International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(12s) 2026 pp. 391-406
https://doi.org/10.70917/ijcisim-2026-3902
Article

Building Information Modeling for Land Use and Impact on Thermal Changes

AbdAlrahman A. Alahmady[1]*, Mohamed A. Abdelfatah[1], Gamal S. El-Fiky[1]

[1] Construction Engineering & Utilities Department, Faculty of Engineering, Zagazig University, Egypt.
Email: abdoelahmady@yahoo.com
Corresponding Author: AbdAlrahman A. Alahmady

Abstract: The impact of land use and urban design on thermal changes in Zagazig City, Egypt, is investigated using Building Information Modeling (BIM) simulations. The study focuses on the urban heat island (UHI) impact, examining how building height, overcrowding, and vegetation affect air temperature, mean radiant temperature (MRT), and relative humidity. The study area, which is characterized by uncontrolled urban growth and rising temperatures, was recreated using a variety of scenarios, including green roofs, tree-lined roadways, and residential zoning changes. The results showed a considerable temperature increase in the contemporary urban reality (32.62°C) compared to the original plan (26.63°C), representing a 22.5% increase. Implementing green roofs (Improve 1) and residential zoning (Improve 2) reduced temperatures by 0.84°C and 0.6°C, respectively, while combined interventions (Improve 1&2) achieved a 1.44°C decrease. Similarly, MRT was reduced by 1.26°C using integrated techniques. However, relative humidity improved just somewhat. The study emphasizes BIM's effectiveness in simulating sustainable urban interventions and promotes its integration with computational tools to improve thermal comfort and energy efficiency. These findings provide policymakers and urban planners with actionable insights into mitigating UHI effects and promoting ecologically sustainable cities.
Keywords: Building Information Modeling (BIM), urban heat island (UHI), thermal comfort, sustainable urban design

1. Introduction

Building Information Modelling (BIM) is a digital technology that operates inside a collaborative work environment. While BIM has been extensively investigated in a variety of contexts, its application to sustainability has piqued interest. However, there has been no in-depth assessment especially concentrating on BIM standards, guidelines, or their usage in promoting sustainability.(1). Contemporary Advanced BIM Development for Sustainability: A systematic review methodology was employed to examine two principal sources of literature: BIM standards and guidelines, and peer-reviewed academic articles. Notwithstanding extensive research and development concerning BIM throughout various project phases, its application in refurbishment and demolition contexts remains inadequately explored. Analysis and Consequences: Emerging BIM Tools: a necessity exists for specialist BIM tools to evaluate sustainability requirements. Interoperability: Enhanced interoperability between BIM software and energy simulation tools is crucial. Refurbishment and Demolition: Optimizing BIM applications in these domains is essential. Social Sustainability: Innovative procurement processes must integrate issues of social sustainability.(2).

Social Sustainability and Building Information Modeling: Building information modeling (BIM) contributes to social sustainability in two primary ways: it improves the design of facilities for better living comfort and it transforms fragmented practices into collaborative efforts among project participants. Stakeholder satisfaction is an important factor in achieving social sustainability outcomes. In a nutshell, Building Information Modeling (BIM) shows potential for sustainability; nevertheless, additional study should be conducted to investigate its applicability in social contexts, destruction, and rehabilitation.(3).

Air temperature refers to how hot or cold the air is. Temperature is the most routinely observed weather parameter. It describes the kinetic energy (energy of motion) of the gas molecules that make up the air. As gas

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molecules move more swiftly, the air temperature rises.(4). Thermodynamics and Temperature: Scientists analyze temperature precisely, going beyond simple definitions like "hot" or "cold." Thermodynamics is a branch of physics that studies the temperature of objects and the flow of heat between objects of different temperatures. Thermodynamics takes into account both the small-scale action of individual air molecules (as described by the kinetic theory of gases) and the large-scale effects of many molecules. From a small-scale perspective, the temperature of a gas is related to the average kinetic energy of its moving molecules. Heating a gas increases the velocity of its molecules, impacting pressure and other variables. On a broader scale, we can qualitatively detect that one gas is hotter than another. However, to assign a quantitative value, we rely on thermodynamic laws.(5).

Thermodynamic Equilibrium: Two items are in thermodynamic equilibrium when they have the same temperature. When two objects with differing temperatures come into touch, they will eventually achieve thermodynamic equilibrium. Understanding temperature enables us to forecast the transfer of heat energy from hotter to cooler bodies.(6). The BIM factors that were looked at changed over time from 3D to ND (for example, energy) in integrated environmental studies. Also, the technologies that were used were picked out with more care to fit different building situations. Dynamic data transfer between BIM and computational fluid dynamics (CFD) needs to be improved, but both are very important to the process of building design. In the future, it is suggested that BIM-CFD merging be used for more advanced risk analysis. Digitizing and quantifying risk information can make risk recognition tools better, which can help with methods for lowering risk.(7).

The urban heat island effect denotes the occurrence where urban regions exhibit elevated temperatures compared to adjacent rural areas. Factors contributing to urban heat islands include anthropogenic activities, heat emissions from buildings and vehicles, diminished vegetation cover, and modified surface characteristics

HI influences energy consumption, human health, and general urban comfort. Vegetation significantly contributes to temperature regulation by mitigating heat effects. Trees, green roofs, and other vegetation absorb solar radiation, provide shade, and release moisture through transpiration. Vegetation cools the surrounding environment by reducing surface temperatures and enhancing evapotranspiration. Urban green spaces facilitate local cooling, enhance air quality, and promote overall well-being. Research on BIM and UHI: The research titled “UHI and Vegetation Cooling: Validating Quantitative Theory through Building Information Modeling” examines the application of BIM tools in the analysis of urban heat islands and their mitigation via vegetation cooling strategies. The project converts empirically validated urban heat island models into the digital building information modeling environment. The project assesses the validity of the initial UHI model through the automation of calculations and their application at larger scales, utilizing satellite thermal imagery for comparisons. Additionally, it addresses challenges associated with BIM implementation in projects. Prospective outlook: The integration of BIM and CFD can improve studies on urban heat islands by simulating heat distribution, airflow, and the effects of vegetation. Additionally, advanced hazard analysis through this integration can assist in identifying and quantifying potential hazards in urban settings. Digitizing hazard information enables the development of precise hazard recognition tools for effective risk reduction strategies.(8).

Numerous methods exist for calculating mean radiant temperature (MRT) in an outdoor metropolitan environment. This parameter is essential for comprehending human energy equilibrium and thermal comfort. Summarize the comparisons among the three methodologies employed in a study done in Gothenburg, Sweden.(9). there are many ways to calculate the mean radiant temperature.

Method 1 (Integral Radiation Measurements and Angular Factors): This method requires data on solar radiation, temperature, and wind speed, utilizing integral radiation measurements and angular factors. Rapid fluctuations are mitigated by employing 5-minute mean values to enhance precision..

Method 2 The 38-mm flat gray globe thermometer measures temperature, with empirical changes to the mean convection coefficient enhancing accuracy. New equations for mean radiant temperature have been derived, and precise measurements of wind speed and air/globe temperature are crucial.

Method 3 It makes use of the Rayman 1.2 software, performs well at midday in July (when the sun is high), and undervalues the MRT in the mornings and nights (when the sun is low) and in October.

Green roofs have become more popular as eco-friendly construction elements in a wide range of nations with wildly varying climates. In this article, we will go over the main benefits of these roofs. (10)Reduction of building energy consumption: green roofs offer insulation, diminish the necessity for heating and cooling, regulate indoor temperatures, result in energy savings by absorbing solar radiation, and enhance thermal comfort.

Problems with the urban heat island effect: Buildings and streets in cities soak up heat, making the places there warmer. By making the surface cooler, green roofs help to counteract this effect. Through evapotranspiration, these places let go of heat that they have stored and lower the temperature in the area. Less pollution in the air: green roofs catch pollution in the air like screens. According to research, plants take in pollution and make the air better, which makes cities healthier. Good water management: green roofs collect rainwater, lower storm water runoff, stop floods, help recharge groundwater, and keep water in the ground to support ecosystems and ease the load on drainage systems. Increase in Sound Insulation: Plants and base layers soak up sound, green roofs cut down on noise pollution from traffic and other sources, and better acoustic comfort is good for people who live or work in the area.

In addition to providing a habitat for birds, insects, and plants, green roofs also serve to protect the environment. These kinds of roofs are beneficial to urban ecology because they increase biodiversity, which in turn improves the health of the ecosystem. The fundamental component that affects the energy balance of a green roof is solar radiation, which is similar to the situation on a conventional roof. Convection, evaporation, sensible heat fluxes from plant surfaces and soil, and conduction into the soil substrate are all processes that work together to offset the effects of solar radiation. Here is an illustration of this energy balance, which can be found in Figure 1. It is possible to define the variables that are presented in this graphic. in the equations that follow(11).

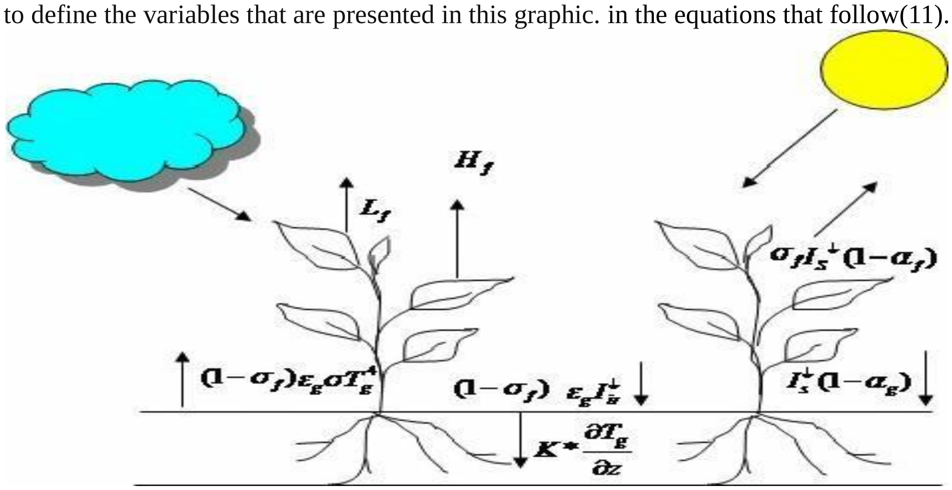


Fig. 1) The energy balance for a green roof

In this study, we looked at how land use affected air temperature, building height, and overcrowding in a certain location, as well as how much each of these characteristics affected future sustainability, design, urban planning, and accessibility to sustainability..

2. Materials

2.1. Study area

One of the urban areas of Zagazig City was planned in the 1980s. The buildings had four or fewer floors. Urban architecture in the region has long been untracked, and temperatures have risen significantly. The study area included approximately 48 acres of the Zagazig area between longitudes E 31◦29’06.99” and E 31◦29’24.55” and latitudes N 30◦35’11.78” and N 30◦35’27.94”, as shown in the area, with various activities of population use involving a wide variety of uses and a large population increase, which covers the environment (see Fig. 2). Therefore, research has been carried out in order to ascertain the reason for this rise in temperature and to discover methods that can be utilized to bring it down. We were able to have a better understanding of the issue and the variables that were associated with it by taking into account all of these elements; nevertheless, the air temperature was the most important factor that was considered because it is the most important factor that is affected by all of the factors that came before it. Improve of Design carried out a simulation of the region in order to gain a better understanding of the changes that have taken place, and they also investigated the current state of affairs in the region. In order to try to comprehend and reduce or find a simple way to lower high temperatures, a simulation was carried out, and the air temperature was increased and decreased during both improvements. However, some of these simulations are expensive, while others are not feasible. The study and simulations were carried out for a variety of various places that may be improved, including residential areas that were devoid of commercial areas, areas that had trees added to the streetscape, areas that had green roofs, and areas that had trees to the street and green roofs.

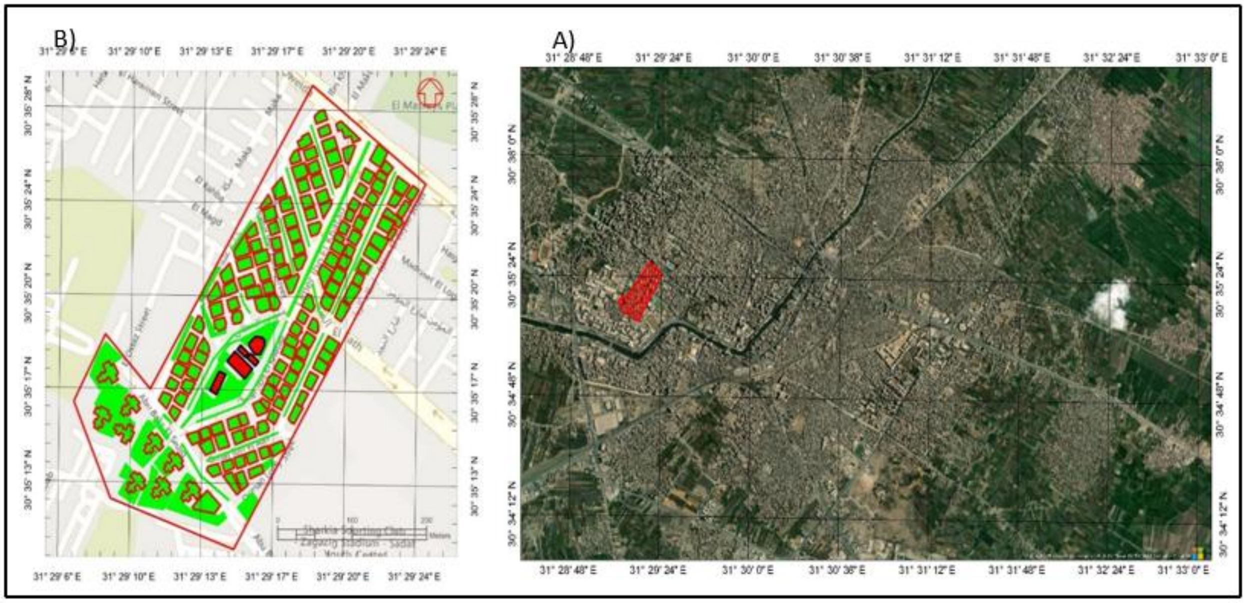


Fig. 2 Study region, a) Sharqiyah Governorate in Egypt. B) Location of the Study Area Governorate in the Sharqiyah Governorate

2.2. Data sources

Weather data and header headers are the two components of an Energy Plus Weather (EPW) file. Data on location, design circumstances, usual or extraordinary times, ground temperatures, holidays or daylight savings, data periods, and other remarks are often contained in the first eight lines of a standard EPW file, which are headers. For meteorological stations in Egypt, Egyptian meteorological files are available. Information is available on the website. (https://Climate. OneBuilding.Org) In addition to the distributed weather observatories data as shown (Fig. 3).

Fig. 3) Weather observatories spread across Egypt

3. Modeling

I created an internal building simulation using Energy Plus, utilizing meteorological data and the actual (Fig. 4) I canceled the HVAC effect to assess the climatic impacts of the area. (Improver 2) It lacks any commercial utility or retail establishments, and I re-entered the region based on the current status of each usage and trade. I conducted a simulation in design mode to evaluate its effects in relation to one year of weather observations. To minimize variables, I employed free speaking agriculture (Improve2) alongside simulations of building utilization and spatial exploitation through cultivation (Improve 1 & 2) to assess their impact on the region. The simulation process follows a specific format, detailing the steps involved.(11).

3.1. Data Initialization.

The simulation commences with the initialization of environmental data, including temperature and humidity, while confirming that all requisite parameters for the simulation duration are accurately configured.

3.2. Simulation Management.

The Simulation Manager oversees the simulation's flow and manages a number of flags to monitor the simulation's current condition, including the environment, day, time step, and simulation start and end times.

3.3. Iterative Solution Method.

Iterative methods are widely used in simulation to solve for variables such as mass flow rates and humidity ratios. Adjustments are done at each simulation time step, and the system's air mass flow rates are kept constant to facilitate iterative convergence.

3.4. Load Distribution.

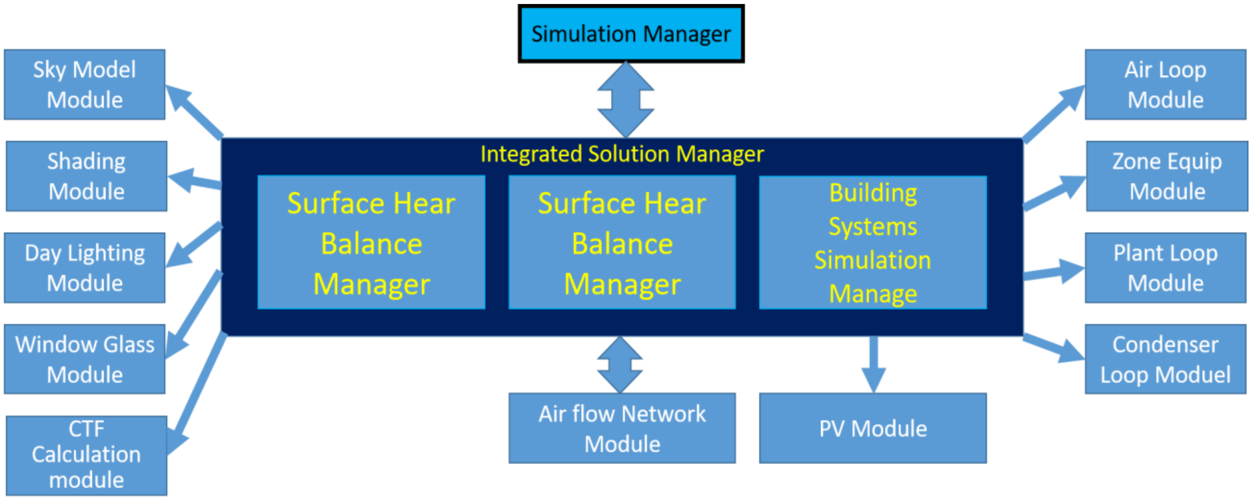
Load distribution is regulated according to user-specified priorities for components connected to a zone. The simulation iterates over the supply air pathways and regulated zones, administering flow and temperature modifications as necessary.

3.5. Thermal and Mass Balance Calculations.

Energy Plus executes thermal and mass balance calculations to determine zone temperature and humidity. This facilitates precise evaluations of energy performance by analyzing factors influencing heat transmission.

.3.6. Output Calculation and Analysis.

Upon concluding the simulations, the findings are examined to yield outputs including energy consumption, cooling, and heating loads, so ensuring the effective integration of all components..



4. Air temperature methods

The troposphere, the base of the atmosphere, is where all the structures are situated. The troposphere begins at sea level and rises to a height of eleven kilometers. (12). In the troposphere, air temperature declines approximately in a linear fashion. at an elevation of roughly 1°C for every 150 m (13). The barometric pressure diminishes at a slower rate. Nonetheless, wind velocity grows with elevation. Due to the variation of the atmosphere with altitude (defined as the height above the earth in this context)(14)Tall edifices may encounter substantial variations in local atmospheric characteristics between the ground level and the uppermost story. Buildings engage with the atmosphere through convective heat transfer between external air and the building envelope's outer surfaces, as well as through air exchange between the interior and exterior via infiltration and ventilation. The method governing the utilization of these models is depicted in the subsequent table. Utilizing a 70-story (284 meters) edifice as an illustration, the atmospheric variables are considerable (15). are shown in Table (1): Atmospheric Variables at Two Different Altitudes Above Ground Level

Table (1) Atmospheric Variables at Two Different Altitudes Above Ground Level(16)

Variable	1.5 Meters	84 meters	Absolute Diff	Percent Diff
Air Temperature	15°C	13.15°C	1.85°C	12.30%
Barometric Pressure	101,325 Pa	97,960 Pa	3,365 Pa	3.30%
Wind Speed	2.46 m/s	7.75 m/s	5.29 m/s	215%

The impact of the change in wind speed is greater than that of the first 10 levels, according to a comparison of the yearly energy consumption among the sixty separately modelled stories of a structure. Nonetheless, the impact of air temperature was about equivalent to that of wind speed on floor 25, and it grew progressively from there. The impact of ambient temperature is now paramount above floor 25. For skyscrapers, it's ideal to model the way air temperature changes with height. Determine the local outdoor air temperature and wind speed independently for every area and surface that is exposed to the outdoors in order to account for atmospheric fluctuation. For this purpose, we use the zone centroid, also called the surface centroid, to find the elevation above ground. At this time, we are only calculating the local outdoor air temperature and wind speed. These variables play a significant role in surface exterior convection calculations (for more on this, see exterior convection below), as well as in zone infiltration and ventilation calculations. But when you use the airflow network objects, you take barometric pressure variation into account.

4.1. Calculation of the local outdoor air temperature

The variation in outdoor air temperature was calculated using the U.S. Standard Atmosphere (1976)(16). According to this model, the relationship between air temperature and altitude in a given layer of the atmosphere is.

$$T_Z = T_b + L(H_z - H_b)$$

where, $T_{z\,=}$ air temperature at altitude z, T_b = air temperature at the base of the layer, i.e., ground level for the troposphere; L = air temperature gradient, equal to – 0.0065 K/m in the troposphere; H_b = offset equal to zero for the troposphere; and H_z= geopotential altitude The variable Hz is defined as follows:

$$H_z = \frac{E_z}{(E + z)}$$

where E = 6,356 km is the radius of the Earth, z = the altitude to model buildings in the troposphere, and *z* refers to the height above ground level, not the height above sea level. The height above ground is calculated as the height of the centroid, or area-weighted center point, for each zone and surface.

The air temperature at ground level, Tb, is derived from the weather file air temperature by inverting the equation above:

$$T_b = T_{z,met} - L(\frac{E_{zmet}}{E + Z_{met}} - H_b)$$

where, $T_{z,\,met}$ = weather file air temperature (measured at the meteorological station), and Z_{met} = height above ground of the air temperature sensor at the meteorological station. The default value for Z_{met} for air temperature measurements is 1.5 m above ground. This value can be overcome by using the site: weather station object.

4.2. Calculation of Local Wind Speed

Vocabulary and frameworks that are already in place are impacted by wind velocity. The wind speed that is included in the meteorological file was recorded by a weather station that was situated in a field that was free of obstructions and was ten meters above ground level. In order to determine the local wind speed at each surface at the construction site, it was necessary to take into consideration the variations in the elevation of the building roofs. The wind speed is modified in accordance with the wind speed that is determined using the equation for the meteorological wind speed.

$$V_Z = V_{met}(\frac{\delta_{met}}{z_{met}})^{\alpha_{met}}.(\frac{z}{\delta})^{\alpha} \quad \textbf{(1)}$$

where, z = altitude, height above ground, V_z= wind speed at altitude z, α = wind speed profile exponent at site δ = wind speed profile boundary layer thickness at site, z_{met} = height above ground of the wind speed sensor at meteorological station, V_{met} = wind speed measured at meteorological station, α_{met} = wind speed profile exponent at the meteorological station, and δ_{met} = wind speed profile boundary layer thickness at the meteorological station. The values of α and δ are shown in Table (2): Terrain-dependent coefficients

Table (2) Terrain-dependent coefficients

Terrain	Description	Exponent, α	Layer Thickness, δ (m)
1	Flat, open country	0.14	270
2	Rough, wooded country	0.22	370
3	Towns and cities	0.33	460
4	Ocean	0.10	210
5	Urban, industrial, forest	0.22	370

4.3. Design Day Temperature Calculations

The design day's temperature was classified as either "high" or "low." Since these two temperatures are inadequate for depicting a complete 24-hour period, the program employs a "range multiplier" profile. to depict the complete daily temps (Fig.5)

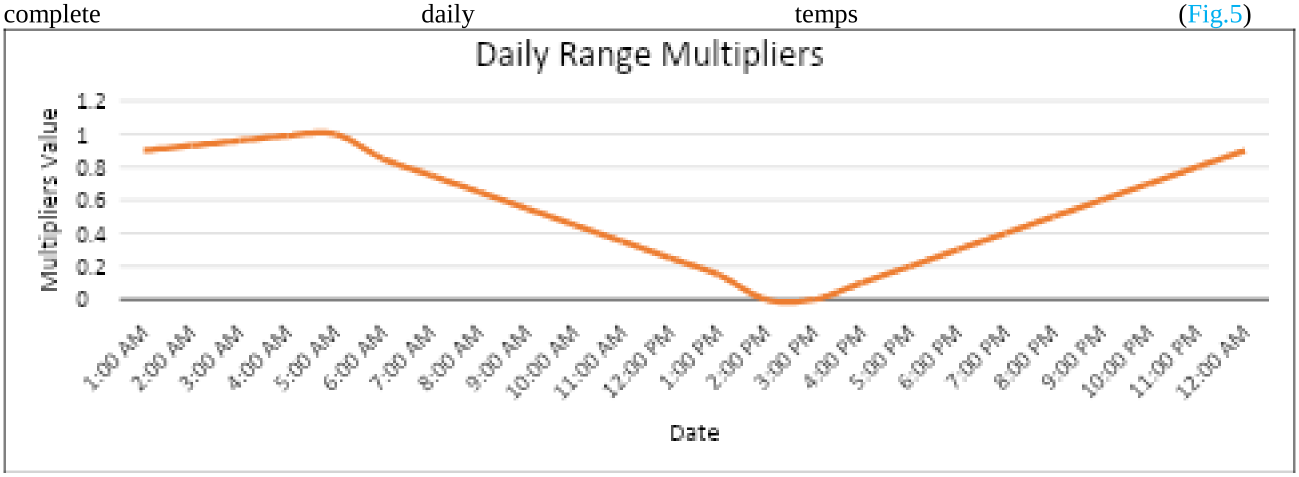


Fig. 5) Default daily temperature range profile

$$\mathbf{T_{current} = T_{Max} - T_{range} \cdot T_{Multiplier}} \qquad \textbf{(2)}$$

where, $T_{current}$ = The air temperature of the current hour of day, T_{Max} = the User Supplied Maximum Dry-bulb Temperature T_{range} = User Supplied Daily Temperature Range; and $T_{Multiplier}$ = the Range Multiplier seen in the preceding graph. The range multiplier values denote standard diurnal temperature circumstances, with the minimum temperature occurring about 5:00 AM and the maximum temperature around 3:00 PM.

4.4. Sky temperature calculation.

By default, the sky temperature (T_{sky}) is calculated from the horizontal infrared radiation(17), intensity (IR_H):

$$T_{sky} = (IR_H/\sigma)^{0.25} - 273.15 \qquad \textbf{(3)}$$

where, T_{sky} = effective mean sky temperature, or sky radiative temperature, in ˚C; IR_H = rate of infrared radiation emitted from the sky falling on a horizontal upward-facing surface, in W/m^2; and σ = Stefan-Boltzmann constant = 5.6697×10^{-8} W/ (m^2 K^4)

Table (3) Outside Dry-Bulb and Dew-Point Temperatures

	Winter	Spring	Summer	Autumn
Outside Dry-Bulb Temperature (◦C)	15.30	21.37	28.47	23.73
Outside Dew-Point Temperature(◦C)	7.57	9.77	18.15	15.10

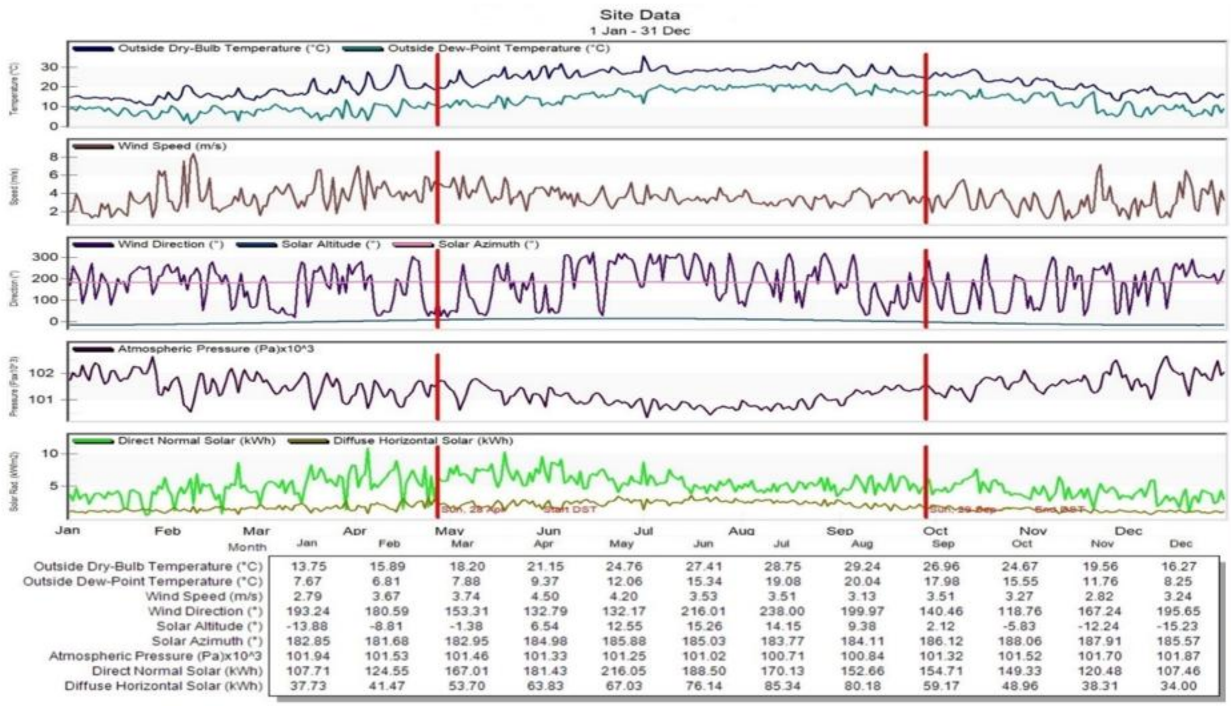


Fig. 6) Site data metrological parameters

5.2. Air Temperature (◦C).

Air temperature is a measure of air temperature or cooling. It is the most common weather coefficient. More specifically, temperature describes the kinetic energy, or motion energy, of the gases that make up the air. As gas particles move more quickly, the air temperature increases The Energy Plus calculates the air temperature, and the results are as follows: design and actual reality. (Decision) is shown in (Fig. 7).

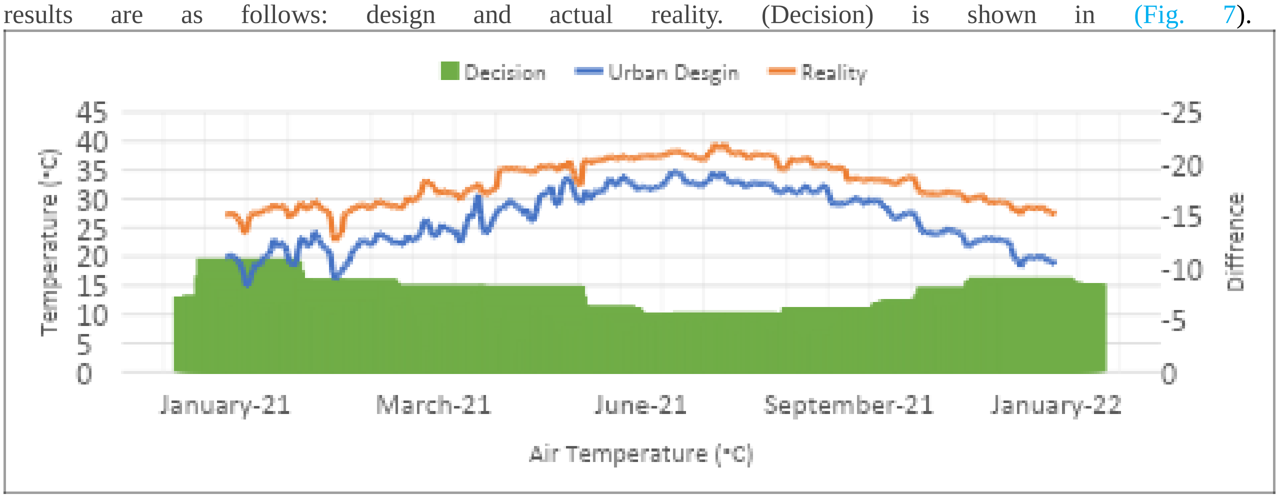


Fig. 7) Daily measurements throughout the year Daily Air Temperature (◦C) Design, Actual Reality, and Decision

Design Mean-σ (25.06◦C), Mean+σ (28.21◦C), Max (34.7◦C), and Min (15◦C). Actual Reality Mean-σ (31.40◦C), Mean+σ (33.83◦C), Max (39.60◦C), and Min (22.70◦C). Green Roof (Improve 1) Mean-σ (30.48◦C), Mean+σ (33.07◦C), Max (39.40◦C), and Min (21.60◦C). Residential use (Improve 2) Mean-σ (30.74◦C), Mean+σ (33.29◦C), Max (39.50◦C), and Min (21.90◦C). If both improvements are used (improves 1&2) Mean-σ (29.81◦C), Mean+σ (32.54◦C), Max (39.3◦C), and Min (21.60◦C) are used as shown in Table (4).

Table 4 Mean Standard Deviation, Max, Min Design, and Reality, and Improve1, and Improve2, and Improve1&2

	Design	**Reality**	**Improve 1**	**Improve 2**	**Improve 1&2**
Mean-σ	25.06	31.40	30.48	30.74	29.81
Min	15.00	22.70	21.60	21.90	20.80
Max	34.70	39.60	39.40	39.50	39.30
Mean+σ	28.21	33.83	33.07	33.29	32.54

The average air temperature of the design was 26.63°C. The average air temperature of the actual reality was 32.62°C, which was increased by 5.98°C. In an attempt to reduce this effect. Green Roof (Improve 1) and Improve 2 were used. The average air temperature was 31.8°C, and the effect was reduced by 0.84°C. Only the residential temperature (Improve 2) was used. The average air temperature was 32.02°C, and the effects were reduced by 0.6°C and improved 1&2 and the average air temperature was 31.13°C. The effect was reduced by 1.44°C, as shown in Table (5). The following formula shows how much the three Improves show (Fig. 8, Fig. 9) and how much it affects air temperature**.**

Table (5) Air temperature variability design, reality, improve 1, improve 2, improve 1&2

Improves	Temperature (◦C)	%	Temperature Increase (◦C)	Temperature Reduction (◦C)
Design	26.63	-	-	-
Reality	32.62	22.47	5.98	-
Improve 1	31.8	15.76	5.17	0.84
Improve 2	32.02	16.94	5.39	0.6
Improve 3	31.13	14.19	4.5	1.44

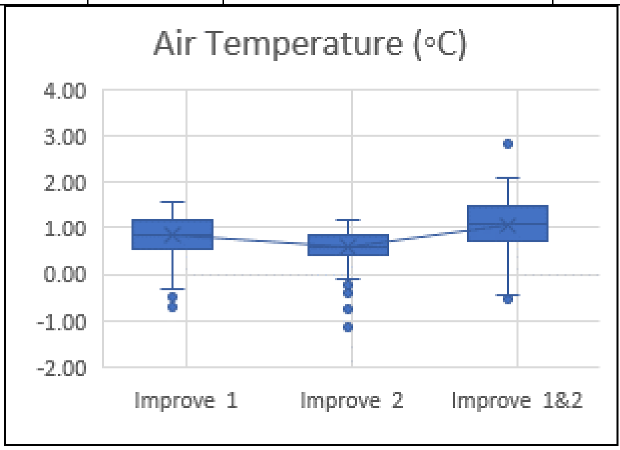


Fig. 8) The Difference between the Three Different Improves

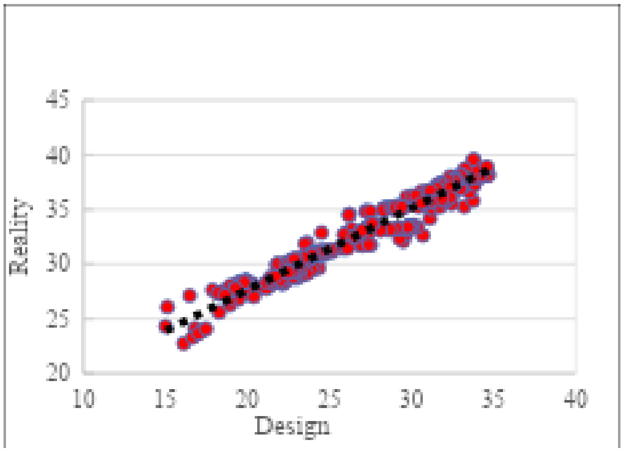


Fig. 9) Linear correlation plot between design and reality.

5.3. Mean Radiant Temperature(◦C).

The mean radiant temperature (MRT) quantifies the flow of radiant heat between an individual and their environment, elucidating the impact of surface temperatures on personal comfort. The mean radiant temperature (MRT) has been qualitatively defined and quantitatively assessed for both indoor and outdoor situations. The MRT enhances energy calculations and determines the mean radiant temperature. The outcomes are as follows: design and empirical reality. The distinction between the decisions is illustrated. in (Fig. 10).

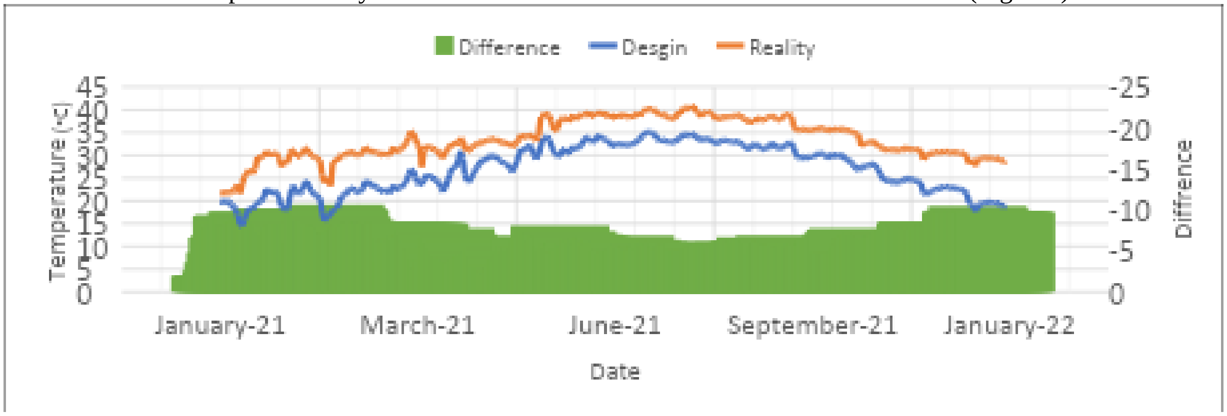


Fig. 10) Daily measurements throughout the year Daily Mean Radiant Temperature (◦C) Design, Actual Reality, Decision

Design Mean-σ (25.2◦C), Mean+σ (28.5◦C), Max (35.1◦C), and Min (14.6◦C). Actual Reality Mean-σ (32.3◦C), Mean+σ (34.9◦C), Max (40.8◦C), and Min (23.4◦C). Green Roof (Improve 1) Mean-σ (31.5◦C), Mean+σ (34.3◦C), Max (40.4◦C), and Min (22.1◦C). Residential use (Improve 2) Mean-σ (31.7◦C), Mean+σ (34.5◦C), Max (40.5◦C), and Min (22.4◦C). If both these improvements are used (Improves 1&2) mean-σ (30.9◦C), mean+σ (33.8◦C), max (40.1◦C), and min (21.1◦C) are used as shown in Table (6).

Table (6) Mean Standard Deviation, Max, Min Design, and Reality, and Improve1, and Improve2, and Improve1&2

	Design	**Reality**	**Improve 1**	**Improve 2**	**Improve 1&2**
Mean-σ	25.2	32.3	31.5	31.7	30.9
Min	14.6	23.4	22.1	22.4	21.1
Max	35.1	40.8	40.4	40.5	40.1

Mean+σ	28.5	34.9	34.3	34.5	33.8

The mean radiant temperature (MRT) of the design was measured at 26.84°C, while the MRT in actual conditions reached 33.63°C, indicating a temperature increase of 6.78°C. This discrepancy suggests a need for strategies to mitigate the impact of elevated temperatures. The Green Roof (Improve 1) was implemented for the MRT, resulting in a temperature of 32.90◦C, with a reduction effect of 0.73◦C. In contrast, the residential option (Improve 2) yielded a temperature of 33.09◦C, with a reduction effect of 0.53◦C. When both improvements (1&2) were applied, the MRT recorded a temperature of 32.37◦C, leading to a total reduction effect of 1.26◦C, as detailed in Table 7. The subsequent format illustrates the extent of improvement demonstrated by the three entities. (Fig. 11, Fig. 12) and how much it affect the MRT**.**

Table (7) Mean Radiant Temperature (MRT) Variability Design, Reality, Improve 1, Improve 2, Improve 1 and 2

Improves	Temperature (◦C)	%	Temperature Increase (◦C)	Temperature Reduction (◦C)
Design	26.84	-	-	-
Reality	33.63	25.27	6.78	-
Improve 1	32.90	18.02	6.06	0.73
Improve 2	33.09	19.00	6.25	0.53
Improve 1&2	32.37	16.70	5.53	1.26

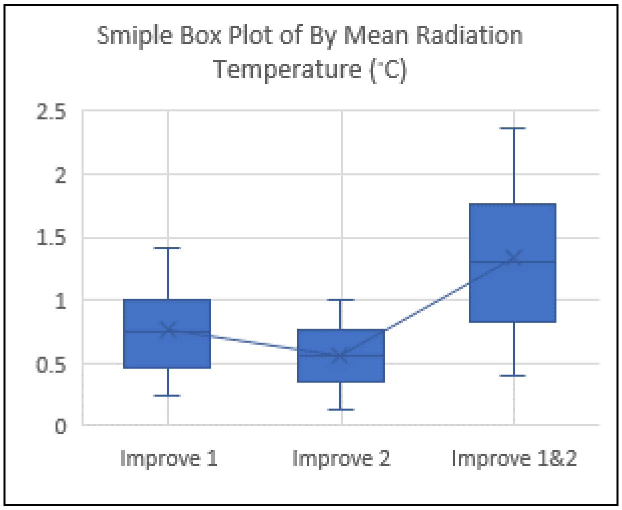


Fig. 11) The difference between the Three Different Improves

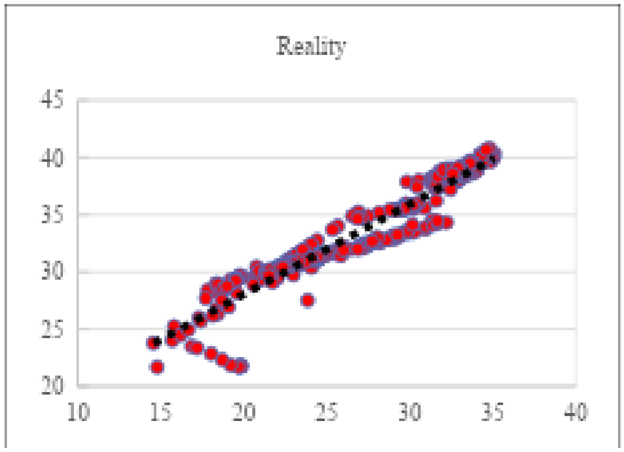


Fig. 12) Linear correlation plot between design and reality.

5.4. Relative Humidity %.

The amount of water vapor in the air is known as humidity. The gaseous state of water, known as water vapor, is typically invisible to the naked eye, while humidity signals the presence of fog, mist, or precipitation. Relative humidity rises Relative humidity is calculated by Energy Plus. The design and real-world outcomes are as follows. The distinction between them (choice) is displayed in (Fig. 13)

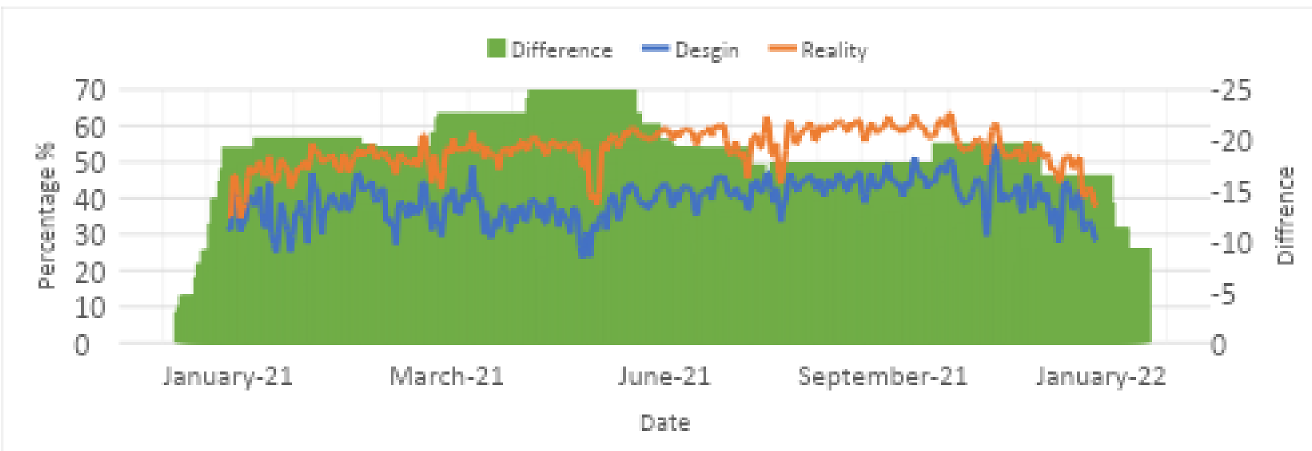


Fig. 13) Daily measurements throughout the year for Daily Relative Humidity %, Design, Actual Reality, and Decision

Design Mean-σ (37.2), Mean+σ (41.9), Max (54.7), and Min (23.5). Actual Reality Mean-σ (51.4), Mean+σ (55.6), Max (63.4), and Min (34.5). Green Roof (Improve 1) Mean-σ (51.3), Mean+σ (55.4), Max (63.5), and Min (34.5). Residential use (Improve 2) Mean-σ (51.2), mean+σ (55.4), max (62.5), and min (34.5). If both of these improvements are used (Improves 1&2) Mean-σ (51.1), mean+σ (55.2), max (62.6), and min (34.5), as shown in Table (8).

Table (8) Mean Standard Deviation, Max, Min Design, and Reality, and Improve1, and Improve2, and Improve1&2

	Design	**Reality**	**Improve 1**	**Improve 2**	**Improve 1&2**
Mean-σ	37.2	51.4	51.3	51.2	51.1
Min	23.5	34.5	34.5	34.5	34.5
Max	54.7	63.4	63.5	62.5	62.6

Mean+σ	41.9	55.6	55.4	55.4	55.2

The relative humidity of the design was recorded at 39.53%, while the actual humidity was 53.51%, resulting in an increase of 13.98%. To mitigate this effect, the Green Roof (Improve 1) was implemented, bringing the humidity down to 53.37%, which reduced the effect by 0.14%. The residential improvement (Improve 2) was also applied, resulting in a humidity level of 53.31%. Further adjustments led to a humidity of 53.18%, with a combined reduction effect of 0.33% from both improvements. as illustrated in Table (9). The formula below illustrates the extent to which the three Improves are displayed (Fig.14, Fig. 15) and their impact on humidity percentage.

Table (9) Relative Humidity %Variability Design, Reality, Improve 1, Improve 2, Improves 1 and 2

Improves	Humidity %	%	Humidity Increase %	Humidity Reduction %
Design	39.53	-	-	-
Reality	53.51	35.3	13.98	-
Improve 1	53.37	35	13.84	0.14
Improve 2	53.31	34.85	13.78	0.2
Improve 1&2	53.18	34.53	13.65	0.33

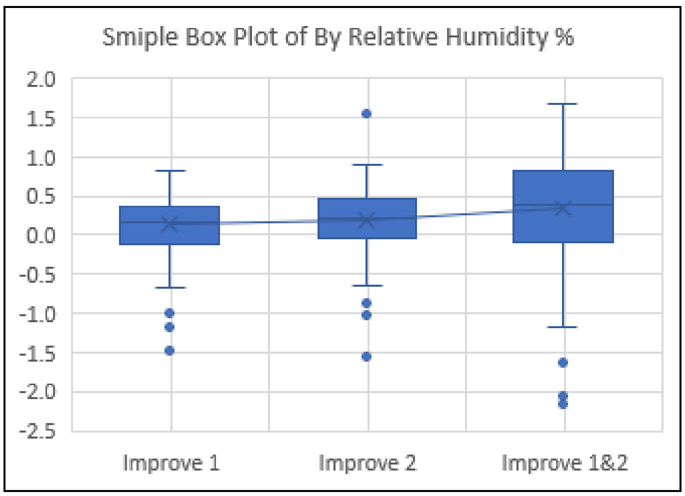


Fig. 14) The difference between the three different improvements

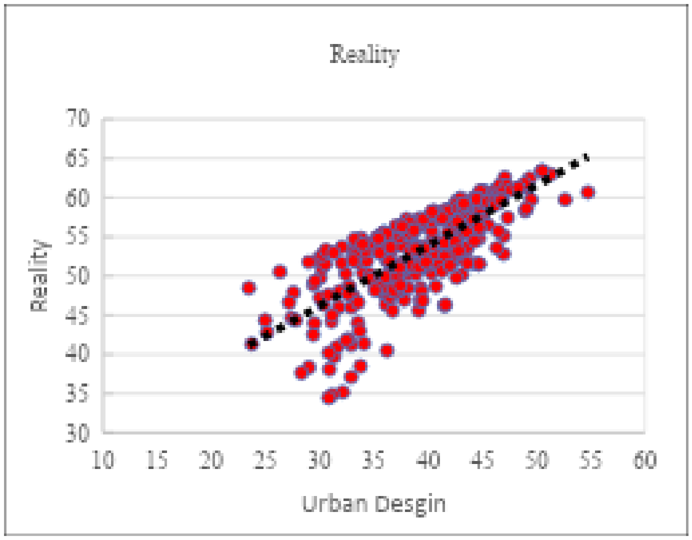


Fig. 15) Linear correlation plot between design and reality.

5.4. Relationship between the mean radiant temperature and air temperature

5.4.1. Mean Radiant Temperature (MRT)

The MRT takes into account the impact of direct solar radiation as well as thermal radiation from surrounding surfaces, reflecting the average temperature of all nearby surfaces as experienced by a person. The MRT significantly shapes human perceptions of comfort, especially in outdoor environments.

5.4.2. Air temperature

Air temperature, as measured by a thermometer, indicates the kinetic energy of air molecules, while our comfort perception is affected by both air temperature and mean radiant temperature (MRT). (18).

5.4.3. Relationship:

The MRT and air temperature are correlated but not invariably identical: Equal mean radiant temperature and air temperature: In a situation where all surfaces, including the ground and walls, maintain the same temperature as the air, the Mean Radiant Temperature (MRT) is equivalent to the air temperature, notwithstanding variations in MRTs and air temperatures. In practical scenarios, the MRT may vary considerably from the ambient air temperature. During bright days, surfaces absorb solar energy and attain temperatures higher than that of the surrounding air. Consequently, the Mean Radiant Temperature (MRT) surpasses the ambient air temperature; throughout the night, surfaces dissipate heat via radiation, resulting in lower temperatures than the surrounding air. When the Mean Radiant Temperature (MRT) is less than the air temperature, it may be further diminished in shadowed places due to decreased sun exposure.(19).

5.4.4. Comfort Considerations:

Designers and architects consider both Mean Radiant Temperature (MRT) and air temperature when assessing comfort. Radiant heating or cooling systems directly affect Mean Radiant Temperature (MRT) and can boost comfort regardless of constant air temperature; in sustainable building design, optimizing MRT by techniques such as cool roofs, shading, or reflective surfaces improves energy efficiency..

5.5. Verification of air temperature

A paired t-test was conducted to see if there was a significant difference in air temperature values between the Design model and the Improve 1, Improve 2, and Improve 3 models, with a 95% probability for the mean, standard deviation, and standard error. The error mean, T value, and significance (2-tailed) are presented in Table 10 for the design, reality, and improvements. T values yield substantial outcomes in design, realism, and enhancements.

Table (10) for the design, reality, and improvements

No	Variables	type of test	Mean	Std Mean error	T Critical	T -value	decision
1	**Reality**	**Improve 1**	**Paired**	Reality	Improve 1	Reality	Improve 1
				32.64	31.82	3.87	4.19
2	**Reality**	**Improve 2**	**Paired**	Reality	Improve 2	Reality	Improve 2
				32.64	32.07	3.87	4.09
3	**Improve 1**	**Improve 2**	**Two-Sample Assuming Unequal**	Improve 1	Improve 2	Improve 1	Improve 2
				31.82	32.07	4.19	4.09
4	**Improve 1**	**Improve 3**	**Paired**	Improve 1	Improve 3	Improve 1	Improve 3
				31.82	31.57	4.19	4.29

To compare Reality and Improve 1 t-tests, paired t-tests were utilized in the initial test. An outcome was deemed rejected if the value exceeded the t-critical value. The second test compared the means of Reality and Improve 2 using paired t tests. The test result was rejected when the t-value was greater than the t-critical. Third, we assumed that Improvements 1 and 2 had different variances and used a two-way t-test to find out. There was some convergence of the values, and the outcomes were satisfactory. To find the average between Improvements 1 and 3, the fourth test employed paired t-tests on two samples. The test result was rejected when the t-value was greater than the t-critical.

6. Conclusion

This research examined the influence of land use and urban design on thermal variations in Zagazig City, Egypt, utilizing Building Information Modeling (BIM) to model scenarios related to urban heat island (UHI) impacts. Key findings indicated a substantial temperature elevation in the present urban arrangement (32.62°C) relative to the original plan (26.63°C), representing a 22.5% increase. Mitigation techniques, such as green roofs (Improve 1) and modifications to residential zoning (Improve 2), decreased air temperatures by 0.84°C and 0.6°C, respectively. The combined therapies (Improve 1&2) resulted in a significant reduction of 1.44°C, illustrating the synergistic potential of integrated strategies. Correspondingly, the mean radiant temperature (MRT) escalated from 26.84°C in the design scenario to 33.63°C in the actual urban situation, representing a 25.3% increase. Green roofs and residential zoning decreased the mean radiant temperature (MRT) by 0.73°C and 0.53°C, respectively, while their combined effect resulted in a 1.26°C reduction. Conversely, relative humidity shown no enhancement across all interventions, with about a 0.33% decrease noted under combined techniques. Statistical validation by paired t-tests demonstrated significant differences ($p < 0.05$) between baseline and intervention situations, highlighting the effectiveness of the suggested strategies. These findings underscore the essential function of sustainable urban design in alleviating UHI impacts. Green infrastructure and zoning rules serve as effective ways to improve thermal comfort and energy efficiency. The minimal effect on humidity indicates the necessity for supplementary strategies, including water-sensitive urban design or sophisticated ventilation systems. Policymakers and urban planners are encouraged to emphasize BIM-integrated simulations to guide climate-responsive planning, promoting environmentally viable cities. Future study should investigate wider socio-environmental interactions and the long-term efficacy of UHI mitigation solutions across various metropolitan settings.

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