Title

Decision Making Frameworks: Streetscape Cooling Interventions

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Publication Date

2020

DOI

10.17610/T6WK5W

UCLA Institute of Transportation Studies

Decision Making Frameworks:

Streetscape Cooling Interventions

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Client: Tree People / Climate Resolve

June 2020

A comprehensive project submitted in partial satisfaction of the requirements for the degree Master of Urban and Regional Planning.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
N/A	N/A	N/A

4. Title and Subtitle Decision Making Frameworks: Streetscape Cooling Interventions	**5. Report Date** 2020 **6. Performing Organization Code** UCLA-ITS
7. Author(s) Madeleine Sims	**8. Performing Organization Report No.** LAS2013
9. Performing Organization Name and Address Institute of Transportation Studies, UCLA 3320 Public Affairs Building Los Angeles, CA 90095-1656	**10. Work Unit No.** N/A **11. Contract or Grant No.** N/A
12. Sponsoring Agency Name and Address UCLA Institute of Transportation Studies www.its.ucla.edu	**13. Type of Report and Period Covered** Final **14. Sponsoring Agency Code** UC ITS

15. Supplementary Notes

DOI: doi:10.17610/T6WK5W

16. Abstract

This project analyzes various decision-making frameworks for climate adaptations within the context of streetscape cooling interventions. By focusing on the streetscape, the project brings together the complex issues facing governance, climate science, and community to analyze a specific hazard within an important component of the urban environment. Our goal was to find the contributing factors of the streetscape to the UHI and understand non-carbon impacts of the UHI and how to address those impacts. We determined three primary contributors to the UHI at the streetscape: impervious surfaces; vegetation (or lack thereof); and anthropogenic heat generation. With these in mind, we discuss three major cooling interventions for streetscape: cool pavement; transit shelters; and, tree canopy. Focusing on reducing the contributing factors to UHI (impervious surfaces, vegetation, and anthropogenic heat), we may be able to avoid the single metric of success thinking that has slowed cool pavement and other innovative cooling strategies. We suggest decreasing reliance on carbon based decision making frameworks, encouraging widespread bus shelters, implementing cool pavement on parking lots, and pursing a holistic approach to streetscape cooling.

17. Key Words	18. Distribution Statement
pedestrian planning, equity analysis, program evaluation	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	51	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgments

Thank you to Edith de Guzman at TreePeople and Jonathan Parfrey at Climate Resolve for lending their expertise. Thank you to Juan Matute for his guidance and support through this project. Additionally, I would like to thank UCLA ITS for their financial support. Thank you to the 2020 MURP cohort for their support through this entire process, Annaleigh Ekman for her patient listening, Charlotte Fagan for her humor, and Falak Zaidi for her collaboration.

Disclaimer

This report was prepared in partial fulfilment of the requirements for the Master in Urban and Regional Planning degree in the Department of Urban Planning at the University of California, Los Angeles. It was prepared at the direction of the Department and of both TreePeople and Climate Resolve as planning clients. The views expressed herein are those of the authors and not necessarily those of the Department, the UCLA Luskin School of Public Affairs, UCLA as a whole, TreePeople, Climate Resolve or any employees associated with TreePeople and Climate Resolve.

Decision Making Frameworks: Streetscape Cooling Interventions

UCLA Institute of Transportation Studies

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Executive Summary

This project analyzes various decision-making frameworks for climate adaptations within the context of streetscape cooling interventions. By focusing on the streetscape, the project brings together the complex issues facing governance, climate science, and community to analyze a specific hazard within an important component of the urban environment. Fundamental to this analysis is understanding how people use the street, what systems support the street, and how extreme heat will impact those systems and people. Understanding what people experience at/in the street, what impacts those experiences, and what can be done to address vulnerabilities and hazards is essential. The Urban Heat Island (UHI) in Los Angeles provides the backdrop for this research. Our goal was to find the contributing factors of the streetscape to the UHI and understand non-carbon impacts of the UHI and how to address those impacts.

We determined three primary contributors to the UHI at the streetscape: impervious surfaces; vegetation (or lack thereof); and anthropogenic heat generation. With these in mind, we will discuss three major cooling interventions for streetscape: cool pavement; transit shelters; and, tree canopy. These interventions were chosen namely for their presence in Los Angeles sustainability and resiliency plans. Additionally, management of these interventions largely falls within a single City of Los Angeles Department, StreetsLA.

How we evaluate and implement cooling interventions into the streetscape often requires some kind of metric of success, whether it is a lower carbon footprint than the-business-as-usual scenario, or in the case of cooling, temperature decreases (seen at local, surface or ambient, or neighborhood levels). If we focus on reducing the contributing factors to UHI (impervious surfaces, vegetation, and anthropogenic heat), we may be able to avoid the single metric of success thinking.

We distilled four recommendations from this research to better inform decision making frameworks:

1. Reexamine the reliance on LCA/Carbon decision-making frameworks for cooling interventions, namely cool pavement and other new technologies.
2. Encourage the widespread adoption of bus shelters to both protect rider health and ridership.
3. Encourage the use of cool pavement on parking lots and other large areas of pavement that are unencumbered by buildings.
4. Pursue a planned, holistic approach to streetscape cooling that includes vegetation, tree canopy coverage and cool pavements.

These recommendations provide inroads to incorporating public health impacts to streetscape cooling decisions. Cool pavement, while not an un-studied product, relies mostly on modeled data and LCA tools to determine effectiveness. We suggest that other

methods of analysis be incorporated into decision making that better reflect public health impacts (non-carbon) such as mortality rates. The City of Los Angeles manages their bus shelter program through an agreement with JCDecaux/Outfront under the management of StreetsLA. The current agreement, set to expire in 2021, is focused on ad revenue and shade. We suggest that officials emphasize the rider safety and prioritize areas where the UHI effect is greatest. We also suggest that the City explore a multitude of bus shelter types and develop criteria for shelter implementation that emphasizes shade efficacy. Additionally, we recommend that cool pavement be encouraged on parking lots and areas unencumbered by buildings. Research has shown that reflective pavement has improved surface temperatures, and some negative pedestrian thermal impacts, thus open spaces are recommended for implementation while further refinements are pursued. Finally, we recommend a holistic approach to streetscape cooling as part of an efficiency streamline and to create a cohesive streetscape program.

Introduction

As the climate crisis continues to impact cities, decision makers are being increasingly pressured to address climate change (Lauter). Though in need of action, there are ongoing discussions surrounding mitigation and adaptation strategies, in addition to the ongoing intertwining between disaster risk reduction and adaptation. How do cities measure impacts? How should cities prepare and respond to climate change impacts? How much should we focus on mitigation or adaptation? These are ambiguous questions, whose answers shape how limited resources are shifted and who may benefit from adaptation interventions.

Distilled from the climate change problem, adaptation is thorny in and of itself, how is adaptation addressed? Do adaptations address the impact? The risk? The people? Vulnerability? Coping capacity? Who and how do we make these decisions? Interventions designed to address climate change come in many forms, from financing large infrastructure projects, built environment changes, economic development redirection, and investments in capacity and/or coping mechanisms for individuals and communities. Understanding how these decisions are made, and other frameworks for making decisions is important as we move into a hotter future.

Project Description

The purpose of this project is to analyze decision-making frameworks for climate adaptations, specifically for streetscape cooling interventions. By focusing on the streetscape, we can bring together the complexity of governance, climate science, and community to focus on a specific hazard within a vital context. This will entail understanding <u>what experiences are had at/in the street</u>, <u>what impacts will be to those experiences</u>, and <u>what can be done to address vulnerabilities and hazards</u> (decision-making). Fundamental to this analysis will be an understanding of how people use the street, what systems support the street and how extreme heat will impact those systems and people. A large component of this will be understanding what the City of Los Angeles uses for adaptation interventions at the streetscape and understanding how these products fit within various frameworks, for example what is prioritized? Greenhouse Gas (GHG) emission reductions or non-carbon benefits?

The primary objectives and deliverables will be a narrative analysis of decision-making policies in other cities experiencing impacts similar to those of Los Angeles, decision-making policies for streetscape cooling interventions, and decision-making in an era of innovation. To address this the following research questions have been developed to ground the research in its applicability to the local government:

1. What is the decision-making process like in Los Angeles as it pertains to climate adaptations? What is valued or prioritized?

2. How can decision makers value non-carbon benefits into their frameworks?

These questions will be addressed through a narrative analysis of decision-making frameworks used by cities and recommended by peer reviewed literature. After disentangling the language we use to describe climate change and its impacts to cities, we can dive deeper into decision-making as a general topic before bringing it to climate change and specifically, adaptation.

Context and the City

The City of Los Angeles will be impacted by climate change and forced to adapt to new realities. Hazards arising from climate change in Los Angeles will include increased extreme heat days, overall temperature increase (and increased drought conditions), and sea level rise. Secondary hazards arising from these conditions include increased wildfire risk and intensity, decreased snowpack and water supply among others.[1] The hazards are measurable within a certain degree of accuracy thanks to advances in climate modeling, however the impacts of these hazards on the city (including individuals, neighborhoods, and economies) have greater uncertainty.

What those realities are can be framed differently, from the anticipated damage to infrastructure to the exacerbated vulnerability people will face in the face of these changes. Los Angeles has acknowledged the need to shift from its business as usual operations to adapt to the changing climate through the Los Angeles pLAn: La's Green New Deal. Additionally, the city has acknowledged reducing GHG emissions and adapting to the new realities facing Angelenos, such as increased temperatures and sea level rise, in addition to anticipated wildfire increases through *Sustainability pLAn 2019*, and *Resilient Los Angeles*. These two plans provide an outline for the City to address climate change, through adaptation and risk reduction strategies, mitigation strategies, and sustainability efforts. Statewide, California has made plans to address UHI through SB 45 and Governor Newsom's Climate Resiliency Bond proposal. SB 45 outlines approximately $40 million in funding for UHI, greenhouse gas emission reduction and increased green spaces funding.[2] The Climate Resilience Bond proposes approximately $200 million for urban forestry and greening, and an additional $125 million for cool surface projects (roof and pavement).

Knowing there is money on table, and plans in progress, this research will address UHI in the context of a hotter future. We know the number of extreme heat days will increase, making outdoor activities harder, energy systems placed under increased stress, and expose existing vulnerabilities in many communities. The streetscape is part of the public realm and public space, though its activities are mostly related to the movement of people, and goods. As an opportunity and hindrance to climate change adaptation and mitigation, understanding the impact of potential programs and interventions is important to this dynamic place, where goods, services, and people meet. Though a meeting place for many activities, how the street impacts people is different. With

[1] Tertiary impacts include hazard induced migration and displacement (from sea level rise for example), food supply impacts and increased spread of vector-borne disease.

[2] Without considering the impact that the COVID-10 pandemic will have on government budgets.

these funding opportunities, strategies for reducing the UHI will need to be robust and equitable in order to ensure our most vulnerable residents are protected.

One of the largest components of the streetscape is the street surface itself. Street surfaces such as pavement and concrete can trap heat, increasing the urban heat island (UHI) effect and neighborhood level heat. However, pavements are required to move people and vehicles, including those on bike and foot. Unlike driving, walking and biking are low carbon emitting activities, driving however is not. The streetscape is symptomatic of our transportation needs; more vehicles to move through can often mean ever wider streets. Those who suffer most from this, are the people who experience the street through walking, biking or other means of being outside. Protecting these individuals is vital. The first step to do it, is to understand the needs of people in the street, and address climate impacts to those needs. The City, however, doesn't need to address just residents' immediate needs; city planners can address future residents' needs and build stronger defenses in the face of future climate hazards.

Urban Heat Island

The Urban Heat Island is derived from the difference between rural and urban temperatures, a climate modification created through a concentration of increased thermal mass and surface roughness, decreased albedo, anthropogenic heat from buildings and cars, and finally, decreased area for evaporative cooling (Ryu 2012). Heat islands are created through the presence of heat-absorptive surfaces, heat-generating activities, and lack of vegetation. Heat absorptive surfaces that contribute to roughness include pavement, sidewalks, buildings, and dark surfaces (Ryu 2012; Taha 2015). Simply put, albedo is a measure of a material/surface ability to reflect and absorb light. Low albedo materials contribute to the UHI effect, through trapping and radiating heat more so than reflective materials (or higher albedo materials). The impacts of the built environment on local climates are well documented, and the same also impacts temperature, wind, humidity, and precipitation within the city (Taha 2015).

How each of these factors contribute to UHI is understood, although their relative impact is lesser known (Ryu 2012).[3] A study categorized these factors into three general groupings to better understand the impact on UHI: anthropogenic heat, impervious surfaces, and three-dimensional urban geometry (Ryu 2012). Three-dimensional urban geometry pulled together three major factors: additional heat stored in vertical walls, radiation trapping, and wind speed reduction (Ryu 2012). The researchers defined impervious surfaces as a "reduction of surface moisture availability and increase in thermal inertia of urban surface materials" (Ryu 2012). The researchers found the largest contributor to daytime UHI was impervious surfaces, followed by anthropogenic heat (Ryu 2012). Nighttime UHI is greatly influenced by anthropogenic heat, followed by impervious surfaces. Urban geometry affected intensity but was not a leading factor that contributed to UHI.

[3] It is important to note that UHI can be looked at in two different time periods: day and night.

Measuring UHI

Measuring UHI poses challenges, both through the methods and choosing a scale of analysis. There are two primary tools of measurement, remote sensing and stationary imaging. Researchers determined three factors that influence UHI: urban surface albedo, vegetated surface and shading, and urban typology including roughness (Taha 2008; Jin et al. 2018). Remote sensing, a popular tool to measure UHI, measures surface level UHI, but not air temperature. Remote sensing uses imagery as a means of measuring reflected or emitted energy to tell the user about the area where imaging occurred. Remote sensing cannot be as granular as other methods as the image resolution is often not of good quality at smaller scales (neighborhood for example), which makes it difficult to use for finer scale projects. Additionally, remote sensing is limited to surface temperature measurements (for UHI purposes). Linking air to surface temperature is not an easy task and is largely dependent on the specific urban geometry which is not captured well in remote sensing (Taha 2018). Stationary monitors are limited by sites willing to host a device, or the existing number/spread of devices, though these devices can measure surface and surrounding air temperature. While mobile monitors are more flexible in terms of deployment, they cannot gather long term data as efficiently (Taha 2018).

When measuring the UHI at the “ultra-fine urban scale” or microclimate, determining effects is more difficult, and comparing findings across neighborhoods poses difficulty to researchers (Hui; Ryu 2012; Taha 2015). When implementing projects such as cool pavement, trees, or other programs, measuring their efficacy is important for monitoring and evaluation.

Los Angeles UHI

The State of California’s Environmental Protection Agency (CalEPA) maintains an index for UHI within the state to allow for cross jurisdictional comparison. The index is based on a 2015 report, which combined multiple climate models, and was developed to characterize and quantify the influence of an urban area on heat. The tool is designed to provide three outcomes:

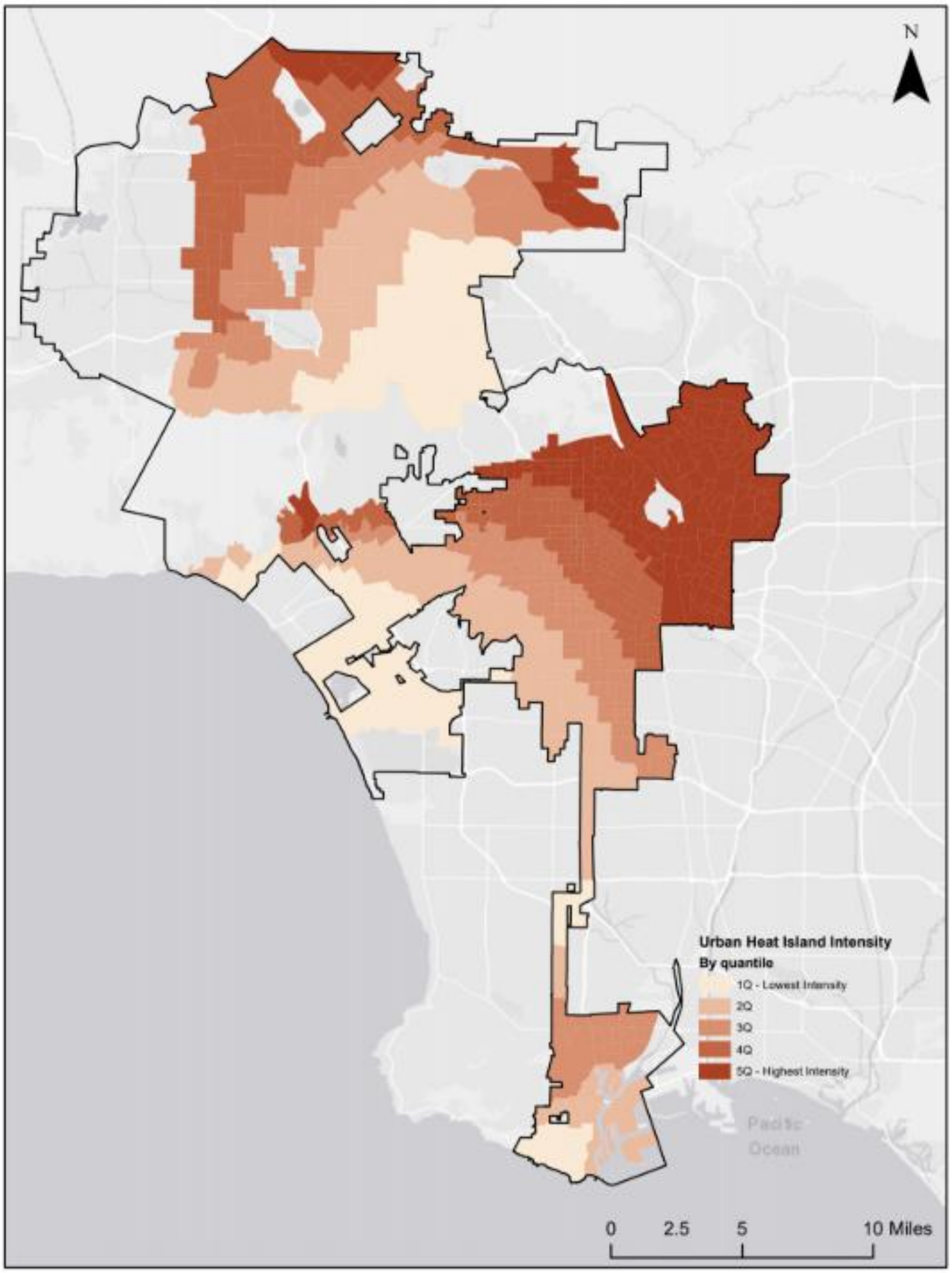
1. Assess health implications of UHI
2. Identify Census Tracts that are prone to impacts
3. Be a potential modifier to CalEnviroScreen scores.

Berkeley National Laboratory researchers analyzed factors influencing Los Angeles UHI. Researchers, using a mixture of measurement methods, determined that dense neighborhoods with increased roof albedo experienced lower near-surface air temperatures (a contributor to UHI). Using mobile measurement devices, researchers concluded that areas with increased vegetated area/canopy cover have a cooling effect (derived from increased albedo). Additionally, researchers connected areas with low albedos to high increased intensity of UHI (Taha 2018).

The report concluded by suggesting that cities can mitigate the UHI through increasing urban albedo and canopy cover.

As seen in the map on the following page, the UHI is most intense in the Valley, South Central and easternmost portions of the City. These are also the areas with the lowest tree canopy coverage. The UHI effect will become even more pronounced with climate change increasing the number, and intensity, of extreme heat days (Watkins et al 2007).

Los Angeles UHI Intensity



Map by Madeleine Sims. Data from the California Healthy Places Index. Percentages organized by quantiles in the City of LA. Census tracts from Us Census Tiger files. LA City boundary from the City of Los Angeles Geodata portal. Basemap from ESRI, Here, Garmin (c) OpenStreetMap contributors and the GIS community.

Figure 1: City of Los Angeles UHI intensity organized by quantile.

Necessity of Research

Climate change adaptations can be as direct as modifying a structure or streetscape to better cope with conditions, but it ultimately ties back to the economy and people. Ensuring people benefit from adaptations is important; it is the “why” of adaptation planning. Interventions are designed with a specific end goal in mind, whether to address extreme heat vulnerability through strengthening the energy grid to prevent blackouts, or requiring all new buildings to use a passive solar design. Planning addresses the built environment through general plans, zoning, building design guidelines, and other regulations pertaining to the built environment. All of which rely on knowledge and decision-making. Decision-making, including public participation, and knowledge can be concentrated in power structures that are inaccessible to individuals. Without a solid understanding of what information is available, its limitations and criticisms, decisions may not be as complete as they could be and tradeoffs could go unknown.

Adaptation

Adaptations are a complex topic. The Intergovernmental Panel on Climate Change (IPCC) identifies multiple types of adaptations including structural or physical, social and institutional options. Administrative Regulation 5 (AR5) defines adaptation as the “process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.” (Noble et al.). The IPCC further delineates adaptations into incremental or transformational categories (Noble et al.). Incremental adaptation is defined as the efforts to maintain existing systems through small adjustments to the affected sector. Incremental adaptations could include using different strains of seeds or plants to continue farming. Transformational adaptations are larger and more intensive interventions, and can involve overturning an entire sector (or large swaths) to change the status quo (Noble et al.). For example, in lieu of using modified seeds to continue farming (incremental), a transformational intervention would be redirecting the economy to a more climate resilient sector to prevent persistent incremental changes. The IPCC also defines “adaptation deficit,” or the gap between the current system and the ideal state that would minimize damage from climate conditions (Noble et al.). The adaptation deficit requires understanding the current state of affairs (including community assets, existing ability to cope/resilience/vulnerabilities), climate change impacts and their effects on the existing system, which will inform the “ideal state.” This can be tricky to address because at the same time there is a push to mitigate climate change through activities such as decreasing greenhouse gas emissions (GHGs), which can run counter to adaptation activities, let alone another activity that drains institutional capacity.

To illustrate the problem, we can analyze a simple scenario using a community prone to extreme heat events both in the near future extending to the long term, older housing stock, and a vulnerable population (low income, elderly, etc). Knowing the community’s existing state and its vulnerabilities, we identify the community’s ideal climate adaptation strategies that would protect residents, workers and visitors from exposure to health or economic impacts caused by extreme heat. An incremental change would be encouraging air conditioning adoption or establishing cooling centers to provide AC to vulnerable people. A transformational adaptation could include moving away from high exposure industries (agricultural work for example) or moving people out of vulnerable housing stock before attempting to retrofit. The short-term solution, increasing AC adoption, will run counter to mitigation efforts which aim to reduce GHGs emissions. This is the conundrum faced by many people and institutions, how do we balance adaptation and mitigation when the outcomes are contradictory, that we will seek to untangle.

Vulnerability

According to the IPCC, vulnerability is the amalgamation of exposure, sensitivity, and adaptive capacity (Satapathy et al., 2014). Simply put, it is the likelihood of systems and people to be impacted by climatic events (Cardona et al, 2012). Vulnerability in general, has different definitions between the frameworks that use it (IPCC). Vulnerability in general is theoretical, it cannot be quantified or directly measured (Satapathy et al., 2014). Vulnerability has multiple dimensions: social, political, economic and geographical.

The UHI and subsequent extreme heat events, can severely impact the population at large, and severely impact fragile groups such as youth, elderly, and individuals with cardiovascular/respiratory disease (Climate Adaptation and Public Health). Human vulnerability can also include a gap in access to air conditioning, however measuring access to air conditioning is difficult to measure at the neighborhood level (Fraser et al, 2016). Though the California Healthy Places Index estimates the City of LA air conditioning penetration rate at 66.1%, this is one component of vulnerability, there are others such as access to transportation, housing status, language and income. Simply put, air conditioning, while an indicator of vulnerability to extreme heat, needs to be expanded upon, for greater understanding of the impact of extreme heat on a neighborhood.

Vulnerability Assessments

Why is measuring vulnerability important? Vulnerability is a needed component to understand and prioritize investments in adaptation, however there is little consensus on the impacts of urban vulnerability in general to climate change (Zhang 2019). Vulnerability assessments are derived from risk assessments primarily used for disaster risk reduction and consist of various indicators that cover geographic and social factors (often overlapping to ensure context is captured) (Zhang 2019). Challenges to developing these assessments include missing or poor-quality data, differing sources of data, using a consistent methodology, stakeholder engagement, expensive information collection, and developing the indicators themselves (Zhang 2019). Using our example about air conditioning penetration rates in the City of Los Angeles, we know this rate is an indicator of a household's ability to provide cooling on-site and mitigate against health impacts from extreme heat, however, we do not know the propensity of that household to use this feature. Coupling this rate with income, for example, we can paint a better picture of a household's overall fragility.

As such, vulnerability assessments compile multiple indicators, assessments can either weight them or aggregate them as is. Weighting allows for priorities to be established and direct resources towards those priorities. Arguments in support of weighting indicators include:

1. Allows for priority identification and efficient distribution of resources
2. Avoids loss of information during aggregation process
3. Allows for public participation

   (Zhang 2019)

Weighting though, is not without its critiques. Weighting in climate vulnerability assessments lacks a broad methodology to ensure consistency across jurisdictions (Zhang 2019). Social and economic indicators are often not integrated into aggregated, weighted indexes because it is difficult to measure the impact of each indicator at the overarching impact of each category into vulnerability (Zhang 2019). Throughout the vulnerability assessment, whether weighted or aggregated, context is key to understanding a community's vulnerability.

Literature Review

The purpose of this literature review is to situate our two research questions within the broader academic literature that exists within the topic: climate change decision-making. Briefly addressing differences between adaptation and mitigation is necessary to help further define the importance of this research within the larger sphere of climate change and will be contextualized within the final report itself. As a reminder, our two research questions are:

1. What is the decision-making process in Los Angeles as it pertains to climate adaptations? What is valued or prioritized?

2. How can decision makers value non-carbon benefits into decision-making frameworks?

Analyzing how governments make decisions about climate change adaptations involves reviewing climate change impacts to the region and modeling, adaptation interventions, perceptions about climate change, and funding mechanisms. Climate Action (or Adaptation) Plans, commonly referred to as CAPs are local government plans to curb the impacts of climate change on communities. These plans, from local to statewide, can be influenced by state government requirements, mitigation efforts, and local perceptions (Koski et al.). Actual actionable items in these plans are more difficult to come by, usually because of the intersection of the many stakeholders that will be impacted by climate change and the tricky balance between mitigation and adaptation efforts, which can contradict each other. CAPs address climate change, but perceptions on what climate change is influence how local government plans for it (Koski et al.). CAPs also vary in quality, and most are merely guiding planning documents rather than the listing of actionable goals (Koski et al.).

Climate Adaptation Frameworks

Addressing climate change can be looked at as a dichotomy, one side is directed at the cause of climate change, the other is directed at the impacts (or symptoms) of climate change. However, our report will instead look at adaptation as an extension of mitigation, that since mitigation was/is not enough to prevent impacts of climate change, adaptation efforts will need to step in to mitigate against human suffering.

Researchers, Koski and Siulagi describe the variation in government plans to address climate change as the difference between natural harm and natural hazards. People that work within mitigation often work to address the harm to the environmental systems people rely on, like environmental services or co-benefits. Adaptation work entails working within the sphere of hazards and risk to people, rather than environmental degradation, a sort of melding between the hazards-management sphere and environmental movement (Koski et al.). Adaptation work thus requires understanding risk to people, not just likelihoods of events, within context (government, communities, funding). Climate change will affect communities differently, notably on their geography but also their individual and community vulnerabilities. This poses challenges in terms of governance and policy marking. Because impacts are different, at different scales, for different groups, creating a cohesive policy document that outlines the plan for adapting to climate change is thorny (Glaas et al.).

The idea of a “successful” adaptation can be greatly influenced by who is analyzing it (Adger et al. 2005). Adaptations for extreme heat may be deemed effective at a block level scale, but success may not translate to a larger scale. This poses problems for measuring and monitoring, adaptations, particularly new interventions or small pilot projects. Stakeholders also have a say in the success of an adaptation; these groups can determine the factors of success and how these are weighted, all of which can shift between interest groups (Adger et al. 2005). Lyle outlines the scales at which decision-making within the climate change adaptation sphere can be influenced, but further complicate success and decision-making (Lyle 2015). Both Lyle and Adger et al., outline that the determinants of a successful intervention are not easily measured, and how interventions can be misconstrued as successful or not through the various frameworks stakeholders and implementers see them through.

Researchers, Koski and Siluagi, provide an understanding of how climate change perceptions have evolved in government literature and planning documents over time. Framed as global warming, rather than climate change, governments organized their efforts around mitigation in terms of air pollution and greenhouse gas emissions. This was evident in the framing of climate change as an environmental harm, meaning that efforts were focused on mitigating the impacts to the environment (Koski et al.). Later perceptions of climate change shifted to a hazards approach, addressing the impacts of climate change to human health, and risks to people (Koski et al.). This shift in framing also brought in new ways to look and measure climate change. Risk based approaches promote risk assessment through identifying climatic variables, creating scenarios based on those variables, sensitivity analysis, identifying impact thresholds, risk analysis, evaluating risk, and stakeholder consultation (Jones 2001; Dessai et al 2005). In 2004, the UK Climate Impact Programme produced a similar decision-making framework but did not use climate scenarios, but instead judged risk based on a problem and objectives (Dessai et al 2005). Human Development approaches frame climate change adaptation not as an environmental problem, but as a development one (Dessai et al 2005). In these approaches, climate change scenarios are not emphasized, instead improving individuals coping capacity and decreasing vulnerability is emphasized (Dessai et al 2005).

Adaptation also complicates matters at the response level, necessitating a discussion on the role of vertical integration of adaptation measures and services (Trude Rauken et al.). Coupled with narrative, cognitive, and governance barriers which apply to individuals and formal institutions, adaptation becomes an even thornier problem to unravel (Millner Heal; Raymond et al.). Examining the various levels of governance and planning through national, state, local and community led adaptations is of interest to this report, in addition understanding the linkage between the scales is important, notably how the money flows and the role of formal institutions. Formal institutions, defined as groups that follow rules enforced through commonly accepted channels, usually refer to government (Raymond et al.). These barriers need to be understood in order to discern how the decision-making process is influenced by knowledge, changing norms, and formal decision-making procedures.

Modeling and Information Gathering

The implementation of a "successful" adaptation requires a granular understanding of community context, and of climate change hazard/impact within a hazards framework. Decisions about adaptations often rely on climate models to indicate the likelihood of a specific impact/hazard and its intensity on a given place. Climate models themselves are not without well documented biases, and problems. Scientific uncertainty lies in the variability between models to determine exact impacts, which can disrupt best practices for adaptation (Millner Heal 2014; Weaver et. al). Climate models are treated as information in the decision-making process, however there are limitations to these models as there is considerable uncertainty with predictions and a lack of integration with granular community level realities, such as vulnerability, nor the degree to which a community may feel an impact (Millner Heal 2014; Weaver et al.).

Climate models also use different data sources, which coupled with differing calculations can lead to different probabilities of various climate scenarios (Millner Heal 2014; Weaver et al.). There is also uncertainty in our understanding of how communities will cope with climate change and adaptation interventions (Heal Millner 2014). Socio-economic uncertainty also persists in modeling and data model application (Miller Heal). The interaction between socioeconomic states and climate is unknown in many circumstances, especially when there is uncertainty about climate impacts and a low level of specificity as it pertains to people's reactions to climate change, in addition to how adaptation efforts can course correct livelihoods. Technological changes will change our emissions output and thus, to a certain degree, the intensity/severity of our climate change scenarios (Millner Heal). Millner and Heal acknowledge the faults with reliance on climate modeling as a source of information for climate adaptation through their literature review, which is key to furthering this research proposal and disentangling the information needed for adaptations at different scales.

Lifecycle Assessments

There are other forms of information gathering used in the decision-making process within adaptation research. Lifecycle Assessments are used to determine the carbon impact of a product from cradle to grave. Since its inception in the 1960s, LCA has been used to determine environmental impacts of system processes and inputs in efforts to increase sustainability (Cowell et al.). The process involves analyzing inputs and measuring their carbon emissions from production through assembling the product, transportation, and carbon emissions from destruction of the product (Cowell et al.). LCA has emerged recently as a tool influencing government decision-making. In addition to the traditional corporate role LCAs have played in the supply chain and optimization attention has shifted from making decisions about supply chain and product processes, to responsible consumption and a development of environmental policy (Field & Ehrenfeld). This shift in usage has generated additional research into the limitations and methodology of LCA, including critiques as specific to cool pavement technologies which will be explored in this research project.

The primary purpose for LCA is to assist corporate/company decision-making about processes and supply chains (Hellweg, Mila I Canals). LCA's reliance on understanding the production process and supply chain means that it can not provide support for choosing the "best" product, merely the product with the least environmentally impactful supply chain (Ayres; Ekvall et al.). LCA process critiques are primarily grouped into issues surrounding data and boundaries of analysis (Hellweg, Mila I Canals). Methodology is also of importance to LCA, notably determining what question the LCA will inform (Ekvall, et al.; Cowell et al.). There are additional critiques of the LCA system when considering 'green' or recycled inputs that are not fully captured in the LCA process, for example recycled concrete inputs (green concrete) are not fully measurable in the LCA process because extraction and emissions from the recycling process itself are not required to be included (Van de Heede, Belie). These issues are explored in detail because they hark back to a more traditional critique of LCA which is determining the boundary of analysis (Van de Heede, Belie). Because of this limitation, when choosing a functional unit of analysis, the most important factor in the LCA should be using a unit of analysis that has enough material to construct a usable feature of its intended purpose (mile of lane, wall, etc.) (Van de Heede, de Belie). However, even with a uniform functional unit of analysis across studies, given that there is no universal standard for choosing that unit, there still lies problems in applicability across geographies and situations (Curran). LCAs satisfy the need to factor environmental damages into decisions in a format that equalizes values to carbon emissions, however it is not without fault and can create confusion for decision makers who are faced with competing assessments (Hertwich et al).

LCA is generally a quantitative analysis, however, there has been a notable uptick in its usage in value judgements or decision-making, but what their role should be is cause for deeper research (Cowell et al.). LCA does not value or judge the magnitude of service or utility of a product, just the impact of its processes over time and identify opportunities for improvement in sustainability (Cowell et al.). Human behavior can deter the LCA predicted environmental outcomes, usually changing how a product is used or changing the rate of usability, which can nullify a predicted outcome (Gutowski; Zhang). There exist many critiques of the increasing role of LCA in decision-making, from a philosophical standpoint that trade-offs exist (i.e., there is a "better" option available) as it relates to environmental impacts, ongoing concerns over input values and data, and finally the inclusion, or failure to include, stakeholders in the input assessment (Cowell et al.).

Streetscape Cooling Interventions

As described by Lyle, individual behaviors can influence climate change adaptations through *perceived* risk and danger to what that individual values (Lyle 2015). Individual perceptions of climate change are greatly influenced by politicians, leaders and organizations, in addition to ideologies (Lyle 2015). The more knowledge a person has, the more likely they will perceive climate change as a threat, whether real or not (Malka et al 2009, McCright and Dunlap 2011, Tranter 2011; Lyle 2015)). Place is a central scale to people, and adaptation because place promotes resilience due to its central place in community (Hess et al 2008; Lyle 2015). Disturbances to communities and place, can create individual psychological issues for individuals (Hess et al 2008; Lyle 2015). This is of importance at the streetscape because it provides an intersection of life in a physical place and where people will experience the impacts of extreme heat when moving from place to place.

Previous studies have been conducted on cool or reflective pavement materials, including in California. Cool pavement programs have been found to generate more carbon emissions from production and cause more carbon emissions from decreased fuel efficiency (Li et al.; California Air Resources Board). It is worth noting that these studies were completed on specific products, and do not include CoolSeal and TopGuard which are deployed in the City of LA. Pavement related LCAs are still generally understudied, namely the interaction between pavement and other carbon emitting factors such as vehicle miles traveled (VMT), albedo and solar reflectance (Santero et al.). These gaps are vital to understanding the role of LCA in analyzing cool seal pavement as it plays a role in this noted literature gap.

Green infrastructure, such as street trees, bioswales, and rain gardens, have proven to have co-benefits that not only help with neighborhood level cooling, but also stormwater management (Norton et al 2015; Lovel Taylor; Tzoulas et al). However, as noted and addressed by Norton et al., there is a lack of literature addressing green infrastructure in Mediterranean climates, like Los Angeles, and microclimates. This is primarily because of the decreased amounts of storms and rainfall that green infrastructure is primarily designed for.

Trees are a proven, successful strategy to mitigating the UHI, increasing human thermal comfort, and decreasing absorbed heat in pavement (Salmond et al). Trees however require land, economic, and environmental services that are not as easily provided for, in addition to being prone to disease and pests (Salmond et al.). In addition, when their benefits are most needed, during hot periods, is often when they are most water stressed and likely unable to provide full benefits (Norton et al.). Mature trees are often some of the most expensive to replace due to cost and time needed for a tree to reach maturity, in addition to concerns over disease and pests that can shorten the lifespan of trees. Trees are also a specific intervention that requires extensive planning.

Conclusion

Put into conversation with our understanding of the barriers to successful adaptation, cooling intervention outcomes can be misunderstood/misclassified when analyzed at a specific institutional scale or when not considered as part of a greater ecosystem. For example, the street tree can be analyzed at the block scale or as part of the larger urban canopy. One tree on a block, may not be a successful adaptation intervention (though there is an argument that something is better than nothing), but if it is analyzed under an overarching goal of increasing the urban tree canopy to decrease UHI, its success may be looked at differently. When adaptations are not integrated into existing codes and plans, and instead placed in a particular climate or environmental plan, the subject intervention is placed at a higher standard for success and can be analyzed at a larger scale than its original intention.

Understanding human behavior and perception of risk and vulnerability as it pertains to adaptation work, is important in the American planning context since there is an emphasis on community involvement, particularly in LA where there has historically been community involvement in the adaptation process. However, the role of individual behavior and misconceptions can move decision-making away from communities and deeper into the hands of experts. This is the point where the research will depart, recognizing not only the hierarchies of decision-making and analysis for climate change adaptations but also that a single intervention cannot be a cure all for adaptation, will be key to our pursuit of how we can frame adaptation decisions at the streetscape.

Methodology

My first research question seeks to bridge the divide between implementation and strategy through addressing decision-making frameworks. The purpose of the project is to identify the various ways local governments use decision-making frameworks to make decisions about streetscape cooling interventions. The end goal of this project is to produce a document that advocacy organizations can use to further their work by grounding advocacy within practice examples of decision-making frameworks.

Evidence and Data Gathering

Professional literature and engineering documents provided the basis for understanding what climate adaptations exist in the market today. Government literature, including reports and adaptation plans, filled the gaps to paint the picture of the suite of cooling interventions available for installation at the streetscape. Government documents also provided the bulk of information pertaining to existing conditions and decision-making frameworks in practice. Government documents were chosen first on the similarity to Los Angeles, and Southern California in climate change impacts, UHI, and size/density. These documents include transportation master plans, climate adaptation plans, resiliency plans, and vulnerability plans as available. A large component of this research will also include understanding how the city uses the streetscape, and how communities utilize it.

Since the project is focused on the streetscape and heat impacts, determining the extent of the Urban Heat Island (UHI) in Los Angeles specifically was vital to outlining the context and importance of this project. UHI information came from the California Urban Heat Island Index accessed through CalEPA, California Environmental Protection Agency. In addition, Cal-Adapt provided data on the number of extreme heat days throughout the State which projects the number of extreme heat days per census tract. Peer-reviewed and academic literature informed the theories that underpin impact assessments and decision-making frameworks.

Describe and Justify

UHI, and climate change impacts were determined through existing literature, including the State of California's Climate Change Assessment Report and the Los Angeles Regional Report. These two reports provided the data to determine not only comparison regions and cities, but also to outline the types of frameworks for climate change adaptations analyzed including Health Impact Assessments, Life Cycle Analysis, Cost-Benefit Assessments, Risk Analysis, and Integrated Assessments in addition to localized frameworks in other jurisdictions. In addition, the literature review identified key theories that underpin climate change adaptation, including the ideas of transformation, coping, vulnerability and resiliency. Frameworks that were mentioned more frequently in both the literature and existing climate adaptation plans in targeted cities were given greater weight, however their mention in peer-reviewed literature was given an almost equal weight in my analysis.

The project methodology allows for a directed approach to looking at decision-making frameworks in climate adaptation by focusing on a specific context (City of LA, streetscapes) and interventions (cooling). Given the limited information available that studies implementation efforts for adaptations, reliance on interviews is necessary to not only fill information gaps, but also provide information on how policy and research connect to the ground work.

Streetscape Cooling Interventions

Transit Structures and Bus Shelters

Though limited, there is evidence that extreme or adverse weather negatively affects ridership rates across cities, and that rider shelters help mitigate against those losses (Welch et al, 2016; Singhal 2014). A 2016 study surveyed Public Transit Agency leaders to determine the impact of extreme weather on ridership and how agencies are preparing for increased incidences of extreme weather. Extreme heat was identified as a frequent event that transit agencies faced, and extreme weather in general was identified as the second highest public safety risk for transit agencies (Welch et al, 2016).

Figure 2: Boulevard Design bus shelter (Outfront/JCDecaux; Department of General Services)

A subsequent study analyzed canopy investments for bus and rail shelters in advance of extreme weather events, seeking to quantify the impacts of the investments and mitigate against ridership loss during extreme weather events at the station level (Miao et al, 2016). The researchers found that bus stop shelters and benches protected ridership on extreme weather days for the Utah Transit Authority, suggesting that additional investments in rider comforts at the stops can improve ridership during extreme weather events (Miao et al, 2016). Researchers translated their findings into a decision-making matrix centered on preserving ridership through canopy coverage to mitigate against increasing instances of adverse, extreme weather associated with climate change (Miao et al, 2016). The cost-benefit analysis (CBA) posed by the researchers depends on the number of extreme heat days, decline in fare revenue experienced during adverse weather, and average fare. Essentially predicating the value of installing a bus or rail shelter on the increase in fare revenue.

Though located on the public right of way, bus shelters are not installed by the City of Los Angeles, or LA Metro. The advertising street furniture firm Outfront/JCDecaux is responsible for installing bus shelters, though their location and maintenance is coordinated with StreetsLA and City Council Offices. The agreement, struck in 2002, allows Outfront/Decaux to install shelters and other street furniture such as kiosks and public toilets, including maintenance, in exchange for ad revenue. The bus shelters are paid for using ad revenue from advertisers, and while achieving geographic equity, are placed based upon ridership and traffic data made available from the City and Streets LA (Chen 2020). Overall, there are currently 1,870 bus shelters in the City of Los Angeles, with plans to increase shade to 750 bus stops through shade sails, trees, or umbrellas by the City itself (Chen 2020). Outfront/JCDecaux plans on expanding the number of bus shelters, and after consulting with StreetsLA determined new locations by identifying bus stops within the top 20% of boarding's and with adequate sidewalk width, though the original agreement form the early 2000s has not been modified to codify this (Outfront/JCDecaux: Now Approaching). Alongside LA Metro Rapid Corridors, all stops were approved to install shelters, totaling 102 shelter locations by LA Metro using federal funding grants, outside of the Outfront/JCDecaux agreement.

Cool Pavement

Cool pavement consists of pavement coatings or sealants that have a higher solar reflectance than typical pavement materials (Freed et al 2019). These are often specially formulated products that (currently) are largely designed for pedestrian and low-traffic areas (Freed et al 2019). Reflective coatings include chip seals, scrub seals or micro surfacing or sealants that coat a substrate such as asphalt (Levine 2011). Of cool pavements, chip seals are common, and "using a light-colored aggregate with polymers, emulsion or resin for the binder, these chips seals create a marked improvement of the pavement's SRI" (Levine 2011). Scrub seals are similar to chip seals, however instead of polymers or resin, scrub seals use crushed rock and asphalt emulsion to top pavement. Finally, microsurfacing includes cool pavement sealants or coatings, which cover pavement and are applied with brushes.

Application of cool sealants is done on-site and can be re-coated throughout the lifetime of the pavement as needed. Maintenance programs for cool pavement include cleaning and re-coating, depending on the lifespan of the product which varies with formulations (Freed et al 2019). Increasing pavement albedo by 10 to 25%, decreases surface temperature around 1.5 degrees Fahrenheit (Pomerantz 2000). Albedo increases, improving albedo minimizes the effect of pavement on UHI. The effectiveness of these particular products at reducing the UHI at the city scale is still unknown, and needs further research using real-world data. The Lawrence Berkeley National Lab Heat Island Group projected in a study that Los Angeles could save $90 million a year by increasing the albedo performance of pavements (Rosenfeld et al 1998). However, pulling real world data is expensive, and would require the application of cool pavement across a larger area than currently spread, especially in Los Angeles. Newly published research studied cool pavement testing sites in the City of Los Angeles, finding that though air temperatures were reduced by 0.5 degrees Celsius, the mean radiant temperature (that pedestrians may sense) were 4 degrees Celsius (Midell et al 2020). These results were centered on the specific project sites and did not include a neighborhood level analysis.

Tree Canopy Coverage

Street trees lower surface and ambient air temperature through evapotranspiration and shade provision. The EPA estimates that a shaded surface can be 20 - 45 degrees Fahrenheit cooler than of unshaded materials during peak temperatures (US EPA 2008). While evapotranspiration can further reduce ambient air temperatures by 2 to 9 degrees Fahrenheit (US EPA 2008).

Integrating trees into the urban landscape is nuanced and requires understanding disease and drought potentials while ensuring adequate water and space is provided to facilitate growth. Trees, however, are not a quick intervention to the streetscape, they require time to grow to reach full canopy potential. Additionally, trees face threats from insects, disease and drought. The challenges with trees, especially in a drought prone environment pose a significant barrier to widespread adoption in Los Angeles. The map below depicts tree canopy coverage by census tract, organized by quantiles. In lieu of focusing on the large swaths of dark green, which indicate the top quartile of greening (these areas largely include the Santa Monica Mountains), instead shift focus to Downtown and Central LA. These areas are densely populated and are not as likely to contain single family housing with yard space that allows for tree growth. It is these areas that should be closely studied for additional tree canopy coverage.

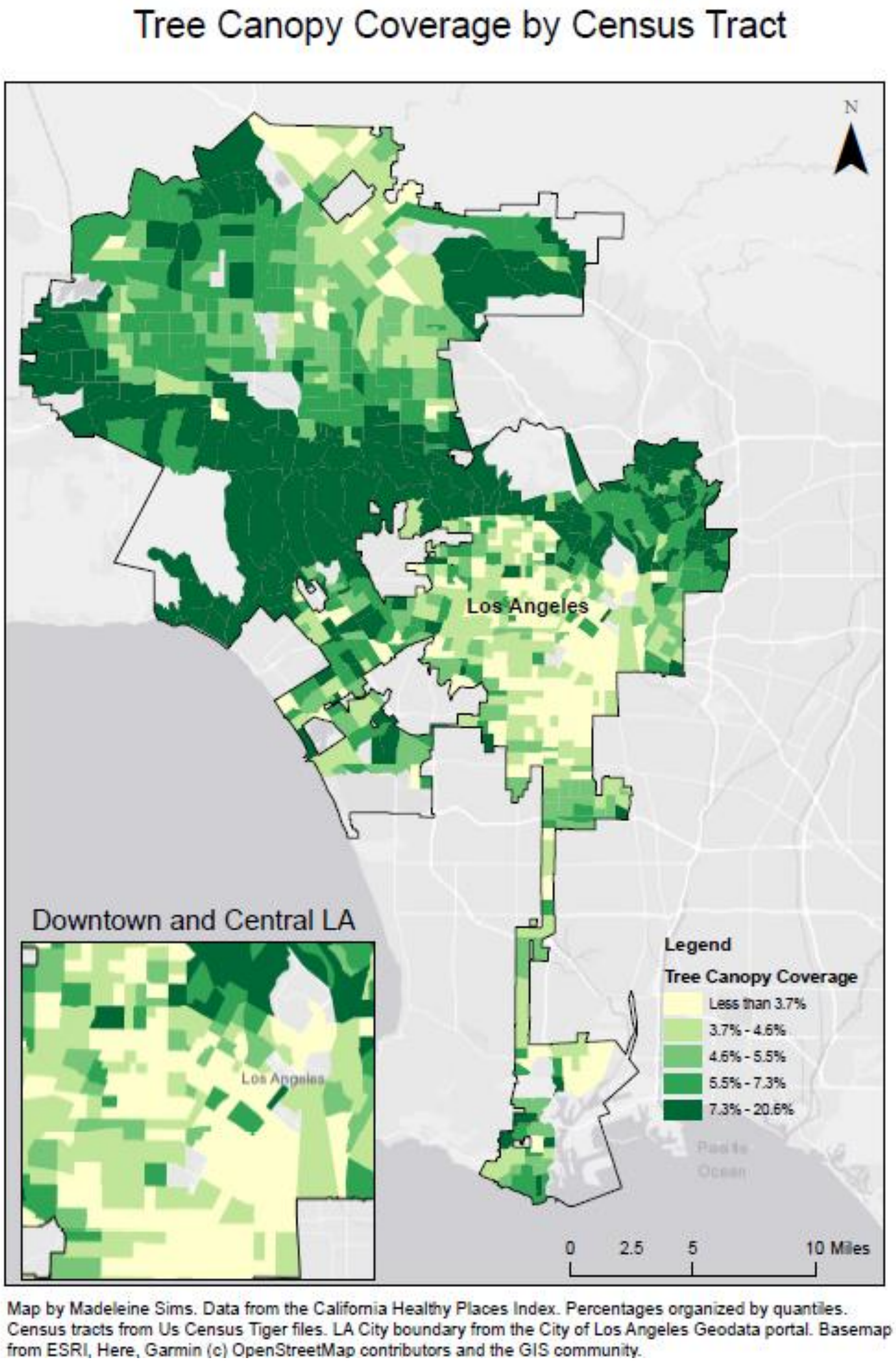


Figure 3:Tree Canopy coverage by Census Tract, organized by quantiles.

Governing Documents

LA's Green New Deal - Sustainable pLAn

The "Green New Deal" or Sustainability pLAn adopted in 2019, is the first update from the 2015 *Sustainability pLAn*, and most recent resiliency and sustainability document from the City of LA. The document, modeled after the failed Green New Deal introduced in Congress in 2019, is oriented around the development of a "green economy" and commitment to four principles including committing to the Paris Climate Agreement, delivering environmental justice and equity through an inclusive economy ("guided by communities themselves"), creating good, green jobs, and finally becoming a leader in the climate/green new deal sphere (H. Res 109 (2019); pLAn). In general, the document is a sustainability plan, and works in conjunction with the City's *Resilient Los Angeles* plan published in 2018.

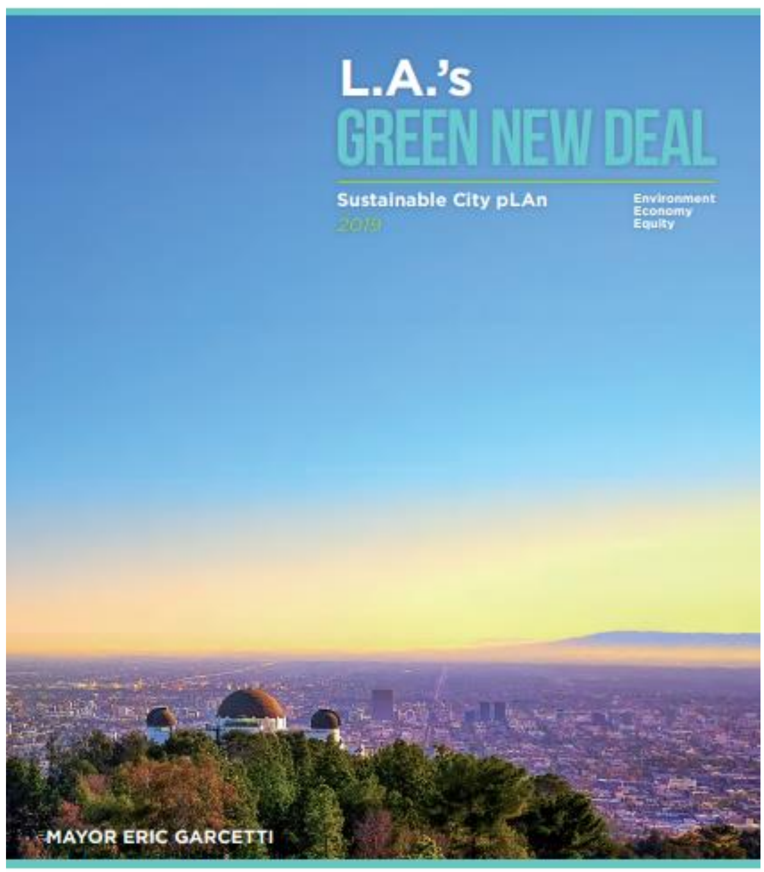


Figure 4: L.A.'s Green New Deal (Sustainability pLAn) cover page.

The update accelerates targets pertaining to stormwater capture, renewable energy, zero-emission vehicle adoption and GHG reduction. The plan defines the metrics used to evaluate the targets and plan recommendations. For the purposes of our report, the City defines Resiliency as "Protect L.A. against future climate change, shocks, and unexpected disasters as described in *Resilient Los Angeles*" (pLAn 2019, 18). The pLAn goes further into defining resilience and how it works in this specific document:

> "Policies that increase resilience – climate adaptation, infrastructure modernization, and economic security – are integrated throughout relevant chapters in this report. Building resilience to extreme heat and protecting against urban heat islands is covered specifically in the Urban Ecosystems and Resilience chapter."

Table 1.1 Environmental Justice Takeaways

CHAPTER	STRATEGY
Environmental Justice	"Develop spatial maps of existing cool roofs and heat risk to develop a strategy to add cool roofs in areas of highest heat vulnerability." (p.27)
Environmental Justice	"Incorporate additional cooling features such as innovative shade design, water features, and cooling centers at parks." (p.27)
Environmental Justice	"Upgrade cooling centers to better meet the needs of elderly and persons with disabilities." (p.27)
Environmental Justice	"Expand communications on types of cooling resources and available cooling spaces including through NotifyLA for homeless populations to increase usage and deployment." (p.27)
Environmental Justice	"Identify opportunities to implement cool corridors and other interventions to improve pedestrian comfort on routes to high-volume transit stops and cooling spaces. (p29)
Environmental Justice	"Implement a Street Furniture program that reduces heat exposure, provides cool transit stops, and improves access to restrooms in high transit use areas." (p.29)

The Environmental Justice chapter focuses on decreasing air pollution to improve asthma rates and other respiratory conditions largely through renewable energy and electric or zero-emissions vehicle policies. Grants highlighted in the plan include the Green Together: Northeast Valley (2.4 miles of pedestrian improvements, 6.8 acre park with trees, 2090 trees planted, 35 cool roof installed, green alley installation), South LA Climate Commons Collaborative, Watts Rising (native plantings, rain gardens, tree plantings, pocket parks, green street). This chapter notes the UHI impact on transit riders, and the need for pedestrian comfort such as shade. The proposed change to the Street Furniture program will require a change to the current agreement with Outfront/JCDecaux which does not require the integration of UHI or equity into the decision making process for bus shelter locations.

Table 1.2 Mobility and Public Transit Takeaways

CHAPTER	STRATEGY
Mobility and Public Transit	“Pedestrian centric design into all applicable projects.” (p 72)
Mobility and Public Transit	“Implement a Street Furniture program that reduces heat exposure, provides cool transit stops, and improves access to restrooms in high transit use areas.” (p 72)
Mobility and Public Transit	“Identify opportunities to implement cool corridors and other interventions to improve pedestrian comfort on routes to high-volume transit stops and cooling spaces.” (p 72)

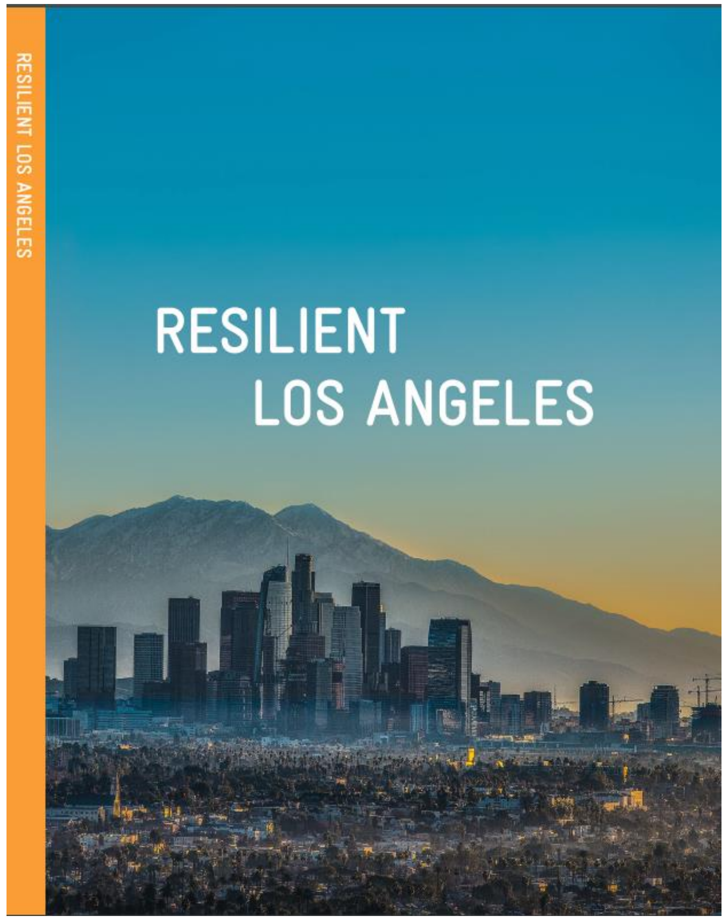
With the sustainability plan, a large focus is on mitigation and decarbonization, as evidenced by their targets and metrics (pLAn 2019). The Mobility and Public Transit chapter outlines goals for exactly that. A number of their milestones to meet their initiatives align with streetscape cooling measures. For example, their target “Increase the percentage of all trips made by walking, biking, micro-mobility / matched rides or transit to at least 35% by 2025; 50% by 2035; and maintain that 50% through 2050” (Sustainable pLAn). Similar to the Environmental Justice chapter, there is an emphasis on pedestrian scale cooling, to enforce public transit ridership and work towards reducing GHG emissions.

Table 1.3 Urban Ecosystems and Resiliency Takeaways

Chapter	Strategy
Urban Ecosystems and Resiliency	"All new roofs must be cool roofs by 2020; and install 13,000 additional cool roofs by 2021." (P. 122)
Urban Ecosystems and Resiliency	"Pilot 6 cool neighborhoods in vulnerable communities by 2021; and 10 by 2025." (p.122)

Under the Urban Ecosystems and Resilience Chapter, the target has been determined to "Reduce Urban/Rural temperature differential by at least 1.7 degrees by 2025; and 3 degrees by 2035" using a 5.58-degree Fahrenheit baseline in 2012 (pLAn 2019, 122). The pilot initiatives include designing these neighborhoods for cool roofs/pavements and urban greening, incorporating additional cooling features for the human experience (pedestrian features and cooling centers). By 2028, the City identified a target to install 250 lane miles of cool pavement, which was greenlighted in the FY2021 City budget. These milestones include "update cool surface regulations to require that at least 50% of all non-roof surfaces around new buildings meet certain criteria to reduce urban heat island effect", "promote cooling strategies and softening of hardscape in alleys and parking lots", "study cool streets and determine maximum potential of cooling strategies to reduce urban heat impacts" (pLAn 2019).

Resilient Los Angeles



Resilient Los Angeles, published in 2018, was one of a short line of resiliency documents from the City. The 96 actions outlined in the plan are oriented around leadership, disasters, economic security, climate adaptation, and infrastructure. Throughout the plan, there is an emphasis on terms such as "strength" and "safety." The plan was developed in response to a shock/stress analysis and born out of the 100 Resilient Cities Network, which the City joined in 2013. The plan defines shocks as "sudden or acute events that threaten or impact Los Angeles' immediate well-being" (Resilient Los Angeles). Stresses are defined as "daily or chronic challenges that weaken our natural, built, or human resources" (Resilient Los Angeles). Extreme heat is classified as a shock event, while the Urban Heat Island effect is considered a stress.

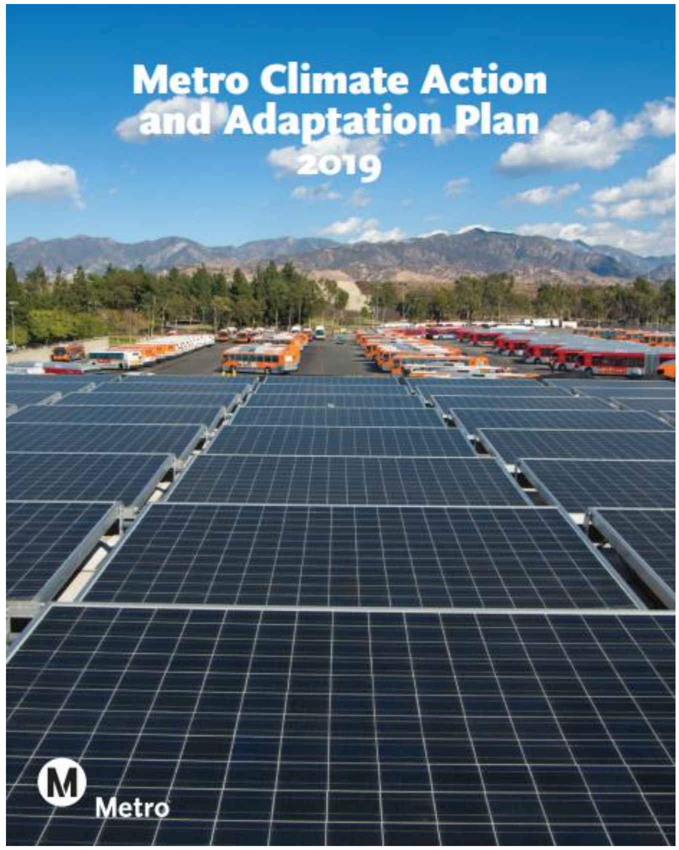
Climate adaptations in the *Resilient Los Angeles* plan are oriented around impacts of climate change, specifically for heat the following are proposed:

1. "Develop an urban heat vulnerability index and mitigation plan to prepare for higher temperatures and more frequent extreme heat."

2. "Develop and launch a neighborhood retrofit pilot program to test cooling strategies that prepare for higher temperatures."

3. "Plant trees in communities with fewer trees to grow a more equitable tree canopy by 2028."

Metro Climate Action Plan



Extreme heat is identified as a hazard, and notes the intensification the UHI will have on LA Metro's transportation network. Subsequent risks to the system include electrical outages, and wildfire, in addition rider and worker health. As it pertains to our analysis, LA Metro identifies shade as a key intervention for rider health.

Takeaways

The *Sustainable pLAn - Green New Deal* and *Resilient Los Angeles* plans outline the City's goals for climate adaptation and mitigation strategies. These two plans emphasize the importance of managing extreme heat impacts, notably pedestrian cooling, second to this are the recommendations for decreasing the UHI effect. Finally, the Metro Climate Action Plan emphasizes infrastructure, ensuring that service can still be provided during and after extreme weather events. The LA Metro Plan does outline the importance of worker and rider safety, though given the expansive nature of the organization physical interventions lie within the city government management realm. The streetscape is managed by many different stakeholders, including StreetsLA, Bureau of Engineering, Bureau of Street Lighting, Department of Cultural Affairs, Department of Public Works, and property owners all of whom have a role to play in streetscape cooling and were involved in the development of these plans.

Table 1.4 Key Takeaways from Planning Documents

SUSTAINABLE pLAn – GREEN NEW DEAL	RESILIENT LOS ANGELES	METRO CLIMATE ACTION PLAN
Implement pedestrian oriented design	Develop a UHI index, and mitigation strategies.	Ensure the transit system is protected from extreme heat.
Implement cool neighborhood programs.	Test cooling strategies in identified neighborhoods	
Implement streetscape cooling interventions near high-volume transit areas	Increase the tree canopy	

The table above outlines key takeaways from applicable planning documents for the City of Los Angeles as it pertains to streetscape cooling.

Non-Carbon Benefits

Non-carbon benefits of streetscape cooling interventions are largely related to public health benefits, such as decreased morbidity, and decreased hospitalizations. Climate change poses severe risks to human health, and livelihoods, however quantifying public health tends to lead to abstractions that are not clear for decision makers largely due to concerns over using a statistical value of human life. The EPA lists the primary impacts of extreme heat on human health to be increases in heat-related illnesses and deaths, particularly related to cardiovascular and respiratory health (Climate Adaptation and Public Health). Specific threats include respiratory difficulties, heat cramps, heat exhaustion, non-fatal heat stroke, and fatal heat stroke (Climate Adaptation and Public Health).

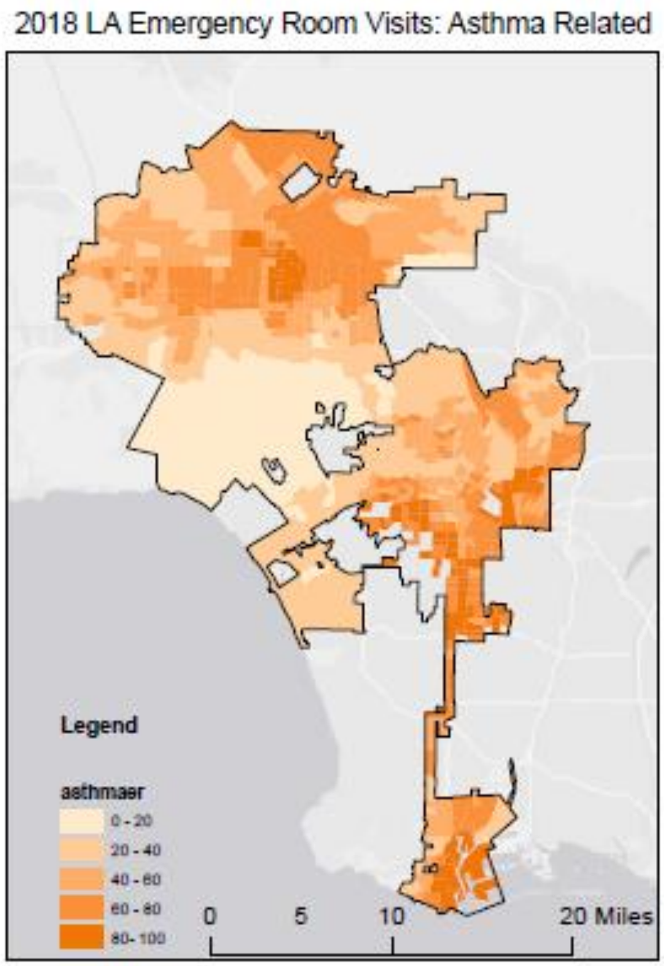


Figure 5: City of LA asthma hospitalizations, data from the California Healthy Places Index and organized by quantiles.

Particularly vulnerable populations include the elderly, children, and people with underlying respiratory/cardiovascular issues (Heat Related Deaths). Death rates and hospitalizations are often used as metrics for determining the susceptibility of an area to heat related illness.

A 2016 study of extreme heat waves in Europe 2003, showed that the mortality count was attributable to anthropogenic climate change (Mitchell et al., 2016). This particular study distilled the impacts of the Summer of 2003 extreme heat temperatures in London and Paris, noting that anthropogenic climate change increased mortality rates (Mitchell et al., 2016). Studies have established a link between the UHI and mortality rates, a 2003 study of a 2003 heatwave in the West Midlands, United Kingdom, suggests “that the UHI contributed around 50% of the total heat-related mortality” (Heaviside 2016). A Ho Chi Minh City centered study concluded that the UHI was also a contributing factor to a higher mortality rate in areas with less vegetative cover (Dang et al. 2018).

Extreme heat contributes to non-fatal medical conditions. A 2004 study found that incidences of high temperatures were mirrored by increased instances of hospital admissions for heart disease, these admissions usually happen after temperatures spike (Schwartz et al 2004). Determining the impact of the streetscape on heat related public health benefits is not easy, largely due to the diversity of uses for the streetscape.

Recommendations

Climate change adaptations, and particularly cooling interventions, are often valued at their cost- and carbon- reduction ability. Cities often rely on ensuring interventions reduce GHG emissions, or save a jurisdiction money/energy, as is the case in LA as evidenced through their various governing plans. Thus, how we evaluate and implement cooling interventions into the streetscape often requires some kind of metric of success, usually whether the carbon impact is lower, and/or in the case of cooling, temperature decreases (at the local, surface or ambient, or neighborhood level). To address the complexity of benefits and costs related to trees, planners are often directed towards one single metric to measure success, in lieu of a holistic or systems thinking / ecosystem services approach (Salmond et al.). If we focus on reducing the contributing factors to UHI as a system, (impervious surfaces, tree canopy coverage, and anthropogenic heat) we may be able to avoid a singular approach and implement new ideas and interventions as part of a suite.

When it comes to the streetscape, three major cooling interventions are discussed: cool pavement, transit shelters, and tree canopy. While all address UHI factors, they also address different aspects of streetscape use. Pedestrians and street vendors may find that tree canopy improves thermal comfort but may feel negative impacts from cool pavement materials reflecting light (Middell et al.). Choices about where to put cool pavement for better success rates, increased albedo (maintained over time), or decreased temperatures, is dependent on the urban geometry, making mass implementation across cities difficult, and highly dependent on neighborhood characteristics (Ryu 2012).

Similar problems arise with tree placement, ideal distances and tree well sizes are needed in order to optimize tree canopy potential. To meet these needs, cities publish standards, including tree palettes and design guidelines to address these needs. Yet trees are subject to drought and water restrictions, and pests/disease, that can be detrimental to their success as an intervention. Bus shelters serve a specific purpose, protect riders waiting for transit vehicles protection from the elements, namely rain and sunlight. The equitable placement of these structures is important, and while structures must be used in order to justify their existence, emphasis should be placed on installing these shelters in census tracts, or neighborhoods, where the UHI is greatest. The purpose is of course, two-fold, shading pavement and shading passengers. The contradicting nature of some of these interventions pose difficulties for planners and policy makers, particularly when trying to measure success.

The greatest good of addressing the UHI in Los Angeles, can and will be, very expensive. Cool pavement is not cheap, and though it can be integrated as part of maintenance plans, studying and determining where it is best implemented can be costly (Freed et al). Addressing the impacts of the UHI on human health lie in addressing what makes people vulnerable: excessive heat exposure. Stemming from this are other impacts, from increased energy bills, increased home interior temperatures, and pollution. Addressing the sources of these issues, UHI, can help decrease the amount of additional adaptation strategies needed for impacts. California has made plans to address UHI through SB 45 and Governor Newsom’s Climate

Resiliency Bond proposal. SB 45 outlines approximately $40 million in funding for UHI, greenhouse gas emission reduction and increased green spaces funding.[4] The Climate Resilience Bond proposes approximately $200 million for urban forestry and greening, and an additional $125 million for cool surface projects (roof and pavement). With these funding opportunities, strategies for reducing the UHI will need to be robust and equitable. While decreasing UHI remains the center of cooling approaches, efforts should be made to incorporate the impact to public health action, or inaction, will have.

1. **Reexamine the reliance on LCA/Carbon decision-making frameworks for cooling interventions, namely cool pavement and other new technologies.**

While modeling of increased surface albedos show improved UHI conditions, the lack of real world data on the performance of cool pavements is of concern. The concern largely lies in the emphasis on LCA as the metric of success for cool pavement in lieu of real-world data. As the City of Los Angeles continues to place emphasis on the co-benefits of adaptation activities, namely reducing GHGs, exploring how to encourage manufacturers to improve production to reduce emissions and advancing research and development for cool pavement can help work towards a scenario where emphasis can be placed on the efficacy of the product rather than focusing solely on emissions. Newly published research on the pedestrian effects of cool pavement recommend that implementers use a cost-benefit analysis before installing cool pavement, a recommendation also suggested by the Materials and Testing team for the City of LA (Midell et al 2020; Department of General Services). In addition to incorporating a CBA, policy makers and planners should continue to research and support the development of cool pavement in conjunction with pavement reduction plans.

Second, research shows that cool pavements can be effective in areas with little, or slow, vehicular traffic and in areas that are open, not crowded by structures (Hui 2012). Encouraging the implementation of cool pavement products in these areas can allow for additional research using real-world data and meet UHI reduction goals by improving albedo. Parking lots, surface lots or top floors of exposed parking garages, can be coated in cool pavement coatings with minimal reflectance impacts and are ideal for pilot implementation (Hui). By avoiding the potential impacts to pedestrians and immediately surrounding building walls, researchers may be able to better study the impacts of cool pavement on neighborhood cooling.

2. **Encourage the widespread adoption of bus shelters to both protect rider health and ridership.**

In Los Angeles, not all bus stops have shelters for various reasons. The LA Metro Climate Action plan identifies shade as a key component for rider health, and the City of Los Angeles pLAn (Green New Deal) also identifies transit-oriented cooling strategies as a strategy. The current

[4] Without considering the impact that the COVID-10 pandemic will have on government budgets.

process for selecting bus shelter locations combines ridership levels with traffic levels, or the need to shelter people in general with ad revenue (TransitCenter). Though ridership levels are incorporated into the current decision-making framework, its weight in the prioritization process is unknown, yet the emphasis remains on vehicular traffic levels and ensuring advertisements can be seen. As the bus shelter program comes up for renewal/reevaluation in 2021, incorporating a more stringent public health emphasis would improve rider safety and in turn protect ridership during extreme weather events (Miao 2016).

However, the transportation network and City agreement with JCDecaux makes the process difficult from an administrative standpoint. Multiple transportation networks intertwine in the City, LADOT, LAMetro, Santa Monica Big Blue Bus, Culver CityBus, and other networks. These networks share stops within the City, but management of stops and street furniture is largely left to the City of Los Angeles StreetsLA department after working with JCDecaux to identify locations for shelters (TransitCenter). Obtaining permits for these structures is a lengthy process, and requires approvals from City Council, the Public Works department and other city agencies before approval (TransitCenter). Encouraging the City to streamline this process, can work to achieve the goals outlined in the LAMetro Climate Action Plan and Los Angeles pLAn (Green New Deal).

Additionally, redesigning the program to prioritize locations that will have greater impacts from extreme heat in the future and fewer shading amenities would shift the focus of the program to public health. While the structure of the current program allows the City to collect revenues from the bus shelter installation, improving bus shelter design is also a consideration. Currently, there are four types of bus shelters in use by JCDecaux (TransitCenter). Solar shading is difficult to implement on a mass scale with a single product effectively due to differences in orientation, thus, alternative methods of bus stop shading should be considered as part of a suite of shelter types.

3. **Encourage the use of cool pavement on parking lots and other large areas of pavement that are unencumbered by buildings.**

Cool pavement, though in production for many years, still lacks adequate real-world data and research that supports its widespread use. The large critiques of cool pavement (outside of LCA related aspects) are primarily concerned with its efficacy in cooling surface temperatures and the surrounding air. New research from Ariane Middel and V. Kelly Turner, summarized these findings by analyzing the City of Los Angeles pilot cool pavement program, concluding that while surface temperatures were lower, pedestrian thermal comfort was negatively impacted though this impact was slight (Middel et al.). Studies tied a large amount of the unknown negative effects of cool pavement to the surrounding built environment, wary of the impacts of reflected light on canyon walls (Li et al; California Air Resources Board). These studies did note that parking lots were a viable location for cool pavement coatings, where they would act more similarly to cool roofs (Golden; California Air Resources Board). As such, the implementation of cool pavement in these areas would allow for more widespread research and testing to quantify the benefits and better understand the impact of cool pavement on UHI more clearly.

Nevertheless, understanding the potential impact of cool pavement on UHI is hampered by a lack of real-world data. The implementation of cool pavement programs can help to fill a demonstrated research gap as long as these programs are wary of potential pedestrian thermal impacts. Hence, by focusing first on parking lots and other large areas of pavement, researchers can work to understand the overall impact of cool pavement at the microscale and continue working towards neighborhood level understanding of the impact of cool pavement.

4. **Pursue a planned, holistic approach to streetscape cooling that includes vegetation, tree canopy coverage and cool pavements.**

With the fragmentation of the bus shelter implementation plan, integrating StreetsLA management of the urban forest with cool pavement implementation (at both the private and public level) could be challenging. However, with the City's stated goals to decrease UHI and increase shading, integrating the numerous StreetsLA programs can help demystify how streetscape cooling is managed. The two primary interventions at the streetscape are shade (bus shelters, tree cover) and pavement interventions (cool pavement coatings). Though real-world data on cool pavement is limited, modeled data shows that cool pavement can decrease the amount of retained heat and surface level temperatures (Middel et al).

One of the largest issues with cool pavement is questions over the efficacy of the product at decreasing the UHI given concerns over wear and tear, reflection potentially increasing energy costs for surrounding buildings, and pedestrian thermal comfort concerns (California Air Resources Board; Li; Middel et al). Trees are not without difficulties. Adequate sidewalk width and watering is needed to ensure a healthy canopy, and in a city with weak sidewalk infrastructure and concerns over water, the implementation of tree programs can be a hard-sell. However, vegetation and trees are a proven, effective strategy to mitigating the UHI and should be pursued or encouraged particularly in conjunction with permeable pavement programs. Nevertheless, as the City moves along with their Vision Zero plan, and moves to reduce reliance on cars, linking reducing paved areas and increasing vegetative cover can create new partnerships and further integrate reducing the UHI across City plans.

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