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SHADE STRUCTURES FOR URBAN GREEN SPACES

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ABSTRACT - Green spaces are essential for improving the standard of living for those living in metropolitan areas. However, their usability and comfort can be significantly affected by environmental factors like excessive sunlight, high temperature, and lack of shade. To address these issues, shade structures have become an essential feature of urban green spaces. Shade structures are architectural elements for urban green spaces that are designed to provide shade from direct sunlight, improve outdoor thermal comfort, and enhance the usability of outdoor spaces within cities. They come in a variety of shapes and sizes, including simple umbrellas, canopies, pavilions, and pergolas. Creating covered places in urban green spaces like parks, plazas, playgrounds, and gardens is the main goal of shade structures. This paper examines the different types and design of shade structures commonly used in urban green spaces, as well as the impact of different urban morphologies (street layouts, building densities, etc.) on outdoor thermal comfort. Furthermore, this paper examines how shade structures influence microclimates in urban green spaces. The research investigates the efficiency of shade structures in lowering solar radiation and establishing comfortable microclimates in outdoor spaces. Finally, the paper investigates how shade structures can improve outdoor thermal comfort by providing tangible benefits. Through the effects of shade structures on temperature moderation and how shade structures can make urban green spaces more usable. The findings presented in this paper how urban morphologies (street layouts, building density, etc.) affect outdoor thermal comfort, how shade structures impact microclimates, and why it's important to include shade structures in urban planning.

Keywords – outdoor thermal comfort; urban areas; microclimate; urban design; street layout

INTRODUCTION

Shade structures in urban green spaces are intended to give shade and shelter in outdoor places such as parks, plazas, gardens, and recreational spaces. Shade structures in urban green areas can be designed and placed in a variety of ways, from permanent installations like pergolas and gazebos to more temporary options like umbrellas or retractable awnings.

Additionally, living components such as trees or vertical gardens may give natural shade in these areas. Improving energy efficiency in buildings by minimizing solar heat gain and air conditioning demand. Providing covered locations for rest, leisure, and socialization will improve pedestrian comfort and safety.

Furthermore, shade structures have gained importance in terms of sustainability and environmental consciousness. They contribute to energy conservation and mitigation of the urban heat island effect by lowering dependency on air conditioning and other energy-intensive cooling systems.
Different urban morphologies, such as street layouts and building density, have a considerable influence on outdoor thermal comfort in urban contexts. These elements influence a variety of microclimatic parameters, including temperature, wind speed, and sun exposure, all of which have a direct impact on human comfort outside.

The orientation of roadways impacts the quantity of solar radiation that reaches outdoor spaces. Narrow roadways with towering buildings on both sides can form urban canyons that trap heat and reduce air circulation, resulting in higher temperatures. In contrast, broader streets and avenues with open areas allow for greater ventilation and less heat build-up. Street trees, awnings, and building overhangs can offer shade, minimizing direct sunlight exposure and lowering temperatures on sidewalks and outdoor seating spaces. By shading outdoor spaces, these buildings help to reduce ambient temperatures and create cooler microclimates in public areas and streetscapes.

Many cities are striving to regulate the local temperature and microclimate in urban areas in order to prevent heat stress and improve living conditions. As a result, one of the goals of urban design and planning is to increase the attractiveness of urban open spaces, which may be partially accomplished by increasing the thermal climate of outdoor places. The ASHRAE (2004) defines human thermal comfort as perceived and hence subjective happiness with thermal ambient circumstances. Human thermal comfort studied in terms of environmental variables and classified as indoor or outdoor thermal comfort.

The purpose of this research paper is to investigate the influence of shaded structures on the microclimate in urban green spaces. The key criteria for assessing the quality of the urban microclimate is outdoor thermal comfort.

The physical elements that impact people outdoor thermal comfort are: air temperature, wind speed, relative humidity, shortwave radiation, longwave radiation, human activity, and clothing level (clo). provide an overview of the outdoor thermal indices typically used in outdoor thermal comfort studies, dividing them into three groups of indices are:

1. Thermal indices are based on human energy balance and the relationship between metabolic activity, clothing, and environmental characteristics.
2. Empirical indices are linear regressions that quantify human comfort for a certain climate.

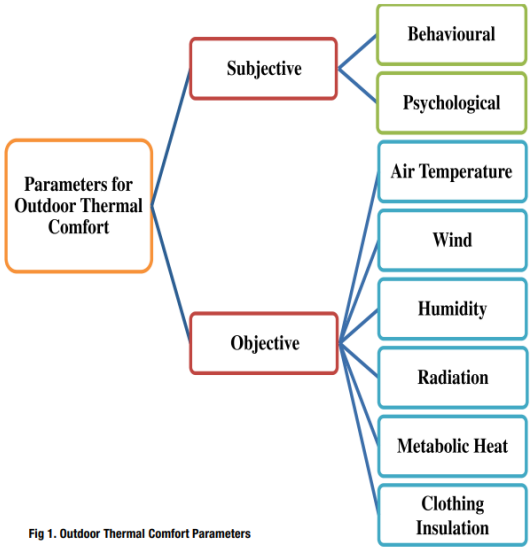


Fig 1. Outdoor Thermal Comfort Parameters

Source - https://www.coa.gov.in/show_img.php?fid=109

METHODOLOGY

1. Conduct an in-depth evaluation of the literature available on shade structures, outdoor thermal comfort, and urban green spaces.
2. Identify the primary factors that play a role in thermal comfort, including shade coverage, orientation, material properties, and user preferences, and examine their implications for urban design and planning.
3. Assessment of street layouts and building densities, influence outdoor thermal comfort in urban environments.
4. Comparison of thermal conditions between shaded and unshaded areas.

1. • Finalisation of topic
2. •Data collection from various sources
3. •Analysis of the data collected
4. •Implementation
5. •Results
6. •Conclusion

OUTDOOR THERMAL COMFORT

The subjective assessment of the environmental temperature that individuals experienced while they are outside is known as outdoor thermal comfort. In addition to individual characteristics like acclimatization metabolic rate, and clothing insulation it is impacted by many different kinds of climatic parameters as well, including air temperature, humidity, wind speed, and sun radiation.

Factors that Affecting Outdoor Thermal Comfort

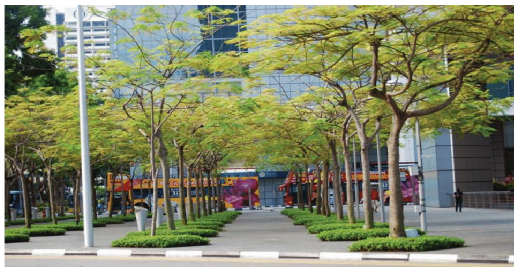
Outdoor thermal comfort is influenced by several factors. These factors are:

1. **Air Temperature**: One of the main factors affecting thermal comfort is the outside air temperature. Warmer temperatures can result in discomfort, particularly if they are too high for the range of comfort for individuals.
2. **Relative humidity (RH)**: is the quantity of moisture in the air relative to the maximum moisture-holding capacity, expressed as a percentage of total water-holding capacity.
3. **Wind Speed**: Wind affects thermal comfort by altering the rate of heat exchange between the body and its surroundings.
4. **Solar radiation**: Direct sunlight may have a major influence on thermal comfort. Solar radiation causes radiant heat gain, which can raise perceived temperatures, particularly in open, unshaded places. Providing shade or using reflecting materials can reduce the impact of solar radiation and increase comfort.
5. **Clothing Insulation**: The kind and amount of clothes people wear affects their temperature sensitivity.
6. **Metabolic Rate**: People with greater metabolic rates, such as those who participate in physical activity, produce more heat inside. As a result, they may feel greater temperatures as less comfortable than those with lower metabolic rates.
7. **Personal factors**:Individual characteristics including age, gender, health status, and cultural background can all have an impact on thermal comfort.

DIFFERENT TYPES OF SHADE STRUCTURE AFFECT OUTDOOR THERMAL COMFORT

Different types of shade structure affect outdoor thermal comfort. Thermal comfort can be affected by different shade structures, depending on their design, materials, orientation, and location. Here are a few shade structures and their effect:

- **Natural Shade Structures:**



Source-https://www.researchgate.net/figure/Introduction-of-trees-and-shrub-planting-as-part-of-Singapores-urban-design-approach_fig10_26597710

1.Trees: Effective natural shading is provided by mature trees with dense foliage, which reduces solar radiation and heat gain in outdoor spaces.

Dappled shade is created by the canopy of trees, which allows for some sunlight penetration while also preventing direct exposure. Trees can help with evaporative cooling by transpiration, which further enhances outdoor thermal comfort.

2.Shrubs and Bushes: Low-lying vegetation like shrubs and bushes can provide shading benefits, especially in areas where large trees are not a feasible. Although their shade may be limited compared to trees, they still help lower surface temperatures and create more comfortable microclimates.

- **Architectural Shade Structures:**

Source - https://www.archdaily.com/906449/shade-structures-for-outdoor-spaces-6-tips-to-incorporate-into-your-next-project

1.Pergolas and Arbors: Arbors and pergolas, which are open-air structures, are usually made with wooden or metal beams and are often covered with climbing plants or fabric canopies. Pergolas and arbors have the ability to provide partial shade and allow for natural ventilation while providing views of the surrounding landscape. The thermal comfort in outdoor areas can be improved through pergolas and arbors that reduce direct sunlight exposure and create visually appealing, inviting spaces.

2.Awnings and Canopies: Overhead structures that can be attached to buildings or freestanding supports are known as awnings and canopies, and they are commonly made of fabric, metal, or polycarbonate material.

Outdoor seating areas, walkways, and building entrances can be shaded with customizable solutions that effectively block solar radiation and reduce sunlight. Thermal comfort is enhanced by using awnings and canopies to create cooler, shaded environments that encourage outdoor activities and social interaction.

3.Shade Sails: The suspension of tensioned fabric membranes between anchor points creates dynamic, sculptural shading elements for shade sails. The variety of shapes, sizes, and colours makes it possible to design and place them in a variety of ways. The installation of shade sails in urban green spaces, playgrounds, and public plazas can enhance thermal comfort and provide effective sun protection.

- **Green Shade Structures:**

Source - https://urbannext.net/mfo-park/

1.Green Roofs and Living Walls: Incorporating vegetation into building structures through green roofs and living walls can provide multiple benefits such as shading, insulation, and storm water management. By incorporating these green infrastructure elements, urban heat island effects can be reduced, air quality can be improved, and biodiversity can be enhanced, all while contributing to outdoor enjoyment.

METHODS AND TOOLS

Different methods and tools are available for measuring outdoor thermal comfort.

1. **Micro-Meteorological Measurement:** This involves taking physical measurements of the microclimatic conditions in the surrounding area of the subjects. The thermal environment and thermal comfort sensation can be described by the four main physical parameters of air temperature, relative humidity, and humidity.
2. **Questionnaire Survey:** Conducting surveys and questionnaires to obtain subjective assessments of thermal comfort. Using standard scales, such as the ASHRAE thermal sensation scale or the predicted mean vote (pmv) index, participants can rate their thermal sensation, thermal preference, and overall comfort.
3. **Physiological measurements:** The physiological responses of individuals, like skin temperature, heart rate, and sweat rate, can be monitored to provide insights into their thermal comfort.
4. **Thermal imaging:** The use of thermal imaging cameras enables the visualization of surface

temperatures and identification of thermal hotspots in outdoor environments.

5. **Mobile monitoring:** Real-time data on thermal comfort as individuals move through outdoor spaces. Temperature can be collected using mobile monitoring techniques, such as wearable sensors or smartphone applications.
6. **Environmental simulation software:** Microclimatic conditions can be simulated using computational models and simulation software, such as Envi-Met and computational fluid dynamics (CFD) models. Is capable of simulating microclimate conditions and forecasting thermal comfort levels in outdoor environments.

MATERIALS USED FOR REDUCING OUTDOOR THERMAL COMFORT

1. **Reflective surfaces:** Materials that have a high albedo, like white or light-colored paints, coatings, or roofing materials, reflect more sunlight and absorb less heat, which contributes to reflecting more sunlight and absorbing less heat. Contributing to a reduction in surface temperatures and a decrease in the urban heat island effect.
2. **Greenery and vegetation:** Natural shading, evaporative cooling, and transpiration are provided by plants, trees, and greenery, which help to reduce air temperatures and increase comfortable microclimates in outdoor spaces.
3. **Permeable paving:** Permeable pavement materials, such as permeable concrete, porous asphalt, and interlocking pavers, allow precipitation to soak into the soil, minimizing surface runoff and heat retention.
4. **Cool roofing:** Cool roofing materials, including reflecting roof coatings, white membranes, and green roofs, decrease solar heat gain and rooftop temperatures. Cool roofs reflect sunlight and radiate heat more effectively than typical roofing materials, lowering inside temperatures and saving electricity.
5. **Natural building materials:** Natural and breathable construction materials like wood, clay, stone, and earth provide thermal qualities that assist control indoor temperatures and produce more pleasant living spaces.

ASSESSMENT OF STREET LAYOUTS AND BUILDING DENSITIES, INFLUENCE OUTDOOR THERMAL COMFORT IN URBAN ENVIRONMENTS

1. **Street Layouts:**

- **Orientation:** The sun's path and the orientation of streets affect solar exposure and heat absorption. During certain times of the day, east-west streets may have more direct sunlight and heat, while north-south streets may have more shade. Street orientation assessments can help identify areas with higher solar exposure and potential heat stress.
- **Width and Canyon Effect:** Urban canyons formed by tall buildings along narrow streets can lead to heat retention and hinder the flow of air. Wide streets facilitate improved airflow and ventilation, thereby mitigating the urban heat island phenomenon and enhancing thermal comfort. Analysing the dimensions of streets and the impact of canyon effects aids in comprehending the patterns of airflow and heat preservation within urban regions.
- **Shading and Vegetation:** Evaluating the arrangement of trees and greenery in urban street designs can reveal shaded spots and offer opportunities for implementing cooling measures to enhance the comfort of pedestrians and outdoor gatherings.

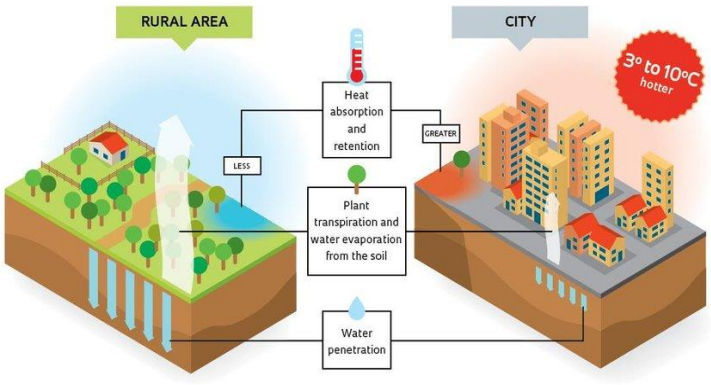
2. **Building Densities:**

- **Heat Absorption and Emission:** Elevated building densities coupled with expansive surface areas have the capacity to trap and hold heat, leading to elevated temperatures in densely populated regions. Evaluating building densities is crucial in measuring heat absorption and release rates, guiding efforts to reduce heat accumulation and enhance thermal satisfaction.
- **Shadowing and Shading:** The density of buildings plays a crucial role in influencing the amount of shadow and shade cast on nearby outdoor areas. Urban areas with high building densities can result in different shadow patterns at various times of the day, impacting how sunlight is distributed and the availability of shade. Assessing the effects of shadows can pinpoint locations with minimal sun exposure and opportunities for implementing shading solutions.

- **Green Spaces and Urban Heat Island Mitigation:** The density of buildings influences the accessibility and spread of green spaces within cities, which are essential in combating the urban heat island phenomenon. Evaluating the placement of parks, green roofs, and vegetated open areas can reveal ways to improve comfort levels and alleviate heat-related issues in heavily populated urban regions.

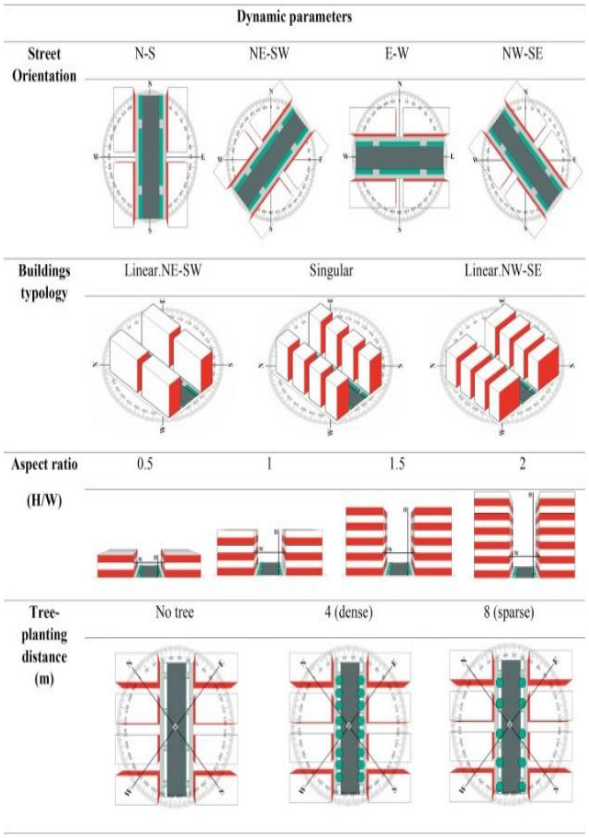
3. Microclimatic Variations:

- **Local Temperature Variability:** Different building densities and street layouts result in the formation of microclimates that possess distinct thermal characteristics. Evaluating the fluctuations in temperature at a microscale level aids in the identification of areas with high temperatures (hotspots) and areas with lower temperatures (cool spots) within urban settings. This assessment serves as a guide for developing specific interventions aimed at enhancing thermal comfort.



Source -https://www.semanticscholar.org/paper/Outdoor-thermal-comfort%3A-Analyzing-the-impact-of-on-AbdollahzadehBiloria/da767503a7cc11e2998d1c916c0a1c6fb8802511

- **Wind Patterns:** Urban areas are impacted by building densities, which can alter wind patterns and airflow. High-density developments have the potential to block prevailing winds, resulting in stagnant air and decreased ventilation. Analyzing wind patterns is crucial for comprehending airflow dynamics and pinpointing ways to improve natural ventilation and cooling techniques.



SHADE STRUCTURES AFFECT THE MICROCLIMATES WITHIN URBAN GREEN SPACES

Urban green spaces greatly benefit from the presence of shade structures, as they have a significant impact on the microclimates. These structures play a pivotal role in influencing environmental factors and thermal conditions, thereby shaping the overall climate within these spaces.

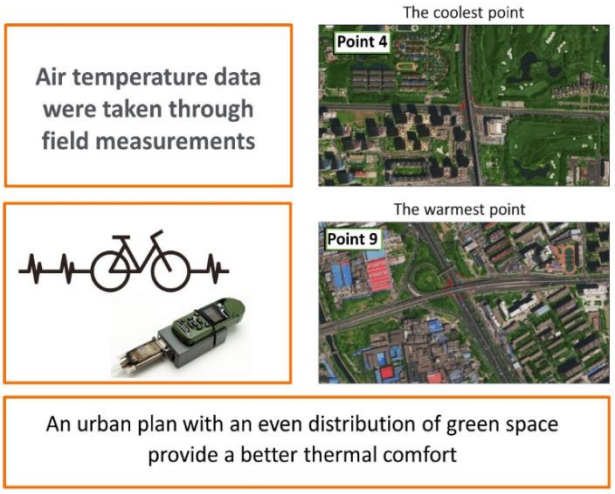
Source-https://www.researchgate.net/figure/The-increase-in-temperature-due-to-infrastructural-differences-between-rural-and-urban_fig2_357528081

- **Temperature Reduction:** Shade structures play a crucial role in effectively minimizing solar radiation and heat absorption in outdoor spaces, leading to a notable decrease in ambient temperatures within shaded areas.

By effectively blocking direct sunlight, these structures create cooler microclimates that significantly enhance visitor comfort, particularly during hot weather conditions.

- **Heat Island Mitigation:** The urban heat island effect often affects urban green spaces, resulting in higher temperatures in developed areas compared to the surrounding rural areas. Shade structures play a crucial role in mitigating this effect by reducing heat absorption and preventing thermal heat buildup, thereby fostering cooler microclimates within green spaces.
- **Solar Radiation:** The purpose of shade structures is to block or filter solar radiation, effectively reducing the amount of direct sunlight that reaches the ground.
  This has a dual benefit of lowering air temperatures and decreasing the heat absorbed by surfaces such as pathways, playground equipment, and seating areas. Consequently, the inclusion of shade structures greatly enhances the overall thermal comfort within urban green spaces.
- **Shading and Vegetation Interaction:** The presence of shade structures in urban green spaces plays a crucial role in modifying microclimatic conditions through their interaction with the surrounding vegetation. Alongside pergolas, arbors, and canopies, trees and other plants further enhance the shading and cooling effects.
- **Wind Patterns:** The presence of shade structures in urban green spaces can have an effect on the local wind patterns and airflow. Some structures may hinder or redirect the movement of air, while others can facilitate natural ventilation and cooling. By understanding these wind patterns, it becomes possible to optimize the placement and design of shade structures, thereby enhancing the microclimatic conditions and promoting both airflow and comfort.
- **Evapotranspiration:** Urban green spaces may experience changes in evapotranspiration rates due to the presence of shade structures.
  Shading reduces direct sunlight exposure and evaporation, which can help in maintaining soil moisture levels and supporting vegetation growth. This process ultimately aids in cooling through transpiration and evaporation.
- **User Comfort and Behaviour:** The behaviour and activity patterns of individuals within urban green spaces are significantly shaped by the presence of shade structures. These structures create shaded areas that have a strong allure, attracting a larger number of visitors.
  Consequently, people tend to spend extended periods of time outdoors, engaging in recreational activities, socializing, or simply finding comfort in these shaded spaces. Additionally, the increased human activity can have an impact on the microclimatic conditions by influencing body heat and airflow.

Source-https://www.mdpi.com/2072-4292/13/22/4703



RESULT

Comparison of thermal conditions between shaded and unshaded areas.

- Lack of shade structures leaves outdoor spaces vulnerable to direct solar radiation, resulting in higher ambient temperatures and increased heat absorption by surfaces such as pavement, buildings, and furnishings.
- Outdoor environments, particularly in urban areas impacted by the urban heat island effect, experience higher air temperatures in the absence of shade. This rise in temperature, along with low

humidity levels, can exacerbate heat stress and discomfort, especially during hot and dry weather conditions.

- Unshaded outdoor areas may experience changes in wind patterns and airflow due to the presence of buildings, topography, and vegetation.
  In the absence of shade structures to manage airflow, stagnant air and localized heat pockets could arise, resulting in reduced natural ventilation and heightened thermal discomfort in specific regions.
- In urban design and planning, the lack of shade structures emphasizes the need to incorporate other cooling strategies like vegetation, water features, and building orientation. By considering natural shading elements such as trees, awnings, and building overhangs, outdoor spaces can be designed to mitigate heat stress and enhance outdoor thermal comfort, providing more comfortable environments for residents and visitors.
- Shading from structures like pergolas, awnings, and trees helps in alleviating heat build-up on surfaces, such as pavement, buildings, and furnishings. This contributes significantly to the reduction of temperatures in shaded areas.
- Due to the decreased rates of transpiration and evaporation, locations that are shaded may have slightly higher humidity levels compared to areas that are uncovered. However, the existence of shade structures has no significant influence on ambient humidity levels.
- People living in shaded areas typically experience greater comfort and satisfaction than those in unshaded areas.
- Shaded environments offer a break from direct sunlight and heat, creating more pleasant conditions for outdoor activities and relaxation.

CONCLUSION

In summary, this research paper has extensively examined the various ways in which shade structures impact the thermal comfort of outdoor spaces in urban environments. Through a comprehensive analysis of existing literature, empirical studies it has been demonstrated that shade structures play a vital role in the creation of outdoor areas that are more comfortable, sustainable, and resilient.

The results obtained from this research highlight the substantial benefits of shade structures in mitigating heat stress and improving outdoor thermal comfort. By effectively reducing exposure to solar radiation, decreasing ambient temperatures, and offering relief from direct sunlight, shade structures contribute to a range of positive outcomes for individuals, communities, and the environment.

One of the key conclusions drawn from this research emphasizes the importance of strategically locating and designing shade structures in urban environments. By thoroughly considering factors such as solar orientation, prevailing wind patterns, and user requirements, designers can maximize the effectiveness of shade structures in establishing comfortable outdoor environments.

Additionally, incorporating vegetation-based shade solutions, such as trees and green roofs, can further amplify the cooling effect and foster biodiversity in urban areas. Prioritizing the integration of shade structures into urban development projects is crucial for urban planners, designers, and policymakers. This requires a holistic approach that takes into consideration the unique characteristics of each site, the needs of diverse user groups, and the broader goals of sustainability and resilience.

In conclusion, this research paper has offered valuable insights into the impact of shade structures on the thermal comfort of outdoor spaces in urban environments. By recognizing the advantages of integrating shade structures into urban design and planning practices, cities can enhance the well-being of their residents, promote public health, and create urban environments that are more sustainable and resilient.

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