat poses health risks and discomfort to the city's pedestrians and can have substantial economic and environmental consequences. Sustainable building design, with a focus on natural cooling and energy-efficient solutions, offers a promising path to address these issues.

This chapter is a culmination of extensive research, data analysis, and computational modeling, aimed at formulating a sustainable building design strategy specifically tailored to the environmental and climatic conditions of Baghdad. It explores the intricacies of our model's design and implementation, emphasizing its potential to reduce temperatures in and around urban structures, creating a more habitable and environmentally responsible urban environment. By incorporating sustainable design principles and innovative technologies, the researcher's main goal is to get the capital of Iraq ready for a time when cities will be more sustainable and green.

As the progresses through this chapter, the researcher will unveil the key features of the sustainable building design model, the methodologies employed, the data collected, and the results obtained. Furthermore, the researcher will assess the implications and benefits of this model in terms of reducing temperatures and enhancing the overall comfort and well-being of pedestrians during the sweltering summer season.

Ultimately, the insights shared in this chapter contribute to the ongoing global discourse on sustainable urban planning and offer a practical solution tailored to the specific needs of Baghdad's residents. By reducing the heat burden on pedestrians, this sustainable building design model stands as a testament to our commitment to creating a resilient and climate-responsive urban environment.

4.2 The Origins and History of Construction in Baghdad

Iraq has a long history, dating back to prehistoric times, during which the country's established building techniques and architectural styles have evolved. Local natural resources were employed in the creation of all the procedures, notwithstanding the modifications. The buildings gained a unique identity as a result. Locally accessible raw materials were combined in various ways to make it more robust and weather-appropriate. The roots of the basic features of the Iraqi civilization focused on ancient Mesopotamia civilization. Then during the Abbasid period it was clearly specified in its characteristic features. The same style of construction was maintained up to (1639- 1917) AD.

1. Ottoman Sovereignty periods (1639- 1917) A.D.

Al Ail et al (1982) explained the architecture of the early Ottoman state remained unchanged. The home kept its original layout, which included an indoor courtyard encircling the rooms and their amenities. The administrators of the Ottoman Empire concentrated on constructing new mosques and restoring existing ones throughout Iraq. Additionally, they built numerous tiny villages along the trade routes, centered on a structure known as the "Khan" (Figure 4.1).

Figure 4.1: Khans On Trade Roads

Source: (Al Ail et al., 1982).

The central marketplace is represented by this Khan. Some towns, like Yousefayah and Mahmoudia, were constructed haphazardly without any prior engineering design. The homes weren't constructed in a particular style. The owner's financial situation and the builders' prior experiences determined the style that was employed.

The floods from the Tigris River obliterated large portions of the city. Reconstructed homes followed the owners' desires and financial means when they were demolished. There was consequently no consistent or unique symmetry or design. The roofs were asymmetrical, and the walls appeared crooked. Roads got smaller as a result of residential growth. Broad streets turned into winding lanes (Drbuna) (Figure 4.2).

Figure 4.2: Old Baghdad Alleys

Source: (Peeri, 2008).

According to Abdul Rasul (1988), houses in Iraq are built in a variety of shapes and designs. This was because construction relied primarily on the availability of raw materials and the skill of the builders. The house's layout consisted of several rooms encircling a courtyard in the middle that resembled a room.

The house's courtyard (Figure 4.3) was situated on one side and was square or rectangular in shape. Plaster, stones (as they were locally available), and gypsum which is moisture-resistant were the building materials used. They also used wood for the ceiling in the entrance.

Figure 4.3: The Courtyard House, Dar Babil in Al-Hilla-Iraq

Source: (Al-Thahab et al., 2014).

Abdel Majeed (2000) mentioned building styles evolved as the time of the Ottomans came to an end. A new style emerged that was mostly influenced by Italian design and the European Renaissance. The Qishla structure, designed as a military barracks, served as a showcase for the new architectural style. This structure is regarded as a watershed in Iraqi building history.

Qishla was constructed between 1851 and 1853 AD on the Tigers River's western bank. It was built using regional resources like wage and gypsum, and as Figure 4 illustrates, wage technology was applied to the roofing.

Figure 4.4: Qishla Building

Source: (United Nations, 2018).

2. British occupation period (1917-1958) A.D.

During the first 12 years of the British occupation of Iraq, no construction was done. Planning and constructing roads and bridges was the initial step in the construction process. The floating bridges that connected Baghdad's two sides were replaced by fixed bridges (Ministry of the Interior, 1962).

British engineers and architects were responsible for the planning and construction. British designs were being implemented by British engineers.

The Iraqi house, depicted in Figure 5, also exhibited an English-Baghdadi style. They divided Baghdad into three sections, as peeri (2008) explained. The first was similar to the old city center, with its narrow roads and old houses with shanashil. The new community, which was spread out and had houses a British architectural style, was the second portion. They were typically constructed from north to south along the Tigris bank. The third section focused on the sporadic or rural clay dwellings that were sprouting up in Baghdad's suburbs. There used to be village residents.

Figure 4.5: The Iraqi local Style Houses (English Baghdadi)

Source: (Peeri, 2008).

3. Independent Iraq periods (1958- present)

Abdul Rasoul (1987) explained the reasons for the development of architectural styles in Iraq. Modern technology, tools, and building materials were employed. In their work, the Iraqis aimed to utilize contemporary materials and technology. The architectural design and how well it suited the local climate and culture were overlooked. The goal was to adopt contemporary Western lifestyle characteristics regardless of how well they suited the Mesopotamian surroundings.

4.3 Residential complexes in Baghdad

Residential complexes in Baghdad have seen significant growth and development in recent years, reflecting the city's ongoing efforts to provide modern and comfortable living spaces for its residents. These complexes are designed to meet the diverse housing needs of the population, offering a wide range of options from apartment buildings to gated communities. The demand for such complexes has risen due to urbanization, population growth, and the desire for improved living standards.

Many residential complexes in Baghdad feature state-of-the-art amenities, including well-maintained green spaces, recreational areas, and shopping centers. These complexes prioritize security and often have gated entrances and security personnel, giving residents peace of mind. The architectural design of these complexes often blends modern aesthetics with traditional elements, reflecting Iraq's rich cultural heritage.

As the city continues to evolve and modernize, the development of residential complexes has played a crucial role in enhancing the overall quality of life for its inhabitants. These complexes not only provide comfortable and convenient living spaces but also contribute to the urban development and the growth of the city as a whole. They serve as a testament to the resilience and ambition of Baghdad as it moves towards a brighter future.

One of the completed projects in Baghdad is the Iraq Gate residential complex as shown in (figure 4.6).Residential complexes like Iraq Gate are typically designed to provide housing and amenities to residents. They often feature various types of residential units, such as apartments or townhouses, along with communal facilities and services. These complexes aim to offer a comfortable and convenient living environment for their residents.

Figure 4.6: Iraq Gate Residential Complex

Source: (Iraq Gate, 2023).

4.4 Baghdad

The Baghdad Governorate is situated approximately 39 meters (128 feet) above sea level and is located to the right of Iraq's center at latitude 33˚18' N and longitude 44˚21' E. Half of the city is divided by the Tigris River, which flows through it from north to south. Al-Risafa is the common name for the eastern side, and Al-Karkh for the western side.

Khatib and Alami (2014) stated that the Baghdad Mayoralty's borders, encompassing most of the governorate's urbanized area and covering an approximate area of 840 km², served as the study area for this research. There are fourteen municipalities in this area, and each municipality is made up of several Mahalas (Figure 4.7).

Figure 4.7: Municipalities of Baghdad City

Source: (Khatib & Alami, 2014).

Baghdad is the capital of Iraq. It was chosen to apply the model in this capital for two reasons, the most important of which is the hot weather prevailing in the summer. The average daily temperature in Baghdad is approximately 95 °F (35 °C) in July and August, with records of 123 °F (51 °C) in the summer. Summertime temperatures vary significantly throughout the day (Britannica, 2023).

The second reason is the increasing population density in the capital, Baghdad. The growing population in the city has led to numerous socio-economic and urban planning challenges, including increased demand for housing, infrastructure, and public services. This population surge has resulted in a higher concentration of people in limited geographical areas, putting additional pressure on the city's resources and contributing to issues related to traffic congestion, housing shortages, and environmental concerns. Examining the impact of this population growth on the city's development and well-being is a critical aspect of understanding the urban dynamics in Baghdad.

As stated by the Ministry of Planning, Baghdad's population is expected to reach 9 million, leading to a growing overpopulation and the necessity of taking concrete action to address the housing situation. It's possible that not many people are aware that the ancient capital has the fourth-highest population density in the world. Baghdad is the fourth most densely populated city in the world, behind Mumbai, India, and three cities in the Philippines, according to the American World Population Review website. International guidelines define overcrowded cities as those that run the danger of experiencing a lack of adequate housing and infrastructure. Infrastructure and resource accessibility. However, a statement issued by the Central Bureau of Statistics affiliated with the Ministry of Planning expected that the population of the capital, Baghdad, will exceed more than 9 million people living in a total area of 4,555 km2, indicating that the population density there is 1,977.2 individuals/km2 (Al Sabah Newspaper Archive, 2023).

4.5 Background on the Outdoor Thermal Comfort

The architectural shape considerably modifies the microclimate, which impacts the thermal comfort outside. Built form is defined by the geometry and characteristics of the dense building materials additionally to the substitution of hard, impermeable layers for the earth's natural surface. Furthermore, albedo the material's ability to absorb solar radiation and the building's morphology and geometry all has an impact on outdoor thermal comfort. The ratio of building height to street width determines the building geometry, which traps incident solar radiation. Hard-impervious pavements, roads, and parking lots increase water runoff at the surface, and less vegetation raises air temperatures at the microclimate level, which affects pedestrian thermal comfort. All of these factors work together to increase surface temperature and store heat.

Careful examination of the architectural form and its impact on the microclimatic factors might lead to an improvement in outdoor thermal comfort (Waite, 2003).

4.5.1 Definition of thermal comfort

According to ASHRAE (1997), a person experiences thermal comfort when they reach a certain level of satisfaction with their overall thermal environment. The human body is constantly subject to a variety of external conditions, which when paired with the requirement that bodily organs maintain particular temperature ranges in order for them to perform as intended throughout physiological processes, result in the human body.

The conscious mind keeps weighing various environmental elements, both internal and external until it determines whether or not the body is comfortable enough.

Thermal comfort is generally attained when the body is kept within certain temperature ranges, the skin is kept at low moisture content, and the physiological effort required to regulate the temperature is kept to a minimum (ASHRAE, 2020).

Regardless of the location, a variety of external environmental factors might impact thermal comfort. For example, air temperature, radiant temperature, wind speed, and relative humidity. Furthermore, individual characteristics like the activity they're engaged in or the number of layers of clothes they're wearing might influence an individual's impression of the perfect thermal comfort.

4.5.2 Thermal comfort indices

Numerous indices have been devised to assess thermal comfort. While some of them are more complicated, others are rather basic and rely on the air temperature and secondary parameters.

Yahia and Johansson (2013) mentioned Many examples of these types are based on steady-state models, which assume that users reach a thermal balance with the surrounding environment. A negative point is that the dynamic aspects of adaptation to the environment are not considered when using steady-state models. Predicted Mean Vote (PMV), Outdoor Standard Effective Temperature (OUT_SET), and Physiologically Equivalent Temperature (PET) are examples of steady-state models.

a. Predictive Mean Vote (PMV)

One of the most used indices for thermal comfort is the Predictive Mean Vote (PMV). By measuring the average thermal reaction of a sizable sample of individuals on a seven-point scale that runs from +3 (cold) to -3 (hot), it examines whether a particular thermal environment satisfies the requirements of comfort (Figure 8). The formula is based on the heat balance technique, which computes the equilibrium thermal balance between people and their surrounding surroundings via heat transmission.

The PMV index was created primarily to quantify thermal comfort indoors, but it has been used in several studies to evaluate thermal comfort outdoors as well (ISO7730, 2005).

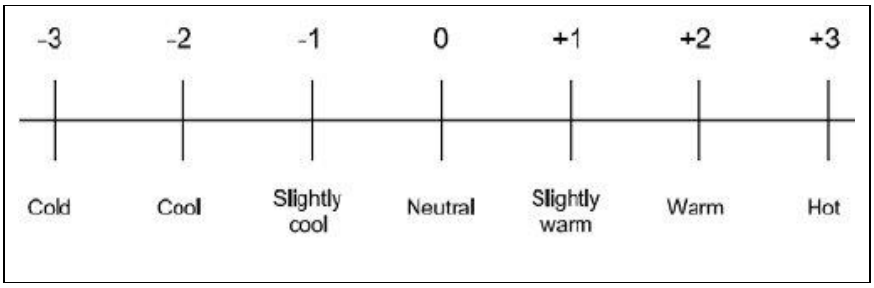

Figure 4.8: Seven Point Thermal Sensation Scale

Source: (Beizaee et al., 2012).

b. The Physiological Equivalent Temperature (PET)

According to Matzarakis et al. (2007) the Physiological Equivalent Temperature (PET) is an effective measure for determining out how radiation and wind speed affect thermal comfort and heat storage in urban areas.

Recent investigations indicated that the PET is the index that could be used to assess the thermal comfort conditions of outdoor environments rather than the indoor based thermal indices.

Table (4.1) shows the ranges of PET for different grades of thermal perception by human beings and physiological stress on human beings.

Table 4.1: The Ranges of the Physiological Equivalent Temperature (PET), Or Thermal Index, For Various Levels of Human Heat Perception and Physiological Stress

PET	Thermal perception	Grade of physiological stress
4 °C	Very cold	Extreme cold stress
8 °C	Cold	Strong cold stress
13 °C	Cool	Moderate cold stress
18 °C	Slightly cool	Slight cold stress
23 °C	Comfortable	No thermal stress
29 °C	Slightly warm	Slight heat stress
35 °C	Warm	Moderate heat stress
41 °C	Hot	Strong heat stress
>41 °C	Very hot	Extreme heat stress

Source: (Matzarakis& Mayer, 1999).

c. Mean Radiant Temperature (Tmrt)

The mean radiant temperature (MRT) is one of the most critical environmental parameters that significantly influence outdoor thermal comfort. The MRT is defined as the "uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual no uniform enclosure" (ASHRAE, 2005).

Rakha et al.(2017) indicated that Short-wave and long-wave radiation, such as direct, diffuse, and reflected solar radiation as well as infrared radiation from the sky and urban surfaces, are the primary variables that affect the value of MRT.

According to Kántor and Unger (2011) The MRT values outside in an urban environment are even more intricate than they are indoors. They go on to say that the MRT value inside is roughly equal to the temperature of the air. However, because MRT values fluctuate, particularly over time and in urban environments, they can be up to 30 °C higher than the air temperature outside under bright situations. Many surfaces have varying rates and intensities of solar radiation absorption, reflection, and emission (Barakat et al., 2017).

4.6 Microclimate Simulation Software

Microclimate simulation software is designed to model and simulate the detailed climate conditions at a micro-scale level in specific environments. These tools are particularly valuable in urban planning, architecture, and environmental impact assessments. Here are some microclimate simulation software options:

1. ENVI-met:

ENVI-met, or Environmental Meteorology for Urban Areas, is widely used microclimate simulation software. It models temperature, humidity, wind patterns, and other meteorological parameters at a high spatial resolution in urban environments (Envi-Met System, 2023).

2. SOLWEIG (Solar and Long Wave Environmental Irradiance Geometry):

SOLWEIG focuses on simulating outdoor thermal comfort by modeling solar radiation and heat exchange in urban environments. It helps assess the impact of urban design on pedestrian comfort (Lindberg et al., 2008).

3. RAYMAN (Radiation and Advective-Convective Model):

RAYMAN is a microclimate simulation model that analyzes outdoor human bio meteorological conditions. It considers solar radiation and heat exchange, providing insights into the thermal environment in urban spaces (Matzarakis et al., 2007).

4.6.1 About ENVI-met software

ENVI-met is a computation fluid dynamics (CFD) based microclimatic simulation software that differently from others, calculates the influence of various parameters to return a wide variety of results. Most micro scale models focus on a single aspect of the microclimate failing to achieve all the following, that belong to ENVI-met specifications (Simon et al., 2018).

- A resolution that is sufficient (less than 10 meters).
- Precise modeling of various surface types and material properties.
- Prognostic and temporary weather process computation.
- Plant physiological and physical property simulation.

Through the fundamental rules of thermodynamics (temperature calculations), generic atmospheric physics (turbulence prediction, for example), and fluid mechanics (wind field), ENVI-met is a micro-scale three-dimensional software model designed to simulate complicated metropolitan settings (Environmental Modelling Group, 2022).

Table (4.2) shows previous studies used for the ENVI-met software and the purpose for which it is used.

Table 4.2: Research Studies that Use ENVI-MET Software to Simulate Microclimate and Analyze Urban Heat Islands (UHIs)

Researches	Using ENVI-met
Huttner et al. (2008)	The effects of global warming on heat stress in Central European cities were investigated. Green spaces are recommended for improved human thermal comfort.
Hedquist et al. (2009)	CFD and ENVI-met models were used to assess changes in local flow caused by the UHI diurnal cycle. The significance of using free tools to refine ENVI-met inputs and pinpoint specific characteristics in the region was emphasized. Recommendations for heat reduction in buildings.
Yang et al. (2012)	A technique for connecting ENVI-met and Energy Plus to provide a quantitative study of the energy efficiency of buildings in an urban setting was proposed. The results demonstrated the ability to assess the impact of microclimatic variables on building energy performance. It is useful for building design and urban planning.
Dardel (2015)	ENVI-met was used to investigate the aspect ratio for two different street orientations in Fortaleza. According to the results, the best aspect ratio may be greater than 1.5, which would affect building shading.
Maleki and Mahdavi (2016)	ENVI-met was used to simulate a portion of Vienna's microclimate. Changes in urban area features (cool roofs, green spaces, and pavement materials) were studied for their effects on microclimate and outdoor temperature. According to the findings, changes made within the urban canopy had a greater impact.
Ridha, S. (2017)	ENVI-met was used to create a simulation for two areas in Baghdad, investigating how the shading arrangement and use of greenery affected the temperature comfort outside.

4.6.2 Significance of ENVI-met

1. **Urban Climate Simulation:**

ENVI-met enables detailed simulations of micro-scale climate conditions in urban areas. It considers factors such as the geometry of buildings, land cover, and surface materials to model temperature, humidity, wind patterns, and other micro-scale meteorological parameters.

2. **Urban Planning and Design:**

Urban planners and designers use ENVI-met to assess the impact of proposed urban developments on local microclimates. It helps in understanding how different design elements, such as building layouts, green spaces, and materials, influence thermal comfort and air quality in specific locations within a city.

3. **Heat Island Studies:**

The model is valuable for studying urban heat islands, where urban areas experience higher temperatures compared to their surrounding rural areas. ENVI-met allows researchers to analyze the factors contributing to heat islands and explore mitigation strategies.

4. **Environmental Impact Assessments:**

When planning new urban developments or infrastructure projects, ENVI-met can be used to assess their potential environmental impact. This includes evaluating changes in local climate conditions, thermal comfort, and air quality.

5. **Bioclimatic Studies:**

ENVI-met aids in bioclimatic studies by providing insights into how variations in micro- scale climate conditions affect plant growth, biodiversity, and other ecological factors in urban environments.

6. **Pedestrian Comfort and Health:**

The model helps assess the thermal comfort of pedestrians in different urban settings. This is crucial for designing urban spaces that promote outdoor activities and contribute to the well-being of residents.

7. **Air Quality Modeling:**

ENVI-met can be coupled with air quality models to study the dispersion of pollutants in urban areas. This is important for understanding the relationship between urban form, meteorology, and air quality.

8. **Green Infrastructure Planning:**

It assists in evaluating the effectiveness of green infrastructure, such as parks and green roofs, in mitigating the heat island effect and improving overall environmental conditions.

4.7 Selected Study Area and Input Data

Choosing Baghdad as the primary application location for our simulation model was based on a careful analysis of its climate, particularly during the summer months. The city is an excellent representation of a challenging urban environment because of its extreme heat. This decision aligns with the model's objective of evaluating and alleviating the impacts of elevated temperatures on urban areas.. The weather data crucial to initializing the simulation models were graciously provided by the Iraqi Meteorological Organization and Seismology. Specifically, the microclimate characteristics chosen for simulation mirror those of Baghdad's hottest summer day, documented on the 12th of July (Hassoon, 2015). Setting the meteorological stage, initial conditions include a wind velocity of 5 m/s and a wind direction of 315 degrees. The simulation unfolds over a 24-hour period, capturing the nuances of a summer day, with the air temperature ranging from a minimum of 35 °C at 6 am to a peak of 50 °C at 4 pm. Relative humidity fluctuates between a minimum of 24% at 4 pm and a maximum of 36% at 7 am.

4.7.1 The proposed model design

The model that was developed consisted of four buildings, all 14 meters tall, with the same shape and size. A courtyard layout with two main entrances and two secondary entrances was used for the placement of these buildings also, i use Colonnades in ground floor they provide shadows for pedestrians below Apart from that, a purposeful 45-degree orientation change was made to bring the main entrances into line with Baghdad's dominant northwest winds. Baghdad's local availability of the materials was carefully taken into account during the selection process. Notably, the sidewalk was made of lightweight concrete, the road was surfaced with black asphalt, and the model's design feature of olive and Sephora japonica trees was thoughtfully included.

Additionally, the researcher used Sophora Japonica, which was selected with grass surrounding the city. A tree with rounded heads and spreading branches, Sophora Japonica is between 4.5 and 9 meters tall. Figure 4.9. Long branches and densely packed twigs characterize Sophora Japonica (Ridha, 2017).

Figure 4.9: Sophora japonica tree

Source: (Ridha, 2017).

From the results, we will notice the importance of the factors affecting the thermal comfort of pedestrians, which are:

- Orientation.
- Building Materials.
- Geometric Design.
- Vegetation.

The researcher presents their proposal for the Baghdad building design that takes into consideration the city's rising summer temperatures (see Figure 4.10).

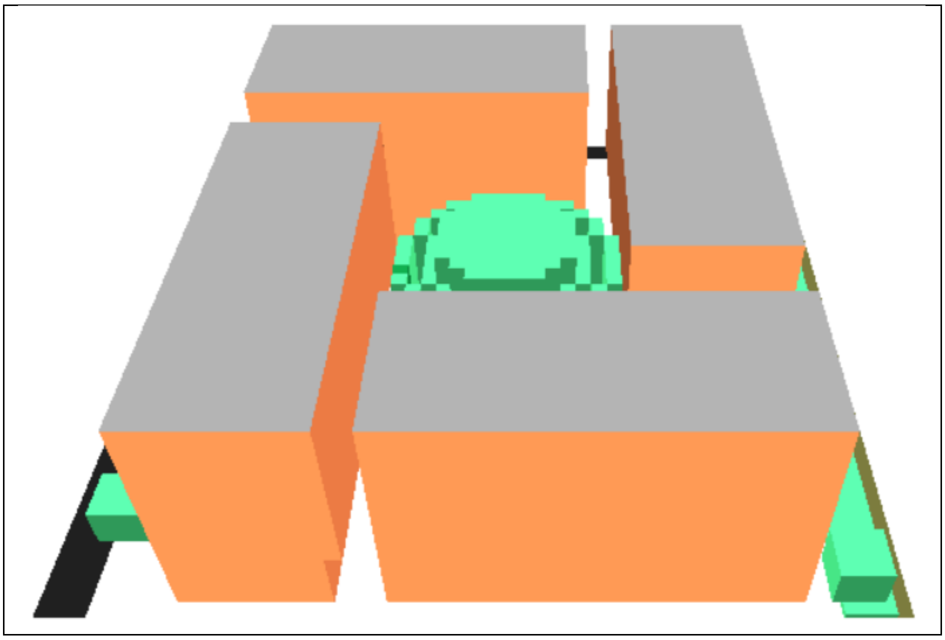

Figure 4.10: Perspective View of the First Model Design

4.7.1.1 Analysis of the simulation results for the first model

All thermal comfort results for the model were plotted at noon when the sun is high overhead Time (12:00).

1. **Air temperature results**

The results are presented in Figure 11 for the model district at noon, 1.8 m above the ground. The results of air temperatures at noon indicate that the maximum temperatures were 44.02 °C for the first model the minimum temperatures were 43.25 °C for the first model.

We also notice that the lowest temperatures are inside the courtyard, and this gives importance to choosing the geometric building design.

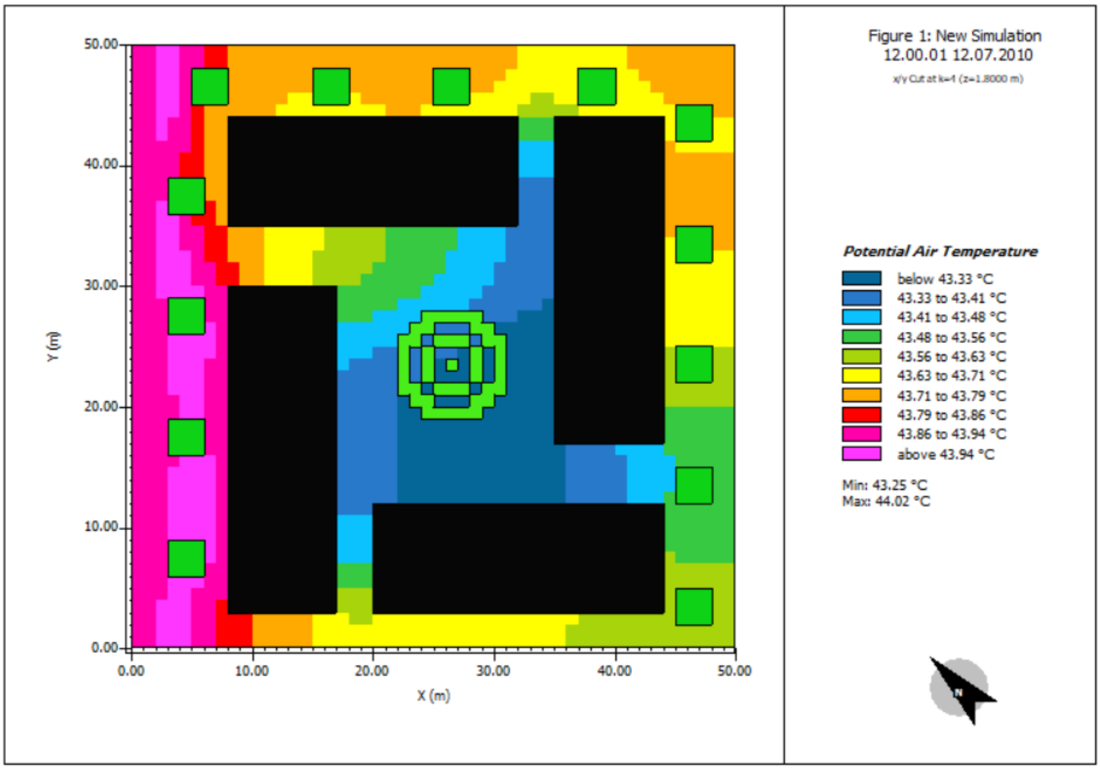

Figure 4.11: Air Temperature Distribution for the First Model at Noon, At 1.8 m above the Ground

2. **Mean radiant temperature results**

Figure 4.12 shows the Tmrt maximum value of 80.83 and the Tmrt minimum value of 37.56. in the first model.

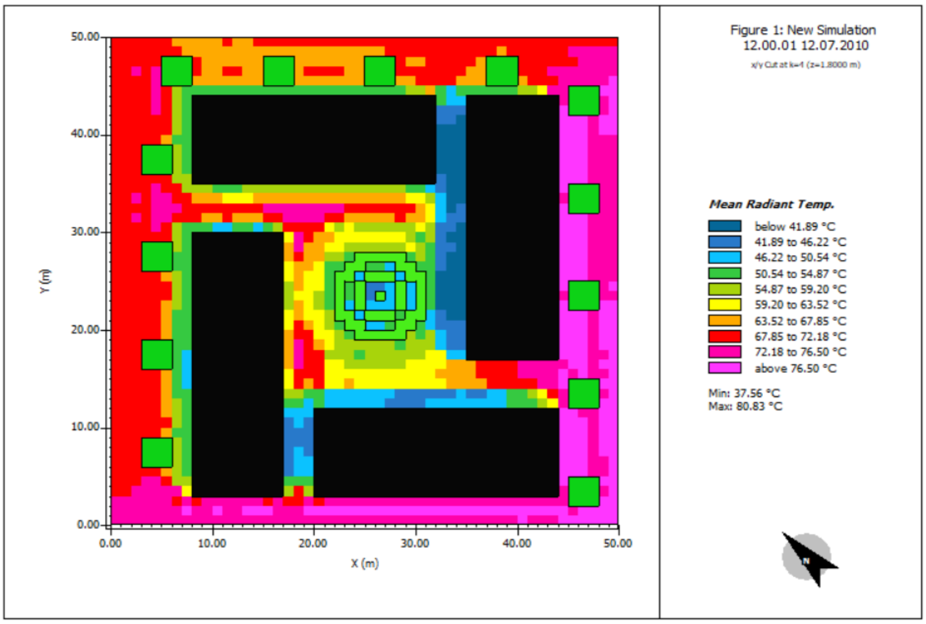

Figure 4.12: Mean Radiant Temperature Distribution for the First Model at Noon, At 1.8 m above the Ground

The sky view factor and the mean radiant temperature during the day have a reasonably strong correlation, according to Aliriza and Mostafa (2012).

One of the limited factors of thermal stress is shading, which lowers the convective heat transfer from the ground surfaces and the sunlit building (Spronken-Smith & Oke, 1999). Furthermore, shading lessens the amount of direct shortwave radiation that reaches ground surfaces, buildings, and people. The distribution of the sky view factor for the first model at noon is shown in Figure 4.13.

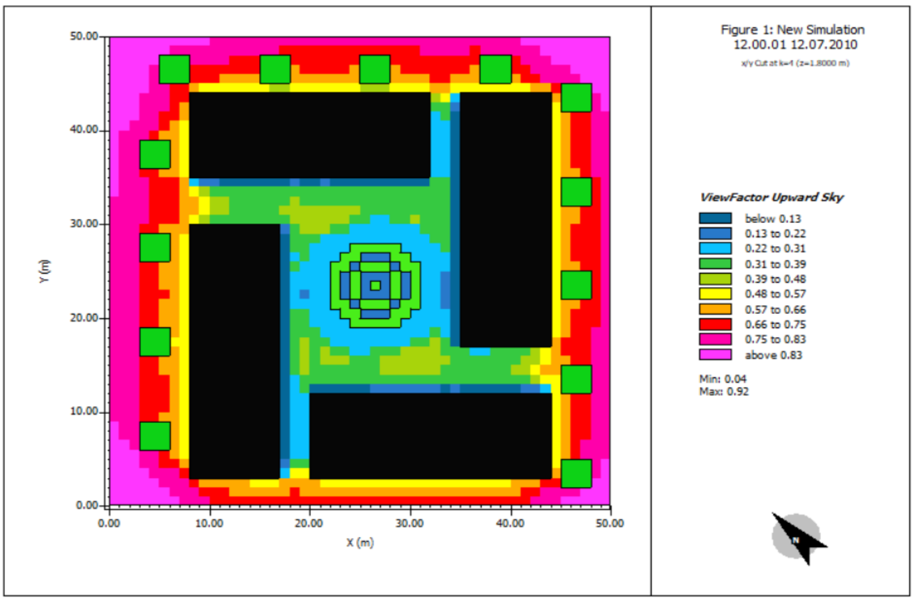

Figure 4.13: Distribution of the Sky View Factor Value for the First Model at Noon, at 1.8 M above the Ground

3. **Predicted Mean Vote (PMV) results**

PMV is a mathematical function of the local climate; in most applications it can also reach above [+4] values, although these are off the scale of the original scale experimental data (http://www.model.envi-met.com/).

Figure 4.14 represents the distribution of Predicted Mean Vote (PMV) at noon for the district. The results of the first model, as shown in Figure 4.13 indicate that the maximum value is 7.57.

The minimum value is 4.18.

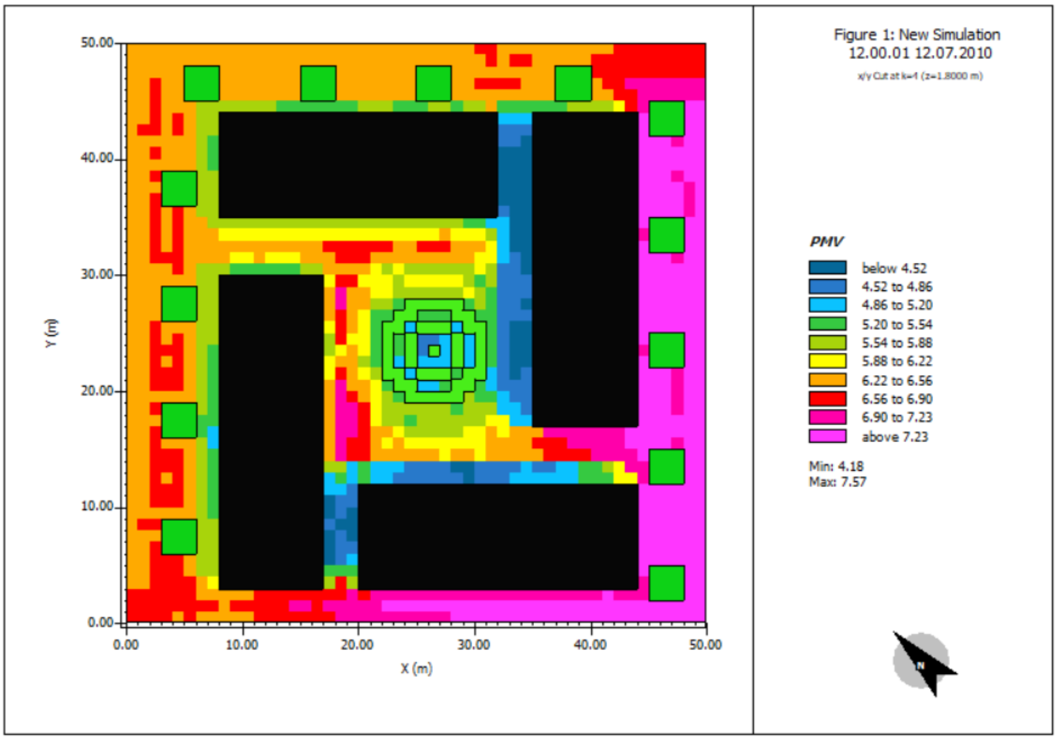

Figure 4.14: Predicted Mean Vote (PMV) Distribution for the First Model at Noon, At 1.8 m above the Ground

4.7.2 Modified designs

As a consequence of the results from the previous design, the researcher observed that the first model has certain issues with thermal comfort that can be fixed. Initially, we altered the building's exterior paint color to white and decided to use glass for the interior walls. We are also adding more trees to make more shadow because we reduced the distance between trees, especially outside, to make something like a green belt. These adjustments are integral to the refinement process aimed at addressing and rectifying the observed thermal comfort challenges.

The second model, as depicted in Figure 15,

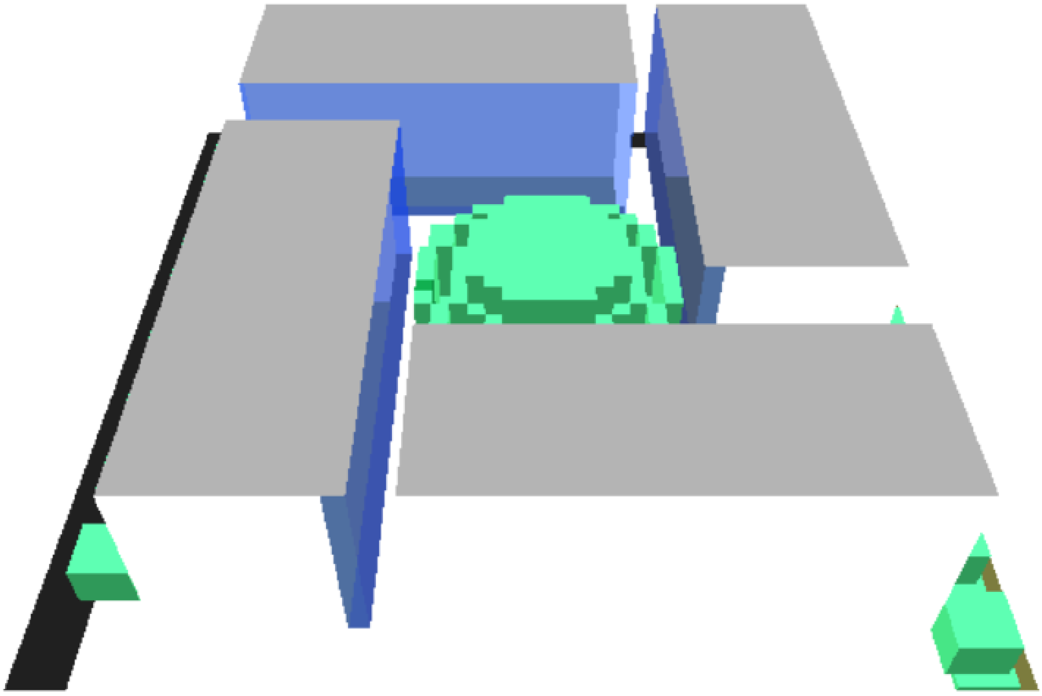

Figure 4.15: Perspective View of the Second Model Design

4.7.2.1 Analysis of the Simulation Results for the second model

All thermal comfort results for the model were plotted at noon when the sun is high overhead Time (12:00).

a. Air temperature results

The results are presented in Figure 16 for the model district at noon, 1.8 m above the ground. According to the results of the air temperature at noon, the first model's maximum and lowest temperatures were 43.59 °C and 42.43 °, respectively. These results indicate that, in comparison to the original model, the modifications made to the second model have resulted in a decrease in the maximum and minimum air temperatures at noon.

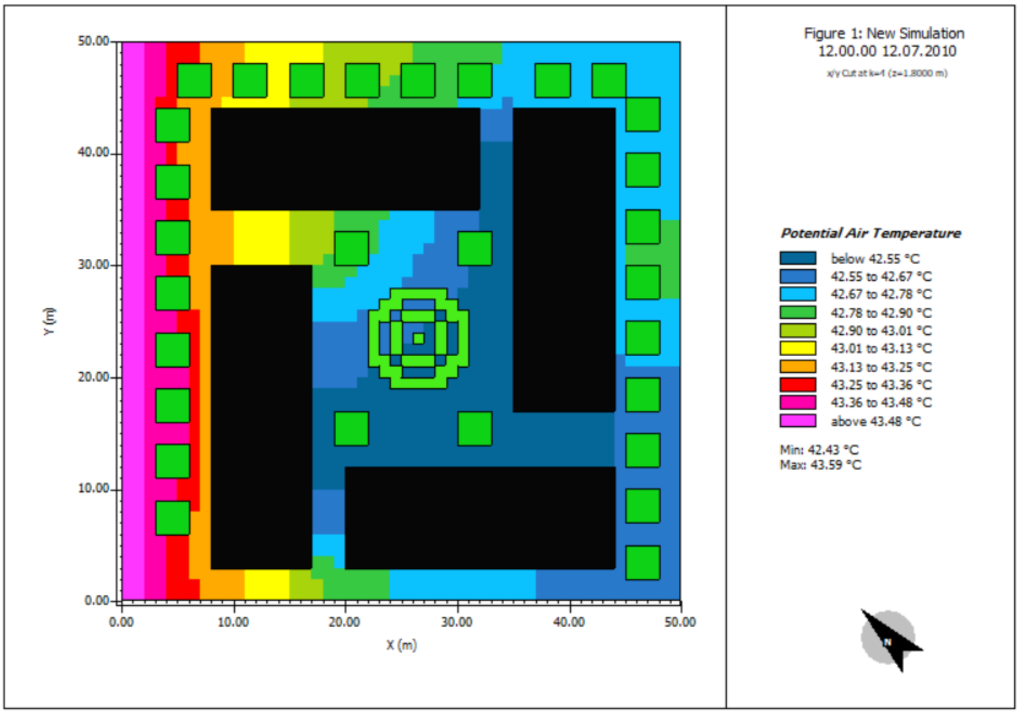

Figure 4.16: Air Temperature Distribution for the Second Model at Noon, At 1.8 M above the Ground

b. Mean radiant temperature results

Figure 4.17 shows the mean radiant temperature distribution (Tmrt) at noon for the second model. By shading it from nearby buildings and vegetation, Tmrt's maximum value can be reduced to 77.39 and its minimum value to 32.71. The second model incorporates various interventions, such as the shadows cast by buildings and vegetation, in an effort to lower the mean radiant temperature. Unlike the first model, this has resulted in a noticeable decrease in both the maximum and minimum Tmrt values.

The reduction in the maximum Tmrt to 77.39 indicates that the shading measures from buildings and vegetation have effectively limited the absorption of solar radiation by surfaces, contributing to a cooler environment. Similarly, the decrease in the minimum Tmrt to 32.71 indicates that the introduced shadows have had a cooling effect during periods of lower temperatures.

These findings underscore the effectiveness of strategic interventions, such as the placement of shadows, in moderating mean radiant temperatures and improving the overall thermal comfort in the modeled area.

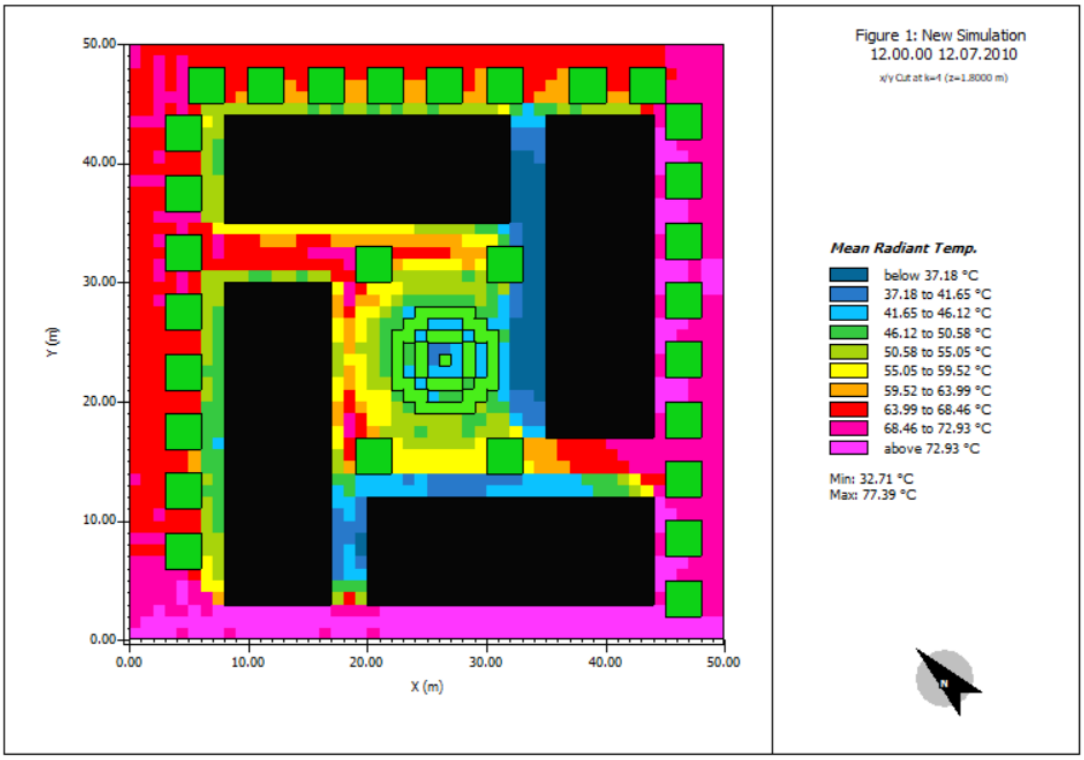

Figure 4.17: Mean Radiant Temperature Distribution for the Second Model at Noon, at 1.8 m above the Ground.

The sky view factor in Figure 4.18 represents the same value as in the first model because the geometry and distances are the same.

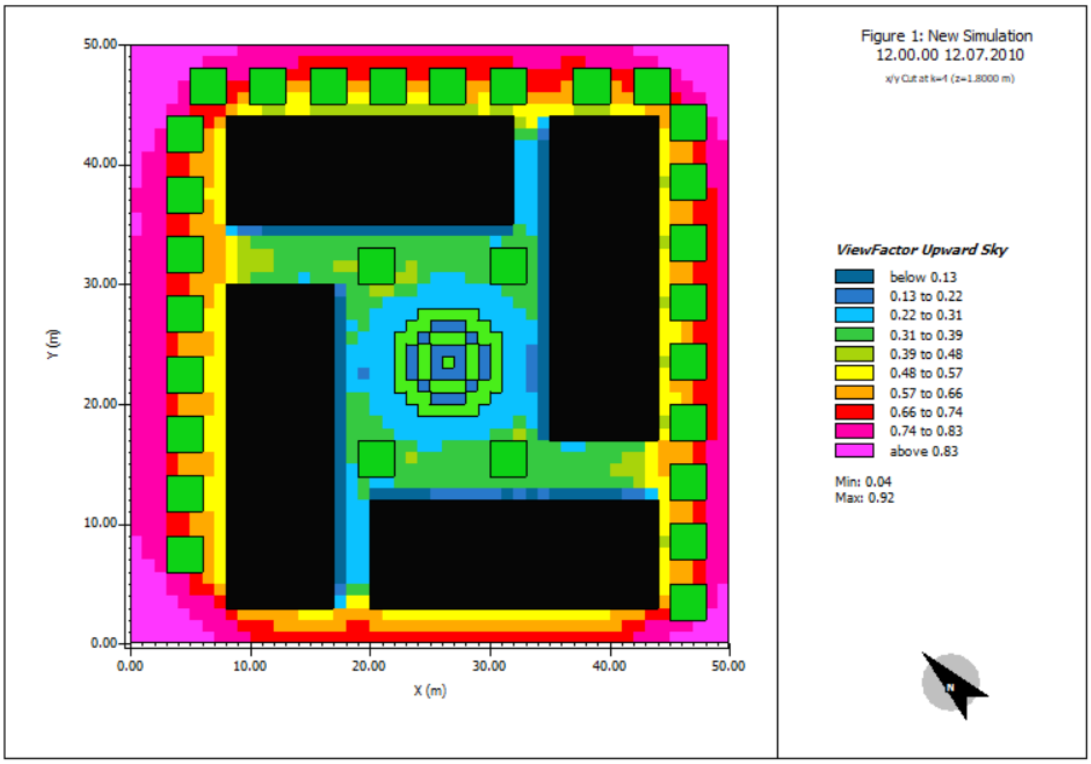

Figure 4.18: Distribution of the Sky View Factor Value for the Second Model at Noon, at 1.8 m above the Ground

c. Predicted Mean Vote (PMV) results

Figure 4.19 represents the distribution of Predicted Mean Vote (PMV) at noon for the district. The results of the second model, as shown in Figure 18 indicate that the maximum value is 7.18.

The minimum value is 3.58.

On the other hand, Figure 13, also representing the first model, shows a slightly wider range of PMV values. Here, the maximum PMV is 7.57, and the minimum is 4.18. These results suggest that, despite the potential for values beyond the typical scale, the adjustments made in the second model may have influenced a reduction in the overall range of PMV values, especially in terms of the maximum PMV. Further analysis is warranted to understand the implications of these differences in terms of thermal comfort and climate impact.

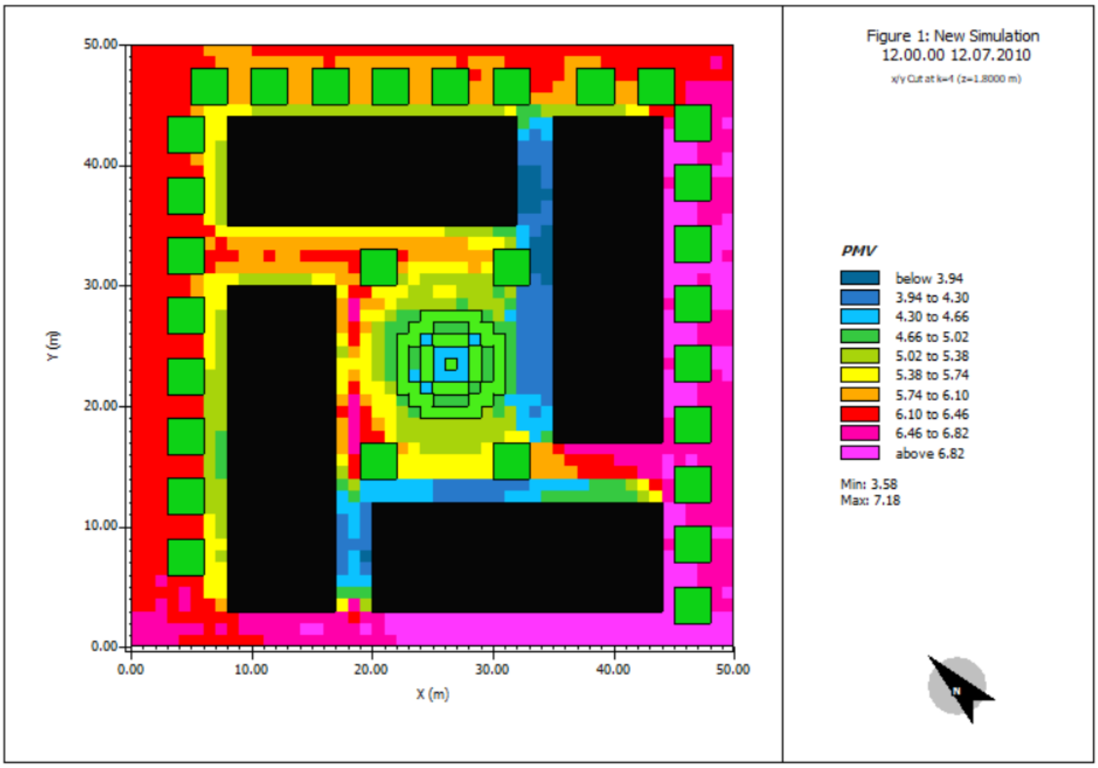

Figure 4.19: Predicted Mean Vote (PMV) Distribution for the Second Model at Noon, at 1.8 m above the Ground

4.8 Results Analysis

The earlier results are compared to those obtained from the first and second models, with the initial and boundary conditions indicated to those from the previous results.

Figure 4.21 shows Dominant air temperatures range from 42 °C to 44 °C better than in the first model as shown in figure 20, we obtain a decrease 67% lower than 43 °C.

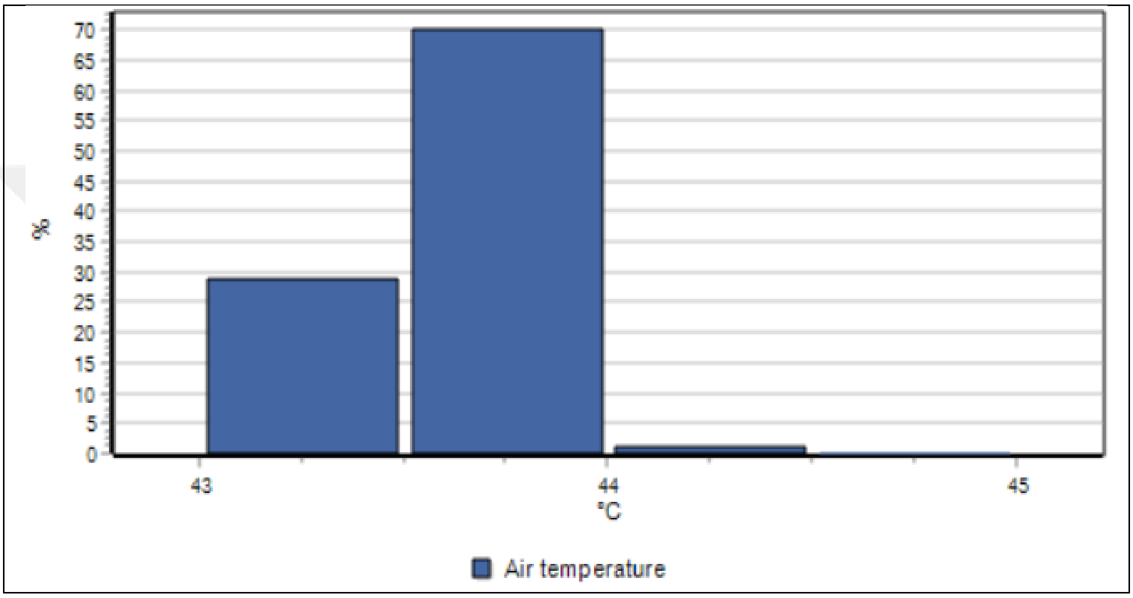

Figure 4.20: Percentage Value of Air Temperature for the First Model at Noon, at 1.8 m above the Ground

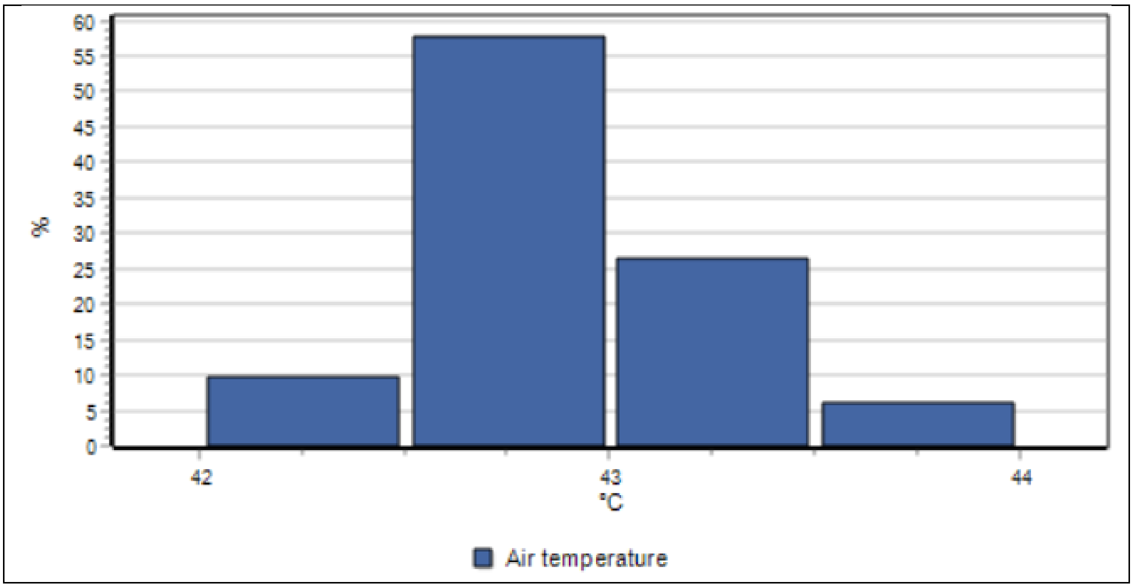

Figure 4.21: Percentage Value of Air Temperature for the Second Model at Noon, at 1.8 m above the Ground

The impact of shadows from the vegetation causes a 9% decrease in the mean radiant temperature in the second model for the mean radiant temperature range of 70 °C to 80 °C, according to the results of the mean radiant temperature in Figures 4.22 and 4.23.

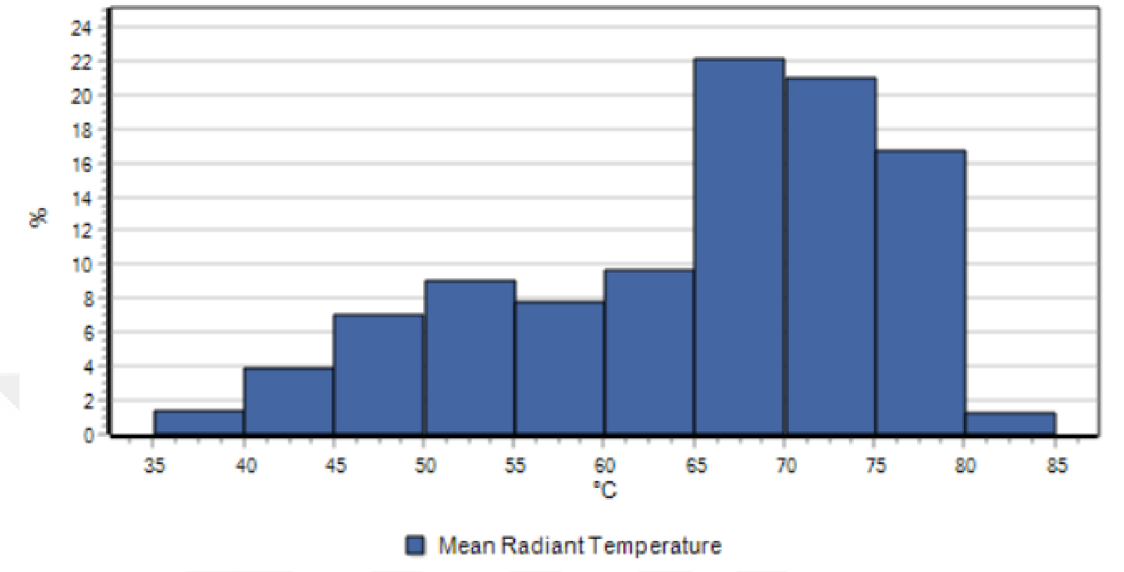

Figure 4.22: Percentage Value of the Mean Radiant Temperature for the first Model at Noon, at 1.8 m above the Ground

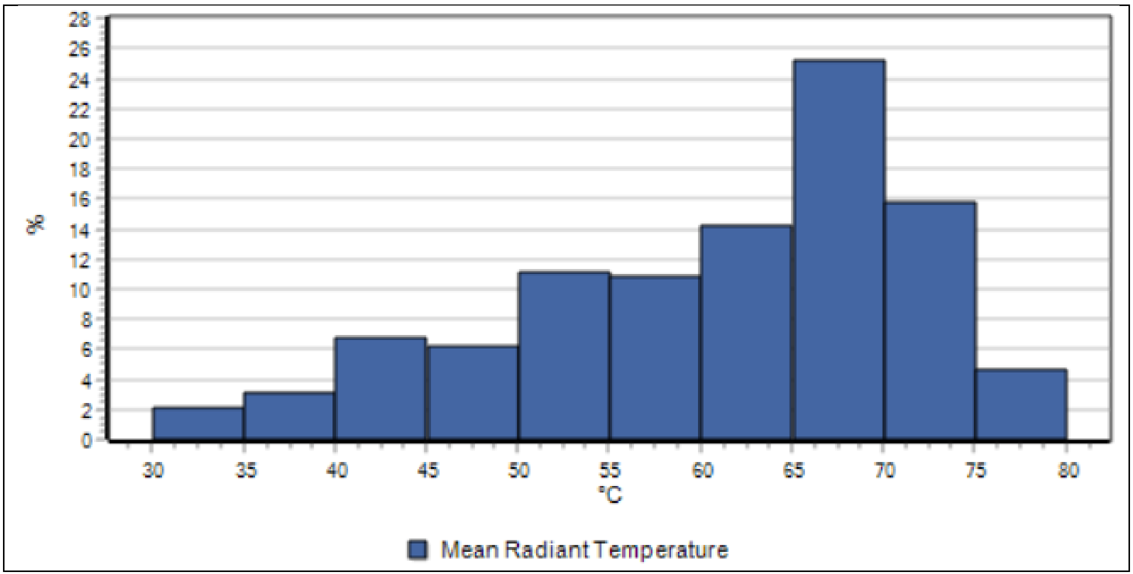

Figure 4.23: Percentage Value of the Mean Radiant Temperature for the Second Model at Noon, at 1.8 m above the Ground

According to PMV results, we note that changing the district's design (Figure 25) could result in an increase in thermal comfort. Figure 4.24 is the first model, which is regarded as a hot region.

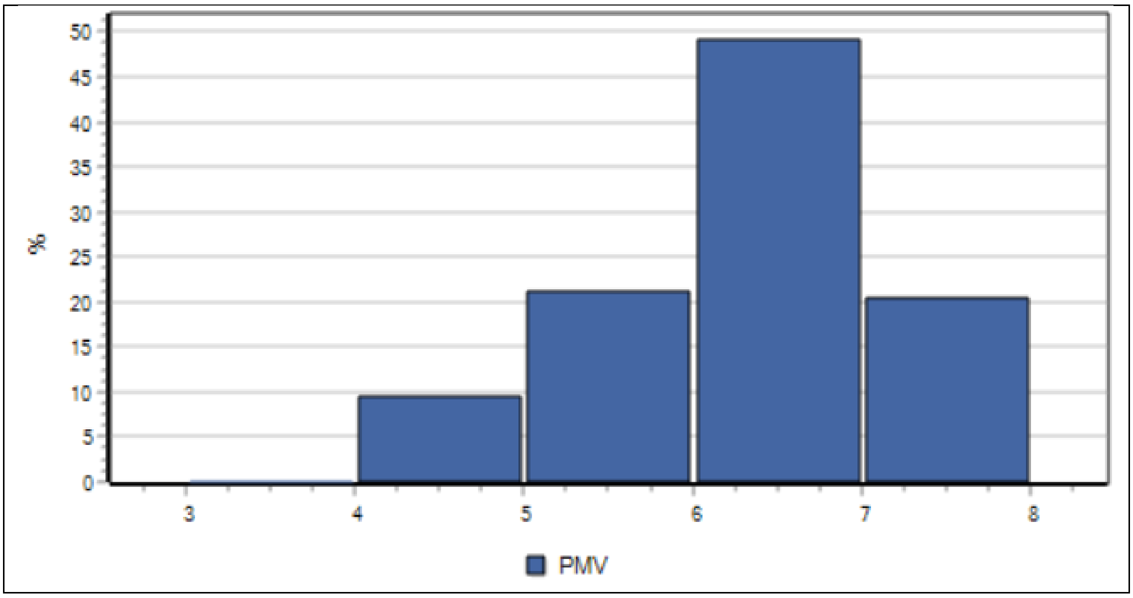

Figure 4.24: Percentage Value of PMV for the First Model at Noon, at 1.8 m above the Ground

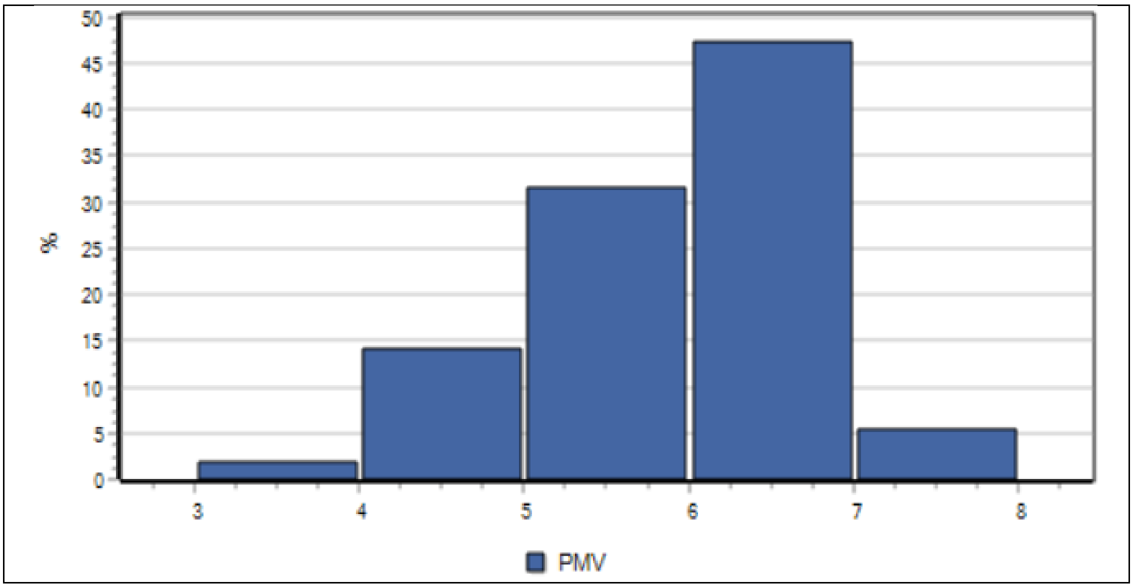

Figure 4.25: Percentage Value of PMV for the Second Model at Noon, at 1.8 m above the Ground

On average, more than 70% of the first model district is characterized by a PMV of more than 6, while the second model has only about 53 % of its surface with a PMV of more than 6. Thus, improved thermal conditions are present in the new design model than the first model.

4.9 Discussions

The iterative process of design modifications, informed by simulation results, significantly to the enhancement of urban thermal comfort district. The strategic incorporation of shading elements, changes in building materials, and additional greenery underscored the importance of holistic design approaches in creating more comfortable and sustainable urban environments. Further analysis and refinement may continue to optimize the proposed model for enhanced thermal performance.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The primary findings of this study are briefly summarized as follows:

1. The length of interior building corridors, the sky view factor, shadow patterns, and urban design all seem to have a major impact on the mean radiant temperature in a hot, dry climate. The assessment of bioclimatic conditions and outdoor thermal comfort is greatly influenced by these factors.
2. Construction materials are essential in hot, dry climates. During the summer, the interior can be kept relatively cool by, for instance employing walls facing the courtyard and thick brick walls on the ground floor to slow down and limit heat gains from the heated outside to the cooler inside.
3. The selection of materials, especially paint, is important when it comes to external construction. Sunlight-reflecting materials should be given priority. White paint is a good example of this because it effectively insulates heat by reflecting the sunlight it receives.
4. The strategic use of glass in building design reduces the need for electrical energy and improves the building's aesthetics by allowing natural sunlight to be captured. In addition to bringing a visually pleasing element to the building, this thoughtful use of glass promotes a harmonious fusion of functionality and aesthetics while also helping to save energy.
5. With careful consideration given to the type and placement of trees, efficient vegetation proves instrumental in optimizing thermal comfort. Notably, as seen in the second model, the thoughtful planting of more trees alongside walkways greatly improved the amount of shade available, which improved pedestrians' thermal comfort. This sophisticated understanding of vegetation's influence on the environment highlights how essential it is to designing outdoor areas that are both sustainable and livable.

6. Narrow walkways reduce heat absorption by the ground and help shade certain areas during the day, which enhances thermal comfort.
7. It is imperative to consider the direction of the prevailing wind when positioning buildings, particularly in areas such as Iraq. Determining a building's orientation is crucial, and orienting the primary hallways to face the direction of the predominant wind becomes essential for improving thermal comfort. Air currents can more easily move through the interior of the building thanks to this purposeful alignment.
8. The selection of building materials in Baghdad is a multifaceted decision involving considerations of both cost-effectiveness and local suitability. Opting for materials readily available in the region ensures not only economic viability but also a harmonious integration with the Iraqi context. For instance, utilizing white paint for walls and external glass can be a prudent choice, not only for its cost-effectiveness but also for its reflective properties, contributing to heat insulation.

Furthermore, landscaping with trees indigenous to Iraq and well-suited to its climate becomes integral to the overall design strategy. Species such as the olive tree and the Sephora japonica tree are not only readily available but also align with the Iraqi environment. This deliberate choice of materials and landscaping elements not only fosters a connection with the local ecosystem but also ensures that the construction is well-adapted to the unique climatic conditions of Baghdad, promoting sustainability and aesthetic coherence.

9. The residential building system is important to keep pace with the increasing population density in Baghdad
10. The results of Tmrt and PMV on the hottest summer day demonstrated that the new model, which was suggested in the thesis's final chapter, had better thermal conditions than the first one.

5.2 Recommendations

Important recommendations to take into account when designing sustainable buildings in general, it's important to focus on the components of sustainable construction and used correctly

1. It must provide the largest possible area of shade for pedestrians in terms of adding umbrellas and paying attention to landscaping.
2. Use building materials available at a reasonable price
3. The aspect ratio ($H/W \geq 1$) determines the distance between buildings.
4. In line with our findings and the housing Technical Standards and Codes of Practice Report of Iraq, which was created by "Polservice" in 1982, the orientation is (NW-SE).
5. Use the shade trees available in the city and distribute them evenly to provide the greatest shade for pedestrians.

5.3 Perspectives

The following proposals are suggested on the evidence and findings of this work: preferably be considered when designing cities in hot, dry climates.

1. Historical Context and Traditional Architecture:

The exploration of ancient building practices unveils a rich historical context where builders sought to harmonize construction techniques with local environments, prioritizing thermal comfort. Future research could delve deeper into specific historical architectural styles and their adaptability to contemporary contexts.

2. Materials and Construction Techniques:

Building on the significance of construction materials, further investigations can explore advanced construction techniques that optimize thermal performance. This may involve a detailed examination of novel materials and their application in diverse climates, contributing to sustainable and energy-efficient building practices.

3. Holistic Approach to Building Design:

Expanding on the strategic incorporation of glass, future research may focus on a holistic approach to building design that seamlessly integrates energy conservation with aesthetic considerations. This could involve the exploration of innovative architectural designs that balance functionality, energy efficiency, and visual appeal.

4. Green Infrastructure and Sustainable Landscaping:

The role of vegetation in optimizing thermal comfort opens avenues for research in green infrastructure. Future studies could delve into the integration of sustainable landscaping practices, exploring diverse plant species that enhance environmental conditions and contribute to urban biodiversity.

5. Microclimatic Considerations:

Research could delve into the microclimatic effects of narrow passages in urban areas, particularly their role in providing shading and reducing heat absorption. Understanding the micro-scale impact of architectural features on thermal comfort can inform design guidelines for urban planners.

6. Optimizing Wind-Driven Ventilation:

Building on the importance of building orientation, subsequent studies could focus on refining strategies for optimizing wind-driven ventilation in various climatic conditions. This may involve a detailed examination of building shapes, heights, and layouts to maximize the benefits of natural air movement.

7. Socio-Economic Implications of Building Material Choices:

The multifaceted decision-making process involved in selecting building materials presents an opportunity to explore the socio-economic implications. Future research could investigate how these choices impact local economies, labor markets, and community well-being.

8. Urbanization Challenges and Residential Systems:

As population density increases in cities like Baghdad, a future thesis could delve into the challenges and opportunities associated with the evolving residential building system. Exploring sustainable, high-density housing solutions and their impact on the urban landscape would be pertinent.

9. Refinement of Thermal Models:

To further enhance our understanding of thermal conditions, subsequent research could refine and expand upon the thermal models proposed in the thesis. This could involve incorporating additional variables, validating results through empirical studies, and extending the applicability of the models to different climatic regions.

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RESUME

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WORK EXPERIENCE:

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  Ramz Altamadoon LLC Freelance.Designing a house 2D plan using Auto Cad.

PROFESSIONAL SKILLS:

- Using Engineering programs (AutoCAD_STAAD PRO MS Project Sketch UP ENVI-met)
- Reading Engineering Charts Calculating quantities for Engineering plans Negotiation
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