Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 21 May 2026
Revised 30 June 2026
Accepted 23 July 2026

Natural Resources for Human Health 2026, Vol. 6 (9s): 1031–1044

KEYWORDS:
climate resilience, extreme heat, inclusive design, environmental justice, public space accessibility, urban heat island, vulnerability, cooling infrastructure

Resilience for Whom? Rethinking Inclusive Design in Climate-Resilient Public Space under Extreme Heat

Zibo Ai

Nanjing Foreign Language School, 60 Huixiu Road, Nanjing, Jiangsu, China 210022
Corresponding Email: LucasAi1314@126.com

ABSTRACT: Urban climate adaptation increasingly invests in climate-resilient public spaces—cooling stations, shaded parks, misting corridors, reflective streetscapes—to mitigate extreme heat. Conventional evaluation frameworks privilege thermodynamic metrics while leaving unexamined whether vulnerable populations can actually reach and use the resulting protection. This narrative review synthesizes research across architecture, urban planning, public health, environmental justice, and public affairs to argue that technical sustainability and social inclusivity operate on different registers, and that the gap between them constitutes a critical blind spot in climate resilience policy. Drawing on empirical evidence from Shanghai, Chongqing, and Portland (Oregon), the paper traces how barriers of distance, institutional exclusion, monolingual information channels, and unequal governance filter vulnerable populations out of nominally public cooling infrastructure. To address this gap, the paper proposes an Inclusive Climate-Resilience Index (ICRI) integrating four evaluative dimensions—thermal performance, spatial accessibility, social inclusion, and participatory governance—across nine indicators organized as a sequential gate model. The ICRI reframes climate resilience from a question about environmental performance to one about distributional justice. The review concludes that climate adaptation without inclusive design reproduces the inequalities that generate heat vulnerability.

1. INTRODUCTION

On July 14, 1995, temperatures in Chicago reached 41°C; over the five days that followed, more than 700 people died—disproportionately Black, elderly, and socially isolated residents of neighborhoods where air conditioning was scarce and community institutions had eroded (Klinenberg, 2002). Three decades later, extreme heat remains the deadliest weather-related hazard in both the United States and China, and the toll is climbing on both sides of the Pacific. During the June 2021 Pacific Northwest heat dome, temperatures in Portland, Oregon, exceeded 46°C, killing at least 96 people in the state, the majority elderly residents dying alone in dwellings without air conditioning (Schramm et al., 2021). In the summer of 2022, China endured its most severe heat wave since national records began in 1961: Chongqing recorded 45°C, Shanghai broke its 149-year temperature record at 40.9°C, and over 900 million people across multiple provinces were affected (Sun et al., 2022; CMA, 2022). Cities in both countries have responded with expanding portfolios of climate-resilient public spaces—cooling stations (*naliangdian*, 纳凉点) in Chinese cities, cooling centers in American libraries and community halls, shade structures, misting corridors, and green infrastructure designed to lower ambient temperatures at the neighborhood scale (Keith et al., 2021; Stone et al., 2012; Tan et al., 2010). These interventions are routinely evaluated by metrics that capture physical efficacy—degrees of temperature reduction, square meters of canopy added, hours of air-conditioned shelter available—and the resulting scores feed into sustainability certifications, climate action plans, and municipal performance reports.

Yet a persistent dissonance runs through the empirical literature on urban heat vulnerability. A cooling station may appear on a city's official map, but if the nearest bus stop operates on a reduced schedule and the facility requires local household registration for entry, its existence offers no protection to the migrant worker whose construction site sits in the midday sun

(Chan, 2019). A park may boast a generous tree canopy, but if its pathways lack curb cuts and tactile paving, wheelchair users cannot navigate it safely (Imrie, 2012). Heat advisories may be disseminated via smartphone applications in a single language, bypassing elderly residents who use neither smartphones nor that language (Sampson et al., 2013). In each instance, the technical performance of the intervention remains intact. What fails is the conversion of that performance into lived protection for the people most at risk.

What might be called the *inclusive-by-design fallacy*—the assumption that a space designed to be open to the public is, by that fact alone, equally usable by all publics—is not an incidental oversight but a structural feature of how climate resilience is currently conceptualized and measured. Mainstream evaluation frameworks operate on the implicit premise that proximity equals access and that the physical presence of an intervention equals its social availability. The empirical record contradicts this premise repeatedly: heat-related morbidity and mortality continue to concentrate along fault lines of income, age, registration status, disability, language, and occupational exposure even in cities with substantial investments in cooling infrastructure (Gronlund, 2014; Harlan et al., 2006; Hsu et al., 2021; Tan et al., 2010). The infrastructure is not failing on its own terms; it is failing on terms it was never asked to meet.

The purpose of this review is threefold. First, it synthesizes evidence on how spatial, institutional, and informational barriers mediate the relationship between climate-resilient public space and actual heat protection for vulnerable populations, drawing on literature from both China and the United States. Second, it proposes a conceptual framework—the Inclusive Climate-Resilience Index (ICRI)—that integrates thermal performance with accessibility, social inclusion, and participatory governance in a single evaluative instrument organized as a sequential gate model (Figure 2). Third, it identifies the policy and design implications of treating inclusivity not as a secondary benefit of resilience but as its constitutive condition.

The review proceeds as follows. Section 2 situates the argument within the literatures on environmental justice, urban heat vulnerability, passive cooling design, and inclusive urbanism. Section 3 describes the narrative review methodology. Section 4 develops the ICRI framework. Section 5 applies the framework to three case contexts—Shanghai, Chongqing, and Portland—drawing on published empirical studies. Section 6 discusses implications for policy, design, and future research, including a critical interrogation of the ICRI's own limitations. Section 7 concludes.

2. THEORETICAL FOUNDATIONS: HEAT, JUSTICE, AND THE POLITICS OF ACCESS

2.1 From Environmental Justice to Climate Justice

The environmental justice movement established that the spatial distribution of environmental harms—toxic waste facilities, polluting industries, contaminated water supplies—was patterned along racial and socioeconomic lines rather than randomly distributed (Bullard, 1990; Mohai et al., 2009). Over time, the framework expanded beyond distributional questions to encompass procedural justice—who participates in environmental decision-making—and recognition justice—whose experiences and knowledge count as legitimate inputs to policy (Schlosberg, 2007; Fraser, 2009; Young, 1990).

Climate justice carries this tripartite analysis into the domain of a warming climate but introduces a complication: climate impacts do not merely overlay pre-existing inequalities; they interact with and amplify them. Extreme heat does not arrive on a level playing field. Its effects are magnified by poverty (which limits access to air conditioning and medical care), by age (which reduces thermoregulatory capacity), by disability (which constrains mobility), by occupational exposure (which compels outdoor labor during peak temperatures), and by administrative exclusion—such as household registration systems that restrict migrants' access to community services (Cutter et al., 2003; Shi et al., 2016; Chan, 2019). A climate justice analysis of urban heat cannot stop at mapping temperature differentials across neighborhoods; it must trace how institutional arrangements, infrastructural choices, and governance practices channel the benefits of cooling interventions toward certain populations and away from others (Schlosberg & Collins, 2014). The distributional question—who bears disproportionate heat burden—is inseparable from the procedural question—who decides where cooling infrastructure goes and how it operates.

2.2 Urban Heat Vulnerability: Beyond Exposure to Access

The empirical literature on urban heat vulnerability has evolved through two generations. The first focused on biophysical drivers of the urban heat island (UHI) effect: surface albedo, vegetation coverage, building geometry, and anthropogenic heat flux (Oke et al., 2017; Stone et al., 2012). This work produced the foundational observation that lower-income neighborhoods and communities of color tend to experience higher surface and air temperatures, a pattern documented in both American cities—where it is rooted in historical redlining (Hoffman et al., 2020; Mitchell & Chakraborty, 2015; Hsu et al., 2021)—and Chinese cities, where rapid urbanization has concentrated impervious surfaces and displaced green space in peri-urban and industrial districts (Peng et al., 2012; He et al., 2019).

A second generation incorporated sensitivity and adaptive capacity. Cutter et al.'s (2003) Social Vulnerability Index (SoVI) aggregates demographic, socioeconomic, and housing variables to identify populations with reduced coping capacity. Applied to heat, this framework highlights that vulnerability emerges from the intersection of climatic exposure with social conditions—age, disability, poverty, housing quality, social isolation (Wilhelmi & Hayden, 2010). Harlan et al. (2006), working in Phoenix, demonstrated that residents of lower-income neighborhoods experienced significantly higher heat stress indices even after controlling for ambient temperature. In Chinese cities, Tan et al. (2010) documented analogous patterns in Shanghai, where heat wave mortality concentrated among elderly residents of older, poorly ventilated housing stock in densely built districts with minimal green space.

Yet even this more comprehensive paradigm tends to treat the availability of cooling resources as binary: a neighborhood either has a cooling station or it does not. What remains underexamined is the chain of conditions that must hold for a specific individual to actually use a specific resource. A cooling station that appears on a municipal map is not the same as one that a given person can physically reach, is permitted to enter, feels safe occupying, and knows is available. Each condition represents a potential exclusion point. This sequential logic—what this paper terms the *accessibility gate model* (Figure 2)—distinguishes the ICRI framework from existing indices that capture exposure and proximity without tracing the full conversion pathway from infrastructure to protection.

2.3 Passive Cooling Design and Thermal Comfort: The Architectural Dimension

The architectural and landscape literature on passive cooling provides the technical substrate that climate-resilient public space is built upon, but that substrate carries its own equity implications. Research on shade geometry demonstrates that the thermal benefit of tree canopy depends critically on species selection, planting density, and crown architecture, with broad-canopied deciduous species providing substantially greater PET (Physiological Equivalent Temperature) reductions than narrow-crowned conifers during peak heat hours (Aminipouri et al., 2019; Shashua-Bar et al., 2011). Material selection is similarly consequential: a metal bench in direct sunlight can reach surface temperatures exceeding 70°C, posing contact-burn risks and rendering the seating unusable precisely when heat relief is most needed (Watanabe et al., 2014). Cool-pavement coatings reduce surface temperatures but can increase pedestrian-level mean radiant temperature by reflecting shortwave radiation upward, a counterintuitive finding that has prompted caution about transferring roof-level albedo strategies to ground-level public space (Middel et al., 2020).

These findings matter for the inclusivity argument because the populations most physiologically vulnerable to heat—elderly adults whose thermoregulatory systems have degraded, individuals on medications that impair sweating, pregnant persons with elevated core temperatures, and outdoor workers whose metabolic heat load compounds ambient exposure (Kenney et al., 2014)—are also the populations least able to tolerate design errors. A design that performs adequately for a healthy adult may fail for an elderly person in a wheelchair or a construction worker in a hard hat and boots.

2.4 From Inclusive Design to the Resilience-Inclusivity Gap

The concept of inclusive design originated in architecture as a response to the disability rights movement but has expanded well beyond ramp gradients and doorway widths (Imrie, 2012; Steinfeld & Maisel, 2012). The seven principles of universal design—equitable use, flexibility, simplicity, perceptible information, tolerance for error, low physical effort, and adequate size and space—formulated by Mace et al. (1997) describe a design philosophy that takes the full range of human variation as its starting point. Fainstein's (2010) normative framework for the "just city" extends this logic to urban planning: she argues that planning should be evaluated against equity (fair distribution of resources), diversity (accommodation of different social groups), and democracy (meaningful participation in decisions). Translated into the context of heat-resilient public space, these criteria suggest that evaluation must assess not only how much cooling a space delivers, but how equitably that cooling is distributed and how democratic the processes by which it was sited and designed.

Yet the concept of urban resilience, as adopted in climate adaptation planning, sits uneasily alongside these justice-oriented frameworks. Meerow et al. (2016) have documented the risk that "resilience" serves as a depoliticized substitute for equity. When resilience is framed in systems-engineering terms—the capacity of an urban system to absorb shocks and maintain function—it can obscure the distributional question of whose functions are maintained and at whose expense (Anguelovski et al., 2016). A city may be "resilient" in aggregate while specific populations within it remain catastrophically exposed. The gap between resilience-as-system-performance and resilience-as-individual-protection is what this paper terms the *resilience-inclusivity gap*, and it is this gap that the ICRI framework is designed to make visible and measurable.

3. METHODOLOGY

This paper adopts a narrative review methodology (Grant & Booth, 2009), synthesizing published empirical research, policy documents, and conceptual analyses to construct an integrated argument about the relationship between climate resilience and social inclusivity under extreme urban heat. Narrative reviews are suited to topics spanning multiple disciplinary literatures where interpretive synthesis and conceptual framework development take priority over statistical aggregation of effect sizes (Baumeister & Leary, 1997).

The literature search was conducted across Web of Science, Scopus, PubMed, and Google Scholar using Boolean combinations of the following terms: ("urban heat island" OR "extreme heat" OR "heat wave") AND ("cooling center" OR "cooling infrastructure" OR "cooling station" OR "public space" OR "green infrastructure") AND ("accessibility" OR "inclusive design" OR "equity" OR "environmental justice" OR "climate justice" OR "vulnerability"). Searches were conducted in English and supplemented by targeted Chinese-language searches on CNKI for empirical studies on *naliangdian* systems and urban heat adaptation in Chinese cities. Searches were limited to publications from 2000 to 2025, with exceptions for foundational texts published earlier (e.g., Arnstein, 1969; Bullard, 1990). The initial search returned approximately 1,400 records. After removing duplicates and screening by title and abstract, approximately 40 sources met the inclusion criteria: (a) empirical studies examining the relationship between cooling infrastructure and access differentials across population groups, (b) conceptual or theoretical papers analyzing justice dimensions of climate adaptation, (c) policy analyses evaluating inclusivity provisions of heat action plans, and (d) architectural or urban design studies assessing thermal performance with attention to user-level outcomes.

The three case contexts—Shanghai (Tan et al., 2010; Chen et al., 2015), Chongqing (Sun et al., 2022), and Portland (Voelkel et al., 2018; Schramm et al., 2021)—were selected to achieve both analytical diversity and geographic breadth. The inclusion of two Chinese and one American case is a deliberate methodological choice: the Chinese and American urban contexts differ substantially in governance structure, population registration systems, and the institutional architecture of public-space provision, yet the dynamics of heat vulnerability and exclusion exhibit striking structural parallels. These parallels—rather than country-specific policy detail—are what the ICRI framework is designed to capture. Each case illustrates a distinct mechanism by which the resilience-inclusivity gap manifests, and together they span the accessibility gate model's range of failure points (Table 2). The ICRI's conceptual structure does not depend on the institutional particularities of either national context; the cases serve as empirical illustrations of a framework whose logic is intended to be transferable.

4. THE INCLUSIVE CLIMATE-RESILIENCE INDEX: A CONCEPTUAL FRAMEWORK

4.1 Rationale and Architecture

Existing evaluation frameworks for climate-resilient public spaces cluster into three categories: building-level sustainability certifications (LEED, BREEAM, China's Three-Star system), area-level heat-vulnerability indices (derived from Cutter et al., 2003; Reid et al., 2009), and spatial-accessibility analyses measuring distance or travel time between vulnerable populations and cooling facilities (Voelkel et al., 2018). Each captures an important dimension of the problem, but none integrates the full chain from thermal performance to lived protection. Sustainability certifications focus on the building envelope without assessing who reaches or uses the certified space. Heat-vulnerability indices map exposure without evaluating mitigating infrastructure. Spatial-accessibility studies measure distance but typically omit non-spatial barriers—operating hours, design compliance, informational accessibility, governance inclusion.

The ICRI bridges these analytical silos by organizing evaluation along four dimensions, each containing specific indicators (Figure 1).

Natural Resources for Human Health
eISSN: 2583-1194

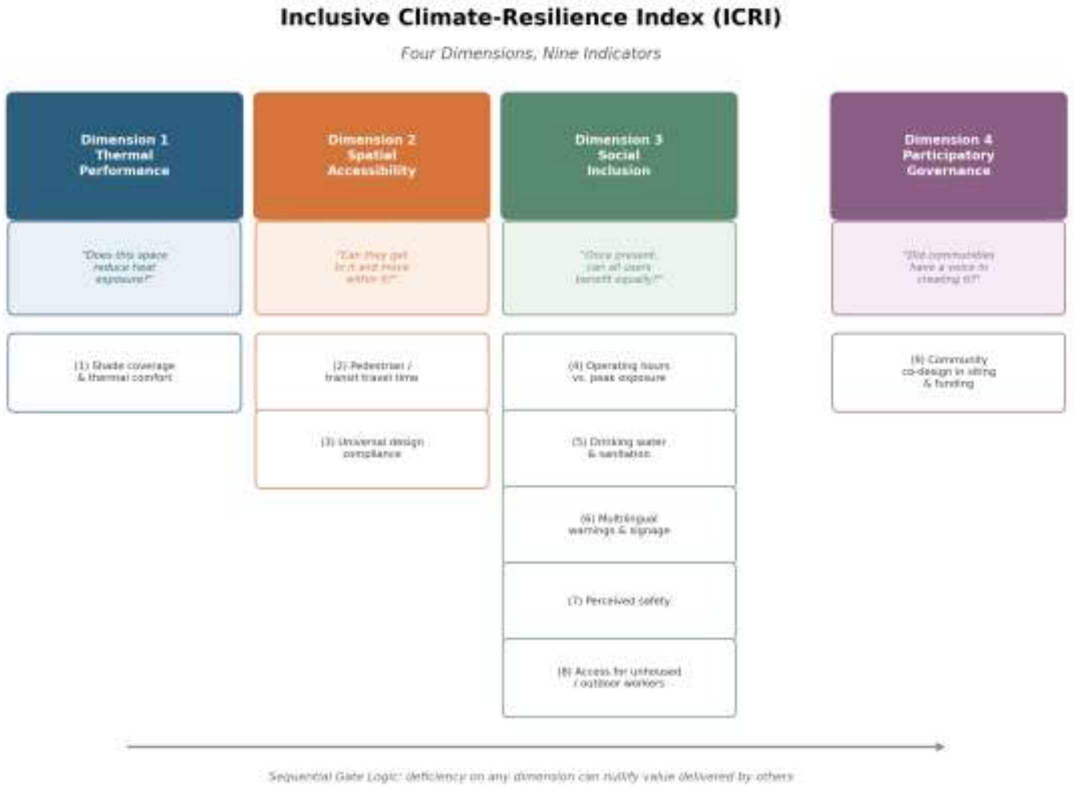

Figure 1. The Inclusive Climate-Resilience Index: four dimensions, nine indicators. The sequential gate logic (bottom arrow) implies that deficiency on any single dimension can nullify value delivered by the others.

Dimension 1: Thermal Performance. This dimension retains the environmental metrics that existing frameworks handle well: shade coverage and thermal comfort measured via PET or UTCI, surface albedo, ventilation characteristics, and material thermal properties (Middel et al., 2020; Shashua-Bar et al., 2011). It answers: *Does this space reduce heat exposure?*

Dimension 2: Spatial Accessibility. This dimension evaluates whether the space can be physically reached by populations most exposed to heat risk. Indicators include pedestrian and public-transit travel time from high-vulnerability areas, following Voelkel et al.'s (2018) network-based methodology, and universal design compliance—whether pathways, entrances, seating, and signage meet accessibility standards for persons with mobility, visual, and cognitive impairments (Steinfeld & Maisel, 2012). It answers: *Can the people who need this space get to it and navigate it?*

Dimension 3: Social Inclusion. This dimension examines whether institutional and informational arrangements enable or obstruct equitable use. Five indicators capture different exclusion mechanisms: (a) operating hours relative to peak heat exposure periods, particularly for outdoor workers whose risk peaks between 11:00 and 16:00 (Hondula et al., 2015); (b) availability of drinking water and sanitation facilities; (c) multilingual or multi-channel availability of heat-warning information and facility signage (Sampson et al., 2013); (d) perceived safety for women, children, and older adults; and (e) explicit access policies regarding populations frequently excluded from public cooling—unhoused individuals in American cities, unregistered migrant workers in Chinese cities—through behavioral ordinances, registration requirements, or informal enforcement (Mitchell, 2003; Chan, 2019). It answers: *Once present, can all users remain and benefit equally?*

Dimension 4: Participatory Governance. This dimension assesses whether affected communities have meaningful input into the siting, design, and funding of cooling infrastructure. Drawing on Arnstein's (1969) ladder of citizen participation and Fainstein's (2010) democratic criterion, the relevant indicator is the extent to which community members—particularly those from high-vulnerability populations—participate not merely as consultees but as co-designers. It answers: *Did the people this space is for have a voice in creating it?*

4.2 The Accessibility Gate Model

The four dimensions are not independent axes to be scored separately and summed. They function as sequential gates: each must be passed before the next becomes relevant (Figure 2).

Figure 2. The accessibility gate model. At each gate, specific barrier types filter out segments of the target population. The populations most likely to be excluded at each successive gate are disproportionately those with the highest heat vulnerability.

A space that performs well on thermal metrics but poorly on spatial accessibility delivers cooling that never reaches its intended beneficiaries. A space that is thermally effective and physically reachable but institutionally exclusionary—open only during hours when its target population cannot visit, or requiring registration documents that migrant workers lack—still fails to convert performance into protection. A space that clears the first three gates but was sited without community input risks misalignment with actual patterns of use, and may lack the social embeddedness that transforms a facility into a trusted resource.

A critical caveat is warranted here, and Section 6 will return to it at length: the strict serial logic of the gate model may overstate the binary character of each transition. In practice, partial accessibility may deliver partial protection, and some gates may matter more than others in specific institutional contexts. The model's analytical value lies not in claiming that every gate is equally decisive but in insisting that the conversion from infrastructure to protection is a multi-stage process that conventional metrics truncate at stage one.

4.3 Positioning Against Existing Frameworks

The purpose of Table 1 is not to criticize individual frameworks for omitting functions they were never designed to perform; LEED is a building-performance certification, not an equity audit, and heat-vulnerability indices were conceived as exposure maps, not access evaluations. The comparison is instructive nonetheless because it reveals that when all available frameworks are considered together, the evaluative ecosystem as a whole still leaves the social inclusion and governance dimensions systematically unaddressed.

ICRI Dimension	Indicator	LEED / Three-Star	Heat-Vulnerability Indices	Voelkel et al. (2018)	ICRI
D1: Thermal Performance	Shade coverage and thermal comfort	Partial (landscaping credits address vegetation but not PET/UTCI)	Yes (core exposure metric)	Yes	Yes
D2: Spatial Accessibility	Pedestrian / transit travel time	Partial (location credits reward transit proximity but not subgroup travel time)	Rarely included	Yes (core variable; network-based)	Yes

	Universal design compliance	Minimum regulatory compliance only	No	No	Yes
D3: Social Inclusion	Operating hours vs. peak exposure	No	No	No	Yes
	Drinking water and sanitation	No	No	No	Yes
	Multilingual / multi-channel warnings	No	No	No	Yes
	Perceived safety (women / children / elderly)	No	No	No	Yes
	Access for excluded populations (unhoused, unregistered migrants)	No	No	No	Yes
D4: Governance	Community participation in siting and design	Partial (integrative process credits exist but do not target heat-vulnerable groups)	No	No	Yes

Table 1. Coverage of accessibility and inclusion indicators across existing frameworks and the proposed ICRI. "Partial" entries specify what is and is not covered. The pattern reveals a systematic gap in Dimensions 3 and 4, not within any single framework but across the evaluative ecosystem as a whole.

The pattern is consistent: existing frameworks concentrate their evaluative power in Dimensions 1 and, to a lesser extent, 2, while the dimensions that determine whether physical cooling translates into equitable protection remain unmapped. The ICRI does not replace existing frameworks; it extends them into uncharted terrain.

5. CASE ANALYSIS: THREE FAILURES OF CONVERSION

The three cases below are drawn from the published literature to illustrate distinct mechanisms by which the resilience-inclusivity gap manifests. Table 2 provides a structured overview.

Case	**Location**	**Object of Analysis**	**Principal Finding**	**Primary ICRI Gate(s)**
Tan et al. (2010); Chen et al. (2015)	Shanghai, heat waves 1998–2013	Heat mortality, cooling station accessibility, migrant worker exclusion	Mortality concentrated among elderly in poorly ventilated housing; *naliangdian* system structurally inaccessible to unregistered migrants	Gate 3 (institutional access via registration) and Gate 4 (community trust / embeddedness)
Sun et al. (2022)	Chongqing, 2022 heat wave	Extreme heat, power crisis, outdoor worker exposure	Record temperatures + hydropower shortfall disabled AC-dependent cooling; outdoor workers and peri-urban residents fell outside the cooling-infrastructure perimeter	Gate 1 (spatial reachability) compounded by infrastructure collapse under compound stress
Voelkel et al. (2018); Schramm et al. (2021)	Portland, citywide + 2021 heat dome	Travel time from vulnerable populations to cooling refuges	Vulnerable populations significantly farther from cooling facilities; 2021 heat dome confirmed lethal consequences of Gate 1 + Gate 3 compound failure	Gate 1 (physical reachability) + Gate 3 (informational legibility)

Table 2. Key cases mapped to ICRI gate model stages.

5.1 Shanghai: Cooling Stations and the Registration Barrier

Shanghai operates one of the world's largest municipal cooling-station (*naliangdian*) networks: by the 2010s, the city maintained over 5,000 designated cooling sites in community centers, shopping malls, bank lobbies, and subway stations, available to residents during heat-alert periods (Chen et al., 2015). The system was developed in response to documented heat-wave mortality—Tan et al. (2010) established that the 1998 and 2003 Shanghai heat waves produced significant excess mortality concentrated among elderly residents of older, poorly ventilated housing in densely built districts with minimal green space. The cooling-station network represented an explicit policy attempt to convert environmental investment into population-level protection.

Yet the conversion is mediated by an institutional gate that the system's designers did not address. Shanghai's *naliangdian* are administered through the community governance structure of *jiedao* (sub-district offices) and *juweihui* (residents' committees), which serve registered (*hukou*-holding) residents. Access is not formally restricted by registration status, but the informational channels through which cooling stations are publicized—community bulletin boards, *juweihui* WeChat groups, neighborhood volunteer networks—flow through the same registration-based infrastructure (Chan, 2019). Migrant workers without local *hukou*, who constitute a substantial proportion of Shanghai's population and who are disproportionately employed in outdoor construction, manufacturing, and delivery work, are structurally disconnected from these channels. They may live in the same district as a cooling station without learning of its existence, and even when aware, may reasonably perceive it as a facility for registered residents rather than for themselves.

The Shanghai case illustrates Gate 3 (informational legibility) and Gate 4 (social trust and community embeddedness) operating through institutional infrastructure rather than through the physical characteristics of the cooling space itself. The stations are thermally functional, spatially distributed, and often physically accessible; what fails is the informational and social pathway by which their availability is communicated to and trusted by populations outside the community-governance network. For the ICRI framework, this case demonstrates that the gate model must accommodate institutional exclusion mechanisms that vary by governance context: what *hukou*-mediated exclusion accomplishes in Chinese cities, loitering ordinances and documentation checks accomplish in American ones. The barrier mechanism differs; the analytical structure—a nominally public resource rendered selectively inaccessible by institutional filtering—is the same.

5.2 Chongqing 2022: Compound Stress and the Collapse of the Cooling Perimeter

The 2022 Chongqing heat wave exposed a mode of failure that the ICRI's gate model captures but that conventional single-hazard vulnerability assessments are not designed to anticipate: the compound collapse of multiple cooling pathways simultaneously. Between July and August 2022, Chongqing recorded temperatures exceeding 40°C for over 30 days, with peaks above 45°C in several districts (Sun et al., 2022). The extreme heat coincided with a severe drought that reduced hydropower generation on the Yangtze and its tributaries, creating a power crisis that forced rolling blackouts and electricity rationing across the municipality. The consequence was that the dominant private cooling strategy—air conditioning—was undermined by the same climatic event that made it most needed. Residents who relied on AC were pushed toward public cooling infrastructure at precisely the moment when that infrastructure was itself compromised by power instability.

Under this compound stress, the spatial distribution of remaining functional cooling resources became the decisive variable, and its inequities became starkly visible. Central Chongqing's commercial districts retained power priority and contained the densest concentration of air-conditioned public spaces—malls, transit stations, government buildings. Peri-urban districts and industrial zones, where much of the city's construction workforce lives in dormitory-style housing with limited or no air conditioning, experienced both higher ambient temperatures (due to the heat-island gradient) and longer power interruptions. The cooling resources that remained functional were concentrated in areas already better served; the populations pushed out of private cooling by the power crisis were concentrated in areas where public alternatives were thinnest.

Outdoor workers in Chongqing faced a doubly compounded exposure. Construction, road maintenance, and agricultural labor continued during peak heat hours, and the work sites—elevated concrete platforms, unshaded road corridors, open fields—offered no shade infrastructure of the kind that the ICRI's Dimension 1 evaluates. Workers' access to cooling was not merely a question of traveling to a cooling station after work but of surviving the workday itself without heat illness. As in the Phoenix literature (Harlan et al., 2006; Hondula et al., 2015), the Chongqing case reveals a population for whom "public space" as defined by urban planning is categorically the wrong unit of analysis: their heat exposure occurs in spaces governed by labor regulation, not by municipal cooling-infrastructure policy.

The Chongqing case extends the gate model in a direction that the framework must acknowledge as a boundary condition. Under compound stress—when the same climatic event that drives heat vulnerability also degrades the infrastructure designed to mitigate it—the sequential logic of the gate model becomes less a matter of individual gate failure and more a matter of systemic collapse. All gates narrow simultaneously. The framework's diagnostic utility is preserved—it can identify which gates narrow fastest and for which populations—but its implicit assumption that gates can be addressed independently through targeted policy interventions is strained when the underlying power, water, and transport systems are themselves destabilized.

5.3 Portland 2021: The Geometry of Exclusion under Temporal Compression

Voelkel et al. (2018) operationalized the spatial accessibility dimension with a methodological precision that no prior study had achieved. Mapping cooling refuges in Portland against the residential locations of heat-vulnerable populations, they calculated network-based travel times using actual pedestrian and transit infrastructure—sidewalk networks, bus routes, stop locations, service frequencies—rather than Euclidean distance. The finding was that vulnerable populations were significantly farther from cooling facilities, with the disparity most acute for elderly residents without vehicles, persons with disabilities, and residents of neighborhoods with low transit frequency.

The June 2021 heat dome subjected this spatial geometry to a lethal test. Multnomah County opened emergency cooling centers, but several were in areas poorly served by transit, and information about their locations was disseminated primarily through English-language digital channels (Multnomah County, 2022). The 96 heat-related deaths in Oregon were concentrated among elderly residents living alone in homes without air conditioning—many unaware of or unable to reach available facilities (Schramm et al., 2021). Gate 1 (physical reachability) failed for carless residents in transit-poor neighborhoods. Gate 3 (informational legibility) failed for those who did not use smartphones or read English. The compound failure of both gates was fatal for the population at their intersection: elderly, linguistically isolated, carless, and alone.

What distinguishes the Portland case from the Chinese cases is the temporal compression of the event. The 2021 heat dome was acute: three days of unprecedented temperatures in a city calibrated for a temperate marine climate. The access failures it exposed were not chronic gaps to be addressed over planning cycles; they were immediate, lethal, and visible. Multnomah County's after-action report (2022) identified transit accessibility and multilingual communication as its two priority recommendations—a post-mortem validation, at the cost of 96 lives, of the gate model's logic. In contrast, Shanghai's exclusion of migrant workers from cooling-station networks operates as a chronic, low-visibility structural pattern that produces excess morbidity without generating the concentrated mortality event that triggers institutional review. The ICRI framework must be sensitive to both temporalities: the acute catastrophe that reveals access failures through concentrated death, and the chronic exclusion that produces diffuse suffering below the threshold of political visibility.

6. DISCUSSION

6.1 Policy Implications

The ICRI framework implies a reorientation of the policy logic governing climate adaptation investment, with implications that cut across governance contexts.

The siting of cooling infrastructure should be determined by the intersection of heat exposure and population vulnerability, weighted by transit accessibility, rather than by land availability or administrative convenience. Spatial justice in cooling provision requires distributing facilities in proportion to need—a principle articulated in the climate-justice literature (Shi et al., 2016) but rarely operationalized at the facility-siting level.

Operating hours for publicly funded cooling facilities should be calibrated to the temporal exposure patterns of target populations. The standard business-hour schedule misaligns with outdoor workers' peak exposure (11:00–16:00), with afternoon hours of greatest physiological vulnerability for elderly residents, and with weekends and holidays when many public buildings close.

Information dissemination must be treated as a structural component of cooling infrastructure, not an ancillary add-on. In American cities, this means multilingual communication through trusted community channels rather than digital platforms alone (Sampson et al., 2013). In Chinese cities, it means extending cooling-station publicity beyond *hukou*-based community networks to reach migrant populations through employer communication channels, labor unions, and social media platforms that migrants actually use. The informational gate is institutionally specific but structurally universal.

Access policies must be designed to include rather than exclude the populations most at risk. In American cities, this requires confronting loitering prohibitions and documentation barriers that bar unhoused individuals from cooling centers (Mitchell, 2003). In Chinese cities, it requires decoupling cooling-station access from the community-governance infrastructure that filters by registration status. The policy mechanism differs; the equity principle is the same.

6.2 Design Implications: Toward Thermal Refuge

For architects and landscape architects, the ICRI framework implies a reconceptualization of design success toward what might be called *thermal refuge*: a space defined not by a temperature threshold but by a constellation of features enabling sustained, safe, equitable occupancy during a heat event. A thermal refuge, operationally defined, requires at minimum: effective shade during peak solar hours (designed for solar angle, not visual effect; Aminipouri et al., 2019), surfaces that remain below contact-burn thresholds in direct sunlight (Watanabe et al., 2014), accessible pathways and seating accommodating wheelchair users, stroller-pushing parents, and workers in protective equipment, drinking water, restroom access, and clear multilingual signage identifying the space as a designated cooling facility available to all. This definition shifts the evaluative orientation from the space-as-object—measured by its thermodynamic properties—to the space-as-social-relationship between a vulnerable body and the built environment that either protects or fails to protect it. A thermal refuge is not a cooler park; it is a park that a specific person, with specific limitations, can reach, enter, understand, occupy safely for hours, and trust.

6.3 Governance Implications: Participation as Precondition

The distributional failures documented in Shanghai, Chongqing, and Portland share a common governance deficit: the populations most affected by extreme heat had the least input into the design and allocation of protective resources. Arnstein's (1969) distinction between tokenistic consultation and genuine co-design remains operative. Participatory budgeting for climate adaptation (Cabannes, 2004), community-based heat action planning, and co-design processes rooted in high-vulnerability neighborhoods are institutional mechanisms for closing this governance gap—mechanisms that must be adapted to the specific governance structures of each context but that rest on a universal principle: procedural justice is not a supplement to distributional justice but its precondition.

6.4 Interrogating the Framework: Limitations and Internal Tensions

The ICRI's analytical power comes with commitments that deserve scrutiny rather than quiet acceptance.

The gate model's serial logic—failure at any stage nullifies preceding value—is its sharpest analytical edge but also its most vulnerable assumption. Partial accessibility may yield partial protection: a cooling station reachable only by car still protects residents who own cars, and signage in the local language still serves local-language speakers. The question is whether partial protection for some populations constitutes adequate resilience or merely redistributes risk. The ICRI takes the latter position as a normative commitment, but the framework would benefit from empirical work examining whether specific gate failures produce absolute exclusion or merely differential access, and whether threshold effects change outcomes significantly.

A second tension concerns failure modes the gate model does not predict. It is possible for a facility to clear all four gates—thermally effective, spatially accessible, institutionally inclusive, participatorily governed—and still experience low utilization because of factors the framework does not capture: cultural stigma associated with using public cooling facilities, distrust of government institutions rooted in historical experience, or the simple inertia of not changing established daily routines in response to a hazard that feels familiar. The Chongqing case, where some residents with access to functional cooling centers chose to remain in dangerously hot homes, suggests that the gate model's necessary conditions may not always be sufficient. This is not a fatal flaw—the framework identifies the barriers whose removal is necessary even if not always sufficient—but it is a limit that future work should address, potentially by adding a fifth dimension capturing the sociocultural preconditions of utilization.

Third, the ICRI as presented here is a conceptual framework, not a validated measurement instrument. Its indicators require operationalization: what threshold of multilingual coverage constitutes adequate accessibility? How should "perceived safety" be measured? How should governance quality be scored when participation is tokenistic? These are empirical questions requiring primary research—community surveys, spatial analyses with disaggregated population data, institutional evaluations. The framework's current value is cartographic: it maps the evaluative terrain that existing instruments leave uncovered, and specifies the research agenda required to fill it.

A fourth limitation is the boundary between public-space governance and labor regulation. The outdoor-worker analysis in the Chongqing and Phoenix literatures pushes the ICRI beyond its proper domain. The framework can register the absence of shade at a construction site, but it cannot evaluate the labor-regulation regime that produces that absence. This boundary should be understood as a diagnostic signal—"this population's heat vulnerability cannot be addressed by public-space interventions alone"—rather than an evaluative claim within the ICRI's scope.

7. CONCLUSION

Climate-resilient public space is among the most tangible expressions of a city's commitment to protecting its residents from a warming planet. Shade trees, cooling stations, misting corridors, and green infrastructure represent real investments that demonstrably reduce ambient temperatures and heat-related physiological stress. The question this paper has pressed is not whether these interventions work in thermodynamic terms—they do—but whether their benefits reach the populations for whom they are most urgently needed. The evidence reviewed here, spanning two national contexts and three cities, answers that question with consistent clarity: they often do not.

The Inclusive Climate-Resilience Index makes the structure of that failure legible. By organizing evaluation along four sequential dimensions—thermal performance, spatial accessibility, social inclusion, and participatory governance—the ICRI traces the conversion pathway from infrastructure to protection and identifies the gates at which vulnerable populations are filtered out. In Shanghai, the gate is institutional: a registration-based community governance system that channels information and trust through networks from which migrant workers are excluded. In Chongqing, the gate is spatial and systemic: a compound crisis that simultaneously intensified heat exposure and degraded the cooling infrastructure meant to mitigate it, with the remaining resources concentrated where they were least needed. In Portland, the gate is geometric and informational: a transit network that does not reach the populations it must serve, and a warning system that speaks only to the already-connected. The mechanisms are context-specific. The pattern is universal.

The deeper argument is about what resilience means and for whom. If measured at the system level—aggregate cooling capacity, canopy coverage ratios, number of designated cooling stations—a city can declare itself resilient while specific populations within it continue to die. If measured at the level of the most vulnerable person who needs protection and does not receive it, the evaluative picture changes fundamentally. The ICRI takes the latter position. It insists that the unit of analysis for climate resilience is not the space, not the city, not the system, but the person—the specific, embodied, socially situated person—who either receives protection or does not.

Climate adaptation that does not attend to accessibility, inclusion, and governance does not fall short of an ideal; it reproduces the conditions that made certain populations heat-vulnerable in the first place. The research agenda that follows is clear: operationalize the ICRI's indicators through primary data collection in diverse urban contexts, test the gate model's serial logic against empirical utilization data, and extend the framework to the rapidly urbanizing cities of the Global South where extreme heat and institutional exclusion are co-accelerating. The evaluative infrastructure for climate justice lags behind the physical infrastructure for climate adaptation. Closing that gap is the task.

REFERENCES

[1] Aminipouri, M., Knudby, A., Krayenhoff, E. S., Zickfeld, K., & Middel, A. (2019). Urban tree planting to maintain outdoor thermal comfort under climate change: The case of Vancouver's local climate zones. *Building and Environment*, *158*, 226–236. https://doi.org/10.1016/j.buildenv.2019.05.022

[2] Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., Reeve, K., & Teicher, H. (2016). Equity impacts of urban land use planning for climate adaptation: Critical perspectives from the Global North and South. *Journal of Planning Education and Research*, *36*(3), 333–348. https://doi.org/10.1177/0739456X16645166

[3] Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, *35*(4), 216–224. https://doi.org/10.1080/01944366908977225

[4] Baumeister, R. F., & Leary, M. R. (1997). Writing narrative literature reviews. *Review of General Psychology*, *1*(3), 311–320. https://doi.org/10.1037/1089-2680.1.3.311

[5] Bullard, R. D. (1990). *Dumping in Dixie: Race, class, and environmental quality*. Westview Press.

[6] Cabannes, Y. (2004). Participatory budgeting: A significant contribution to participatory democracy. *Environment and Urbanization*, *16*(1), 27–46. https://doi.org/10.1177/095624780401600104

[7] Chan, K. W. (2019). China's hukou system at 60: Continuity and reform. In R. Yep, J. Wang, & T. Johnson (Eds.), *Handbook on urban development in China* (pp. 59–79). Edward Elgar. https://doi.org/10.4337/9781786431639.00011

[8] Chen, K., Zhou, L., Chen, X., Ma, Z., Liu, Y., Huang, L., Bi, J., & Kinney, P. L. (2015). Urbanization level and vulnerability to heat-related mortality in Jiangsu Province, China. *Environmental Health Perspectives*, *124*(12), 1863–1869. https://doi.org/10.1289/EHP204

[9] CMA (China Meteorological Administration). (2022). *China climate bulletin 2022*. China Meteorological Press.

[10] Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

[11] Fainstein, S. S. (2010). *The just city*. Cornell University Press.

[12] Fraser, N. (2009). *Scales of justice: Reimagining political space in a globalizing world*. Columbia University Press.

[13] Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, *26*(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

[14] Gronlund, C. J. (2014). Racial and socioeconomic disparities in heat-related health effects and their mechanisms: A review. *Current Epidemiology Reports*, *1*(3), 165–173. https://doi.org/10.1007/s40471-014-0014-4

[15] Guardaro, M., Messerschmidt, M., Hondula, D. M., Grimm, N. B., & Redman, C. L. (2020). Building community heat action plans story by story: A three neighborhood case study. *Cities*, *107*, 102886. https://doi.org/10.1016/j.cities.2020.102886

[16] Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. *Social Science & Medicine*, *63*(11), 2847–2863. https://doi.org/10.1016/j.socscimed.2006.07.030

[17] He, B.-J. (2019). Towards the next generation of green building for urban heat island mitigation: Zero UHI impact building. *Sustainable Cities and Society*, *50*, 101647. https://doi.org/10.1016/j.scs.2019.101647

[18] Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). The effects of historical housing policies on resident exposure to intra-urban heat: A study of 108 US urban areas. *Climate*, *8*(1), 12. https://doi.org/10.3390/cli8010012

[19] Hondula, D. M., Davis, R. E., Leisten, M. J., Saha, M. V., Veazey, L. M., & Wegner, C. R. (2015). Fine-scale spatial variability of heat-related mortality in Philadelphia County, USA, from 1983–2008: A case-series analysis. *Environmental Health*, *11*(1), 16. https://doi.org/10.1186/1476-069X-11-16

[20] Hsu, A., Sheriff, G., Chakraborty, T., & Manya, D. (2021). Disproportionate exposure to urban heat island intensity across major US cities. *Nature Communications*, *12*, 2721. https://doi.org/10.1038/s41467-021-22799-5

[21] Imrie, R. (2012). Universalism, universal design and equitable access to the built environment. *Disability and Rehabilitation*, *34*(10), 873–882. https://doi.org/10.3109/09638288.2011.624250

[22] Keith, L., Meerow, S., & Wagner, T. (2021). Planning for extreme heat: A review. *Journal of Extreme Events*, *6*(3–4), 2050003. https://doi.org/10.1142/S2345737620500037

[23] Kenney, W. L., Craighead, D. H., & Alexander, L. M. (2014). Heat waves, aging, and human cardiovascular health. *Medicine and Science in Sports and Exercise*, *46*(10), 1891–1899. https://doi.org/10.1249/MSS.0000000000000325

[24] Klinenberg, E. (2002). *Heat wave: A social autopsy of disaster in Chicago*. University of Chicago Press. https://doi.org/10.7208/chicago/9780226026718.001.0001

[25] Mace, R. L., Hardie, G. J., & Place, J. P. (1997). *Accessible environments: Toward universal design*. Center for Accessible Housing, North Carolina State University.

[26] Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011

[27] Middel, A., Turner, V. K., Schneider, F. A., Zhang, Y., & Stiller, M. (2020). Solar reflective pavements—A policy panacea to heat mitigation? *Environmental Research Letters*, *15*(6), 064016. https://doi.org/10.1088/1748-9326/ab87d4

[28] Mitchell, B. C., & Chakraborty, J. (2015). Landscapes of thermal inequity: Disproportionate exposure to urban heat in the three largest US cities. *Environmental Research Letters*, *10*(11), 115005. https://doi.org/10.1088/1748-9326/10/11/115005

[29] Mitchell, D. (2003). *The right to the city: Social justice and the fight for public space*. Guilford Press.

[30] Mohai, P., Pellow, D., & Roberts, J. T. (2009). Environmental justice. *Annual Review of Environment and Resources*, *34*, 405–430. https://doi.org/10.1146/annurev-environ-082508-094348

[31] Multnomah County. (2022). *2021 extreme heat event after-action report*. Multnomah County Emergency Management.

[32] Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). *Urban climates*. Cambridge University Press. https://doi.org/10.1017/9781139016476

[33] Peng, S., Piao, S., Ciais, P., Friedlingstein, P., Ottle, C., Bréon, F.-M., Nan, H., Zhou, L., & Myneni, R. B. (2012). Surface urban heat island across 419 global big cities. *Environmental Science & Technology*, *46*(2), 696–703. https://doi.org/10.1021/es2030438

[34] Reid, C. E., O'Neill, M. S., Gronlund, C. J., Brines, S. J., Brown, D. G., Diez-Roux, A. V., & Schwartz, J. (2009). Mapping community determinants of heat vulnerability. *Environmental Health Perspectives*, *117*(11), 1730–1736. https://doi.org/10.1289/ehp.0900683

[35] Sampson, N. R., Gronlund, C. J., Buxton, M. A., Catalano, L., White-Newsome, J. L., Conlon, K. C., O'Neill, M. S., McCormick, S., & Parker, E. A. (2013). Staying cool in a changing climate: Reaching vulnerable populations during heat events. *Global Environmental Change*, *23*(2), 475–484. https://doi.org/10.1016/j.gloenvcha.2012.12.011

[36] Schlosberg, D. (2007). *Defining environmental justice: Theories, movements, and nature*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199286294.001.0001

[37] Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: Climate change and the discourse of environmental justice. *WIREs Climate Change*, *5*(3), 359–374. https://doi.org/10.1002/wcc.275

[38] Schramm, P. J., Vaidyanathan, A., Radhakrishnan, L., Gates, A., Harber, K., & Hsu, P. (2021). Heat-related emergency department visits during the Northwestern heat wave—United States, June 2021. *Morbidity and Mortality Weekly Report*, *70*(29), 1020–1021. https://doi.org/10.15585/mmwr.mm7029e1

[39] Shashua-Bar, L., Pearlmutter, D., & Erell, E. (2011). The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. *International Journal of Climatology*, *31*(10), 1498–1506. https://doi.org/10.1002/joc.2177

[40] Shi, L., Chu, E., Anguelovski, I., Ayber-Nishi, A., Debats, J., Goh, K., Kiser, T., Mauzerall, D. L., Schantz-Klause, R., & Schulman, S. (2016). Roadmap towards justice in urban climate adaptation research. *Nature Climate Change*, *6*(2), 131–137. https://doi.org/10.1038/nclimate2999

[41] Steinfeld, E., & Maisel, J. (2012). *Universal design: Creating inclusive environments*. Wiley.

[42] Stone, B., Vargo, J., Liu, P., Habeeb, D., DeLucia, A., Trail, M., Hu, Y., & Russell, A. (2012). Avoided heat-related mortality through climate adaptation strategies in three US cities. *PLoS ONE*, *7*(8), e44497. https://doi.org/10.1371/journal.pone.0044497

[43] Sun, Y., Dong, S., Hu, T., & Zhang, X. (2022). Attribution of the unprecedented heat event of 2022 across the Yangtze River Valley. *Climatic Change*, *175*(3–4), 22. https://doi.org/10.1007/s10584-022-03446-0

[44] Tan, J., Zheng, Y., Tang, X., Guo, C., Li, L., Song, G., Zhen, X., Yuan, D., Kalkstein, A. J., Li, F., & Chen, H. (2010). The urban heat island and its impact on heat waves and human health in Shanghai. *International Journal of Biometeorology*, *54*(1), 75–84. https://doi.org/10.1007/s00484-009-0256-x

[45] Uejio, C. K., Wilhelmi, O. V., Golden, J. S., Mills, D. M., Gulino, S. P., & Samenow, J. P. (2011). Intra-urban societal vulnerability to extreme heat: The role of heat exposure and the built environment, socioeconomics, and neighborhood stability. *Health & Place*, *17*(2), 498–507. https://doi.org/10.1016/j.healthplace.2010.12.005

[46] Voelkel, J., Hellman, D., Sakuma, R., & Shandas, V. (2018). Assessing vulnerability to urban heat: A study of disproportionate heat exposure and access to refuge by socio-demographic status in Portland, Oregon. *International Journal of Environmental Research and Public Health*, *15*(4), 640. https://doi.org/10.3390/ijerph15040640

[47] Watanabe, S., Nagano, K., Ishii, J., & Horikoshi, T. (2014). Evaluation of outdoor thermal comfort in sunlight, building shade, and pergola shade during summer in a humid subtropical region. *Building and Environment*, *82*, 556–565. https://doi.org/10.1016/j.buildenv.2014.10.002

[48] Wilhelmi, O. V., & Hayden, M. H. (2010). Connecting people and place: A new framework for reducing urban vulnerability to extreme heat. *Environmental Research Letters*, *5*(1), 014021. https://doi.org/10.1088/1748-9326/5/1/014021

[49] Young, I. M. (1990). *Justice and the politics of difference*. Princeton University Press.