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Viewpoint

Necessary Considerations When Framing Urban Heat Resilience as an Infrastructure Issue

Theodore C. Lim

ABSTRACT

Conceptualizing urban heat resilience as an infrastructure problem emphasizes the urgency with which we must adapt to global climate change, but also risks ignoring the continued marginalization that vulnerable populations experience as a result of infrastructure decisions. In this Viewpoint, I use my experience with participatory action research (PAR) in building urban heat resilience to show the ways in which an infrastructure framing presents opportunities, and the ways in which planners a) need to be aware of infrastructure as socio-technical systems and b) recognize spatial networks of social capital to appropriately approach interventions that benefit those most likely to be adversely affected by rising temperatures in cities.

Keywords: climate justice, heat resilience, infrastructure planning, participatory action research, resilience implementation gap

Increased temperatures, a consequence of global climate change, are associated with increased deaths as well as other impacts on livability and wellbeing (Ballester et al., 2023; Hansen et al., 2008; Sailor et al., 2019; Sanz-Barbero et al., 2018; Thomson et al., 2019). With climate change, heat waves are increasing in frequency, intensity, and duration (Habeeb et al., 2015). The urban heat island (UHI) effect—the phenomenon in which urban areas have average temperatures 1 °C to 4 °C hotter than their rural surroundings—is well documented (Grimm et al., 2008; Oke, 1982). Within cities the spatial distribution of social vulnerability to rising temperatures has implications for climate justice (Hsu et al., 2021). Though UHIs have been documented for decades, planning for urban heat is still a new area of planning (Keith et al., 2023). In considering how urban environments should be modified to address both the risks of climate change and ensure just outcomes, what are the opportunities and challenges in viewing heat resilience as an issue that could be addressed through the tools and frameworks of infrastructure planning?

This viewpoint draws on my experiences with participatory action research (PAR) in heat resilience planning in Roanoke (VA). *Heat resilience* refers to the capacity of a community to deal with the negative impacts of increased temperatures and heat waves. Roanoke has relatively mild summers compared with other cities in the American South, and therefore many do not recognize heat as a problem. Yet, our work[1] has revealed that residents already struggle to cope with heat, lack access to air conditioning, and perceive heat as exacerbating other problems. The purpose of this viewpoint is twofold: 1) to outline the ways in which *infrastructure* provides a useful theoretical and practical framework and how it does not and 2) to illustrate how deep community engagement reveals the nature of the problem of urban heat and its potential solution space. Opportunities for framing heat resilience as an infrastructure issue include enabling access to resources and processes for project implementation and shifting perceptions of thermal comfort as an individual/-private issue to a structural/public issue. Shortcomings include the fact that infrastructure planning processes are viewed with distrust in vulnerable neighborhoods, that infrastructure logics tend to be dominated by neoliberal and technocratic tendencies that may not benefit those most at risk of increased temperatures, and that the compartmentalized nature of infrastructure planning can exacerbate existing trust issues between residents and public agencies. I conclude by connecting experiences in Roanoke with an emerging area of planning theory and practice: reparative planning.

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Table 1.. Sociotechnical theories explaining infrastructure.

Theory	Explanation	Representative works
Large technical systems	Infrastructure systems are reproduced through material (roads, bridges) and immaterial (norms of training programs, standards, knowledge-granting institutions, government agency protocols) components. Both material and immaterial components of infrastructure exhibit durability/obduracy that make change difficult.	(Hughes, 1983)
Actor–network theory	Infrastructure systems are scientific and technical objects that are integrated within networks of social relations and meanings. Infrastructural components (rebar, cement) take on a human-like agency of their own, through how they interact with humans and other artifacts, including engineers, politicians, marketing strategies, and manufacturing techniques.	(Latour, 1999)
Social construction of technology	Social groups construct meanings and different relationships to infrastructures. Infrastructure may be associated with ideas that change or persist over time given the social context, and these ideas draw on values, goals, and tacit knowledge and practices used by the social group.	(Bijker et al., 1987)

What Is Infrastructure?

The *Oxford English Dictionary* defines *infrastructure* as "the basic physical and organizational structures and facilities (e.g., buildings, roads, power supplies) needed for the operation of a society or enterprise" (Oxford University Press, 2020). The definition of infrastructure is dependent on one's perspective: As infrastructure expert Susan Leigh Star (1999) pointed out: "For the person in a wheelchair, the stairs and doorjamb in front of a building are not seamless subtenders of use, but barriers. One person's infrastructure is another's … difficulty" (p. 380). What constitutes infrastructure is also dependent on political context: In the United States, the Cybersecurity and Infrastructure Security Agency lists 16 critical infrastructure sectors within its Infrastructure Resilience Planning Framework, including health care and public health and emergency services (Cybersecurity and Infrastructure Security Agency, 2022), whereas Republicans argued against even counting concrete and steel structures of transportation and wires and pipes for utilities as "real infrastructure" in the months leading up to the passage of the Bipartisan Infrastructure Law in 2021 (Rizzo, 2021). What we recognize as infrastructure therefore reflects our priorities as a society, as well as our motivations to invest capital to address collective problems.

In addition, though we may recognize needs to improve infrastructural systems or adapt them to changing conditions—such as global climate change, population growth or decline, or even changing societal standards—doing so often proves difficult. The theories in Table 1 emphasize how infrastructure extends beyond the physical to include elements of meaning, norms, and institutions, depicting infrastructure as *sociotechnical systems*. Adapting and planning infrastructure therefore requires addressing both its physical/technical components and its social components.

Opportunities: Reasons to Frame Heat Resilience as an Infrastructure Issue

Infrastructure Decisions Contribute to Urban Heat Islands

The UHI effect is caused, in part, by infrastructure. Infrastructure decisions contribute to intra-urban heat islands. Urban renewal was a period of rapid infrastructure development in many U.S. cities that forcibly removed residents of African American neighborhoods. In Roanoke, where I work, the vibrant African American neighborhood of Gainsboro was declared blighted, enabling the city to obtain properties with very little compensation and scattering residents across the city (Fullilove, 2001). Urban renewal projects in the Gainsboro neighborhood included the 581 Highway, a convention center, and a Coca-Cola bottling and distribution plant. Each of these sites comprised entirely heat-holding impervious materials—concrete and asphalt—and very little vegetation. According to a 2020 community science air temperature mapping campaign

conducted in Roanoke, these and other previously segregated neighborhoods are some of the hottest areas of the city. This pattern holds across many U.S. cities (Hoffman et al., 2020; Wilson, 2020).

As the critical benefits derived from trees, vegetation, and open space are recognized and valued, they are increasingly recognized as green infrastructure. Tree canopy cover, which can lower temperatures in cities, is also associated with income and race in the United States (Locke et al., 2020; Schwarz et al., 2015).

There Are Established Processes of Infrastructure Planning

If various infrastructures have caused the risks associated with extreme heat, then new infrastructures could be planned and built to mitigate those risks. Interventions can include networks of cooling shelters, removal of impervious surface and highways, changing of surface albedo, shade structures, green roofs and walls, vegetation, open space, and trees (Keith & Meerow, 2022). For many of these interventions, cities already have means of planning and prioritizing projects. Infrastructure planning also has a clear relationship to implementation through capital improvements programs and budgeting processes and both funding and financing mechanisms.

In the United States, the passage of the Bipartisan Infrastructure Law in 2021 and the Inflation Reduction Act in 2022 have focused attention on how to plan and implement infrastructure quickly and justly, especially with respect to climate mitigation and adaptation. Together the Bipartisan Infrastructure Law (2021) and Inflation Reduction Act (2022) reflected a once-in-a-generation infusion of federal funding into infrastructure. Because *resilient* infrastructure planning is now receiving attention and resources, it is appealing to frame urban heat resilience as an infrastructure issue to direct resources toward proactive planning to address higher temperatures in cities.

Infrastructure can also be delivered through development regulations and fees (Elmer & Leigland, 2013). In Roanoke, we have conducted exploratory analyses of what a development impact fee for a new development converting forested land to single-family home development could look like and how the collected fees might be used to mitigate temperatures in other areas of the city. This idea is not unlike how many cities already charge stormwater utility fees differentially for properties' generation of stormwater runoff. These collected fees are used to make improvements to water quality or flood mitigation infrastructure, including green infrastructure (Cousins & Hill, 2021). Indeed, the idea of defining a new utility to fund UHI mitigation has previously been proposed (Larsen, 2015); if such measures were recognized as infrastructure, it could be one way of ensuring future sources of funding.

Framing Heat as an Infrastructure Issue Allows People to Connect Their Personal Experiences With Structural Issues That Can Be Addressed Through Collective Action

Unlike the impacts of other weather-related disasters, which occur very visibly in public spaces, deaths and other negative experiences related to elevated temperatures are often experienced privately. Moreover, many informational documents on how to stay safe during heat waves tend to emphasize personal behaviors, such as staying hydrated and finding air-conditioned spaces, which can decouple experiences of coping with heat from wider structural issues of inequality and poverty (Hamstead, 2023a).

In my work with middle school students in Roanoke, I have observed shifts in perception from heat as an individual issue—to be solved by getting more air conditioning, taking cold showers, or drinking more water—to a structural issue that is caused by infrastructure and land use decisions that can be addressed through collective action. This shift coincides with conversations about how decisions have been made about infrastructure (Lim et al., 2022). I have observed as students who were initially embarrassed to talk about feeling too hot in their homes in front of their peers eventually opened up and talked about how their neighborhood lacks trees and shade and has roads that are too wide and stay hot even after the sun goes down.

Talking about green and conventional infrastructure decisions shifts conversations away from whether someone's family can or cannot afford air conditioning and toward how to present information to city officials about neighborhood improvements. Focusing on what can be done from an infrastructure and collective action perspective also importantly gives youth hope and agency to face the challenges of climate change. Indeed, others have pointed out that infrastructure can be an important *locus of action and focus* for achieving reparations for past harms due to its indispensable, normative, and networked nature (Song & Mizrahi, 2023).

Shortcomings to Address

Infrastructure Planning Processes Have Caused Alienation From Civic Participation and Distrust of Government Intervention

Given the relatively recent history of forced displacement from urban renewal, many African American residents of Roanoke have long-standing suspicions of any government action on infrastructure decisions. In particular,

residents questioned *for whom* infrastructure improvements were being made. For example, conversations about how the hottest neighborhoods had the least amount of tree canopy cover led to the suggestion that tree canopy should be increased. However, residents had mixed reactions and questioned *for whom* trees were being planted, with some expressing concern about displacement (Anguelovski et al., 2019). This question was especially pointed given that trees could require decades to grow large enough to provide enough shade to mitigate the risks and impacts of rising temperatures.

Tree planting as an approach to mitigating temperatures also did not take into account concerns that maintenance costs would fall on residents and that tree upkeep—branch removal, leaf raking and disposal, and damage to homes and cars from falling branches—was a financial burden on residents. These concerns have also been documented in other cities (Carmichael & McDonough, 2019; Riedman et al., 2022). Residents also expressed perceptions that the city often unreasonably enforced code requiring upkeep of landscaping. They told stories of older residents with health issues who were unable to mow their lawns receiving citations from the city. These stories were shared to illustrate how residents did not think the city was engaging them in good faith on ways to improve their landscapes but rather taking advantage of instances to exert power through punishment and policing.

Planners need to be sensitive to their perceived roles as state actors and the social meanings, such as policing and displacement, that are attached to land and landscape, including trees and vegetation.

Infrastructure Logics Tend to Be Dominated by Neoliberal and Technocratic Tendencies That May Not Benefit Those Most at Risk of Increased Temperatures

Neoliberalism refers to an ideology that prioritizes free markets, economic growth, limited government intervention, and efficiency. Neoliberal ideology underlies urban austerity and been used as a logic for reducing government-provided services, which often results in further marginalization of the poor and entrenchment of inequality, including the idea of urban resilience (Slater, 2014). For example, requirements that developers build green infrastructure are often touted as economically efficient because public funds do not have to be allocated to build and maintain infrastructure on private property. However, leaving this collective responsibility of infrastructure provision to the market results in spatial inequities in access to and benefits from green infrastructure (Mandarano & Meenar, 2017). In addition, maintenance of both conventional and green infrastructures has often been inadequate in lower-income areas of cities (Hendricks & Van Zandt, 2021; Rivera & Hendricks, 2022).

Infrastructure planning also often relies on the concept of a quantified *level of service* to prioritize new projects (Elmer & Leigland, 2013). This practice can presume a direct relationship between quantification of inequitable services and a prescription to increase service provision, but reliance on quantified measures risks not serving the actual needs of residents. For example, numerous quantitative studies have documented inequitable public green space in minoritized and lower-income neighborhoods, but the amount of park area did not necessarily capture the historical or lived experience of inequity (Hoover & Lim, 2021).

Quantitative measurements of outdoor air or surface temperatures that might be used as proxies for level of service have not captured the lived experience of how people cope with heat and how this intersects with other issues they face. Home weatherization and availability of and the ability to afford air conditioning, as well as residents' occupations, all influence how they *weather* thermal insecurity (Hamstead, 2023b). Quantification of outdoor air temperature and its association with tree canopy cover also has pointed to a presumed solution (tree planting) that has been shown to have very limited effect on experienced temperatures indoors during heat waves (Larsen et al., 2023).

In Roanoke, community partners expressed that existing parks have been underused because of lack of safe transportation routes for residents who do not drive and because parents worry about gun violence in outdoor spaces and lack of adult supervision for children. Residents expressed needs to expand youth development and other programs that could activate use of existing parks and that the city needed to address pedestrian safety.

Planners need to question the status quo of infrastructure practice by interrogating whom these practices have benefited historically. Planners need to create authentic engagement contexts in which quantitative data are used to elicit and affirm personal experiences of heat and thermal comfort. Planners should actively seek out partnerships to incorporate diverse kinds of knowledge and spatiality of participation and better tailor infrastructure interventions to specific communities.

Compartmentalized Nature of Infrastructure Planning Can Exacerbate Existing Trust Issues Between Residents and Public Agencies

In cities that have created heat resilience officer positions, one of their roles is to coordinate efforts between existing city agencies. Usually, this is motivated by better internal efficiency to provide services. In our work, I

have also observed another effect of compartmentalization of government functions: The failure to respond to the needs of residents by one agency providing infrastructure services resulted in further mistrust of the intentions of another agency attempting to provide infrastructure services.

We were surprised when another infrastructure planning example was raised during discussions of heat: the construction of bike lanes to increase safety throughout the city. Residents were suspicious about whom the bike lanes were being built for. This suspicion was compounded by two other factors: 1) The city had recently redrawn the Downtown boundary to incorporate part of Gainsboro, a historically African American neighborhood, which angered some residents who believed that this was another attempt to displace them through real estate development. Bike lanes that would increase connectivity from within Gainsboro to Downtown appeared to serve the interests of outsiders of the African American neighborhood rather than the residents themselves. 2) Residents of the African American neighborhoods had long been organizing for other transportation-related improvements—more reliable bus service, sidewalks to bus stops, and improved bus shelters—with little success. In this case, infrastructure provision, even purportedly motivated by equity goals (trees and bike lanes in the places that do not have them), made residents feel ignored and further alienated them from public decision-making processes. In the eyes of residents, representatives from the city who were narrowly focused on singular goals were not listening to the voices of residents and were not aware of important context.

Planners need to be aware of historically contextualized, interrelated experiences of the built environment, including how different infrastructures and social programs are prioritized in relation to one another. Planners need to understand the social meanings attached to infrastructure by different social groups to avoid perpetuating distrust.

A Way Forward: Reparative Planning and Infrastructure

The above sections illustrate how PAR revealed important aspects of infrastructure as sociotechnical systems. In our experience, an *infrastructure* framing also has the potential to be useful in another sense: recognizing the critical nature of social capital and the need to invest in its repair.

Social capital[2] is a key indicator of how a neighborhood will fare during a heat wave (Klinenberg, 2003). Social capital can serve as the information infrastructure through which residents find out about the risks of heat waves and available resources. Social cohesion determines whether neighbors check in on older residents. Social trust and sense of community safety determine whether residents feel safe leaving windows open at night to cool down and increase ventilation. Together, these spatially dependent networks of social capital form an infrastructure that is necessary to ensure a community can withstand the risks of rising urban temperatures and trust civic engagement processes enough to participate. Rebuilding social capital is aligned with the emerging paradigm of *reparative planning*, which includes and extends concepts of equity, advocacy, and therapeutic and trauma-informed planning (Davidoff, 1965; Erfan, 2017; Knapp et al., 2022; Krumholz, 1982; Sandercock & Attili, 2014; Williams, 2020).

Planners are increasingly recognizing the importance of care and repair.[3] Though heat resilience may not be a priority in marginalized communities, in Roanoke we have found that building networks of care *is* a priority. Involving organizations that are already involved in care—churches and faith groups, community artists, after-school programs, libraries, and youth and family development organizations—has been one promising avenue. These organizations have been eager to incorporate the message of heat risks into their programming and activities. Churches have expressed interest in coordinating their buildings to serve as cooling centers open to the broader community. Groups that work with youth and families already have strong connections within the community that could be mobilized to do more planning in the future or to quickly deploy resources and information during an emergency heat wave.

Recognition of social capital and networks of care (Binet et al., 2022) as *infrastructure* is important because its dismantling has been the result of past sociotechnical infrastructure decisions. Infrastructure decisions and policies of investment and disinvestment reflect, reinforce, and reproduce social marginalization, weakening the social infrastructure and capacities of vulnerable communities (Fullilove, 2001; Graham & Marvin, 2001). Given this relationship, substantive changes are needed in the logics and processes of infrastructure planning.

Conclusion

In Roanoke, where heat as a structural issue is underrecognized, yet the risks of increased temperatures already overburden marginalized communities and will continue to worsen, *synthesis* (Campbell, 2012) has clarified the need to connect urban heat to community care and repair of social capital. When considering the path forward that will enable a just approach to heat resilience, we need to a) clearly recognize the sociotechnical aspects of infrastructure and b) support and repair networks of *social capital* that have been broken because

of past infrastructure decisions. Planning theories are extending the equity models of action to include repair and healing-based approaches that center the role of community activism and organization. However, social capital that enables healthy civic engagement in public decision making and functioning in daily life is not widely recognized as *infrastructural*. Planners should continue to recognize the sociotechnical nature of both conventional and green infrastructure and connect infrastructure planning to the repair of social capital in marginalized communities.

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NOTES

1. For the past 3 years, I have been engaged in several PAR projects in the city of Roanoke. These projects include partnerships with neighborhood organizations, the local hospital system, the public school system (teachers, administrators, students), librarians, civic service and activist groups, environmental organizations, church and faith organizations, community-based artists, youth development organizations, and representatives from city government.

2. In describing the role of social capital in community resilience, Aldrich and Meyer (2015) stated:

> Disaster research has long recognized that … neighbors regularly serve as actual first responders. Neighbors check on the well-being of others nearby and provide immediate life-saving assistance. … Individual and community social capital networks provide access to various resources in disaster situation, including information, aid, financial resources, and child care, along with emotional and psychological support. [pp. 255–256]

This echoed the critical role that social ties played in Klinenberg's (2003) analysis of the 1995 Chicago (IL) heat wave.

3. Binet et al. (2022) illustrated the infrastructures needed for care to happen within communities. Erfan (2017) showed how the act of engaging community in the process can help in processing past community trauma. Sandercock and Attili (2014) encouraged the practice of *therapeutic planning*, in which planners work in a way that lifts up marginalized voices and give them agency. Others have called for planners to recognize the importance of emotion, connection, healing, and repair in planning processes (Hoch, 2006; Inch et al., 2020; Knapp et al., 2022; Lyles & Swearingen White, 2019).

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