AI-DRIVEN DETECTION AND MITIGATION OF URBAN HEAT ISLAND EFFECTS USING IMAGE ANALYSIS AND IOT

R25-002

Project Proposal Report

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Declaration

I declare that this is my own work, and this proposal does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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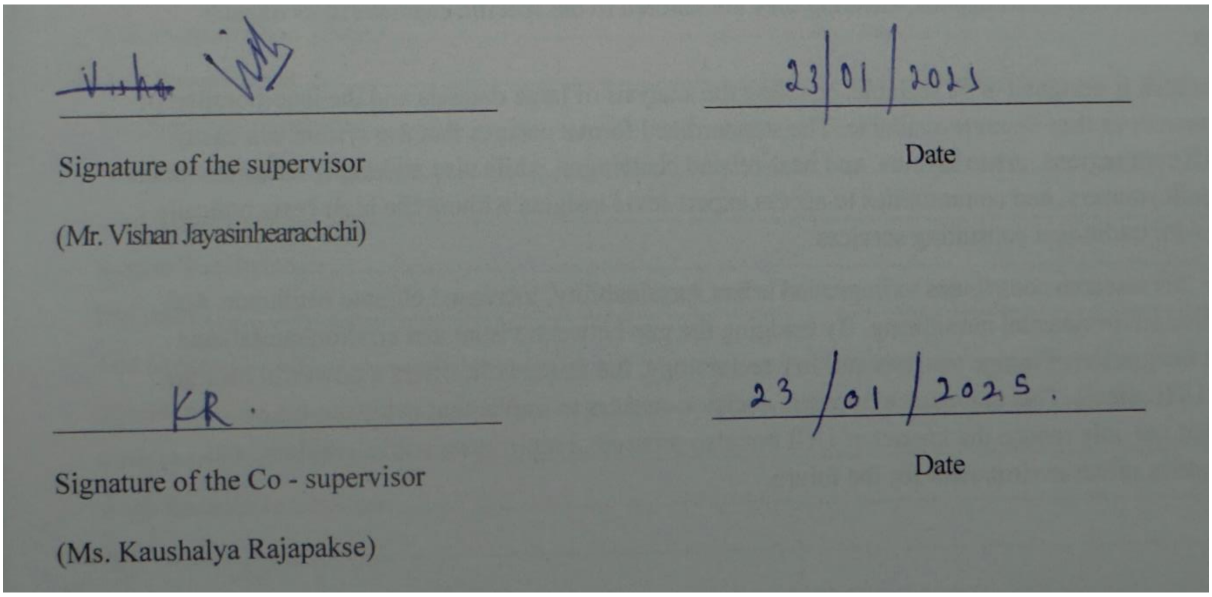

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ABSTRACT

Urban Heat Islands (UHIs) present a significant environmental challenge, there are certain problems affecting the environment that stand out, urban areas suffer from high temperatures relative to their rural surroundings; in Urban Heat Islands this is clearly a problem. It comes about due to the use of landscapes that are more natural being substituted for housing that is constructed using materials like concrete and asphalt that will retain heat. This results in increased energy usage, greenhouse gas emissions, and an array of health issues. Solving these problems will require novel scalable approaches that can be used in predicting.

The goal of the research is to develop a mitigation UHI effect tool that integrates twin technology, GIS, and environmental data. The goal of this unprecedented tool is to imitate the environment of populated urban areas and to combine with planning for proposed sustainable urban structures, advance urban planners with great insights for development. The study utilizes modular architecture which will make it possible for users to import existing digital twins and GIS data. Incorporating advanced simulation algorithms, the system is able to predict thermal impacts using real-life environmental parameters like wind flow, solar radiation, and material specific heat. The system receives real world environment data such as wind direction and speed, the amount and angle of solar radiation incidents as well as the heat retaining qualities of specific materials.

Unlike prior approaches, which depend on reactive approaches or static analyses, the tool presented here makes it possible to address decision making proactively through integration of a flexible and data-driven architecture. The system will undergo enhancement in its predictive capabilities through validation against real world benchmarks, therefore closing gaps in scalability and integration of existing solutions.

Expected results of this research are a strong simulation platform for mitigating UHI effects, increasing urban sustainability, and supporting climate resilience initiatives. This helps to create smarter cities that can deal with the problems of over urbanization and climate change.

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List of Abbreviation

UHI	Urban Heat Island
GIS	Geographic Information System
AI	Artificial Intelligence

01.INTRODUCTION

Urban Heat Islands, or UHIs, represent an emerging problem in the heat islands phenomenon where urban areas are experiencing much higher temperatures than surrounding regions. This happens because heat retaining materials such as concrete, glass and asphalt replace natural vegetation and due to the increment in human activities. The impacts of UHIs are serious and include increased anthropogenic energy usage and emissions, worsening public health, especially during summer heat waves, and higher greenhouse gas emissions. As more people are tending to migrate towards cities which aggravate the problem, the UHI phenomenon has become a growing problem that needs immediate attention regarding urban planning and environmental protection [1].

This copious body of research has tried to find approaches to mitigate UHI effects in general, and more so try to integrate more green infrastructure like tree planting, urban parks, and green roofs [2]. One of the solutions is to reduce the amount of heat absorbed by the city using reflective materials such as cool pavements and roofs. Alongside these, static thermal imaging and manual surveying techniques have also been employed to track the mapping of the heat zones. These techniques suffer from a multitude of problems that are not accurate, non-scale, or able to give actionable insights in real time.

Using these approaches as a starting point, this project seeks to offer a new solution that revolves around a real-time simulation engine that features a digital twin of the existing geospatial and environmental context. Digital replicas of physical structures, or digital twins, accurately model urban development proposals [3]. These models are augmented by Geographic Information System (GIS) data to accurately site and contextually place the structures in the real-world urban environment. By incorporating environmental factors into the model like the solar radiation pattern, wind profile, and material's heat capacity, the proposed tool is able to predict the thermal impacts of the new constructions with dynamically changing parameters.

A thorough understanding of precise digital twin models, GIS data incorporation for spatial context, and sophisticated environmental simulation algorithms are some of the key concepts that need to be grasped. This tool differs from the conventional one as it provides an automated and data-driven approach to assessing the UHI mitigation measures by real time simulation, hence actively involves the urban planners during the stages of construction design.

Currently, the most advanced technologies focus on static methods, such as the use of thermal images or separate evaluation of the environment. However, these methods are limited in their scope and do not allow for dynamic assessment and forecasting of the interactions between the designed objects and the environment. This project aims to tackle that shortcoming by providing a modular, holistic solution that integrates digital twins, GIS, and real-time environmental Multiphysics modeling. By overcoming these shortcomings, the proposed solution not only enhances the accuracy and effectiveness of UHI combating strategies but also provides deep guidance for sustainable urban development [4]

1.1 Background & Literature survey

1.1.1 Urban Heat Island Mitigation Technologies

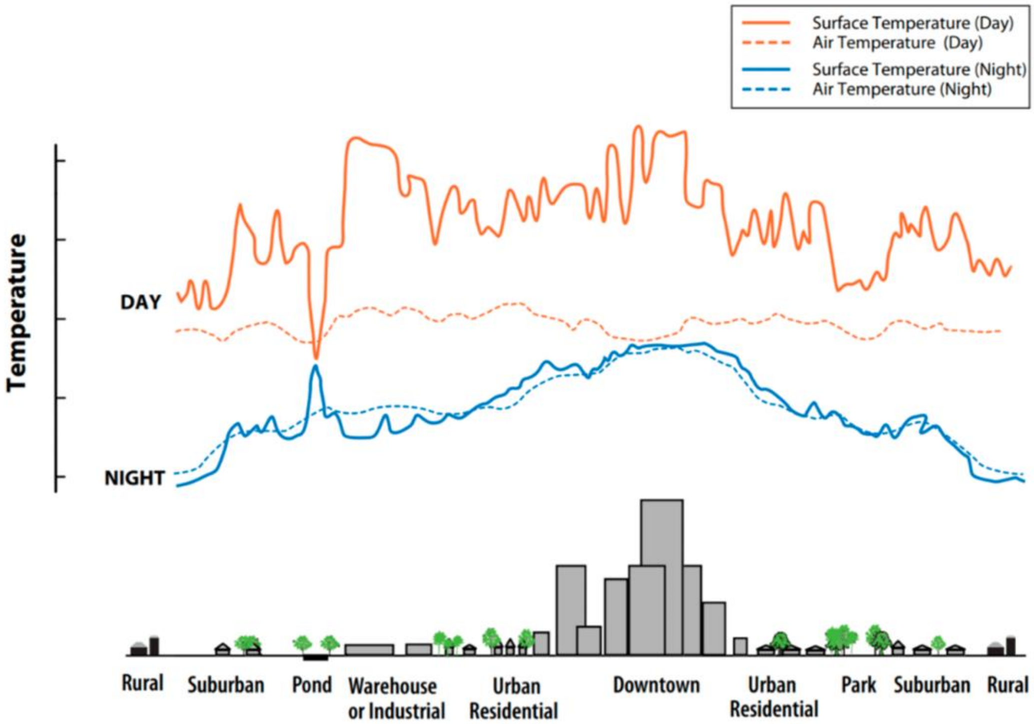

Figure 1 Illustration of how nighttime temperatures remain warmer in the urban areas due to the UHI

Urban sustainability is compromised by Urban Heat Islands (UHIs), resulting in increased energy consumption, greenhouse gas emissions, and deterioration of public health. Many methods have been put in place over the years to address UHI problems. One evergreen component of urban infrastructure such as urban green space, green walls and roofs, as well as cool pavements has received ample attention. Studies show a correlation between the amount of vegetation in the city and decrease of urban temperature due to evapotranspiration and shading. Likewise, in the last years cool roofs and cool pavements, which have been adopted by a number of cities like Tokyo and Los Angeles to reduce temperatures, have become increasingly popular [2].

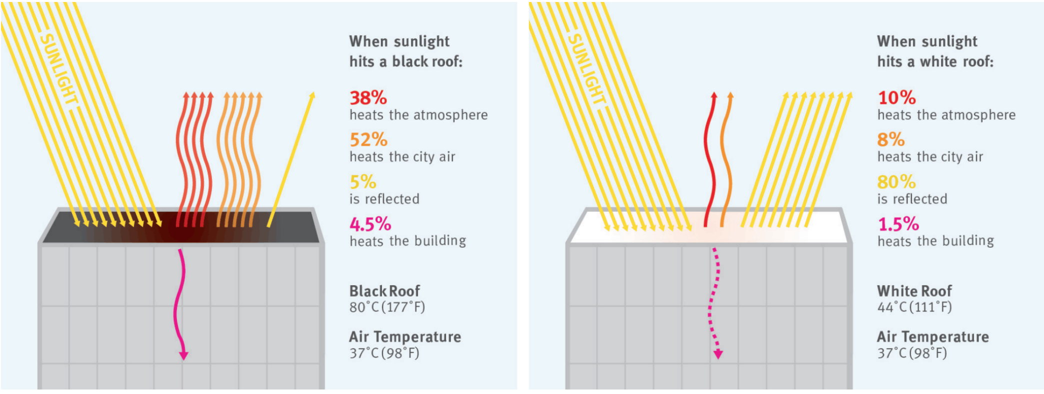

Figure 2 Cool roof and Cool Pavement effect

To identify UHI patterns, thermal imaging and GIS are used but these ultra-modern techniques are very limited as they only show static snapshots and are not able to simulate or predict changes in real-time [1]. In addition, older mitigation techniques solve the problem of overheating but do not integrate urban planning with simulation and prediction features for future problems.

1.1.2 Digital Twin Applications in Urban Planning

The concept of digital twins has emerged as a transformative technology in urban planning. Digital twins as a concept allow simulation and monitoring of an urban town virtually which makes it possible to create a replica of existing cities to see how changing factors like traffic or infrastructure may affect the environment [5].

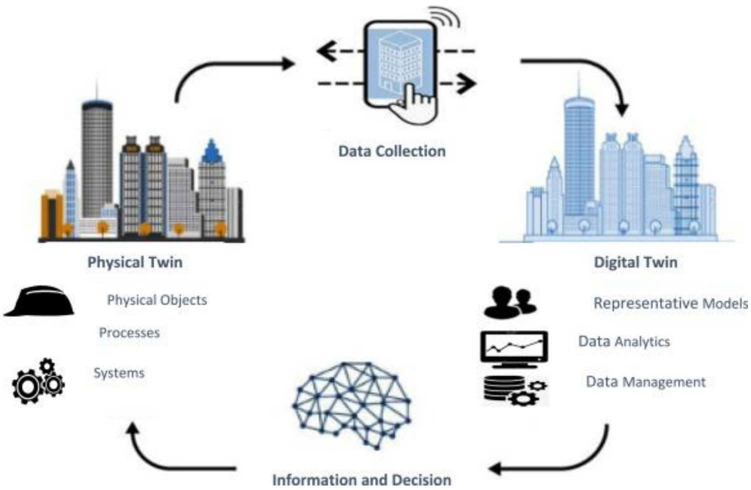

Figure 3 Digital twin technology [7]

One example is their use in energy management systems within smart cities. Such city models allow simulating energy usage and optimizing service management. Digital twins have also been used for simulating the effect of design choice in urban planning on UHI as well. For instance, transforming thermal properties of materials used in building into heat absorbing and heat dissipating digital twins enables precision modeling and analysis. Despite their potential, the use of digital twins for real-time environmental simulation remains limited, particularly in combining GIS data with advanced environmental parameters like wind flow and solar radiation.

1.1.3 Environmental Simulation Tools

Environmental simulation tools are critical for predicting and mitigating the effects of urbanization. Tools like ENVI-met [6] and Autodesk CFD [7] provide capabilities for simulating microclimatic conditions in urban areas. ENVI-met, for instance, models the interactions between buildings, vegetation, and atmospheric conditions to analyze heat and airflow patterns. Similarly, Autodesk CFD enables detailed thermal analysis of urban structures, aiding in the design of energy-efficient buildings.

These tools work well in evaluating particular environmental conditions though they need a lot of resources and skills. Furthermore, they do not have any linkage with GIS data and digital twin models, making their use in practical urban planning almost impossible. Some work has been done on integrating AI-based techniques with simulation tools to improve prediction and computing efficiency, but this is still a novel approach [8].

1.2 Research Gap

There has been considerable progress made in Urban Heat Island (UHI) mitigation and digital twin technology as well as environmental simulation tools, yet there exist significant unfilled voids in research and application. Most of the current UHI mitigation measures focus on adding more green infrastructures like green roofs or cool pavements after problem areas have been established. Although these methods do work, they tend to ignore how the development of the urban area will change the thermal environment of the region in the future. Therefore, city planners are limited in their capacity to combat the UHI issue during the developmental planning processes.

Digital twin technology has made significant strides in urban planning, primarily in areas like traffic optimization and energy consumption. However, most existing applications focus on static analyses, overlooking real-time environmental factors such as wind flow, solar radiation, and the thermal properties of materials. These elements are crucial in understanding how new structures interact with their surroundings, especially in changing climatic conditions.

While tools like ENVI-met and Autodesk CFD offer powerful environmental simulations, they often function in isolation and struggle to integrate seamlessly with GIS platforms or digital twin models. Additionally, their computational intensity makes them impractical for large-scale urban planning projects.

To address these challenges, this project introduces a new approach: a real-time simulation tool that merges digital twin technology, GIS data, and dynamic environmental modeling. This tool will enable urban planners to assess how proposed structures interact with their environment, factoring in key variables such as sunlight exposure, wind patterns, and the heat retention properties of different materials. By delivering accurate predictions of thermal impacts, it empowers decision-makers to design cities that actively reduce the Urban Heat Island (UHI) effect and promote sustainability.

What makes this project unique is its integration of Artificial Intelligence (AI). AI algorithms will process vast amounts of data from digital twins, GIS platforms, and environmental sensors to detect patterns and generate predictive models. Unlike traditional simulation tools, this AI-driven system will dynamically adjust based on real-time inputs, providing a level of accuracy and adaptability that current methods lack.

Beyond just reacting to UHI challenges, this project focuses on proactive mitigation strategies. By predicting the thermal impact of urban developments before construction begins, planners can implement sustainable solutions upfront, reducing the need for expensive retrofitting later. This forward-thinking approach enhances the effectiveness of UHI mitigation while aligning with broader goals of climate resilience and sustainable urban growth.

Ultimately, this project aims to bridge the gap between digital twin technology, environmental simulation, and AI-driven predictive modeling. By offering a scalable, data-driven solution, it contributes to the development of smarter, more resilient cities that can adapt to the challenges of rapid urbanization and climate change.

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1.3 Research Problems

Urban Heat Islands (UHIs) create serious challenges for city sustainability, leading to higher temperatures, increased energy consumption, and greater greenhouse gas emissions. While we know the risks, most current solutions—like adding green spaces or using reflective materials—are reactive rather than proactive. These methods help reduce localized heat but don't fully address the complex and interconnected nature of urban environments. Additionally, existing technologies, such as static thermal imaging and standalone environmental simulation tools, lack the predictive power needed for forward-thinking urban planning [2].

Digital twin technology has emerged as a game-changer for urban development, allowing planners to create virtual models that simulate real-world conditions. However, its potential for tackling UHI effects remains largely untapped. Most digital twins focus on static tasks like optimizing energy use or managing infrastructure but fail to incorporate real-time environmental factors such as wind flow, solar exposure, and material-specific heat retention. Without these crucial elements, they offer limited value in assessing the long-term thermal impact of new urban development's [9] [10].

Moreover, traditional environmental simulation tools like ENVI-met [6], while powerful, are computationally heavy and work in isolation, making them difficult to integrate with Geographic Information Systems (GIS) or digital twin frameworks. This lack of connectivity restricts scalability and limits their use for large-scale urban planning.

This research aims to close these gaps by developing an integrated**,** real-time simulation tool that combines digital twins, GIS data, and dynamic environmental modeling. By bringing these elements together, urban planners will gain actionable insights to proactively design cities that mitigate UHI effects, ensuring more sustainable and climate-resilient urban environments [4].

02. OBJECTIVES

2.1 Main Objective

The main goal of this research is to create a real-time simulation tool that brings together digital twin models, GIS data, and environmental factor**s** to tackle Urban Heat Island (UHI) effects. This tool will allow urban planners to visualize and predict how new buildings and city layouts impact urban temperatures, helping them make informed, proactive decisions to minimize heat buildup. By using advanced environmental modeling, the framework will provide valuable insights, supporting the development of greener, more sustainable cities that are better prepared for climate challenges.

2.2 Specific Objectives

2.2.1 Development of the Simulation Tool

The primary goal is to develop a versatile simulation framework that allows for the effortless integration of **prebuilt digital twin models**. This tool will serve as a flexible platform, enabling urban planners and stakeholders to analyze environmental interactions within different urban settings. By ensuring adaptability, the framework will accommodate various planning needs, making it a valuable resource for designing more sustainable and climate-resilient cities.

2.2.2 Integration of Environmental Data

Integrate real-time environmental factors such as Wind flow, solar radiation, temperature fluctuations, and material-specific thermal properties into the simulation. By capturing these dynamic conditions, the tool will provide more accurate and relevant predictions, enabling planners to make informed decisions based on real-world environmental interactions.

2.2.3 Thermal Impact Analysis

Enhance the simulation tool’s capabilities to analyze how imported digital twin models interact with their surroundings under varying conditions. This includes predicting heat retention, dissipation, and overall thermal distribution, allowing planners to identify potential hotspots and their underlying causes for more effective urban heat mitigation strategies

2.2.4 Validation and Refinement

Conduct validation studies using benchmarks from real-world scenarios to test the accuracy of the tool's predictions. This process will involve refining the algorithms and improving the usability of the tool based on user feedback and performance evaluations.

03. METHODOLOGY

3.1 Overview of the Proposed System

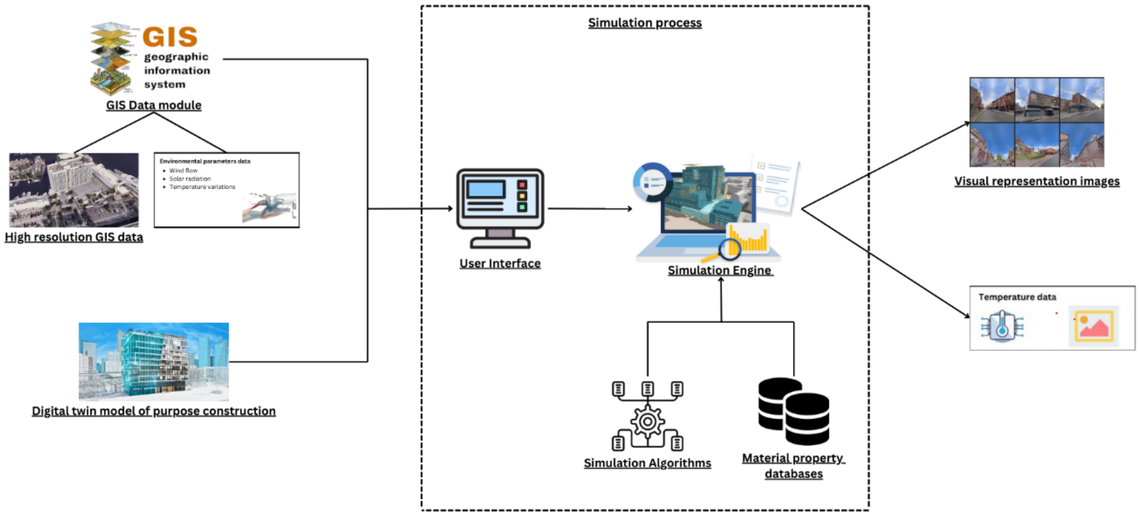

Figure 4 High level System Diagram

This system is designed to provide a comprehensive and innovative approach to mitigating Urban Heat Island (UHI) effects by combining digital twin models, GIS data, and advanced environmental simulations. By offering a dynamic, real-time framework, it empowers urban planners with actionable insights to create cooler, more sustainable cities.

At the heart of this system is its modular architecture, allowing users to **seamlessly import prebuilt digital twin models**—highly detailed virtual replicas of buildings and urban structures. These models, enriched with material properties, dimensions, and structural data, are aligned with high-resolution GIS maps, ensuring precise placement within real-world city landscapes.

What sets this system apart is its ability to incorporate real-time environmental data, including wind patterns, solar radiation, temperature variations, and thermal properties of different materials. Using advanced simulation algorithms, the tool can predict how buildings retain and release heat, where hotspots might form, and how different structures interact with their environment. This level of insight enables planners to test and refine urban designs before construction begins, ensuring long-term sustainability.

Designed for scalability and usability, the system can accommodate everything from small-scale projects to entire citywide developments. Its flexible structure allows for continuous updates and new data integration, ensuring it remains relevant as urban planning needs evolve.

Ultimately, this simulation tool revolutionizes UHI mitigation by shifting from traditional reactive solutions to proactive, data-driven strategies. It provides a smarter, more adaptive way to design urban environments that are climate-resilient, energy-efficient, and better suited for future generations.

3.2 Collect GIS Data and Environmental Parameters

The process of collecting GIS data and environmental parameters is a foundational step in the development of the proposed UHI simulation tool. This step ensures that the system has the necessary inputs to create accurate, context-aware simulations of thermal impacts within urban environments.

3.2.1 Data Requirements

The system requires two primary types of data: GIS data and environmental parameters:

3.2.1.1 High-resolution GIS data:

- GIS data is essential for mapping urban landscapes, providing spatial context for integrating digital twin models.
- This data includes information on topography, land use, building footprints, road networks, and vegetation cover, offering a comprehensive view of the urban environment.
- Open-source platforms like **QGIS** and proprietary tools such as **ArcGIS** will be used to collect and preprocess GIS data.
- These platforms offer access to high-resolution maps, building footprints, and spatial datasets that can be aligned with digital twin models.
- Preprocessing steps include georeferencing data, ensuring spatial accuracy, and

organizing data layers for efficient integration.

3.2.1.2 Environmental Parameters:

- These parameters are critical for simulating real-world interactions between the environment and urban structures.
- Key environmental factors include:
  - **Wind Flow:** Influences how heat dissipates or accumulates around buildings and open spaces.
  - **Solar Radiation:** Determines the intensity and distribution of heat absorption by materials.
  - **Temperature Variations:** Provide baseline data for simulating heat retention and dissipation over time.
  - **Material-Specific Thermal Properties:** Include data on conductivity, emissivity, and heat absorption rates of materials commonly used in urban construction.

3.2.2 Data Collection Methods

3.2.2.1.GIS Platforms:

- Open-source platforms like QGIS and proprietary tools such as ArcGIS will be used to collect and preprocess GIS data.
- These platforms offer access to high-resolution maps, building footprints, and spatial datasets that can be aligned with digital twin models.
- Preprocessing steps include georeferencing data, ensuring spatial accuracy, and organizing data layers for efficient integration.

3.2.2.2 Environmental Data Sources:

- **Government Datasets:** Publicly available datasets from meteorological departments or urban planning agencies serve as a valuable resource for historical and real-time environmental data.

- **Third-Party APIs:** Online platforms, such as OpenWeatherMap or WeatherAPI, offer APIs to access real-time environmental data for specified locations. These APIs simplify data retrieval and allow dynamic updates to the simulation framework.

3.2.2.3 Material Property Databases

- A dedicated database for material-specific thermal properties will be created or referenced to ensure accurate modeling of heat behavior.
- These properties will be linked to the digital twin models to simulate how different materials interact with environmental factors

3.3 Generate 3D Virtual Models of Proposed Structures

The creation of 3D virtual models is a critical step in enabling accurate simulations of thermal impacts in urban environments. These models, also referred to as digital twin models, represent virtual replicas of proposed buildings or urban infrastructure. They include comprehensive details such as structural dimensions, material specifications, and architectural features, providing a precise foundation for environmental simulation.

However, it is important to emphasize that the 3D virtual models are **not built within the proposed simulation tool itself**. Instead, users are expected to prebuild these models using external industry-standard tools such as **AutoCAD**, **Revit**, or other specialized 3D modeling software. These platforms are widely recognized for their robust capabilities in generating high-quality, detailed digital representations of structures.

3.3.1 Model Requirements

To ensure compatibility and functionality within the simulation tool, the prebuilt digital twin models must include:

- **Material Specifications:** Each model should specify the thermal properties of the materials used, such as conductivity, emissivity, and heat absorption rates. These attributes are essential for accurately simulating how the structure interacts with environmental parameters like solar radiation and temperature.

- **Structural Dimensions:** The dimensions of the proposed structure, including height, width, and depth, must be defined to provide spatial accuracy during the simulation process.
- **Architectural Details:** Features such as window placements, roof types, and façade designs should be included, as they influence heat retention and dissipation.

3.4 Overlay Models on GIS Data for Placement

A crucial step in the simulation process is overlaying the prebuilt digital twin models onto Geographic Information System (GIS) data. This integration ensures that the models are placed within a spatially accurate and context-aware representation of the urban landscape, enabling realistic and meaningful simulations of environmental interactions.

3.4.1 Importing GIS Data and Digital Twin Models

The process begins with importing high-resolution GIS data, which provides a detailed spatial map of the urban area. This data includes information such as building footprints, road networks, elevation, and vegetation cover. Alongside this, the prebuilt digital twin models—constructed externally by the users using tools like AutoCAD or Revit—are uploaded into the simulation tool. These models include material specifications, structural dimensions, and architectural details, ensuring that they accurately represent the proposed structures.

3.4.2 Aligning Models with Geographic Coordinates

To achieve accurate placement, the simulation tool aligns the digital twin models with the geographic coordinates provided by the GIS data. This alignment involves georeferencing, a process that ensures the model's position, orientation, and scale correspond precisely to its real-world location. By doing so, the simulation environment replicates the spatial relationships and context of the urban area, allowing for realistic simulations of thermal and environmental impacts.

3.4.3 Integrating Models with Real-World Spatial Data

Once aligned, the digital twin models are fully integrated into the GIS data layers. This integration combines the structural and material details of the models with the geographic and

environmental attributes of the area. For instance:
By embedding the digital twin models within the GIS framework, the simulation tool creates a comprehensive representation of the urban landscape. This integration ensures that the environmental simulations consider all relevant spatial and contextual factors, providing accurate and actionable insights for urban planners.

3.4.4 Use Simulation Algorithms to Predict Thermal Impacts

The core functionality of the simulation tool is to predict the thermal impacts of proposed structures by simulating their interactions with environmental conditions. This is achieved through the development and implementation of advanced simulation algorithms that can dynamically analyze how urban structures influence and are influenced by surrounding environmental factors. By doing so, the tool provides urban planners with actionable insights to address Urban Heat Island (UHI) effects proactively.
The simulation algorithms are designed to process a combination of inputs, including the structural details of digital twin models, GIS data, and real-time environmental parameters such as temperature, wind flow, and solar radiation. These algorithms account for material properties, spatial placement, and contextual factors, ensuring that the simulations reflect realistic and site-specific conditions.
The algorithms are tasked with modeling key thermal interactions, including:

3.4.4.1 Heat Retention and Dissipation:
Simulations evaluate how proposed structures retain and release heat over time, depending on material properties like thermal conductivity and emissivity. For example, buildings made of concrete or asphalt typically absorb and retain more heat, contributing to localized UHI effects. The algorithm identifies such behaviors and predicts the thermal footprint of these structures.

3.4.4.2 Wind Flow Dynamics Around Buildings:
The flow of wind through and around buildings is a critical factor in heat dissipation and ventilation. The algorithms simulate how structures block or channel wind, creating areas of stagnation or enhanced airflow, and determine their impact on surrounding temperatures.

3.4.4.3 Solar Radiation Effects on Surfaces and Materials:
The algorithms calculate how solar radiation interacts with building surfaces, taking into

account orientation, shading, and reflective properties. This includes determining hotspots caused by high solar exposure and assessing the effectiveness of reflective or shaded surfaces in reducing heat absorption.

The implementation of these algorithms relies on specialized computational tools, including:

- **ENVI-met:** A widely recognized microclimate modeling software capable of simulating complex urban environments. ENVI-met can process detailed environmental and structural data to predict wind flow, solar radiation, and thermal behaviors with high accuracy.
- **Custom-Built Simulation Software:** If project-specific requirements demand greater customization, algorithms can be developed in-house using programming frameworks like Python or MATLAB. Custom-built tools offer the flexibility to tailor simulations to the unique needs of UHI mitigation studies, ensuring alignment with project objectives.

By leveraging advanced simulation algorithms, the tool bridges the gap between virtual modeling and real-world application, offering a dynamic and precise approach to understanding and mitigating UHI impacts. This capability supports the broader goal of fostering sustainable and climate-resilient urban development.

3.5 Validate Results and Refine Models

Validation is a critical phase in the development of the simulation tool, ensuring that the results generated by the system are accurate, reliable, and reflective of real-world conditions. This process involves systematically comparing the simulation outcomes with established benchmarks or validated studies and iteratively refining the system to minimize discrepancies. The goal is to enhance the predictive precision of the tool, making it a dependable resource for urban planners tackling Urban Heat Island (UHI) mitigation.

3.5.1 Comparing Simulation Outcomes with Real-World Benchmarks

To assess the accuracy of the simulation tool, its outputs are evaluated against real-world data and results from previously validated studies. Benchmarks for comparison may include:

- **Thermal Profiles:** Observed temperature patterns in urban environments, collected through field measurements or IoT sensors, are compared with simulated temperature distributions.

- **Heat Retention and Dissipation Rates:** Real-world data on how specific materials behave under varying conditions is used to validate the simulation's modeling of material-specific thermal properties.
- **Wind Flow and Solar Radiation Effects:** Data from existing studies on airflow and solar exposure in urban environments is analyzed alongside the simulation's predictions to ensure consistency.

This comparison not only highlights the tool's current level of accuracy but also identifies areas where the simulation might deviate from expected or observed results.

3.5.2 Refining Algorithms and Parameters

When discrepancies are identified between simulated and real-world data, the algorithms and parameters used in the simulation are refined. This process include:

- **Algorithmic Adjustments:** Modifying the computational logic to account for previously overlooked variables or to improve the representation of complex interactions, such as turbulence in wind flow or shadowing effects from adjacent structures.
- **Parameter Tuning:** Calibrating inputs such as material properties, environmental factors, or simulation time intervals to align more closely with empirical data.
- **Iterative Testing:** Re-running simulations with refined parameters and comparing the results to benchmarks again to confirm improvements in accuracy.

By rigorously validating and refining the tool, urban planners are provided with a highly dependable simulation system that delivers actionable insights for UHI mitigation. The increased accuracy ensures that recommendations, such as material choices, structural modifications, or the placement of green infrastructure, are based on robust and trustworthy data, ultimately contributing to more effective and sustainable urban development practices.

This validation and refinement process underscores the commitment to delivering a state-of-the-art simulation tool that bridges the gap between theoretical models and practical, real-world applications.

04.PROJECT REQUIREMENT

4.1 Functional Requirement and Non-Functional Requirement

Table 1Functional and non-functional requirements

Functional Requirement	Non-Functional Requirement
Importing Digital Twin Models: Allow users to upload prebuilt 3D models of urban structures, including material properties and structural dimensions.	**Scalability**
GIS Data Integration: Integrate high-resolution GIS data to provide spatial context for digital twin models.	**Performance**
Simulation Execution: Simulate interactions between proposed structures and environmental parameters, such as wind flow, solar radiation, and heat retention/dissipation.	**Accuracy**
Thermal Impact Analysis: Generate predictive thermal profiles to identify potential hotspots and areas of concern.	**Compatibility**
Actionable Recommendations: Provide UHI mitigation strategies, such as material changes, structural modifications, or green infrastructure placement.	**Usability**
Data Visualization: Present simulation results using thermal maps, charts, and reports for easy interpretation.	**Security**

4.2 User Requirement

- **Accessibility:** The tool should be easily accessible via desktop or web-based platforms.
- **Ease of Use:** Provide a streamlined process for importing models, configuring simulations, and interpreting results.
- **Customization:** Allow users to adjust environmental parameters and select specific areas for focused analysis.

4.3 System Requirement

4.3.1 Hardware requirements

- Minimum: 16 GB RAM, quad-core processor, and 500 GB storage.
- Recommended: 32 GB RAM, high-performance GPU, and 1 TB storage for large-scale simulations.

4.3.2 Software requirement

- GIS platforms for data preprocessing.
- D modeling tools for digital twin creation.
- Python or MATLAB for algorithm implementation and refinement.

4.4 Gantt chart

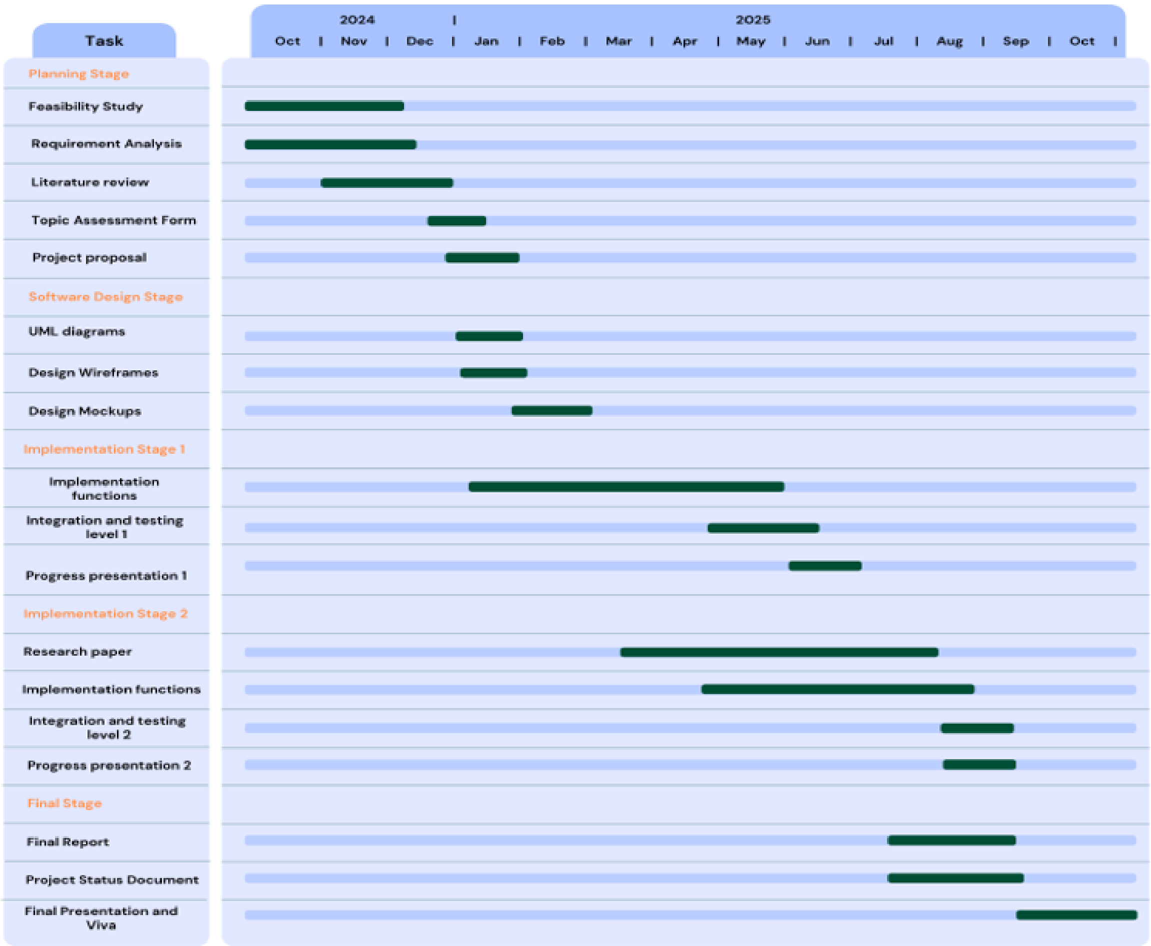

Figure 5 Gantt chart

4.5 Work Breakdown Structure

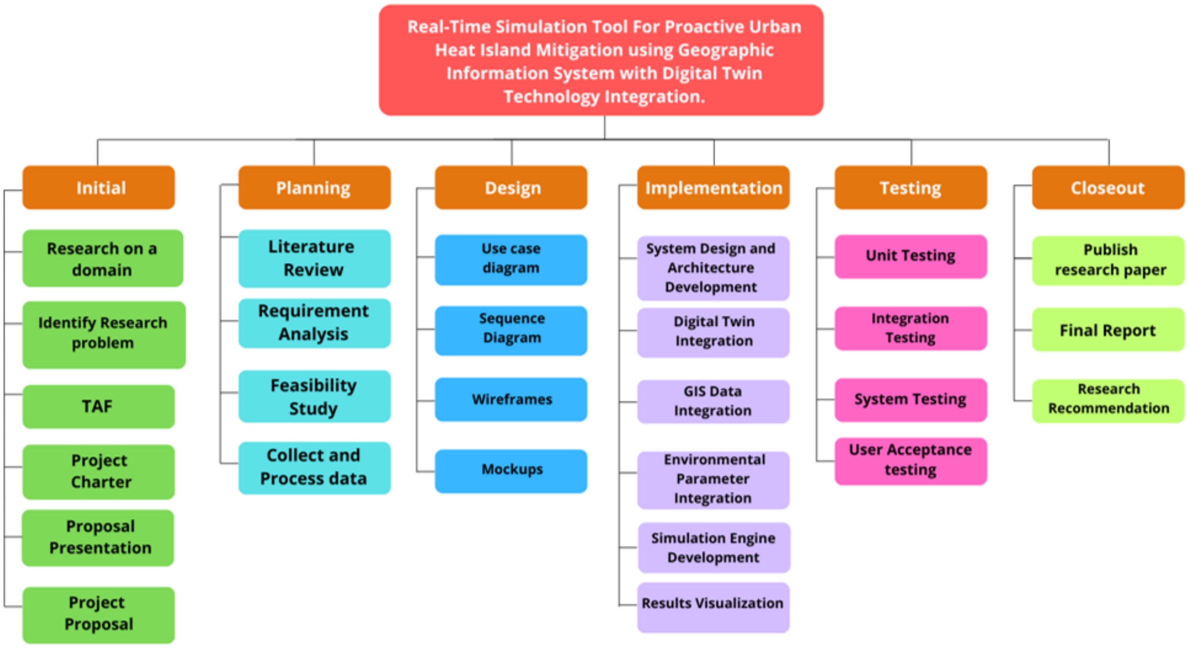

Figure 6 Work Breakdown Structure

05. Description of personal

Facilitators

1. Mr. Vishan Jayasinghearachchi - Supervisor
2. Ms. Kaushalya Rajapakse – Co Supervisor
3. Dr. Rajitha De Silva – External Supervisor

06. Budget Plan

Table 2 budget plan

Requirements	Price (Rs.)
Cloud Computing Service	10000.00
Domain registration	4000.00
Hardware products	20000.00
Internet and Wi-Fi charges	6000.00
Others	5000.00
Total estimated cost	45000.00

07. Commercialization

Target Audience

- Urban planners and Architects
- Environmental Researchers
- Smart city Developers
- Construction and Real Estate Developers
- Government Agencies and Policy Makers

Market space

- Urban Development Sector
- Construction and Real state Market
- Sustainability Consulting Firms

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