NATIONAL CAPITAL REGION EXTREME HEAT TOOLKIT FOR TRANSPORTATION PLANNING

Transportation Design Guidance

June 2026

National Capital Region
Transportation Planning Board

NATIONAL CAPITAL REGION EXTREME HEAT TOOLKIT FOR TRANSPORTATION PLANNING: TRANSPORTATION DESIGN GUDIANCE
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ABOUT COG
The National Capital Region Transportation Planning Board (TPB) is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. It is responsible for developing and carrying out a continuing, cooperative, and comprehensive transportation planning process in the metropolitan area. Members of the TPB include representatives of the transportation agencies of the states of Maryland and Virginia and the District of Columbia, local governments, the Washington Metropolitan Area Transit Authority, the Maryland and Virginia General Assemblies, and nonvoting members from the Metropolitan Washington Airports Authority and federal agencies. The TPB is staffed by the Department of Transportation Planning at the Metropolitan Washington Council of Governments (COG).

CREDITS
This report was prepared for the Metropolitan Washington Council of Governments (COG) Transportation Planning Board (TPB) by ICF and Rhodeside & Harwell, Incorporated (RHI). This project was led by Katherine Rainone and Pierre Gaunaurd from TPB. This report was prepared in close collaboration with TPB by individuals from ICF including Brenda Dix, Amanda Vargo, Emelia Suljic, Jasmyn Noel, Dasha Latvis, and D'Arcy Carlson and individuals from RHI including Sukirti Ghosh, Eric Feldman, and Benjamin Valente.

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Introduction

The Transportation Design Guidance is one component of the National Capital Region Extreme Heat Toolkit for Transportation Planning, which explores extreme heat impacts to the transportation system and provides a series of resources to member agencies to help kick-start their own efforts to identify and adapt to heat risks.

Goals & Objectives

The Transportation Design Guidance supports regional resilience efforts by:

I. Providing best practice considerations for siting and designing effective cooling solutions for streetscapes, bus station areas, and trailhead plazas.

II. Providing regional context and examples to help implement heat mitigation and heat management elements.

This resource builds on TPB's 2024 risk-based vulnerability assessment, which evaluated extreme heat vulnerability for several transportation asset types, including roads, bus stops, rail stations, and rail lines. The results indicated that public transit and active transportation are highly sensitive to extreme heat. Transportation users, particularly those traveling via transit or active transportation (walking and bicycling), can be exposed to extreme heat over the course of their journeys. This includes walking to and from transit stations, specifically during first- and last-mile connectivity from residences to transit stations and from transit stations to destinations.

The longer an individual is exposed to extreme heat, the higher the risk. Heat vulnerable populations face increased risk of health impacts on their transit journey potentially forcing them to select longer routes, alternate modes of travel, or cancel trips, to minimize their heat exposure and risk. Therefore, minimizing the impact of extreme heat on transit users and those traveling on foot or bicycle is important to protect public health and build resilience.

Heat Vulnerable Populations

- Individuals with chronic health conditions
- Older adults and young children
- Outdoor workers and commuters
- Socially vulnerable populations
- Individuals without air conditioning or access to cooling spaces
- Individuals without a personal vehicle who may be more dependent on transit and active transportation modes

TPB's subsequent Transportation Resilience Improvement Plan (TRIP) identified a need for additional resources to better understand and support solutions that address extreme heat impacts on public transit and active transportation users. The **Transportation Design Guidance** is responsive to this need by providing best practice considerations for siting and designing effective cooling solutions that reduce heat exposure on people navigating the public realm, with a focus on first-last mile connections to transit and active transportation.

TPB identified three regional typologies to target for extreme heat mitigation and management (Figure 1):

- Streetscapes
- Bus Station Areas, and
- Trailhead Plazas

Streetscapes **Bus Station Areas** **Trailhead Plazas**

Figure 1. Regional Typologies.

Regionally, multimodal streetscapes facilitate connections between homes, jobs, and transit, and contain many first and last mile trips. While rail transit stations are often enclosed or covered, many bus stops lack adequate facilities to protect riders from extreme heat while they wait for a vehicle. The National Capital Region also has a strong trail network, and many multimodal journeys include travel on bike routes and trail segments. Strategies for cooling the public realm should take these places into account as well.

Following a research process, which included a literature review of published research, case studies, and similar planning documents, TPB identified appropriate heat mitigation and management elements to consider for each regional typology. TPB prioritized elements that were applicable, effective, and contextually appropriate to each typology.

Measuring Thermal Comfort and Heat Stress

Urban heat is not defined and measured equally, and it is important to focus specifically on the heat that affects human comfort:

- Land surface temperature (LST) is the temperature of the ground in a given area. LST is more easily measured than air temperature but does not directly correlate to the comfort of an environment for humans.[1]
- Air temperature is the ambient temperature, usually measured 2 meters from the ground. It is more directly related to human thermal comfort than LST. As humans move through the environment, the air around them affects their thermal comfort and can cause heat stress. Different mitigation strategies may be favored when specifically designing for human thermal comfort.[2]

Figure 2 and Figure 3 list the heat mitigation and management elements studied in this report. The list represents a diverse group of more impactful elements but does not seek to be exhaustive of all considerations that may influence urban cooling and thermal comfort.

[1] Ioannou, L.G. et al. 2022. Indicators to Assess Physiological Heat Strain – Part 1: Systematic Review. *Temperature* 9(3): 227–62. https://doi.org/10.1080/23328940.2022.2037376.
[2] Lanza, K. et al. 2025. Heat Stress Mitigation by Trees and Shelters at Bus Stops. *Transportation Research Part D: Transport and Environment* 140: 104653. https://doi.org/10.1016/j.trd.2025.104653.

Figure 2. Heat Mitigation Elements.

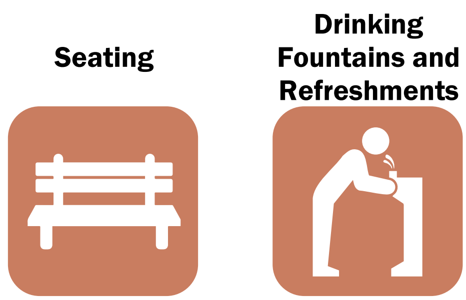


Figure 3. Heat Management Elements.

For each typology, this document examines specific extreme heat issues and considerations and provides guidance on the application of cooling elements in these contexts across the region. This document is organized into the following sections:

- **Regional Typologies:** Definition of each of the typologies, and specific guidance for each relevant mitigation and management element in context.
- **Heat Mitigation Elements:** Additional, detailed guidance and implementation best practices for trees, paving, groundcover and bioretention areas, shade structures, and water features.
- **Heat Management Elements:** Additional, detailed guidance and implementation best practices for seating and drinking fountains and refreshments.

Regional Typologies

Streetscapes

The streetscape covers the active portions of a journey, including routes to and from transit—commonly referred to as the first and last mile. Heat stress accumulates as people walk, cycle, and roll outside from place to place, with streets facilitating much of this travel. Streetscapes in urban areas tend to have high percentages of impervious surfaces, and the tree canopy cover along streetscapes is constrained by other land uses. Suburban streetscapes with transit routes tend to be arterial roads, with wide expanses of pavement and insufficient shade trees.

Figure 4 depicts a model streetscape scene, providing one example of how the different cooling elements relate to each other in a space. It can be used as a visual aid for interpreting the written guidance that follows.

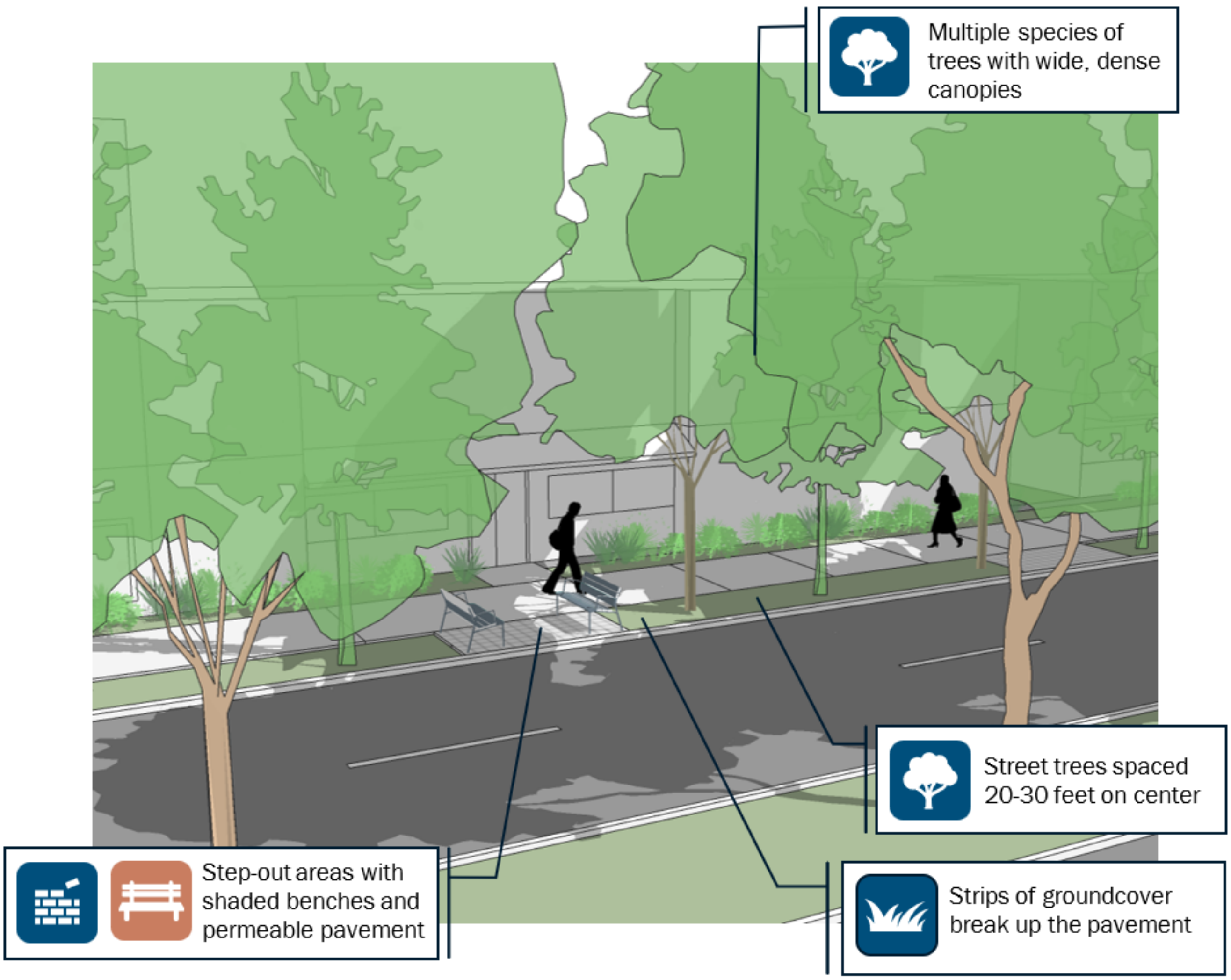


Figure 4. Model Cool Streetscape.

ELEMENTS IN CONTEXT

Table 1 presents key guidance and considerations for the heat mitigation and management elements that are most important to consider in streetscapes: trees, paving, groundcover and bioretention areas, and seating.

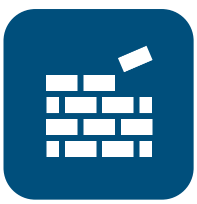
Table 1. Streetscape Elements in Context.

Trees

Regularly spaced trees are the most effective cooling strategy for streetscapes. Spacing tree specimens to minimize canopy overlap will maximize shading potential.

Key Guidance

- **Spacing:** Plant trees 20 to 30 feet apart from each other, on center, minimizing overlap and gaps between canopies, to maximize their cooling potential.
- **Dense Canopies:** Select species with high leaf-area index scores to maximize shading and evaporative cooling potential.
- **Resilient Species:** Select trees expected to thrive in current and future climate conditions and plant a variety of species within a district to promote species diversity.



Paving

Paving can be a secondary cooling strategy, best implemented with other elements including trees and groundcover. Intentional paving design can also directly support the success of trees.

Key Guidance

- **Application:** Paving must be functional, durable, and accessible to work in a streetscape setting. Portland cement and light-colored pavement are suitable for pedestrian through-zones. Permeable pavements can include permeable concrete or pavers that have gaps between units to enable infiltration and are best left for step-out areas and locations with lower travel.

Groundcover and Bioretention Areas

Groundcover along streetscapes is typically included in medians, tree planting beds, and landscape buffer strips. Specifically for groundcover patches with trees, minimum width of 5 feet of planting area is recommended for healthy tree growth. Small patches and strips of groundcover can break up pavement and help decrease LST and nighttime air temperatures.

Key Guidance

- **Application:** Encourage co-location of groundcover, bioretention, and trees to maximize cooling potential and co-benefits.
- **Species Selection:** Water-resilient grass and shrub species are required for bioretention areas that regularly swing between dry and saturated soil.
- **Connectivity:** Connected strips of groundcover provide more co-benefits to trees and can help reduce LST.

Seating

Standalone benches are the main type of seating provided along streetscapes. They can be placed close to building facades, to take advantage of the shading from the structure, or under trees. Priority should be balanced between locations that will receive shade during summer afternoons and sun in the winter.

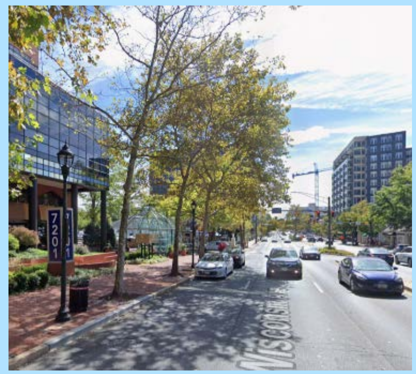
Key Guidance

- **Material:** Wood, stone, and concrete are naturally cooler materials and are more comfortable to sit on in the heat. Metal tends to be warmer to the touch and can be dangerously hot at times, but lighter colors and surface coatings can reduce this to an extent.
- **Orientation:** Benches should be oriented towards pedestrian activity whenever possible. Along building facades, seating should face the pedestrian through-zone. Within step-out areas and amenity zones along the curb, as space allows, seating should face perpendicular to the street to maintain visibility of both the sidewalk and the street.

RECOMMENDATIONS FOR DIFFERENT REGIONAL CONTEXTS

Table 2 shows how implementation of the elements may change depending on actual site conditions and regional context. Given the size of the National Capital Region, what works in one place may not be suitable for another. The table bridges the gap between the model streetscape in Figure 5 and real sites across the National Capital Region. Representative examples of locations in the region, ranging from suburban to urban in context, are included to illustrate how conditions may vary in different contexts. Subsequent rows of the table detail typical applications of the elements within each context.

Table 2. Streetscape Recommendations for Different Regional Contexts.

	Suburban Arterial Road	Mixed-Use Arterial Road	Constrained Urban Street
Representative Regional Example	 Richmond Highway, Fairfax County, VA (Source: Google Maps)	 Wisconsin Avenue, Bethesda, MD (Source: Google Maps)	 Commonwealth Avenue, Alexandria VA (Source: Google Maps)
Trees	• Continuous landscape strips with shade trees planted on sides of streets and in medians	• Street trees spaced at projected full canopy distance, in continuous strips, individual tree planting beds, and bioretention areas as context allows	• Continuous landscape strips with shade trees on sides of streets with selective trees in medians where street cross-sections allow
Pavement	• Continuous light-colored concrete sidewalks	• Light-colored two-toned pavers • Permeable pavement step-out areas for street furniture and bus stops between tree planting beds	• Continuous light-colored concrete sidewalks • Permeable pavement step-out areas for street furniture and bus stops between tree planting beds
Groundcover	• Can be dictated by other project needs and goals	• Native grasses and low shrubs in tree planting beds and along building footprints	• Native grasses and low shrubs in tree planting beds and along building footprints
Seating	• Located regularly along streets, co-located with other heat mitigation and management elements	• Located regularly along streets, co-located with other heat mitigation and management elements	• Located regularly along streets, co-located with other heat mitigation and management elements

Bus Station Areas

Bus station areas are used as places to sit or stand in between stretches of walking or riding transit. Compared to streetscapes, they focus more on stationary rest rather than active movement. They vary significantly in size and composition based on location, intended level of service, and municipality. Shelters, furnishings, and amenities can expand waiting capacity, increase comfort, and even mitigate heat stress. The National Capital Region's bus network has many operators and types of service, from commuter buses to bus rapid transit (BRT). The heat mitigation and management strategies can vary greatly depending on location, service type, and available space.

Figure 6 depicts a model bus station scene, providing one example of how the different cooling elements relate to each other in a space. It can be used as a visual aid for interpreting the written guidance that follows.

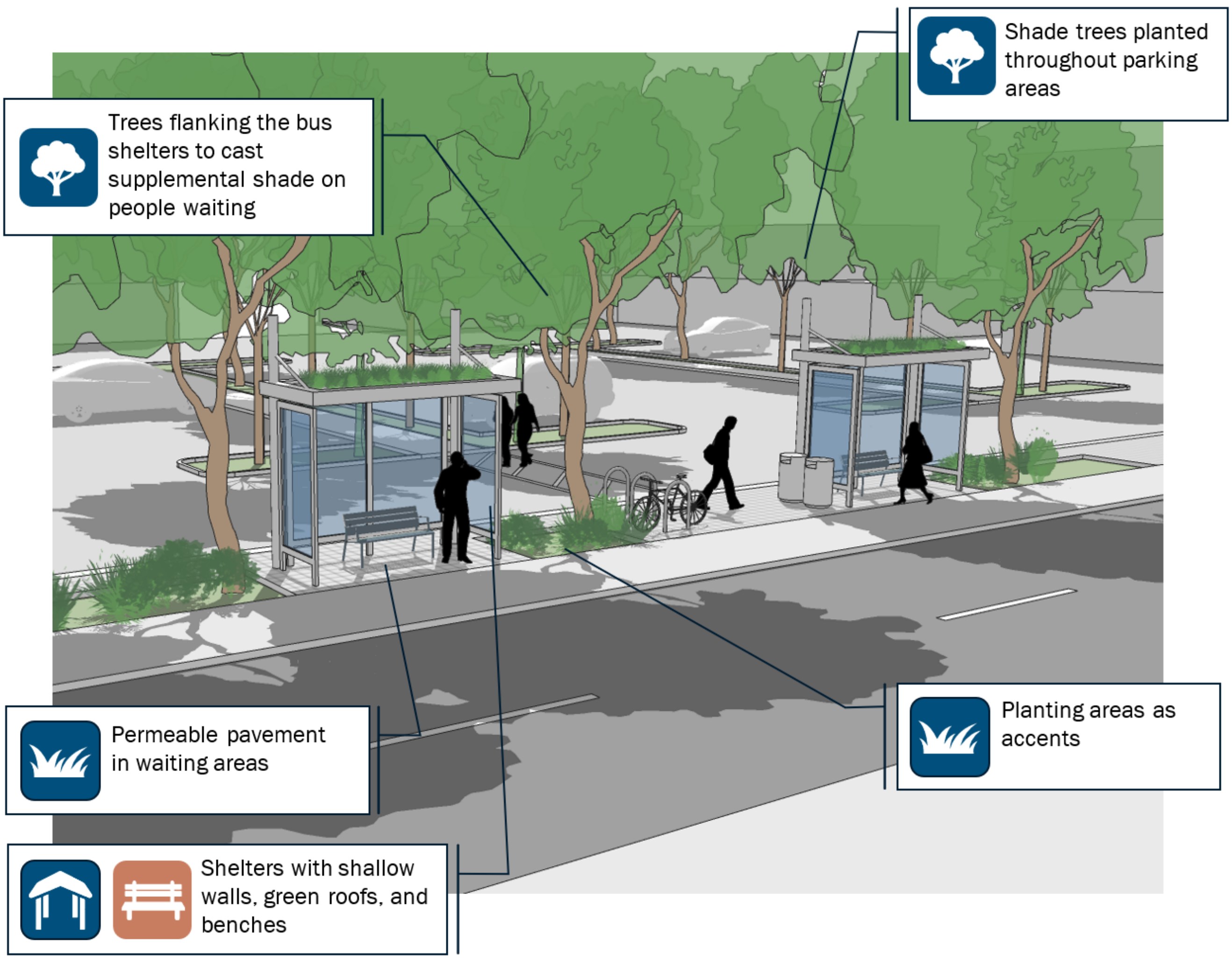


Figure 5. Model Cool Bus Station Area.

ELEMENTS IN CONTEXT

Table 3 presents key guidance and considerations for the heat mitigation and management elements that are most important to consider in bus station areas: trees, groundcover and bioretention, shade structures and seating.

Table 3. Bus Station Area Elements in Context.

Trees

Trees should be placed to provide shade over and around bus waiting areas, both where shelters are present as well as where they are absent. Redundancy in shading from trees and shelters can improve cooling when shelters cannot adequately shade their interiors due to the angle of the sun, and minimize the thermal gain caused by shelter material choices.

Key Guidance

- **Spacing:** Plant 20 to 30 feet on center; minimizing overlap and gaps between canopies maximizes the efficiency of tree cooling. Where space allows, grids of trees can create large, shaded areas of continuous canopy when mature.
- **Tree Grates and Supported Pavement:** Areas surrounding bus stations have high foot traffic, which can cause soil compaction and root damage to be exposed trees. Tree grates and supported pavement (including silva cells, pier-supported slabs, and structural soils) are recommended measures to support long-term tree health.

Groundcover and Bioretention Areas

Interspersing patches of groundcover in impervious areas helps to mediate overall surface temperatures, and longer, complex borders have been shown to facilitate more significant heat exchange between hard and soft surfaces.[3] Planting beds increase the overall greenspace of an area, contributing to the perception of coolness and comfort during the day and helping to cool the air more quickly in the evening.

Key Guidance

- **Siting:** Groundcover should not impede the need for bus station areas to facilitate orderly movement of people, especially at peak times. Greenspace should be located along edges of station areas and away from travel areas.
- **Maintenance and Upkeep:** High traffic bus station areas can be prone to litter accumulation. Installation of waste receptacles at bus stops and regular groundskeeping can minimize the accumulation of litter in planting areas.
- **Space Delineation:** Fence skirting delineates space and discourages walking and standing in planting areas, helping to preserve the greenspace in high-traffic areas.

[3] Beele, E. et al. 2024. Spatial Configuration of Green Space Matters: Associations between Urban Land Cover and Air Temperature. *Landscape and Urban Planning* 249: 105121. https://doi.org/10.1016/j.landurbplan.2024.105121.

Shade Structures

Transit shelters are shade structures designed specifically for waiting for a bus or train. Their purpose is to maximize comfort and capacity of a waiting area and to provide relief from the elements, including solar radiation. Transit shelters are the most visible infrastructure for active transportation apart from transit vehicles themselves and have co-benefits for transit ridership independent from comfort.

Key Guidance

- **Shelter Design:** Transit shelters typically feature acrylic or glass walls which protect from wind and rain while retaining clear sightlines. However, they can also trap warm air through the greenhouse effect. A study of bus shelters in Houston found that shelters without supplemental shade from trees could be hotter than a bus stop with trees but no shelter[4] and that shallower walls and those that permit airflow can minimize the greenhouse effect.
- **Overlapping Shade Sources:** The amount of solar radiation reaching people under and adjacent to bus shelters can be minimized by siting other shadow-casting elements close by. Buildings, canopy trees, and other types of shade structures can also shade people when the shelter's own roof does not fully protect them at different times of the day. Green roofs on bus shelters also offer great potential to cool bus stop areas in the future. This approach is currently being tested by communities around the United States, but green roofs have not yet been adopted widely.

Seating

Benches provide a resting place while waiting for the bus and are effective at reducing heat stress for users. They can be installed in a shelter or standalone. Design factors influence the usefulness of a bench to manage extreme heat within a UHI.

Key Guidance

- **Material:** Wood, stone, and concrete are naturally cooler materials and are more comfortable to sit on in the heat. Metal tends to be warmer to the touch and can be dangerously hot at times, but lighter colors and surface coatings can reduce this to an extent.
- **Cooling Synergy:** Benches can be more effective at helping people to reduce their heat stress when located within a shelter or other shaded area. Where benches are proposed, also prioritize shelters and tree plantings.

[4] Lanza, K. et al. 2025. Heat Stress Mitigation by Trees and Shelters at Bus Stops. Transportation Research Part D: Transport and Environment 140: 104653. https://doi.org/10.1016/j.trd.2025.104653.

RECOMMENDATIONS FOR DIFFERENT REGIONAL CONTEXTS

Table 4 shows how implementation of the elements may change depending on actual site conditions and regional context. Given the size of the National Capital Region, what works in one place may not be suitable for another. The table bridges the gap between the model bus station area in Figure 6 and real sites across the National Capital Region. Representative examples of locations in the region, ranging from suburban to urban in context, are included to illustrate how conditions may vary in different contexts. Subsequent rows of the table detail typical applications of the elements within each context.

Table 4. Bus Station Area Recommendations for Different Regional Contexts.

	Suburban Commuter Station	Roadside Constrained Stop	Urban Transfer Station
Representative Regional Example	 Horner Road Commuter Lot, Prince William County, VA (Source: Google Maps)	 Mall at Prince George's, Prince George's County, MD (Source: Google Maps)	 King St-Old Town Bus Loop, Alexandria, VA (Source: Google Maps)
Trees	• Trees planted on the bus stop island • Trees planted in the parking area medians and aisle caps	• Ideally provided as part of streetscape; can be planted otherwise	• Grid of trees as part of plaza • Smaller tree planting beds or tree grates recommended for high-traffic areas
Groundcover	• Small accents where practical and unobtrusive	• Provided as part of streetscape	• Minimal, as part of general landscape design
Shade Structures	• Highly prioritized	• Highly prioritized where ridership meets threshold	• Highly prioritized
Seating	• Highly prioritized	• Highly prioritized	• Highly prioritized

Trailhead Plazas

The National Capital Region's trail network is used daily by commuters walking, cycling, and rolling—as full trips as well as parts of journeys to and from transit. The rise of shared mobility systems has further expanded the user groups making trips on trails. They are also recreational amenities, used for exercise and leisure. Trails include urban segments with high building and pavement cover, and more natural segments surrounded by groundcover and trees. Trails are used by people running, cycling, or rolling modes of transportation that require more exertion than walking, meaning that heat stress builds up more quickly and opportunities to cool down become more important. In addition, trails are separated from vehicular traffic and located within smaller, more constrained sites requiring different approaches to heat mitigation and management than those along streetscapes. This section focuses specifically on trailheads and plazas along trails that can serve as "cool zones" where amenities are clustered and people can rest.

Figure 7 depicts a model trailhead plaza scene, providing one example of how the different cooling elements relate to each other in a space. It can be used as a visual aid for interpreting the written guidance that follows.

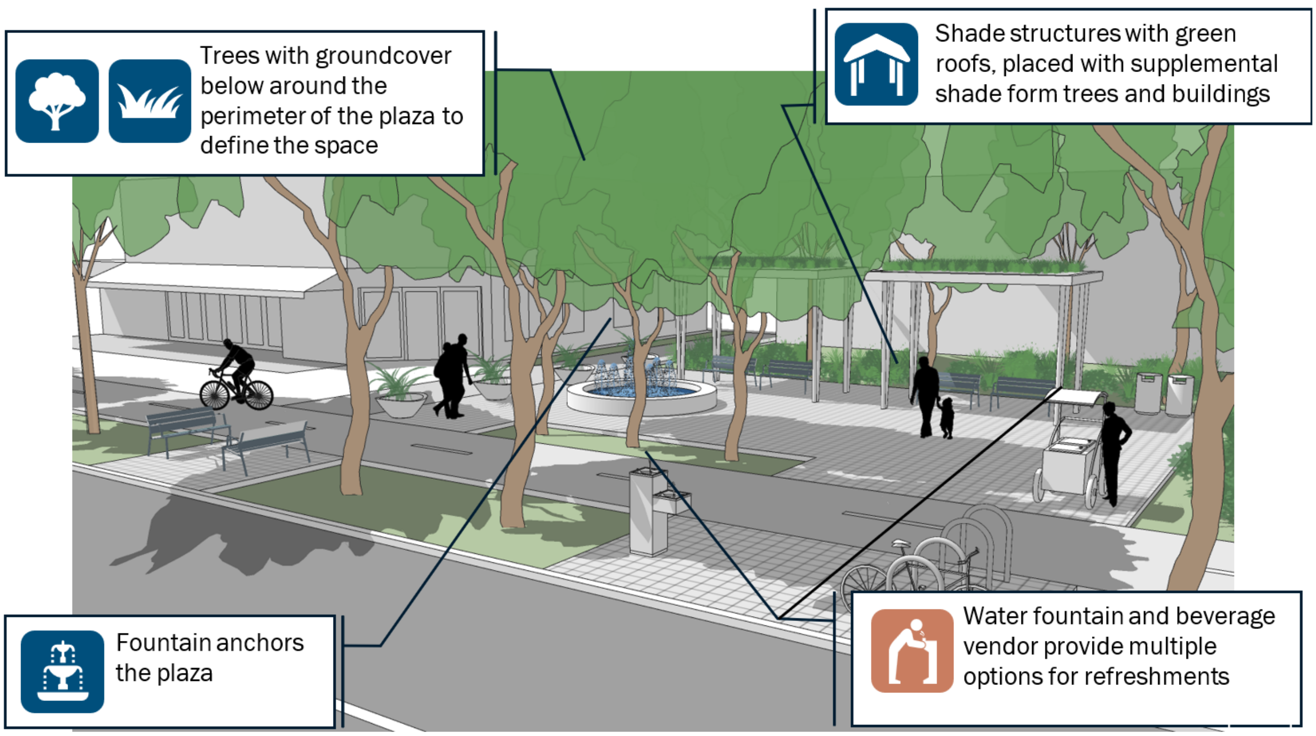


Figure 6. Model Cool Trailhead Plaza.

ELEMENTS IN CONTEXT

Table 5 presents key guidance and considerations for the heat mitigation and management elements that are most important to consider in trailhead plazas: trees, shade structures, water features, and drinking fountains and refreshments.

Table 5. Trailhead Plaza Elements in Context.

Trees

Many trails have existing tree cover along their routes. At trailheads and plazas along routes, surrounding forest tree cover may not provide sufficient functional shade to cool people resting on their journeys. Much like in the other regional typologies, the combination and configuration of elements is important to maximizing cooling potential.

Key Guidance

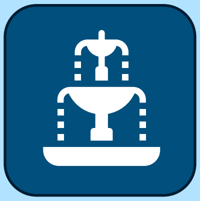
- **Spacing:** Plant 20 to 30 feet on center; minimizing overlap and gaps between canopies maximizes the efficiency of tree cooling. Where space allows, grids of trees, when mature, create large, shaded areas of continuous canopy where the air is most comfortable.
- **Orientation:** Shade studies can help to identify areas where additional trees could fill gaps and cool more evenly across the space.

Shade Structures

Pavilions and shade sails provide shelter while allowing breezes to circulate and cool the air and skin, reducing heat stress. Both types of structure are frequently installed in parks and plazas where they can be pass-through or waiting spaces for active transportation users seeking refuge from heat and rain.

Key Guidance

- **Structure Selection:** The type of structure and design is highly dependent on the specific project location and should respond to municipal design standards and aesthetic context. Solid roofs cast the greatest shadows, but pergolas with slatted roofs allow for more airflow and have potential for plants to fill in between slats.
- **Co-location of Elements:** Shade structures are ideal places to install benches, tables, play equipment, bicycle racks, and other amenities as appropriate that improve the quality and experience of the space and create opportunities for respite.



Water Features

Typically installed as placemaking elements, fountains and water features cool their surroundings through evaporation. They can define spaces and create an inviting environment while lowering air temperatures. The edges of trailheads and plazas, often defined by buildings or continuous vegetation, filter and slow wind down, meaning that the air cooled by water features lingers longer before being carried away.

Key Guidance

- **Water Feature Design:** Water features cool through evapotranspiration, in which tiny droplets are dispersed and then evaporate. Because all water features with a fountain/spray element of similar volume will cool similarly, creative and engaging water features can maximize their placemaking and recreation potential. Splash pads, cascading fountains, decorative pools, and misting sculptures can fit into different contexts and fulfill a range of project needs.
- **Siting:** Water features cool most effectively in the sun, where heat can more easily evaporate water droplets. Sunny paved surfaces also minimize residual surface moisture which can otherwise lead moss and algae to grow, creating maintenance and safety issues.

Drinking Fountains and Refreshments

Trailhead plazas are ideal locations for drinking fountains. They can service trail users and others passing by.

Access to water and snacks helps people recover from heat stress and improves comfort. Public drinking fountains are the most equitable and permanent fixtures that meet this need, but vending areas for stalls, carts, and food/beverage trucks can also provide flexible access to food and drinks that help to manage heat stress.

Key Guidance

- **Abundance of Options:** Water fountains, vending machines, and staffed beverage and snack vendors all activate spaces and make them more welcoming. People are more likely to linger and return when they know they can stop to refresh themselves while travelling.
- **Siting:** Water fountains should be placed in accessible, prominent locations to incentivize their use. Commercial vendors should be permitted where space is intentionally designed for them, while not blocking travel paths. Seating, waste receptacles, and other amenities become more important to provide.

RECOMMENDATIONS FOR DIFFERENT REGIONAL CONTEXTS

Table 6 shows how implementation of the elements may change depending on actual site conditions and regional context. Representative examples of trailhead plazas in a range of suburban to urban contexts are included for illustrative purposes. Compared to other typologies, application of trailhead plaza elements is less likely to vary across regional contexts.

Table 6. Trailhead Plaza Recommendations for Different Regional Contexts.

	High Traffic Urban Park	Mixed-Use Rail/Bike Plaza	Small Town Trailhead
Representative Regional Example	 Alethia Tanner Park, Washington, DC (Source: Google Maps)	 Riverdale Park Town Center, Prince George's County, MD (Source: Google Maps)	 W&OD Trailhead, Purcellville, VA (Source: Google Maps)
Trees	Recommendations consistent across contexts and scales. See general guidance for each element in previous section under "Elements in Context."		
Shade Structures			
Water Features			
Drinking Fountains and Refreshments			

Heat Mitigation Elements

The impacts of extreme heat on people can be reduced through heat mitigation elements. These are passive design choices that reduce the air and surface temperatures of a place. Each heat mitigation element is introduced and given context before specific design and implementation guidance is provided to help achieve the desired cooling effect and ensure long-term success.

Trees

Trees are highly effective at mitigating urban heat because they provide two forms of cooling. They reflect solar radiation and absorb less heat than harder surfaces, decreasing both LST and air temperature. They also release water from their leaves during the day, cooling the air through evapotranspiration. Planting trees in urban and suburban environments also has many co-benefits such as helping manage stormwater, providing habitat space, and dampening sound.

COOLING AND DESIGN CONSIDERATIONS

Tree Species

Trees with denser canopies tend to cool more effectively than other species because there is more surface area of leaves to shade and cool. This metric is measured through Leaf Area Index (LAI), calculated as the ratio of total leaf area of a tree divided by ground surface area defined by the tree's extents.[5]

The District of Columbia Department of Transportation (DDOT) has studied the impacts of long-term shifts in climate on the District's urban forests and developed guidance to manage the impacts. Part of this effort included vetting suitable tree species for future planting based on factors such as climate and pest vulnerability. Many of the trees recommended for increased and sustained rates of planting in the District in the future have high LAIs, meaning there is ample opportunity to select for both resilience and cooling. For example, many species of oak trees (of the *Quercus* genus) score highly on the District's resilience criteria and have dense canopies, and are already some of the most common street trees found the District.[6] Note that the species listed below do not comprise a definitive, comprehensive list of tree species suitable for planting in the region, and collaboration with arborists and landscape architects will help to determine the ideal species to plant in different locations.

Figure 7. Fruitless Sweetgum Tree. Source: Hannele Lahti.

[5] Alonzo, M. et al. 2025. Urban Trees and Cooling: A Review of the Recent Literature (2018 to 2024). *Arboriculture & Urban Forestry* 51 (5): 420–44. https://doi.org/10.48044/jauf.2025.023.
[6] District Department of Transportation. Urban Forest Climate Adaptation. https://climatereadyforests.dc.gov/.

HIGH LEAF DENSITY SPECIES

DC Tree Planting List: Recommended to Increase Planting Frequency

- Liquidambar rotundiloba (Fruitless sweetgum)
- Platanus occidentalis (American sycamore)
- Gleditsia triacanthos var. inermis (Honey locust)
- Quercus lyrata (Overcup oak)
- Quercus bicolor (Swamp White oak)
- Quercus muehlenbergii (Chinquapin oak)

Figure 8. Row of American Sycamores. Source: Van Den Berk Nurseries.

DC Tree Planting List: Recommended to Maintain Planting Frequency

- Aesculus hippocastanum (Horse chestnut)
- Liriodendron tulipifera (Tulip tree)
- Metasequoia glyptostroboides (Dawn redwood)
- Liquidambar styraciflua (American sweetgum)
- Tilia americana (American linden)

For additional guidance on resilient tree species and planting, see Fairfax County's *Resilience of Trees in Fairfax County* guide.

Tree Spacing

To achieve maximum cooling potential, there should be no overlap between individual tree canopies, maximizing relative canopy cover. The optimal planting distance should be determined during project design, taking into consideration the species and amount of space available for planting.[7] The same number of trees dispersed across a space, rather than clustered together, can provide more shade over a greater area. Studies recommend that expanding tree canopy in built-up areas focus on dispersing trees across the space, forming complex shapes and minimizing shade overlap.[8]

Solar Orientation

With shading being the primary cooling mechanism of trees, planting location in relation to the sun and other shade-casting structures is an important consideration in design. On the hottest days during summer, trees planted to the south, southwest, and southeast of buildings are shaded *the least* by surrounding structures compared to other relative orientations.[9] Generally, urban streets that run north/south are less shaded by buildings

Future Considerations

As temperatures in the National Capital Region rise and precipitation patterns change, certain tree species may be more vulnerable to disease, pests, and stress, resulting in shorter lifespans. Urban heat islands have higher temperatures than surrounding areas and can be more stressful on trees. Tree species selected specifically for cooling should be resilient to water availability and heat stress. Existing and future resources can help guide which species will be more resilient and suitable for planting in the future.

[7] Zhu, Y. and Kensek, K.M. 2024. MITIGATING THE URBAN HEAT ISLAND EFFECT: The Thermal Performance of Shade-Tree Planting in Downtown Los Angeles. *Sustainability* 16(20): 8768, https://doi.org/10.3390/su16208768.

[8] Beele, E. et al. 2024. Spatial Configuration of Green Space Matters: Associations between Urban Land Cover and Air Temperature. Landscape and Urban Planning 249: 105121. https://doi.org/10.1016/j.landurbplan.2024.105121.

[9] Zhu, Y. and Kensek, K.M. 2024. MITIGATING THE URBAN HEAT ISLAND EFFECT: The Thermal Performance of Shade-Tree Planting in Downtown Los Angeles. Sustainability 16(20): 8768, https://doi.org/10.3390/su16208768.

than streets that run east/west, meaning more trees are required to shade an equivalent amount of street space. Thus, trees should be prioritized for planting on north/south streets and southern block faces to balance this deficiency and have higher impact relative to other locations.

Planting Bed Size

Trees grow healthier and more successfully when their roots have adequate space. Trees that reach their full size potential can cool more than those stunted by lack of space or water. Tree planting areas of 5 feet by 8 feet are recommended as a minimum, with continuous planting area strips between trees being ideal.[10] Continuous soil panels, where street trees can share soil volume beneath solid pavement, may be feasible where continuous landscaping or sufficiently wide planting beds are not. Silva cells, pier-supported slabs, or sand-based structural soils can all been used to provide more growing space and connect root systems. The chosen medium is then surfaced with permeable or conventional paving.

Early Tree Maintenance

Trees require consistent maintenance in the first few years after planting to ensure survival and long-term cooling benefits. Survival rates are strongly influenced by the level of maintenance and stewardship provided, with newly planted trees especially vulnerable during this time.[11] Regular watering and basic care are essential to support healthy growth and canopy development, after which maintenance needs generally decline.[12]

Prioritization

Shading benefits from canopy trees can be more impactful in lower-income neighborhoods due to the correlation between higher temperatures and lower-income neighborhoods, and between lower-income neighborhoods and higher vulnerability and lower adaptive capacity to heat stress.[13]

Paving

Pavement refers to open impervious surfaces in urban spaces, including asphalt, poured concrete, brick, and pavers of various materials. Paving material factors that impact heat are color and permeability. High albedo pavement can reflect solar radiation back into the atmosphere rather than absorbing it and radiating it back out, and pavement that holds moisture can help cool through transpiration.

Pavement composition and configuration have the largest influences on daytime LST and nighttime air temperature. During the day, pavement absorbs solar radiation, heating the surface and interior of the pavement. As the air cools in the evening, UHI shifts from being generated from direct solar radiation to radiative heat from the surface. This causes pavement to have a small impact on UHI severity during summer afternoons, when heat stress is most severe.[14]

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[10] New York State Urban Forestry Council. 2023. The Urban Heat Island and Extreme Heat: Eight Guidelines for Trees in the Urban Landscape. https://nysufc.org/the-urban-heat-island-and-extreme-heat-eight-guidelines-for-trees-in-the-urban-landscape/2023/08/29/.

[11] Hilbert, D.R. et al. 2019. Urban Tree Mortality: A Literature Review. *Arboriculture & Urban Forestry* 45(5): 167-200. https://doi.org/10.48044/jauf.2019.015.

[12] U.S. Environmental Protection Agency. 2008. Trees and Vegetation. *Reducing Urban Heat Islands: Compendium of Strategies*. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_2.pdf.

[13] Pickett, S.T.A. et al. 2019. Science for the Sustainable City: Empirical Insights from the Baltimore School of Urban Ecology. *Yale University Press*. https://doi.org/10.2307/j.ctvqc6gb7.

[14] Beele, E. et al. 2024. Spatial Configuration of Green Space Matters: Associations between Urban Land Cover and Air Temperature. Landscape and Urban Planning 249: 105121. https://doi.org/10.1016/j.landurbplan.2024.105121.

COOLING AND DESIGN CONSIDERATIONS

Pavement Color

The color of paving materials affects its albedo, which impacts both LST and air temperature. Light-colored and reflective paving reflects less solar radiation than darker colored pavement. This reduces LST, as less heat is stored in the material and then radiated out in the evenings and nights. However, high albedo pavement positively correlates with heat stress because the reflected radiation can be absorbed by human skin and warm the body.[15] Specific reflective coatings should be limited in busier areas, as the heat stress during afternoon periods can outweigh the benefits to LST and air temperature in the evenings.

Figure 9. Two-tone Pavers in Boston, MA. Source: Landscape Perspectives.

While cool ground surfaces are not a strong strategy for reducing heat stress, green and cool roofs can be effective. This is because they reflect solar reflection above human height.

Permeable Pavement

Permeable pavement refers to a group of pavement types that have sufficient structure to walk, roll, or drive on while permitting water to infiltrate through the surface into a substrate or soil layer. Permeable pavement has potential to slightly cool near-surface air temperatures through evaporation and lower thermal mass, which improves thermal comfort.[16] Their cooling efficacy is tied closely to the amount of water available in the material to evaporate from its surface and will vary based on season and weather conditions. Coarse aggregate and capillary tubes to keep water close to the surface of the permeable pavement layer help to maximize the amount of water available to evaporate from the surface and cool the air.

Figure 10. Permeable Paver Step-out Areas. Source: MNLA.

Pavement Maintenance Over Time

Cool and reflective coatings on pavement and roofs rely on a clean, exposed surface to reflect solar radiation and, in the case of permeable pavement, to absorb water. Regular surface cleaning and refinishing over time will restore the cooling potential of light-colored pavement and roofs. Permeable pavement requires vacuuming of deposited sediment over time to maximize water infiltration performance.

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[15] Pigliautile, I. et al. 2020. Humans in the City: Representing Outdoor Thermal Comfort in Urban Canopy Models. *Renewable and Sustainable Energy Reviews* 133: 110103. https://doi.org/10.1016/j.rser.2020.110103.

[16] Li, H. et al. 2012. The Use of Reflective and Permeable Pavements as a Potential Practice for Heat Island Mitigation and Stormwater Management. *Environmental Research Letters* 8(1): 015023. https://doi.org/10.1088/1748-9326/8/1/015023.

Future Considerations

Retro-reflective surfaces

Current reflective pavement treatments are not effective treatments for reducing air temperature and heat stress in humans as the reflected solar radiation scatters onto skin and heats the body instead of the paved surface. A new generation of finishes, called retroreflective materials, can greatly increase the percentage of solar radiation that is reflected back into the atmosphere, rather than onto building facades and people. Application of these finishes on urban pavement can reduce air temperatures during the hottest parts of the day. Due to their novelty, real-world applications of these materials have been rare, and further study is required before implementing these treatments on a large scale. This intervention may become more technologically viable and economically feasible in the future and is worth investigating (Huang et al., 2024).

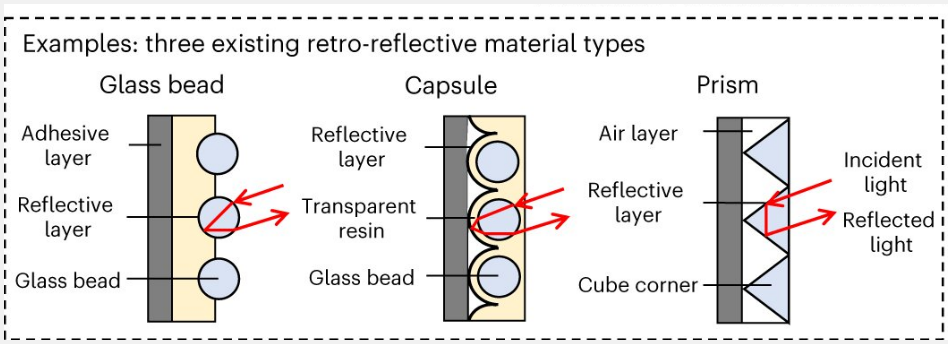

Figure 11. Types of Retroreflective Surfaces. Source: Colton Poore, Princeton University.

Placement Best Practices

Cool pavements with reflective treatments are best suited to areas away from high pedestrian activity. As cool pavement treatments have negligible effect on air temperature and heat stress, there is no significant negative impact from focusing their application in areas where LST reduction is the priority such as longer-term parking lots. Permeable pavement has more co-benefits alongside cooling and no negative impact on heat stress, and it is best suited for pedestrian areas with lower direct traffic.

Groundcover and Bioretention Areas

Groundcover refers to green, pervious land covers, such as grass and shrubs found in tree beds, medians, along roads, within parks, and on private lots. Groundcover has many co-benefits alongside cooling potential, such as stormwater management and recreation space. Bioretention areas, an increasingly popular type of blue-green infrastructure, are natural or structured pervious areas planted with trees and groundcover that divert and filter water before slowly releasing it into the soil or a stormwater system.

COOLING AND DESIGN CONSIDERATIONS

Nighttime Cooling

Grasses and shrubs contribute relatively little to cooling the air doing the day; the rates of evapotranspiration and shading are not significant enough to meaningfully impact air temperature. They do provide value in quickly cooling the air in the evening when the source of heat shifts from direct solar radiation to the release of heat stored in surfaces and structures. After the sun goes down, the air above groundcover cools down much more quickly than pavement. In this context, groundcover is more effective than trees, which can actually trap heat in the evening and night, causing the air to cool more slowly. Groundcover therefore serves as a good complement to trees in urban and suburban areas to provide necessary cooling in the evening and at night.[17]

Perception of Temperature

While groundcover and shrubs do not provide substantial daytime relief, greenery contributes to a psychological feeling of coolness. Physical and psychological factors both contribute to thermal comfort and stress. Aesthetic-minded planting areas can make the public realm more attractive and comfortable to linger in.[18]

Figure 12. Bioretention Area Along Streetscape. Source: Cape Code Green Infrastructure Guide.

Bioretention and Evaporative Cooling

Studies suggest that blue-green infrastructure can effectively lower LST and air temperature through evapotranspiration and shading. They are most effective when trees and groundcover are planted together.[19] Small bioretention areas that are typically found along streets are likely to cool at the hyperlocal scale but lack sufficient aggregation to cool past the block level.

Breeze-Friendly Planting Patterns

A mix of grasses and shrub heights is recommended when planting for visual interest as the layers create movement and dimension. An important consideration for urban cooling is minimizing wind breaks. Low grasses and shrubs permit air to circulate throughout the area, moving warm air away from the surface. Tall, thick shrubs and hedges can channel the wind to exchange the warm air with cooler air.[20] Designing breaks into softscape and hardscape elements can minimize the impact of these factors and direct air into pedestrian areas.

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[17] Beele, E. et al. 2024. Spatial Configuration of Green Space Matters: Associations between Urban Land Cover and Air Temperature. Landscape and Urban Planning 249: 105121. https://doi.org/10.1016/j.landurbplan.2024.105121.

[18] Steinharter, L. et al. 2025. Hot Stops, Cool Looks: Aesthetic Solutions for Thermal Comfort at Transit Stops. *Urban Climate* 64: 102606. https://doi.org/10.1016/j.uclim.2025.102606.

[19] Budzik, G. et al. 2024. Understanding Urban Cooling of Blue–Green Infrastructure: A Review of Spatial Data and Sustainable Planning Optimization Methods for Mitigating Urban Heat Islands. *Sustainability* 17(1): 142. https://doi.org/10.3390/su17010142.

[20] Richards, D.R. et al. 2020. Differential Air Temperature Cooling Performance of Urban Vegetation Types in the Tropics. *Urban Forestry & Urban Greening* 50: 126651. https://doi.org/10.1016/j.ufug.2020.126651.

Shade Structures

Shade structures can include permanent and temporary coverings that provide shelter and shield from the sun and rain. This is a diverse category that includes bus shelters, pavilions, fabric shade sails, pergolas, and awnings. They reduce LST and air temperature through shading. Shade structures are best suited for areas where trees would not grow well or where more complete shelter from the elements is necessary.

COOLING AND DESIGN CONSIDERATIONS

Cool and Green Roofs

Shade structures cool primarily through shading. Solar radiation is captured or reflected by the roof structure, preventing heat from reaching the air near the surface and increasing temperatures. Traditional roofs absorb most of the radiation and slowly releases it back into the air when temperatures start to cool in the evening. Low albedo surfaces reflect this radiation back into the air, reducing the embedded heat in the shade structure and the air.

Figure 13. Green Bus Stop in Boston, MA. Source: City of Boston.

Green roofs can increase the cooling capacity of shade structures by reflecting more solar radiation back into the atmosphere[21] like cool roofs, while also facilitating evapotranspiration from the vegetation and soil they hold. Pilot projects in U.S. cities[22] including Bladensburg, MD, and Boston, MA, have shown green roofs to be effective at reducing air temperatures and LST inside the shelters themselves, increasing thermal comfort. Regular irrigation is important while the vegetation establishes itself and during dry periods, as the thin soil layer is prone to drying out and its cooling potential relies in part on soil moisture to evaporate.

Figure 14. West Falls Church Bus Loop. Source: flickriver.com.

Shade Structure Walls

Shade structures, especially bus shelters, may have walls on their sides and backs to protect users from the elements while waiting. Clear materials are commonly used to increase transparency and environmental safety while reducing the impact of rain and wind on people inside them. This can create a warmer microclimate caused by solar radiation passing through the wall material. Perforations or gaps in the wall can reduce this severity. Trees should

[21] Li, D. et al. 2014. The Effectiveness of Cool and Green Roofs as Urban Heat Island Mitigation Strategies. *Environmental Research Letters* 9(5): 055002. https://doi.org/10.1088/1748-9326/9/5/055002.
[22] Balcoff, Z. 2025. How These Green Bus Stops Help Bees and Communities. *The Washington Post*. https://www.washingtonpost.com/climate-solutions/interactive/2025/green-bus-stops-shelters-bees-heat/.

also be planted around shelters, wherever possible, to minimize the amount of direct solar radiation the shelter areas receive.[23]

Water Features

Water features such as fountains, splash pads, and misters enliven spaces visually and sonically, while also helping to reduce heat stress in the public realm through evaporative cooling. They can be a defining placemaking element when integrated into spaces.

The air-cooling effect of water features is very localized, with strong impact directly within and adjacent to the feature. Benefits diminish further from the water source and are eventually negligible. One study of a ground-mounted spray fountain measured decreased air temperatures as far as 35 meters away. Cooling potential is dependent on local atmospheric factors such as air temperature, humidity, and wind velocity.

COOLING AND DESIGN CONSIDERATIONS

System Design

Water spray features and waterfall style fountains both lower local air temperatures, but water spray features are most effective because they distribute more fine mist particles in the air. A study investigated various nozzle sizes on spray features and found that smaller nozzles cool more effectively because they disperse more fine droplets through the air compared to larger fixtures. This means that water features that produce more mist will cool more than other types of features with the same volume of water flow.[24]

Impact of Wind and Sun

Wind direction and speed impact the cooling efficiency of water features. Low, steady breezes can distribute the fine mist across a space, but when wind speeds are too high, the cooling effect is effectively negated.[25] Sunlight also affects cooling efficiency as sufficient heat is necessary for evaporative cooling to take place. Taken together, the optimal environment for cooling water features are sunny areas with low to moderate wind.

Figure 15. Sculptural Misting Installation in Alexandria, VA. Source: Site See Alexandria.

Figure 16. Small Spray Fountain in Aspen, CO. Source: TripAdvisor.

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[23] Lanza, K. et al. 2025. Heat Stress Mitigation by Trees and Shelters at Bus Stops. Transportation Research Part D: Transport and Environment 140: 104653. https://doi.org/10.1016/j.trd.2025.104653.

[24] Nishimura, N. et al. 1998. NOVEL WATER FACILITIES FOR CREATION OF COMFORTABLE URBAN MICROMETEOROLOGY. *Solar Energy* 64(4): 197–207. https://doi.org/10.1016/S0038-092X(98)00116-9.

[25] Ulpiani, G. et al. 2020. Mist Cooling in Urban Spaces: Understanding the Key Factors behind the Mitigation Potential. *Applied Thermal Engineering* 178: 115644. https://doi.org/10.1016/j.applthermaleng.2020.115644.

Heat Management Elements

Heat management elements help people to cope with and recover from thermal stress and the related risks to health and wellbeing. While they do not directly cool the surface or air, they are essential to address extreme heat on transit and active transportation journeys. Each heat management element is introduced and given context before specific design and implementation guidance is provided to help achieve the desired cooling effect and ensure long-term success.

Seating

Seating is a powerful placemaking element to create public spaces that are inviting and comfortable to linger in. It is especially suitable along active transportation and transit routes. Benches, chairs, and built-in seating arrangements help facilitate activities and interactions. They provide places of respite for sitting and reducing heat stress and can be co-located with heat mitigation elements for greater impact.

COOLING AND DESIGN CONSIDERATIONS

Seating Material

Common seating materials have different thermal properties that can make them feel hotter or colder. Finish, density, and color all impact how much heat the material can absorb and transfer to the body. Concrete and wood have low thermal conductivity and transfer little heat when in contact with the body. Metal has a much higher thermal conductivity rate and will feel hotter regardless of temperature. This can be offset with coatings on the metal, which insulate it from skin. Wood benchtops and light-colored perforated metal increase air circulation within the bench structure and balance durability and thermal comfort.

Figure 17. Concrete Seat-bench with wooden seats. Source: Anston Architectural Products.

COOL BENCH MATERIALS

- Wood and composite wood
- Resin
- Concrete
- Light-colored perforated metal

Placement Location

As a heat management strategy with no inherent cooling capacity, seating relies on other shading practices to be effective places to recover from heat stress. Studies have shown that shaded benches are better utilized than those in direct sunlight.[26] Seating should be placed in the shade and close to heat mitigation and management elements to maximize their potential. Solar radiation comes from the southwest during the hottest part of the day, casting shadows to the northeast. Seating placement should prioritize areas where structures and trees shade them during summer afternoons.

Figure 18. Wooden bench placed in building shadow, College Park, MD. Source: Google Maps.

[26] Lindley, S.J. 2025. Streetscapes and Heat Tolerance. *Nature Climate Change* 15(9): 919–20. https://doi.org/10.1038/s41558-025-02416-9.

Movable Seating

Flexible and movable seating can maximize shading in summer and sun exposure in the winter. Where appropriate, movable chairs, benches, and tables can be selected. This works best in spaces with active management and low risk of the furniture being removed from the intended area, such as fenced parks or surveilled public squares.

Drinking Fountains and Refreshments

Hydration and nutrition are important for the body to function and deal with heat stress. Multimodal journeys can be long, and during extreme heat events, taxing. Heat and movement cause sweating, depleting the body of water. Access to water and other refreshments is an important part of heat management in the public realm. Public drinking fountains are the most accessible and permanent fixtures that meet this need, but vending stalls, carts, and food/beverage trucks can also provide flexible access to food and drinks that help to manage heat stress.

COOLING AND DESIGN CONSIDERATIONS

Siting

Drinking fountains and vending areas should be placed in shaded locations—under trees, building overhangs, or shade structures. They should be located near natural breezeways when possible, improving perceived comfort and encouraging people to linger and hydrate and refresh themselves. Trails and walkways tend to channel breezes unobstructed, meaning co-locating these elements bring heat mitigation, management, and people traveling through public space all together.

Figure 19. Beverage vendor along Four Mile Run Trail, Arlington, VA. Source: Google Maps.

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