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| Table A1. The Forming and Intensifying Indicators of SUHI and their Impact on SUHI According to Aspects of Urban Form | | | | | | | | |
| References | **The Effect of the Indicator on SUHI** | **Code** | **Indicators Influencing the Development and Intensification of SUHI** | | | **UD Indicators** | | |
| (Chen et al., 2023; S. W. Kim et al., 2021; Kong et al., 2021; Manoli et al., 2019; H. Su et al., 2021) | The SUHI effect becomes more pronounced as urban populations grow. A report from the Environmental Protection Agency highlights that areas with a population of one million people can experience annual urban air temperatures that are 1.8 to 5.4 degrees Fahrenheit (1 to 3 degrees Celsius) warmer than their surrounding natural environment. | P | Population | | | **Socio-Economic Indicators** | | |
| (Che-Ani et al., 2009; M. A. Su et al., 2021) | The SUHI can result in a rise in peak electricity demand, estimated at around 21 watts per degree of temperature change per person. Additionally, it incurs an extra cooling energy penalty of approximately 0.7 kilowatt-hours per square metre of urban area for each degree of temperature change. | DEP | Demand for Electric Power | | |
| (ESMAP, 2020a; Y. Wang et al., 2018) | The SUHI effect, by nature, contributes to the higher energy consumption of air conditioning systems. This combination of factors ultimately gives rise to the SUHI phenomenon. | AH | Anthropogenic Heat | | |
| (Che-Ani et al., 2009; Y. Lu et al., 2021) | The impact of key land use indicators on SUHI intensity varies depending on the type of land use at different sites. In densely populated areas with diverse residential and commercial land uses, the three-dimensional building morphology plays a more significant role in influencing SUHI intensity compared to other regions. Land use type indirectly affects SUHI intensity through its influence on land cover and building morphology processes. | LUA | Land Uses and Activity | | | **Land Use**  **Indicators** | | |
| (Ritu, 2023) | Utilising land cover indicators in the analysis of multi-temporal Landsat images enables the detection of the SUHI effect. Researchers can assess the extent and intensity of the SUHI effect in urban areas by studying land use and land cover (LULC) patterns and land surface temperature (LST) data. | LCT | Land Cover Type | | |
| (de Almeida et al., 2021; L. Lu et al., 2020) | Research findings highlight that the proportion of bare soil areas significantly contributes to the development of the SUHI effect. Consequently, urban planning and mitigation strategies should take this factor into account to address and minimise the SUHI impact. | RABSA | Relative Area of Bare Soil Areas | | |
| (Ma et al., 2021) | These surfaces have the capacity to absorb heat during the day, which subsequently contributes to an increase in surface temperatures. As a result, urban areas experience higher temperatures compared to their surrounding rural areas. | RAIS | Relative Area of Impervious Surfaces | | |
| (Erdem et al., 2021; Sharifi, 2019) | The results of a study indicated that areas with higher levels of centrality in the street network are associated with a more pronounced SUHI effect. | DC | Degree Centrality | Centrality | Network Topology | | Physical Form of Street Network | **Transportation and Accessibility** |
| (Erdem et al., 2021; Sharifi, 2019) | In Izmir, Turkey, a study demonstrated that the SUHI effect is more pronounced in areas exhibiting higher levels of centrality in the street network. | CCe | Closeness Centrality |
| (Erdem et al., 2021; Sharifi, 2019) | A study conducted in Izmir revealed that the SUHI effect is more pronounced in areas characterised by higher levels of centrality in the street network. | BC | Betweenness Centrality |
| (Erdem et al., 2021; Sharifi, 2019) | The effectiveness of cooling systems and vehicle engines plays a crucial role in mitigating the effects of SUHI. | SNE | Street Network Efficiency |
| (Erdem et al., 2021; Sharifi, 2019) | Research findings indicated that the SUHI effect is more pronounced in areas with higher levels of centrality in the street network. | SC | Straightness Centrality |
| (Erdem et al., 2021; Sharifi, 2019) | Research findings indicated that the SUHI effect is more pronounced in areas with higher levels of centrality in the street network. | IC | Information Centrality |
| (Erdem et al., 2021; Rajagopalan et al., 2014; Sharifi, 2019) | Studies have revealed a negative correlation between CPL (Characteristic Path Length) and SUHI, indicating that as CPL decreases, SUHI intensity increases. This phenomenon occurs because a reduction in CPL enhances urban area connectivity, leading to a higher retention of absorbed heat within the urban environment. | CPL | Characteristic Path Length | Connectivity |
| (Sharifi, 2019; Silva et al., 2017) | The cyclomatic number, which quantifies the number of prime loops in a network, is a significant factor influencing SUHI through its impact on the pattern and form of urban fabric. | CN | Cyclomatic Number |
| (Sharifi, 2019) | The alpha connectivity index assesses the connectivity of a street network by counting the number of nodes with three or more edges (intersections) per unit area. A higher alpha index signifies a more connected network with increased intersections per unit area, directly correlating with higher heat generation in the urban environment. | AI | Alpha Index |
| (Sharifi, 2019) | The beta complexity index evaluates the complexity of a street network by counting the number of edges (street segments) at each node (intersection). A higher beta index indicates a more intricate network with increased street segments at each intersection, which directly relates to higher heat generation in the urban environment. | BI | Beta Index |
| (Sharifi, 2019) | The gamma resilience index quantifies the resilience of a street network by assessing the number of alternative paths between any two points within the network. A higher gamma index signifies a more adaptable network with an abundance of alternative paths between points, directly influencing heat generation in the urban environment. | GI | Gamma Index |
| (Erdem et al., 2021; Karimimoshaver et al., 2021) | Narrow streets experience higher temperatures as they receive more direct sunlight. Furthermore, the SUHI intensity tends to increase when there is a decrease in the height-to-width ratio (H/W) of urban structures. | SW | Street Width | Street Design | |  | | |
| (Erdem et al., 2021) | The street edge parameter influences the SUHI effect through various factors, including street canyon geometry, urban green patterns, and the arrangement of streets and buildings. | SE | Street Edges |
| (Cui et al., 2023; Erdem et al., 2021) | The orientation of streets can significantly impact energy consumption in urban areas. For instance, a study found that streets with an aspect ratio of 0.5 and a northeast-southwest or southeast-northwest orientation tend to exhibit lower energy consumption levels. | SO | Street Orientation |
| (Glazener et al., 2021; Zhu et al., 2017) | Urban infrastructure development, like flyovers and highways, can facilitate high-speed traffic flow, effectively reducing the SUHI phenomenon by minimising the time vehicles generate heat. Moreover, the surrounding air temperature may vary depending on the technology used in vehicles and the efficiency of ventilation infrastructure. | TT | Transportation Technology | | Transportation |
| (Kamruzzaman et al., 2018; Ruefenacht et al., 2017) | The choice of travel mode encompasses various options, such as private cars, public transportation, walking, cycling, and other means. While sprawl development is acknowledged as a significant factor influencing the SUHI effect, the choice of travel mode can also contribute to mitigating the SUHI impact. | CTM | Choice of Travel Mode | |
| (Louiza et al., 2015; Ruefenacht et al., 2017) | Transportation infrastructure can have dual effects on the SUHI. On the one hand, public transportation can help reduce the number of vehicles on the roads, leading to a decrease in the heat generated by vehicles. However, transportation infrastructure can also contribute to SUHI by replacing natural land cover with buildings and other surfaces that absorb heat, thereby intensifying the SUHI effect. | TI | Transportation Infrastructure | |
| (H. Su et al., 2021; Zhou et al., 2017) | Among 5,000 large cities, the intensity of SUHI increases with the logarithm of city size. Generally, small, dispersed, and elongated cities are preferred when aiming to reduce the SUHI effect. | CS | City Size | | Physical Form in Macro Scale | **Morphology Indicators** | | |
| (Giridharan et al., 2018; H. Su et al., 2021) | Urban density can have both positive and negative effects on the SUHI. The influence of urban density on SUHI is contingent on internal variables, such as urban geometry, as well as external factors, including the presence of large heat sinks. | UCp | Urban Compactness | |
| (Oke, 1995; H. Su et al., 2021) | The complexity of urban boundaries can have a significant impact on air flow, air pollution dispersion, and microclimate, subsequently influencing the SUHI effect. | UBC | Urban Boundary Complexity | |
| (Debbage et al., 2015; H. Su et al., 2021) | The spatial configuration of cities, or urban proximity, can amplify the intensity of the SUHI effect. Urban development characterised by high density is frequently linked to higher SUHI intensity, as many mechanisms contributing to SUHI effects are more pronounced in densely built areas. | UCg | Urban Contiguity | |
| (Chapman et al., 2018; Sobstyl et al., 2017) | Urban density can influence the SUHI effect through several factors, including increased building density, the formation of urban canyons, and changes in the surface albedo of buildings. | UD | Urban Density | | Urban Tissue |
| (Simon et al., 2023; Sobstyl et al., 2017) | The urban pattern can have a potential impact on the SUHI effect through factors like building density and street orientation. | UTP | Urban Tissue Pattern | |
| (Che-Ani et al., 2009; Gao et al., 2022) | Increasing building density leads to a stronger intensity of SUHI, and the spatial aggregation of buildings exacerbates the SUHI effect. Therefore, reducing the number of buildings per block and increasing green spaces can help mitigate the SUHI effect. | NBB | Number of Buildings per Block | | Blocks and Parcels |
| (Che-Ani et al., 2009; Y. Li et al., 2020) | Higher building density is associated with a more pronounced SUHI effect, and the spatial aggregation of buildings further exacerbates this phenomenon. Therefore, implementing strategies such as reducing the number of buildings per block and increasing green spaces can aid in mitigating the SUHI effect. | UBM | Urban Block Morphology | |
| (Che-Ani et al., 2009; N. Zhang et al., 2022) | The spatial aggregation of buildings intensifies the SUHI effect, posing challenges to the sustainability of a city. | BA | Building Aggregation | |
| (Che-Ani et al., 2009; Simon et al., 2023) | Providing sufficient spacing between buildings to allow for proper ventilation can potentially lead to a decrease in the SUHI effect. | DBB | Distance Between Buildings | |
| (S. W. Kim et al., 2021; Y. Li et al., 2020) | Enlarging the footprint area of a building results in a more rapid increase in SUHI intensity compared to adding vertical height to the building. This is attributed to the differing effects of relative dimensions on the SUHI phenomenon. | AR | Aspect Ratio | |
| (Che-Ani et al., 2009; S. W. Kim et al., 2021) | Buildings are recognised as one of the primary factors contributing to the SUHI effect, as they have the capacity to store substantial amounts of heat during the day and release it gradually during the night. Hence, the arrangement and layout of buildings play a crucial role in shaping this phenomenon. | BL | Building Layout | |
| (Che-Ani et al., 2009; S. W. Kim et al., 2021; Xi et al., 2021) | The height of buildings can have dual effects on the SUHI. Positive effects include shading and increased wind speed. Conversely, negative effects encompass reduced natural ventilation and an amplified SUHI intensity. | HB | Height of Buildings | |
| (Berger et al., 2017; S. W. Kim et al., 2021; Takkanon, 2016) | A study has demonstrated that the height-to-width (H/W) ratio significantly impacts the intensity of SUHI. A higher H/W ratio corresponds to a higher SUHI intensity. | WB | Width of Building | |
| (Berger et al., 2017; S. W. Kim et al., 2021; Sobstyl et al., 2018) | The impact of urban geometry on SUHI has been investigated in the studied research, revealing that the building footprint indeed plays a role in SUHI effects. | BF | Building Footprint | |
| (Che-Ani et al., 2009; S. W. Kim et al., 2021; X. Li et al., 2019) | An increase in the volume of a building correlates with higher energy consumption, which, in turn, can contribute to a higher intensity of the SUHI effect. | BV | Building Volume | |
| (Berger et al., 2017; S. W. Kim et al., 2021; X. Li et al., 2019) | An increase in the volume of a building correlates with higher energy consumption, which, in turn, can contribute to a higher intensity of the SUHI effect. | BVF | Building Volume per Floor | |
| (Berger et al., 2017; S. W. Kim et al., 2021; Y. Li et al., 2020) | According to a study, there is an almost linear increase in the SUHI effect with the natural logarithm of the gross volume of buildings. | GFA | Gross Floor Area | |
| (Berger et al., 2017; S. W. Kim et al., 2021; Simon et al., 2023) | The SUHI effect can become more intense in areas with high building density, as buildings tend to absorb and re-emit heat, contributing to the heat island phenomenon. | BD | Building Density | |
| (Berger et al., 2017; Jung et al., 2021; S. W. Kim et al., 2021) | Research indicates that a higher surface area ratio is linked to increased wind speeds. Tall buildings can influence the local wind environment around urban street canyons, potentially impacting the microclimate and the dispersion of suspended particles. | FAR | Floor Area Ratio | |
| (S. W. Kim et al., 2021; Kong et al., 2021; Lopez-Cabeza et al., 2022) | Albedo represents the measurement of the amount of solar radiation reflected by a surface. A higher albedo indicates that more radiation is reflected and less is absorbed, resulting in a cooler surface. | SMA | Surface Material Albedo | | Materials |
| (S. W. Kim et al., 2021; Kong et al., 2021; Shamsaei et al., 2022) | High thermal conductivity can decrease heat capacity, and the use of highly conductive materials can help lower surface temperatures in warm air. | TCHCSM | Thermal Conductivity & Heat Capacity of Surface Materials | |
| (Dirksen et al., 2019; S. W. Kim et al., 2021) | Limited sky view is a crucial factor in SUHI studies as it leads to increased net heat storage in buildings, contributing to the intensification of the SUHI effect. | SVF | Sky View Factor | | | **Townscape** | | |
| (Ke et al., 2021; S. W. Kim et al., 2021) | Green spaces have the potential to reduce the amount of heat absorbed by urban surfaces, leading to lower ambient air temperatures. However, the effectiveness of urban green spaces in mitigating the SUHI effect varies depending on their spatial pattern and connectivity. | GSC | Green Space Coherence | | | **Structure of the Urban Spaces** | | |
| (de Almeida et al., 2021; S. W. Kim et al., 2021) | The SUHI effect decreases significantly and exponentially as one moves away from urban areas and city centres characterised by tall buildings and high density. This reduction is noticeable in most cities. | D2UA | Distance to Urban Area | | |
| (S. W. Kim et al., 2021; Oke, 1995) | The extent of the SUHI effect can be established by defining the footprint of SUHI. It is crucial to comprehend the characteristics, causes, and impacts of SUHI at the urban boundary layer to effectively mitigate its effects on the environment and human health. | U&NB | Urban Boundary and Neighborhood Boundary | | |
| (S. W. Kim et al., 2021; Lee et al., 2022) | Open public spaces play a significant role in mitigating the intensity of SUHI by fostering ventilation and wind circulation within the urban environment. | OS | Open Public Spaces | | |
| (Masson et al., 2020; R. Yang et al., 2022) | The climatic zone of a city is subdivided into different areas based on the density of building heights and other land covers, which directly impacts the intensity of the SUHI effect. | CZ | Climate Zone | | Weather | **Environmental Indicators** | | |
| (S. W. Kim et al., 2021; Shareef, 2022) | The absorption of solar radiation by structures in developed areas can contribute to the SUHI effect, while the reflection and energy balance of solar radiation also play significant roles. | SR | Solar Radiation | |
| (Al-Obaidi et al., 2021; S. W. Kim et al., 2021) | When wind speeds exceed 2 metres per second, the intensity of nighttime SUHI decreases with increasing wind speed. However, during the daytime, the intensity of SUHI is reduced in low-wind conditions. | WV | Wind Velocity | |
| (Al-Obaidi et al., 2021; S. W. Kim et al., 2021) | Several studies suggest an inverse relationship between wind speed and the magnitude of SUHI. This implies that as wind speed increases, the intensity of SUHI may decrease. | WD | Wind Direction | |
| (S. W. Kim et al., 2021) | Air temperature plays a pivotal role in the SUHI effect. SUHI can result in daytime temperatures in urban areas being approximately 1 to 7 degrees Fahrenheit higher than temperatures in surrounding rural areas, while nighttime temperatures are around 2 to 5 degrees Fahrenheit higher. | AT | Air Temperature | |
| (Feinberg, 2022; S. W. Kim et al., 2021) | Research has indicated that relative humidity significantly impacts human thermal comfort, particularly during heat waves. Additionally, a study assessed water vapour feedback (WVF) in humid SUHI environments based on temperature differences. The findings revealed that high estimates of water vapour feedback can exacerbate heatwave-related issues in urban areas.. | RH | Relative Humidity | |
| (S. W. Kim et al., 2021; Masson et al., 2020; Morris et al., 2001) | Statistically significant reductions in the magnitude of SUHI were observed with an increase in cloud cover and wind speed frequencies exceeding 2.0 metres per second. | CC | Cloud Cover | |
| (Hamed Fahmy et al., 2023; S. W. Kim et al., 2021; X. Y. Lu et al., 2021; Masson et al., 2020) | Infrared remote sensing imagery has been extensively employed to study the SUHI phenomenon through the retrieval of land surface temperature (LST). In fact, approximately 44% of articles related to SUHI in urban thermal environment studies have utilised LST as a synonym for SUHI. | LST | Land Surface Temperature | |
| (S. W. Kim et al., 2021; J. Li et al., 2020; Masson et al., 2020) | Variations in humidity between urban and rural areas can result in differences in downward longwave radiation (DLR) caused by water vapour, which can significantly impact the SUHI effect. | WVDF | Water Vapor Density Fluctuations | |
| (de Almeida et al., 2021; S. W. Kim et al., 2021; Masson et al., 2020) | Generally, the dryness index can amplify the SUHI effect, leading to higher temperatures in urban areas compared to the surrounding regions. For instance, moist regions, primarily in the eastern United States, experience the most significant temperature differences due to SUHI. | DI | Dryness Index | |
| (S. W. Kim et al., 2021; Masson et al., 2020; Ulpiani, 2021) | Research indicates that high SUHI intensity is linked to increased levels and accumulation of air pollutants during the night, which can subsequently impact the air quality of the following day. | AP | Air Pollution | |
| (Ivajnšič et al., 2014; Masson et al., 2020) | Various neighbourhoods within a city can exhibit varying levels of vulnerability to higher temperatures based on their geographical locations. | GPI | Geographic Position Index | | Topography |
| (Emran et al., 2018; Masson et al., 2020) | The Topographic Position Index (TPI) can influence the distribution of vegetation coverage, consequently impacting the SUHI effect. Areas with higher TPI values typically have more vegetation coverage, which aids in mitigating the SUHI phenomenon. | TPI | Topographic Position Index | |
| (Y. Li et al., 2020; Masson et al., 2020) | A temperature inversion happens when a layer of warm air becomes trapped above a layer of cooler air, often occurring in areas with significant changes in elevation. This trapping of warm air in the lower layer can lead to higher temperatures, exacerbating the SUHI effect. | E | Elevation | |
| (C40 Cities, 2016; Kleerekoper et al., 2018; A. K. Nassar et al., 2016) | Urban areas in close proximity to large bodies of water generally exhibit lower SUHI intensity due to the cooling effect of the breeze generated from the water bodies, which helps dissipate heat. | DWB | The Distance to the Centroid of Any Nearby Water Body (Proximity to Heat Sink) | | Water |
| (C40 Cities, 2016; Kleerekoper et al., 2018; Lin et al., 2023) | Water bodies can have both positive and negative effects on the SUHI. On the one hand, they contribute to reducing the SUHI effect by increasing the potential for cooling through evaporation and acting as natural cooling systems for urban areas, lowering the surrounding air temperatures. On the other hand, water bodies can amplify the SUHI effect by increasing local humidity levels and exhibiting warmer temperatures during the night. | RWB | Rivers and Other Water Bodies | |
| (Kleerekoper et al., 2018; Zhao et al., 2022) | The effects of tree height on Urban SUHI can be complex and influenced by factors like tree species, location, and the surrounding environment. Nevertheless, trees can play a significant role in mitigating the SUHI effect and enhancing microclimate conditions. | TH | Tree Height | Trees | Vegetation |
| (Kleerekoper et al., 2018; Rafiee et al., 2016) | The volume of trees can influence the SUHI through various mechanisms. Trees intercept solar energy, and their shade reduces the temperature of underlying surfaces while increasing latent heat exchange through evapotranspiration processes. | TV | Tree Volume |
| (EPA, 2016; Kleerekoper et al., 2018) | The relative area of tree cover that directly shades buildings can reduce the demand for air conditioning, leading to energy savings and a decrease in SUHI intensity. | RAT | Relative Area of Trees |
| (Chen et al., 2023; Ke et al., 2021; Kleerekoper et al., 2018; Tabrizi et al., 2023) | Increasing greenery in urban areas can help mitigate the SUHI effect and its negative impacts on human health and the environment. | NDVI | Degree of greenness | Green Space |
| (Chapman et al., 2018; Kleerekoper et al., 2018) | The SUHI effect arises from a change in surface energy partitioning, favoring lower latent heat flux and higher sensible heat flux, which is influenced by multiple factors, including reduced evaporation and transpiration due to the loss of vegetation cover. This results in an increase in the release of anthropogenic heat from human activities and the trapping of radiation in urban canyons due to changes in building albedo. | VF | Vegetation Fraction |
| (Ke et al., 2021; Kleerekoper et al., 2018) | Research has demonstrated that urban green spaces play a crucial role in reducing the SUHI effect. Increasing the proportion of green spaces, such as parks, street trees, and green roofs, is a widely adopted strategy to mitigate SUHI. | GSP | Green Space Proportion |
| (Balany et al., 2020; Kleerekoper et al., 2018) | According to a study, vegetation coverage is identified as the most effective strategy for reducing the SUHI effect, whereas water bodies exhibit greater flexibility in their impact on SUHI. | RAGS | Relative Area of Grass/Shrubs |
| (Aram et al., 2019; Kleerekoper et al., 2018) | The extent of cooling in green spaces is directly related to the amount of temperature reduction. A study showed that green spaces with an area ranging from 0.5 to 2 hectares can lead to a temperature reduction of up to 0.3 degrees Celsius within a distance of 40 metres. | DGS | The Distance to the Centroid of Any Nearby Green Space (Proximity to Heat Sink) |