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MASTER THESIS

Navigating Under the Redline

Heat Risk, Vacancy, and Infrastructure for Transition in Vulnerable Communities of Chicago

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Abstract

English

In the City of Chicago, urban heat risk is unequally distributed and strongly associated with post-industrial restructuring and previous redlining. This thesis examines how structural inequality continues to shape contemporary climate vulnerability and seeks to assess urban heat risk through an integrated spatial framework. The study evaluates three interrelated dimensions: social vulnerability, heat hazard measured through Urban Heat Island intensity, and heat exposure associated with pedestrian network accessibility and cooling resource availability.

Methodologically, the study creates a multi-scalar assessment of heat risk by integrating demographic information, historical redlining overlays, urban network modeling, and geospatial heat analysis. To find regions where vulnerability, heat hazard, and heat exposure intersect, these dimensions are examined at the citywide and local levels. The results demonstrate that historically redlined communities experience compounded heat burdens characterized by higher surface temperatures, limited tree canopy, fragmented mobility systems, and persistent vacancy.

The findings reveal vacancy as both a spatial consequence of historic disinvestment and a potential resource for adaptive intervention. Building on this assessment, the thesis proposes a typology-based transitional climate infrastructure framework that aligns vacant land conditions with modular, reversible interventions. By prioritizing flexible strategies over permanent high-intensity development, the research advances a governance-aware and spatially explicit approach to urban heat resilience. The study contributes a structured model for integrating climate adaptation, spatial justice, and land governance in post-industrial urban contexts.

Italian

Nella Città di Chicago, il rischio da calore urbano è distribuito in modo diseguale ed è strettamente associato alla ristrutturazione post-industriale e alle precedenti pratiche di redlining. Questa tesi analizza come le disuguaglianze strutturali continuino a modellare la vulnerabilità climatica contemporanea e mira a valutare il rischio da calore urbano attraverso un quadro spaziale integrato. Lo studio esamina tre dimensioni interconnesse: la vulnerabilità sociale, il pericolo termico misurato attraverso l'intensità dell'Urban Heat Island (UHI) e l'esposizione al calore associata all'accessibilità delle reti pedonali e alla disponibilità di risorse di raffrescamento.

Dal punto di vista metodologico, la ricerca sviluppa una valutazione multi-scalare del rischio da calore integrando dati demografici, sovrapposizioni storiche del redlining, modellazione delle reti urbane e analisi geospaziale delle temperature. Per individuare le aree in cui vulnerabilità, pericolo termico ed esposizione si intersecano, tali dimensioni vengono analizzate sia a scala urbana sia a livello locale. I risultati dimostrano che le comunità storicamente oggetto di redlining sperimentano oneri termici cumulativi, caratterizzati da temperature superficiali più elevate, limitata copertura arborea, sistemi di mobilità frammentati e persistente presenza di lotti vacanti.

I risultati evidenziano come i vuoti urbani rappresentino sia una conseguenza spaziale del disinvestimento storico sia una potenziale risorsa per interventi adattivi. A partire da questa valutazione, la tesi propone un quadro di infrastruttura climatica transizionale basato su tipologie, che allinea le condizioni dei lotti vacanti a interventi modulari e reversibili. Privilegiando strategie flessibili rispetto a sviluppi permanenti ad alta intensità, la ricerca promuove un approccio alla resilienza al calore urbano consapevole delle dinamiche di governance e spazialmente esplicito. Lo studio contribuisce a un modello strutturato per integrare adattamento climatico, giustizia spaziale e gestione del suolo nei contesti urbani post-industrali.

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CHAPTER I

Introduction

Chapter I: Introduction

1.1. Background and Context

The urban heat island (UHI) phenomenon, identified in the early 19th century by Luke Howard, is the way in which cities are generally warmer than their rural environment. Urban communities have higher heat absorption and retention because of the concentration of constructions, impervious surfaces such as asphalt and concrete, and lower vegetation. Therefore, urban areas observe several degrees of temperature difference with the rural surroundings, especially under quiet, clear conditions and at night. These warmer city temperatures have several implications: they accelerate cooling energy consumption, strain electricity infrastructure, worsen air quality through smog formation, and escalate heat-related illness risk. In fact, extreme heat is today the deadliest weather hazard in the United States, causing more annual deaths than hurricanes or flooding. Chicago knows this threat all too well, the infamous 1995 heatwave killed more than 700 heat-related deaths in the city.

Heat exposure does not affect every urban resident to the same extent. Certain populations are disproportionately exposed and impacted by intense heat: the elderly and very young, low-income and vulnerable communities, individuals with disabilities, the homeless, and outdoor workers are all more severely impacted by heat. The majority of these populations rely significantly on active mobility, walking, cycling, or wheeling as cheap means of transport. Ironically, the neighborhoods that they live and work in will have less trees and parkland and more asphalt roadways. This lack of greenery permits such neighborhoods to be fairly warmer than greener portions of the metropolis; Chicago measurements, for example, have found that temperatures in some of the treeless, extremely paved neighborhoods can become up to 20°F (11°C) warmer than in cooler portions of the metro area. These intra-city heat inequities also expand existing social inequities since low-income or minority groups overwhelmingly experience perilous heat exposure.

Under these conditions of rising urban heat, mobility and accessibility become prominent analytical lenses through which to judge urban livability and equity. Accessibility means the ease with which people reach desired services, activities, and destinations their possibilities in the city. Mobility, conversely, is the freedom and fluidity with which individuals traverse city space. Together, the two words emphasize not just movement, but access to work, schooling, health care, and other essentials on an equal plane. Inclusive mobility entails catering to the needs of all members in a community; income, age, or disability should not be an issue so that all members have the ability to move through the city safely. Prolonged heat risks undoing inclusive mobility. Adequate ambient and sidewalk temperatures cause walking or cycling to be uncomfortable and even hazardous for frail pedestrians and bicyclists who can become dehydrated, experience heat stroke, or have cardiovascular stress when exercising outside. Cities built primarily for vehicles (with widespread heat-absorbing pavement and minimal shade) worsen this problem. As global warming forces more powerful summers and heatwaves, cities like Chicago are faced with the condition where active mobility is dissuaded at exactly the moment when it's most required.

Chicago, a city of approximately 2.7 million people, illustrates the complexity of "navigating under heat". It is a pedestrian-friendly city with much paved space and tall downtown "urban canyons" that absorb and store heat. The city's summer weather is hot and humid, and climate modeling indicates that intense heat episodes like the 1995 heatwave are likely to occur much more frequently than they will happen as regularly as once every decade or so by mid-century. Chicago has begun to tackle urban heat in the guise of adaptation planning; e.g., the city's Climate Action Plan prioritizes heat event preparation and implemented measures such as green roofs, cool roof reflective surfaces, additional tree planting, and neighborhood heat hot-spots mapping. These measures have co-benefits (e.g., stormwater management and air quality) and suggest that heat is being taken seriously by the city.

Considering these challenges, this thesis develops a spatio-temporal urban network analysis model to evaluate the impact of urban heat on active mobility within the City of Chicago. It looks at the interconnectivities between UHI trends and pedestrian and cycling infrastructure of the city, access to significant services, and the socio-demographic vulnerability pattern. By linking climate data with mobility data, this study aims to identify spatial disparities e.g., places where heat exposure greatly restricts walkability and develop climate-sensitive urban planning and policy interventions. In its concern with the everyday experience of walkers and cyclists in heat stress, this study is part of broader debates around urban resilience, environmental justice, and livable transportation in the era of global warming.

1.2. Statement of the Problem

The consequences of urban heat islands (UHIs) on energy use, air quality, and public health have been extensively studied in the past. The ways that past planning techniques, especially redlining, still influence unequal exposure to urban heat and hinder pedestrian mobility in vulnerable communities, however, have received little attention. **Long-standing trends of racial segregation, underfunding, and spatial inequality have created urban environments in places like Chicago where mobility disadvantage and environmental danger are closely related.**

Throughout the 20th century, **redlining policies intentionally limited investment in neighborhoods that were mostly populated by Black and minority residents**, leading to long-lasting differences in land use, urban design, and environmental quality. Today, there is a limited tree canopy, a high concentration of impermeable surfaces, fragmented pedestrian infrastructure, and a high incidence of vacant or underutilized land in many of these formerly redlined locations. Certain features raise the ambient and surface temperatures, making certain neighborhoods more susceptible to high heat events. Nevertheless, modern urban heat studies are frequently still divorced from mobility planning, especially when it comes to pedestrians.

Macroscale temperature trends, building energy use, or aggregate health consequences like heat-related deaths and hospitalizations are frequently the subject of current UHI research. Similar to this, research on walkability and mobility usually focus on land-use mix, connectivity, and infrastructure quality while ignoring temperature exposure as a significant environmental stressor. Because of this, typical measures of accessibility and walkability may not fully reflect the lived conditions in communities that are exposed to high temperatures. Even if a city has a high ranking for street connection or closeness to destinations, it may still be practically impossible to walk in during hot weather because of the extreme heat, lack of shade, and lack of cooling facilities.

For vulnerable groups living in previously redlined neighborhoods such as low-income households, the elderly, children, individuals with disabilities, and those who rely significantly on walking and public transit this disparity is especially significant. These groups frequently have fewer options for physical transport than higher-income groups, who may be able to avoid heat exposure by driving air-conditioned luxury automobiles. Walking is discouraged, physical risk is increased, and pre-existing mobility and health disparities are made worse by prolonged exposure to heat along daily routes to work, education, healthcare, and other critical services.

The absence of comprehensive frameworks connecting redlining history, urban heat exposure, and pedestrian mobility poses a significant planning problem in Chicago, where climate change is increasing the frequency and intensity of heat events. Even while local agencies may have access to comprehensive mobility and temperature data separately, these are rarely examined in tandem to show how heat exposure physically overlaps with historically marginalized communities and regular pedestrian traffic. Planning initiatives run the danger of ignoring communities where heat serves as a subtle yet potent mobility barrier if this integration is not made.

Research that connects environmental risk, migration analysis, and historical injustice is therefore desperately needed. In order to inform equitable urban planning, climate adaptation plans, and pedestrian-oriented design solutions that address the lived reality of Chicago's vulnerable populations, this gap must be closed. **By investigating how redlining increases urban heat exposure and alters pedestrian movement patterns in the city's modern urban landscape, this thesis aims to address this issue.**

1.3. Research Aim and Objectives

Research Aim

This thesis looks at how the City of Chicago's historical redlining practices have influenced long-term trends in neighborhood development, environmental vulnerability, and pedestrian mobility. It also looks at how these trends lead to vulnerable communities experiencing unequal exposure to urban heat. The study **aims to demonstrate how the effects of disinvestment continue to affect urban heat exposure in the present, access to safe and comfortable transportation, and overall spatial equality by combining historical, environmental, demographic, and mobility-based spatial analysis.** The study also intends to investigate how underutilized and vacant property could be used as a vehicle for environmental mitigation, neighborhood activity, and the lessening of spatial inequalities related to redlining. By identifying the communities and populations most at risk and highlighting opportunities for focused policy and design interventions, the overall objective is to enable socially inclusive and climate-responsive urban development.

Research Objectives

- to investigate the effects of Chicago's historical redlining practices on long-term community development, land use, infrastructure investment, and the continuation of underutilized or unoccupied land in impacted communities.
- to map surface temperature trends and Urban Heat Island (UHI) intensity in order to evaluate the spatial distribution of urban heat exposure, paying special attention to areas that have been affected by redlining and long-term disinvestment.
- to assess which neighborhoods are disproportionately exposed to urban heat and mobility limitations, sociodemographic factors (such as age, income, race, health vulnerability, and transit dependency) will be integrated to identify and define vulnerable populations.
- to assess pedestrian mobility and access conditions in historically redlined and heat-exposed districts, looking at how land-use patterns, urban heat, lack of shade, and fragmented pedestrian infrastructure impact walking comfort, route selection, and access to necessary services.
- to use spatial overlays and clustering techniques that pinpoint locations where environmental, social, and infrastructure vulnerabilities converge in order to investigate the cumulative and compounding consequences of redlining, urban heat, and restricted mobility.
- to map and assess vacant and underutilized parcels within historically redlined and heat-vulnerable neighborhoods, evaluating their spatial relationship to pedestrian networks, mobility corridors, and areas of high heat exposure.
- to investigate vacancy as a vehicle for activation and intervention, finding ways to strategically repurpose unoccupied property to assist cooling measures, improve pedestrian environments, increase access to green or shaded spaces, and lessen historical spatial inequities.
- to provide evidence-based insights on how vacancy-led interventions might enhance thermal comfort, mobility, and resilience for vulnerable communities in order to guide equity-driven, climate-sensitive planning and urban design policies.

1.4. Research Questions and Hypotheses

Research Questions:
The following are the guiding research questions for this study:

1. **How does the historical legacy of redlining in Chicago shape present-day patterns of urban heat exposure and environmental vulnerability at the neighborhood scale?**
2. **In what ways does intensified urban heat function as a mobility barrier for vulnerable populations in historically redlined neighborhoods, affecting pedestrian movement and access to essential services?**
3. **How can vacant and underutilized land in historically redlined and heat-vulnerable neighborhoods be leveraged as an activation mechanism to mitigate urban heat and reduce long-standing mobility and spatial inequities?**

Hypotheses: Based on preliminary literature review and rational supposition, the study tests the following hypotheses

- H1: Redlining and Urban Heat Exposure - Due to the long-term effects of disinvestment and unequal urban development, historically redlined neighborhoods in the City of Chicago have much higher levels of urban heat exposure as indicated by land surface temperature and Urban Heat Island intensity than neighborhoods that were not redlined.
- H2: Urban Heat as a Mobility Barrier - Reduced pedestrian mobility and accessibility, especially for vulnerable populations that depend on walking and public transportation, are linked to elevated urban heat exposure in historically redlined neighborhoods. This suggests that heat acts as a spatial barrier that limits daily mobility and access to necessary services.
- H3: Vacancy as an Intervention Opportunity- Areas of high thermal exposure and restricted pedestrian mobility spatially coincide with vacant and underutilized land in historically redlined and heat-vulnerable neighborhoods, making these areas prime locations for urban interventions that are equity-driven, cooling-oriented, and pedestrian-supportive.

1.5. Scope and Delimitation of the Study

This study **focuses on the City of Chicago both geographically and philosophically, with a concentration on communities that have historically been redlined and still face increased socioeconomic vulnerability**. Selected redlined community areas where urban heat exposure, inadequate pedestrian infrastructure, and vulnerable populations physically overlap are the focus of the analysis, however citywide datasets are used to offer comparative context. While retaining relevance at the city scale, this targeted strategy enables the study to investigate regional trends of inequality.

The research's focus is on the relationship between redlining, exposure to urban heat islands (UHIs), pedestrian mobility, and access to basic services. Surface temperature and UHI intensity are used to analyze urban heat as environmental stressors that have a direct impact on outdoor mobility. Since pedestrian and walking-based access are the modes most susceptible to temperature changes and the ones most frequently used by vulnerable people, mobility analysis is restricted to these modes. The study also looks at land vacancy, which is frequently the result of long-term disinvestment in redlined districts, as a possible opportunity for intervention, especially for cooling methods and pedestrian-oriented improvements, as well as a sign of spatial deterioration.

Using geographical datasets pertaining to historical redlining, urban heat, sociodemographic vulnerability, mobility, and land use, the study employs a spatial and scenario-based analytical methodology. The goal of the study is not to create dynamic simulations, forecast behavior in real time, or evaluate how each person adapts to heat by changing their routine or using coping mechanisms. Rather, it concentrates on locating structural patterns, cumulative vulnerabilities, and spatial relationships that limit access and mobility. To keep the scope simple and manageable, large-scale transportation systems, indoor spaces, and climate stresses unrelated to heat are not included.

1.6. Significance of the Study

This study is significant for urban planning because it shows **how uneven urban heat exposure and limited pedestrian mobility caused by historical redlining continue to impact current spatial inequities.** The research shows that urban heat is not only a climatic condition but also a structural planning outcome that affects access, safety, and daily movement inside the city by connecting previous planning decisions to current climate hazards. This viewpoint urges planners to embrace place-based, equity-driven strategies that give historically underserved neighborhoods first priority within frameworks for mobility and climate adaptation, rather than relying solely on citywide or technically oriented climate responses.

From a policy perspective, the study offers a geographically grounded body of evidence to back more equitable and focused mobility and climate policies. **The study assists policymakers in setting investment priorities and coordinating climate adaptation strategies with public health and transportation objectives by pinpointing the intersections of redlining history, social vulnerability, urban heat intensity, restricted pedestrian access, and land vacancy**. The results highlight how crucial it is to include historical consciousness into current policy-making in order to make sure that climate resilience plans address long-standing spatial injustices ingrained in the urban environment rather than perpetuating current disparities.

The study emphasizes how the built environment influences human mobility experiences and mediates heat exposure in terms of urban planning and architecture. It highlights how walkability and thermal comfort are impacted by design choices made regarding land use, materials, street layout, and shade, especially in historically underinvested areas. The research supports design and architectural methods that can turn underutilized and vacant land into inclusive, cooling, and connecting pieces of the urban fabric by framing these places as opportunities for action. In the end, the study presents architecture and urban planning as proactive instruments for repairing damaged spaces, adapting to climate change, and building more resilient and egalitarian cities.

1.6.1. Theoretical Contributions

Theoretically, by combining ideas from mobility justice, urban climate science, and socio-spatial planning history, this study promotes interdisciplinary scholarship. Instead of being static features of urban form alone, it reframes walkability and accessibility as dynamic variables influenced by temperature exposure. The study expands on current theories of urban resilience and environmental justice by directly connecting redlining to environmental stress and pedestrian mobility. This provides a spatially grounded framework for comprehending how historical injustice influences climate risk and daily urban experience.

1.6.2. Practical and Policy Implications

The study offers spatially explicit insights that can guide equity-driven and climate-sensitive urban solutions from a practical and policy standpoint. The research supports targeted planning strategies like cooling-oriented pedestrian infrastructure, activation of vacant land, and improved access to shaded and thermally comfortable routes by identifying neighborhoods where redlining history, high urban heat exposure, social vulnerability, limited mobility, and land vacancy intersect. In Chicago and other cities dealing with comparable legacies of segregation and climate stress, our findings can help politicians, planners, and designers prioritize investments, integrate climate adaptation with mobility planning, and address long-standing spatial imbalances.

1.7. Definition of Key Terms

In short, in this section the main terms are described as they are used within the framework of this thesis:

- **Redlining: A historical approach to planning and lending that involved routinely denying public resources, mortgages, and investment to communities that were frequently populated by racial and ethnic minorities on the basis of perceived financial risk.** Redlining, which was first made official by laws like the Home Owners' Loan Corporation (HOLC) maps, has had a lasting effect on urban growth, causing socioeconomic disadvantage, environmental fragility, and ongoing spatial inequality.
- Urban Heat Island (UHI): The state where urban temperatures are higher than those in the adjacent rural environments due to human-manipulated activities and man-made surroundings. The origin of the UHI effect is heat-absorbing surfaces like pavement and buildings, reduced vegetation (and thereby less evaporative cooling), and vehicle and industrial waste heat. In day-to-day life, a UHI will warm a city center by several degrees above the rural area, especially on calm nights.
- Urban Heat Exposure: The extent to which people or groups are exposed to high surface or ambient temperatures in urban settings. Land use, urban form, vegetation cover, and infrastructural quality all influence urban heat exposure, which differs geographically between communities.
- Social Vulnerability: The vulnerability of people or groups to environmental stressors as a result of sociodemographic characteristics including wealth, age, race, health, and resource accessibility. According to this study, social vulnerability is a condition that develops over time and affects a community's ability to prepare for, manage, and recover from the effects of heat.
- Vulnerable Communities: Due to historical marginalization, resource scarcity, and systemic injustices, certain populations or communities are more vulnerable to environmental, social, and infrastructure pressures. Vulnerable communities are defined in this study as those that are disproportionately impacted by urban heat exposure and limited mobility, especially in historically redlined regions.
- Accessibility: Urban planning accessibility refers to how easily one can reach desired destinations, services, or activities from a given location. Good accessibility means that required opportunities (e.g., jobs, schools, stores, parks) are within reach or can be reached quickly and affordably by available transportation. It is the result of both land use (how close things are to each other) and mobility (the transport to get to those things).
- Mobility: Individuals' ability to move freely, effectively, and securely across the city environment. Mobility typically refers to the operation of the transport system how well it facilitates individuals (or commodities) to move. In the course of this thesis, we focus on individuals' mobility at the personal level (as opposed to vehicular mobility), with specific focus on walking, cycling, or traveling under one's own power. Good mobility implies few impediments to movement, including aspects such as satisfactory infrastructure, safety for individuals, and physical capacity.
- Active Mobility: Human-powered transport modes, most commonly walking and cycling. Active mobility also includes running, wheelchair or assistive devices, skating, and other non-motorized modes requiring physical effort. These modes are active and green (more exercise, no emissions), but they put travelers directly in contact with the ambient conditions, and that is why heat can be a significant concern for active travelers.
- Thermal Comfort: A condition when an individual is not uncomfortably hot or uncomfortably cold. Environmental conditions such as air temperature, humidity, wind speed (air movement), and solar radiation affect thermal comfort, along with personal conditions such as clothing and activity level. Thermal comfort in outdoor urban environments can be promoted by shade, breezes, or cooler surface materials, and reduced by high humidity, direct sun, or heat-trapping infrastructure. Achievement of outdoor thermal comfort is crucial to make public areas habitable during warm climatic conditions.
- Pedestrian Walkability: A measure that reflects how hospitable and walkable an area is. Walkability encompasses the presence and quality of sidewalks and crosswalks, traffic and crime safety, connectivity (accessibility to several destinations on foot), and comfort/aesthetics (availability of shade, vegetation, benches, and absence of unnecessary noise or pollution). High walkability refers to walking as a viable and pleasant way of moving around. In this study, we broaden the concept to thermal walkability, keeping in mind that features like shade trees or heat-resurfacing material have an impact on how walkable an area is when it is hot.
- Spatial Injustice - the uneven allocation of opportunities, resources, and environmental factors over space, frequently as a result of structural and historical planning choices. Inequalities in access, movement, and exposure to the environment within cities are examples of spatial injustice.

1.8. Organization of the Thesis

This thesis is divided into five chapters, as follows:

- **Chapter I: Introduction.** The current chapter has provided the background and context of the research, posited the research problem, purpose, objectives, research questions, and hypotheses, defined scope and significance, and clarified key terms. Generally, Chapter I presents why there is a need for the research and what it seeks to accomplish.
- **Chapter II: Review of Related Literature.** This chapter discusses the current literature and theoretical background of the research study. It incorporates research on urban heat islands (historical findings and new studies on heat inequity), studies on urban walkability and livability in hot climates, and reviews spatial analysis techniques and predictive modeling techniques used in earlier research. The literature review validates the prevailing knowledge gap that the thesis aims to bridge and draws from the past in setting up the research design.
- **Chapter III: Research Methodology.** This chapter defines the methodological approach of the study. It delineates the data sources utilized (e.g., satellite thermal images, city mobility datasets, census information), the utilized technology and software tools (GIS, statistical packages, etc.), and the actual analysis techniques applied (e.g., spatial interpolation of heat information, network analysis measurements for accessibility, prediction via regression or machine learning models). The chapter also describes how variables were operationalized (e.g., how one defines a "heatwave day" or a "high walkability score"), and it addresses reliability, validity issues and limitations or ethical issues related to the use of data.
- **Chapter IV: Results and Discussion.** The empirical results are presented in this chapter together with their translation into planning and spatial strategies. In order to identify high-risk neighborhood locations where mobility limitations and thermal vulnerability converge, it maps the geographic distribution of urban heat exposure, pedestrian mobility patterns, and vacancy typologies throughout Chicago. After that, the chapter suggests targeted, temporary, and adaptable treatments for various kinds of unoccupied parcels, going beyond diagnosis. It provides a staged implementation structure (short-, medium-, and long-term), describes the selection of high-risk sectors, and lays out criteria for priority. The chapter shows how network-based analysis and geographical assessment can guide practical, equity-oriented cooling and mobility initiatives inside the urban fabric, as opposed to concentrating on abstract models.
- **Chapter V: Conclusion.** The study's main conclusions are summarized in the last chapter, which also highlights how structural inequality, which has its roots in past planning choices, manifests in both social and physical. The integration of urban heat analysis, pedestrian network assessment, and vacancy-based intervention options within a justice-oriented planning framework is one of the study's primary accomplishments, as highlighted in this statement. The innovative connection between heat hazard and phased spatial action and network accessibility is also covered in this chapter. Lastly, it considers how future research might extend or improve the framework while acknowledging its limitations, which include data limitations, methodological bounds, and transferability difficulties.

CHAPTER II

Review of Related Literature

Chapter II: Review of Related Literature

2.1. Urban Risk, Climate Justice, and Spatial Inequality

2.1.1. Urban Risk and Climate Hazards in Cities

In modern cities, there is a growing recognition that urban danger is not only a natural occurrence but also a socially constructed situation. Urban populations are not equally affected by climate disasters such excessive heat, flooding, and drought; rather, the spatial distribution of exposure, vulnerability, and adaptive capacity within the urban fabric shapes the impacts of these hazards. Urban risk is a physical and socio-spatial construct, as recent research highlights, and it arises from the interplay between climate hazards and long-standing patterns of urban development, governance, and inequality (IPCC, 2022; UN-Habitat, 2020).

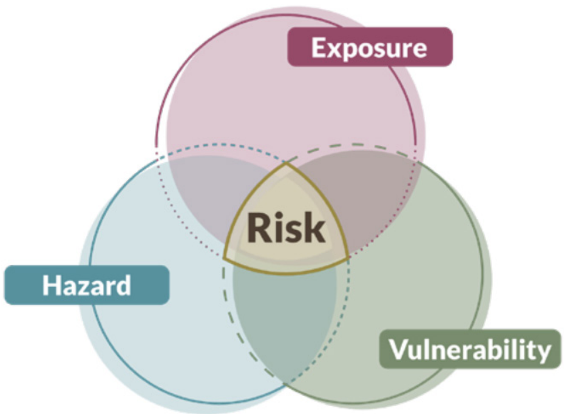


Figure 1. Factors of Disaster Risk: Interaction between Hazard, Exposure, and Vulnerability Adapted from World Bank & GFDRR (2021, Figure 1.10, p. 38).

Hazard: The term "hazard" describes the possibility of physical events, either natural or man-made, that could endanger exposed and vulnerable components. It includes any human activity, action, or phenomenon that has the potential to cause death, serious injury, property damage, negative health impacts, or disturbance of the social and economic order or damage to the ecosystem. Hazards that result from the interplay between human activity and natural processes can be classified as natural, anthropogenic (caused by humans), or socio-natural (Cardona et al. 2012; UNDRR 2017).

Exposure: The term "exposure" describes the existence, distribution, and inventory of infrastructure, resources, and biological, social, and economic systems in places that are prone to hazards. Although exposure is a required but not sufficient factor of risk, elements can be exposed without being vulnerable; yet, exposure is a prerequisite for vulnerability (Cardona et al. 2012).

Vulnerability: The tendency of a society, system, or asset to suffer negative consequences from dangers is referred to as vulnerability. Environmental, social, economic, and physical variables all contribute to its formation and make people more vulnerable to damage (UNDRR 2017b).

Risk: The probability of death, harm, or destroyed or damaged property that could happen to a system, society, or community within a given time frame, as assessed probabilistically as a function of hazard, exposure, vulnerability, and capacity" is what is meant by risk (GFDRR 2014).

Disaster risk is influenced by a combination of factors, including the overlap between hazard intensity, asset and human exposure, and the susceptibility of social, economic, and physical systems, as shown in Figure 1. This approach, which offers a fundamental lens through which to view why comparable climatic occurrences can result in wildly disparate outcomes across urban neighborhoods, is frequently employed in current climate and catastrophe risk research.

Extreme heat and Urban Heat Island (UHI) effects are among the most urgent urban climate threats in the world as a result of climate change, which has increased the frequency, length, and severity of heat-related hazards in cities. Heat acts as a chronic and cumulative hazard, unlike sudden-onset disasters, and is frequently overlooked in planning practices while having serious negative effects on public health and society. According to empirical research, dense, impermeable, and vegetation-poor places are disproportionately affected by urban heat, as the built environment's features increase ambient temperatures and decrease cooling capacity (Santamouris, 2020; Weng et al., 2019).

All three risk components are significantly shaped by urbanization, according to modern urban risk frameworks. While climate-sensitive planning and inclusive urban design can lower risk and improve resilience, patterns of land use, infrastructure provision, and population density can increase exposure and susceptibility.

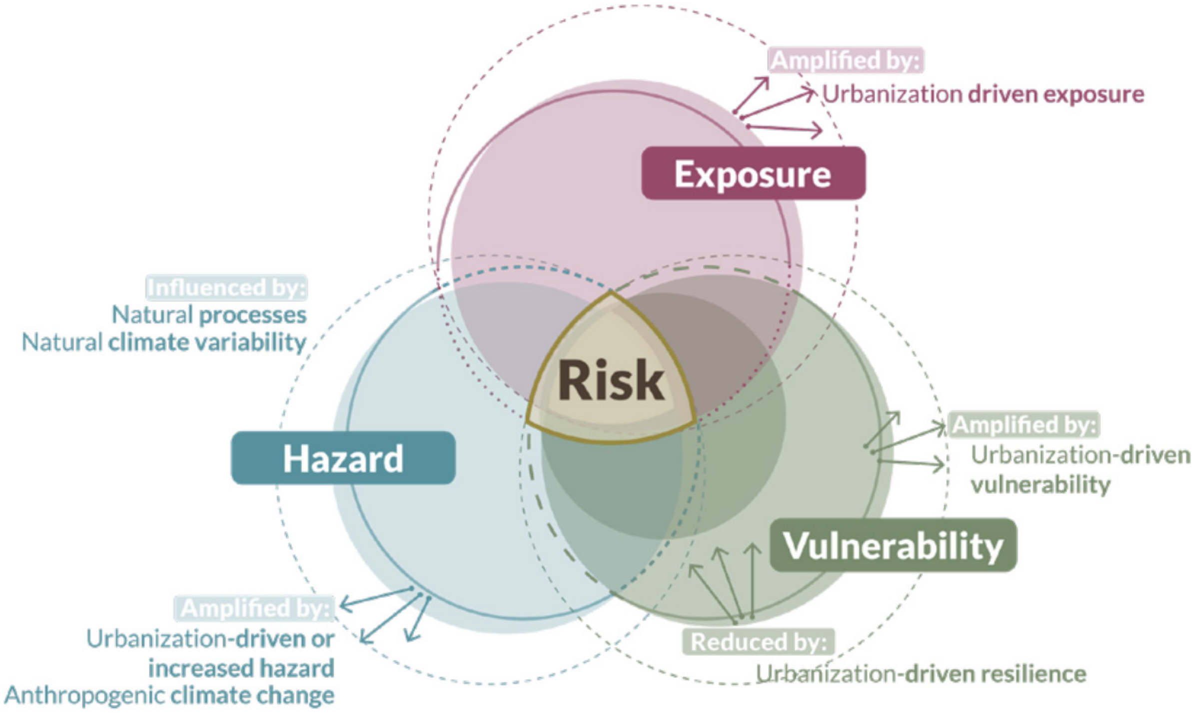


Figure 2. Interplay between Urbanization and Risk. Adapted from World Bank & GFDRR (2021, Figure 2.1, p. 46).

Urbanization can serve as both a source of resilience and a driver of risk, as seen in Figure 2. While well-planned urban systems can reduce risk through increased resilience and adaptive capacity, urban expansion and infrastructure development may increase hazard intensity, exposure, and susceptibility, especially when motivated by unequal investment and geographic segregation. awareness how climatic risks like high heat become ingrained in the urban landscape requires an awareness of the dual function that urbanization plays.

In this context, urban heat serves as a crucial prism through which more general trends in spatial inequality and poor planning can be investigated. Heat danger is closely linked to urban shape, land-use choices, infrastructure quality, and socioeconomic circumstances; it is not only a result of rising temperatures. By acknowledging urban heat as a climate hazard within an urban risk framework, planners and designers may pinpoint the intersections between historical injustice and climate stress, establishing the foundation for adaption measures that prioritize fairness. This viewpoint is especially pertinent to cities like Chicago, where ingrained patterns of segregation and unequal growth are exacerbated by climate change, increasing the risk for already vulnerable areas.

Urban heat falls under the larger category of climatological hazards, as illustrated in Figure 3, and interacts with other hazard types, such as hydrometeorological and geophysical processes. The image emphasizes that heat-related hazards are frequently exacerbated by drought, wildfire, and infrastructure stress, despite the fact that this study focuses solely on excessive heat and UHI. This emphasizes the need to approach heat as a systemic urban risk rather than a discrete environmental condition.

Urban heat is a crucial lens through which more general patterns of spatial inequality and planning failure can be investigated within this integrated hazard paradigm. Rising temperatures are not the only factor contributing to heat danger; urban design, land-use choices, infrastructure quality, and socioeconomic circumstances all play a significant role. The foundation for equity-driven adaptation methods is laid when planners and designers acknowledge urban heat as a climate hazard within a multi-hazard urban risk framework. This enables them to pinpoint the intersections between historical injustice and climate stress. This conceptualization is especially pertinent to places like Chicago, where ingrained patterns of segregation and unequal growth are exacerbated by climate change, increasing the risk for already vulnerable areas.

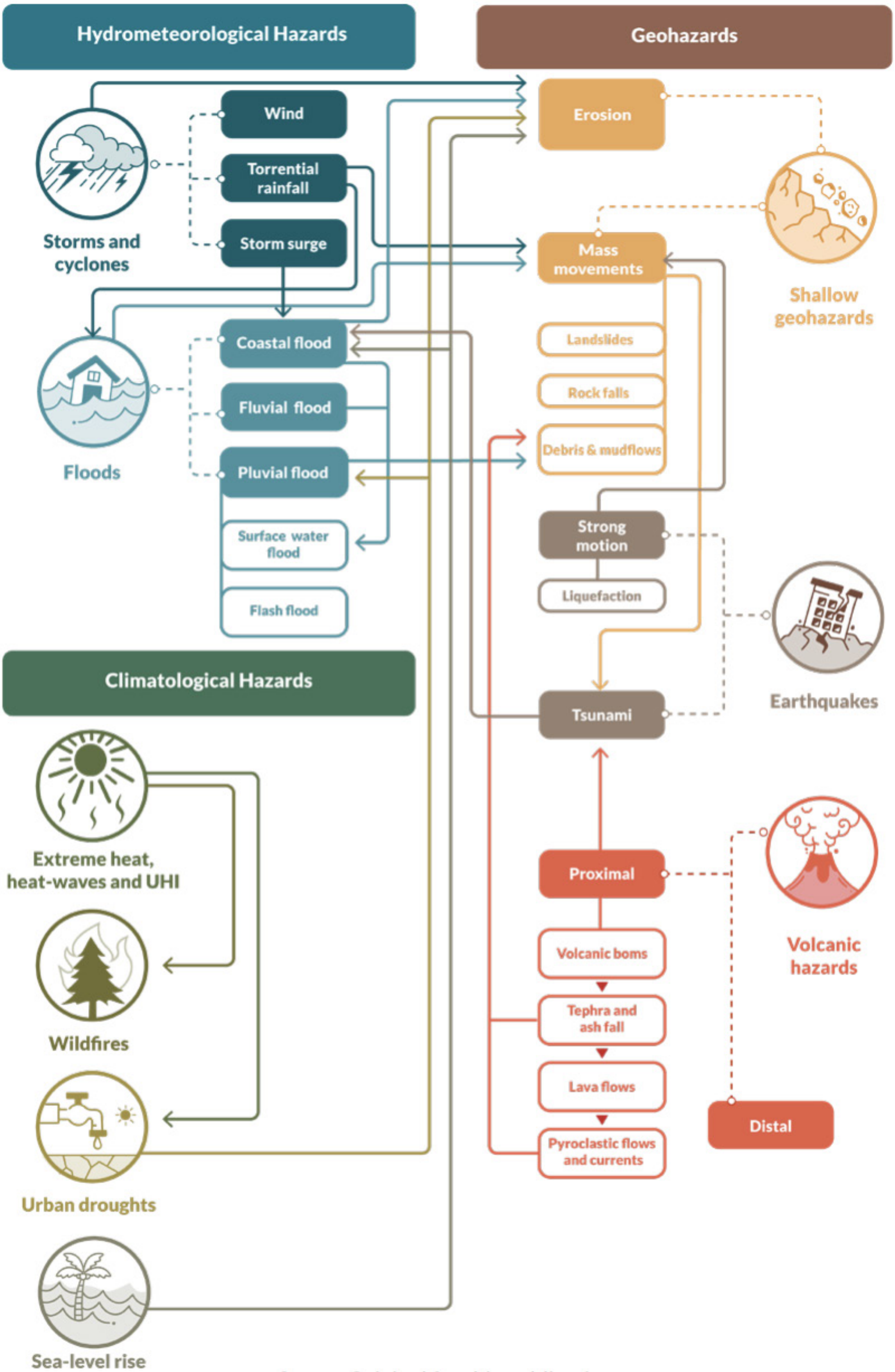


Figure 3. Examples of Common Hazards and Their Interactions. Adapted from World Bank & GFDRR (2021, Figure 2.3, p. 54).

2.1.2. Spatial Justice and Environmental Inequality

The unequal distribution of urban climate risks among cities is a reflection of historical trends in marginalization, inequality, and uneven growth. Perspectives on spatial justice highlight that historical planning choices, governmental frameworks, and socioeconomic hierarchies that influence where people live and the standard of their immediate surroundings create environmental risk rather than it being assigned at random. When underprivileged groups are disproportionately concentrated in regions with greater exposure to environmental stressors and less ability to manage their effects, environmental inequality arises and causes long-lasting spatial disparities throughout urban landscapes (UN-Habitat, 2020; IPCC, 2022).

Unequal exposure to environmental risks is one of the main ways that spatial unfairness appears. In urban contexts, exposure is strongly related to land-use patterns, population distribution, infrastructure placement, and economic activity. Exposure is defined as the presence of people, assets, and activities in environments impacted by climatic stressors. Planning and investment choices that have historically placed marginalized people in less protected and more environmentally burdened places have generated these exposure patterns, which are not neutral consequences.

Indicators including population density, building and asset kinds, vital infrastructure, and economic activity can be used to understand exposure in cities, as shown in Figure 4. From the standpoint of spatial justice, these indicators show how aged building stock, dense residential patterns, and restricted access to cooling or protective infrastructure make marginalized districts more susceptible to concentrated exposure. Such exposure circumstances exacerbate everyday thermal stress and raise the possibility that severe temperatures will impair mobility, comfort, and health in the context of urban heat.

However, exposure by itself does not adequately account for the uneven effects of climatic threats. By influencing sensitivity and adaptive ability, vulnerability shapes how exposure is experienced by both people and groups. Urban vulnerability is multifaceted and encompasses social, economic, institutional, and service-related elements that impact one's capacity to predict, manage, and recover from environmental stress in addition to physical or structural conditions.

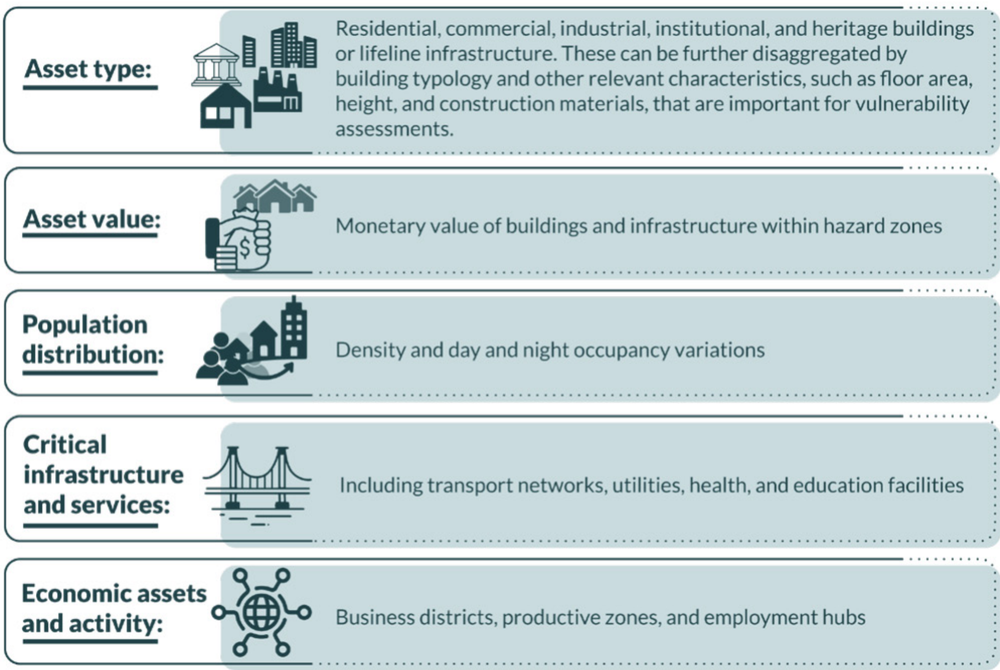


Figure 4. Common Indicators for Urban Exposure Assessment. Adapted from World Bank & GFDRR (2021, Figure 2.4, p. 58).

Physical or structural vulnerability, social vulnerability, economic and institutional vulnerability, and service or functional vulnerability are some of the important aspects of vulnerability that are pertinent to urban settings and are highlighted in Figure 5. These factors commonly overlap spatially in historically marginalized neighborhoods, increasing their vulnerability to climate disasters. Even in situations where danger levels are similar throughout the city, the effects of environmental exposure are amplified by lower household incomes, higher prevalence of health issues, restricted access to services, and weaker institutional support networks.

When combined, unequal exposure and multifaceted vulnerability show how environmental inequality is not the result of isolated circumstances but rather of cumulative and interrelated processes. Extreme heat is one example of a climate hazard that reproduces existing spatial inequities in daily urban living by limiting mobility, access to services, and general well-being. It is possible to gain a better understanding of how historical and structural factors contribute to current climate risk by examining urban heat through the lens of spatial justice.

The theoretical underpinnings for investigating how particular planning techniques entrenched unequal exposure and vulnerability over time are provided by this conceptual framing. Building on this viewpoint, the next section examines redlining as a significant historical process that created and sustained environmental inequality and spatial injustice in urban districts.

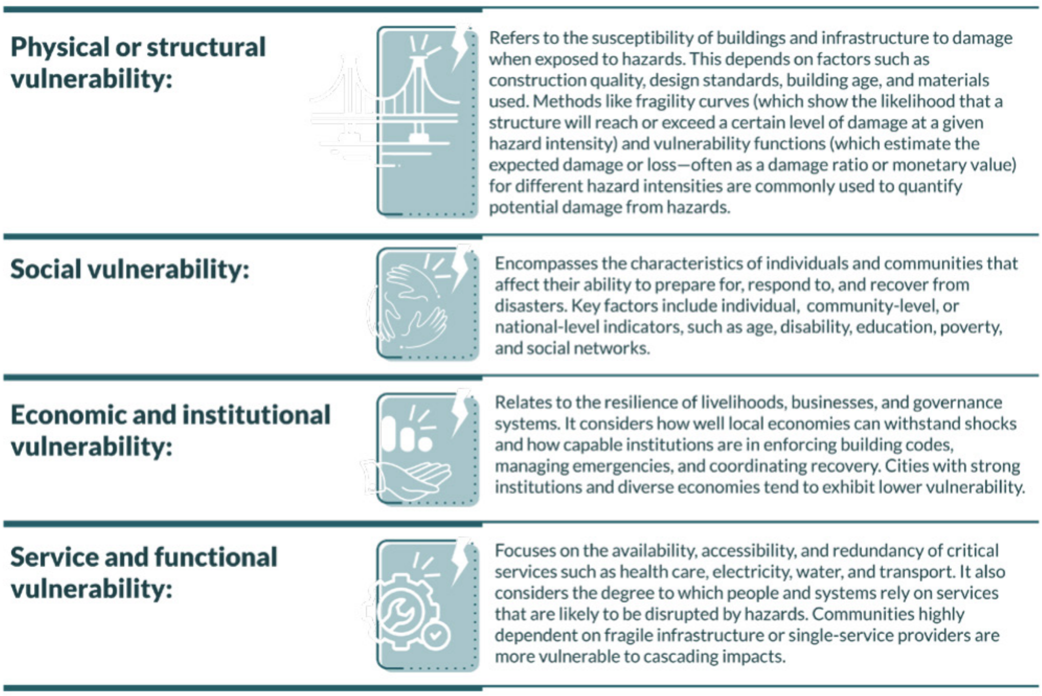


Figure 5. Relevant Dimensions of Urban Vulnerability. Adapted from World Bank & GFDRR (2021, Figure 2.5, p. 59).

2.2. Redlining and the Historical Production of Urban Vulnerability

2.2.1. Redlining as Institutionalized Disinvestment

It is becoming increasingly clear that urban risk in contemporary cities is a socially and institutionally constructed phenomenon as well as a product of natural hazards. Climate-related stressors like excessive heat, flooding, and drought do not effect urban populations equally; rather, the extent of impacts is largely determined by the spatial distribution of exposure, sensitivity, and adaptive capacity within the urban fabric. According to recent studies, urban risk arises from the interplay of historical patterns of urban development, governance, and inequality with environmental threats (IPCC, 2022; UN-Habitat, 2020).

Redlining is one of the most significant processes that have traditionally been used in the US to create urban vulnerability. Redlining was institutionalized in the late 1930s by the Home Owners' Loan Corporation (HOLC), which converted socioeconomic and racially presumptions into official financial and planning documents. Perceived mortgage risk was used to grade neighborhoods; those categorized as "D" or "hazardous" were routinely excluded from investment, insurance, and credit. Racial makeup, immigration status, and economic levels all had a significant influence on these categories, which were not objective evaluations of building quality.

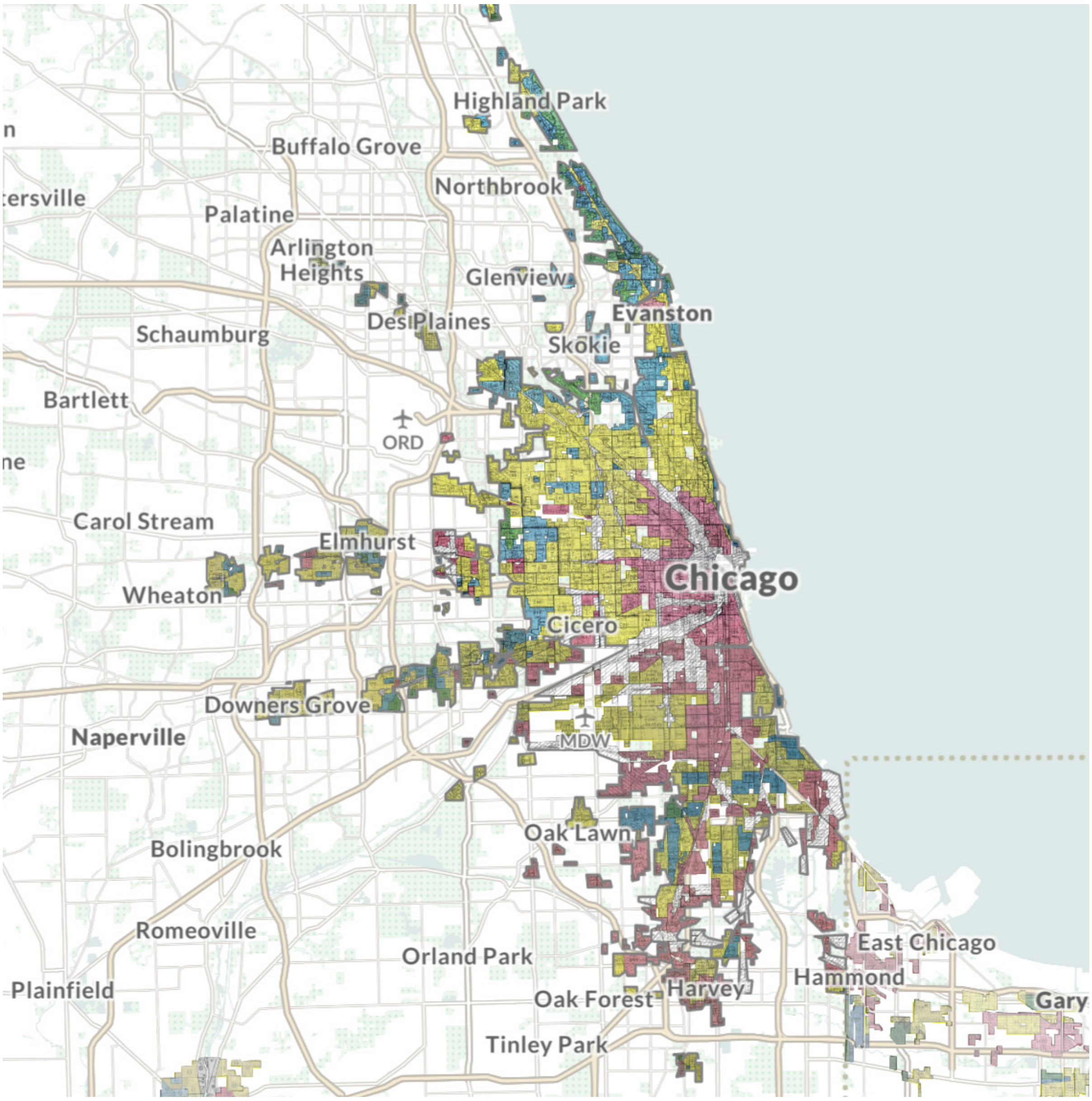


Figure 6. Home Owners' Loan Corporation (HOLC) Residential Security Map of Chicago (c. 1939).

The first federally approved spatial classification of neighborhood danger in the city was the HOLC Residential Security Map of Chicago (c. 1939), as shown in Figure 6. A distinct spatial pattern can be seen on the map, with largely white and wealthy neighborhoods receiving favorable ratings while sizable sections of the South and West Sides were classified as high-risk areas. Long after the official practice of redlining was abolished, this spatial disparity created an unequal opportunity landscape.

From the standpoint of risk-informed planning, redlining is not a single historical occurrence but rather a process of cumulative risk production. Vulnerability is increased when exposure is coupled with diminished social, physical, and institutional capacities, as stressed in modern urban risk frameworks. Decades of underfunding of public services, infrastructure, and housing maintenance in redlined communities created an environment that made residents more vulnerable to future environmental stresses. By limiting later development paths through early planning decisions, this type of route dependency reinforced disadvantage across generations.

Therefore, when urbanization is influenced by unfair investment practices, it acts as a risk-increasing rather than resilience-promoting factor. According to the Handbook for Livable and Resilient Cities, when planning systems consistently give priority to some areas while ignoring others, risk builds up over time. Disinvestment in the context of redlining made people more vulnerable even when there were no immediate dangers, setting the stage for more severe effects when new climate-related threats, such urban heat, surfaced. Therefore, redlining's effect goes beyond housing markets, influencing how people are exposed to the environment, the quality of infrastructure, and their ability to adapt.

Interpreting modern urban vulnerability in places like Chicago requires an understanding of redlining as organized disinvestment. Where environmental threats are concentrated and which communities have the biggest obstacles to adaptation are still determined by the spatial patterns created by HOLC classifications. This study places redlining as a basic planning legacy that directly influences contemporary discussions on climate justice, equitable urban development, and risk-informed design and policy by placing it within a risk-accumulation framework.

2.2.2 Disinvestment, Urban Form, and Environmental Exposure

In addition to being visible in social and economic metrics, the long-term impacts of redlining and systematic disinvestment are also physically reflected in the city's layout. Uneven investment trends have influenced neighborhood morphologies, infrastructure quality, and land use configurations over time, systematically increasing marginalized groups' exposure to the environment. These spatial results in cities like Chicago are the result of decades of planning choices that gave certain regions priority over others in terms of service delivery and capital accumulation.

A high concentration of impermeable surfaces, an aged housing stock, poorly maintained public infrastructure, restricted access to green space, and fragmented land-use patterns are all common features of disinvested areas. Higher exposure to environmental stresses, especially intense heat, is intimately linked to certain urban forms. Environmental factors that increase thermal discomfort and heat-related danger include poor sidewalk conditions, a dearth of street trees, little shade, and limited access to parks or cooling facilities. These circumstances are not coincidental; rather, they are the culmination of policies that have consistently limited environmental improvement and investing in historically underserved communities.

The persistence of spatial inequality is evident in contemporary patterns of residential segregation. Figure 7 illustrates the racial composition of Chicago neighborhoods in 2010, revealing enduring concentrations of Black and Latino populations in areas that overlap significantly with historically disinvested zones. This spatial continuity underscores the concept of path dependency, wherein early planning and financial decisions continue to shape urban outcomes decades later. Segregation, in this context, is not merely a demographic pattern but a structural condition that influences access to environmental amenities, infrastructure quality, and adaptive capacity.

Urban shape serves as a crucial mediator between environmental exposure and socioeconomic inequality from the standpoint of risk-informed planning. Uneven urbanization processes can increase risk when land-use decisions and infrastructure neglect place vulnerable populations in hazardous areas, as the Handbook for Livable and Resilient Cities emphasizes. Disinvestment makes neighborhoods less physically resilient, making them more vulnerable to climatic extremes and less able to withstand environmental stress. Residents with fewer means to adapt are disproportionately affected by isolated hotspots created by densely populated areas with little greenery and high surface sealing.

Particularly for communities who strongly rely on walking, public transportation, and outdoor activities, these spatial conditions have a direct impact on daily exposure patterns. During times of high temperatures, heat-prone urban morphologies limit mobility, lower thermal comfort, and raise health hazards. As a result, disinvested neighborhoods have higher and more persistent levels of environmental exposure, which influences day-to-day experiences and strengthens larger trends of urban vulnerability.

Interpreting Chicago's current climate risk requires an understanding of the interplay among disinvestment, urban form, and environmental exposure. By placing environmental dangers into a larger socio-spatial framework influenced by past planning legacies, this viewpoint goes beyond seeing them as isolated occurrences. This work lays a crucial basis for investigating urban heat as a climate risk and for creating fair, place-based adaption methods by charting the ways in which redlining and segregation have created heat-prone urban environments.

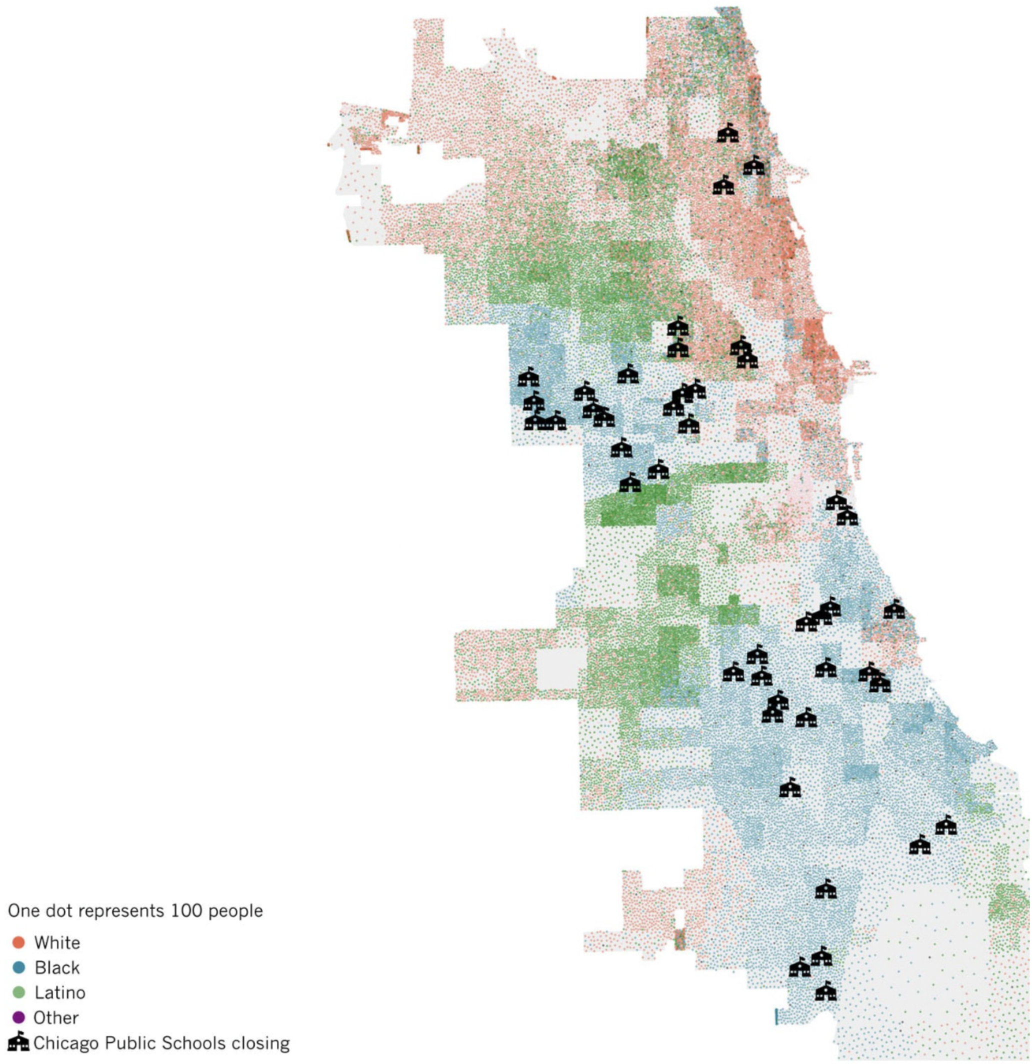


Figure 7. Segregation Map of Chicago in 2010. Source: South Side Weekly

2.3. Urban Heat as a Climate Risk in Cities
2.3.1. Urban Heat Island as an Urban Hazard

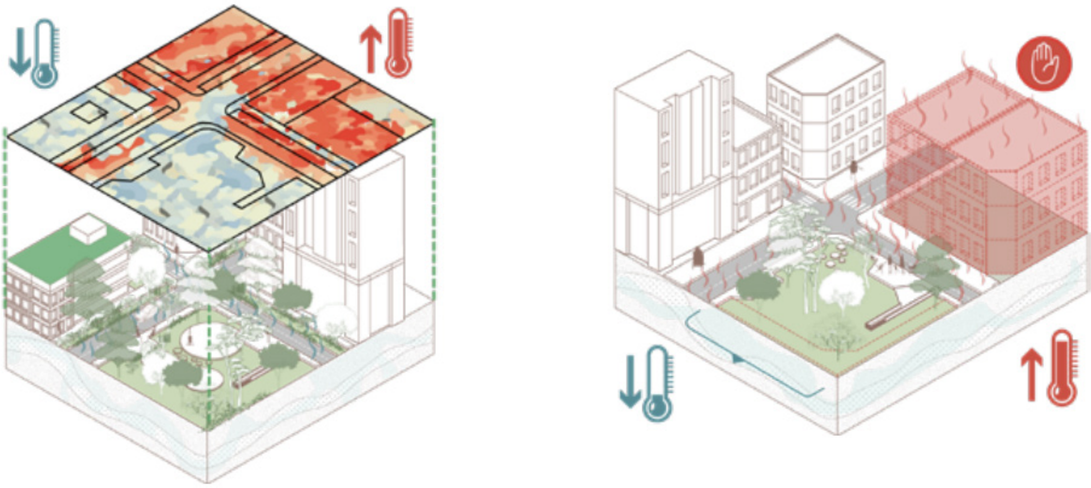


Figure 8. Conceptual Diagram of Urban Heat Island Formation and Cooling Effects. Adapted from World Bank & GFDRR (2021, Table 7.4, p. 205).

One of the most prevalent and lethal climate-related dangers affecting cities is urban heat, which is becoming more well acknowledged. In contrast to sporadic calamities like floods or storms, urban heat acts as a chronic stressor due to the Urban Heat Island (UHI) effect's continuously high temperatures as well as an acute hazard through intense heat waves. The tendency of urbanized areas to have higher surface and ambient temperatures than nearby rural areas as a result of changes in land cover, building density, and anthropogenic heat emissions is known as the UHI phenomena.

High densities of impermeable surfaces, decreased vegetation and evapotranspiration, dense building layouts that trap heat, and waste heat from buildings and vehicles are some of the material and urban form features that contribute to the UHI impact. These factors change the local energy balances, decreasing nightly cooling and increasing heat absorption during the day. Because of this, urban heat exposure frequently lasts past the peak temperatures of the day, exacerbating physiological stress and hindering recuperation during heat events.

Conceptual maps of UHI development show how diverse thermal conditions are created within a single metropolis by variations in land cover, building morphology, and green infrastructure. While heavily populated places with little vegetation exacerbate heat accumulation, areas with tree canopy, permeable surfaces, and open space encourage shading and evapotranspiration, lowering surface and air temperatures. These illustrations support the idea that urban heat is not a constant meteorological condition but rather a spatially distinct hazard influenced by planning and design choices.

In addition to its physical severity, urban heat is considered a hazard from the standpoint of risk-informed planning due to its relationship with vulnerability and exposure. Hazards become deadly when they interact with communities and systems that are unable to adapt, as highlighted in current frameworks for assessing climate risk. Thus, UHI functions as a structural urban hazard that is ingrained in the built environment and made worse by enduring trends of spatial inequality and disinvestment. Therefore, including heat into planning, design, and climate adaptation methods requires acknowledging UHI as an urban hazard.

2.3.2 Heat Exposure and Public Health Risk

In urban settings, heat exposure poses a serious risk to public health through both acute and cumulative mechanisms. The human thermoregulatory system is strained by high temperatures, which raises the risk of dehydration, heat exhaustion, heat stroke, and the deterioration of respiratory, cardiovascular, and renal diseases. Prolonged daytime heat and little evening cooling in cities impacted by the Urban Heat Island effect increase these hazards, especially during heat waves but also through long-term exposure throughout the summer.

The direct and indirect effects of excessive heat on urban systems are demonstrated via conceptual heat-health risk models. Heat-related illnesses and deaths are examples of direct effects, but stress on the infrastructure, disruptions to daily routines, and greater strain on healthcare systems are examples of indirect effects. These models place vulnerable groups at the center of heat-related suffering by highlighting the fact that exposure, sensitivity, and adaptation ability interact to shape heat risk rather than temperature alone.

Social and regional inequality are intimately associated with the unequal distribution of heat-related health concerns. Low-income households frequently lack access to cooling supplies and live in heat-prone zones, while infants, the elderly, people with disabilities, outdoor workers, and those suffering homelessness are particularly sensitive to high temperatures. Poor housing conditions, limited mobility, and a lack of green infrastructure in historically segregated and underinvested communities increase exposure and decrease adaptability. Urban heat therefore serves as a socially distinct public health hazard, highlighting the need for equity-oriented climate adaptation initiatives and exacerbating already-existing health disparities.

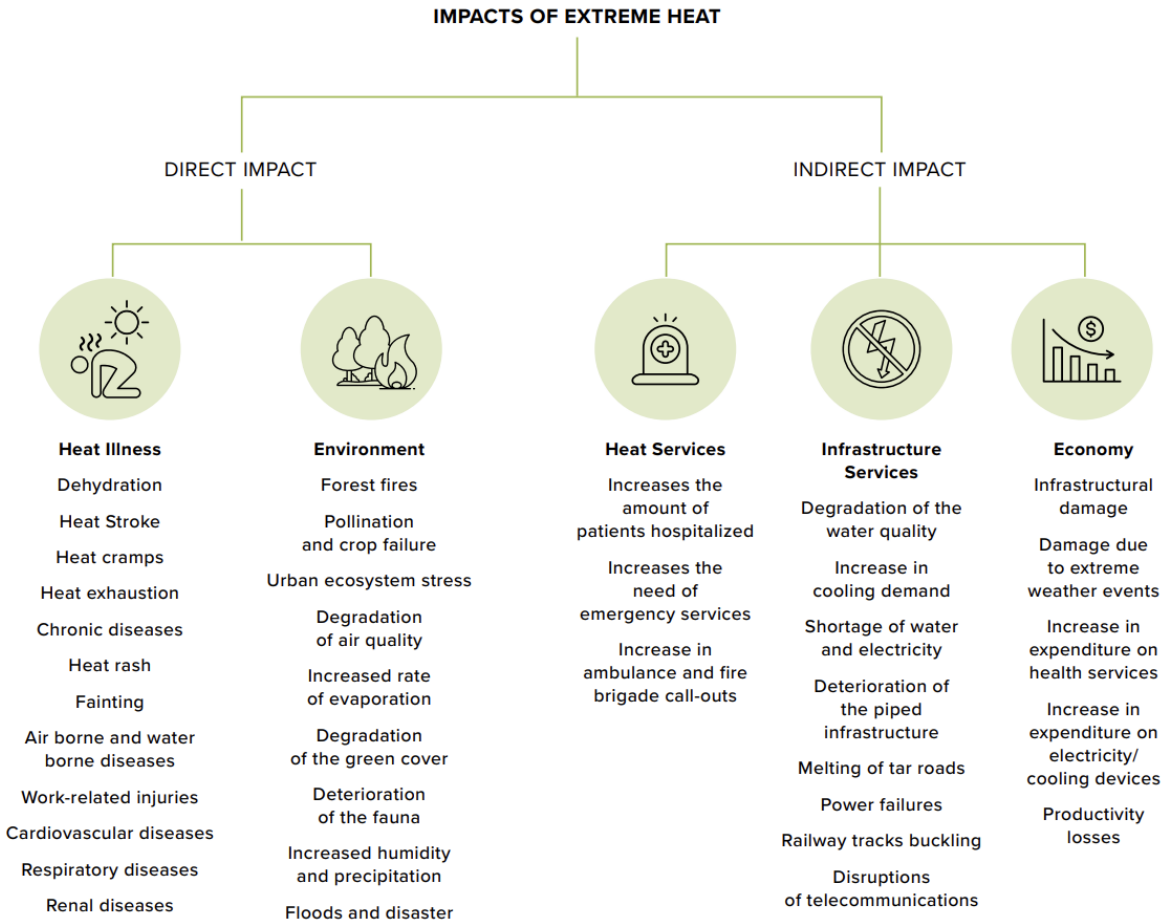


Figure 9. Conceptual Model of Heat Impacts on Public Health. Adapted from World Bank & UN Group (2025, Figure 2-10, p. 42).

2.4. Vulnerable Populations and Differential Heat Exposure

2.4.1. Social Vulnerability and Adaptive Capacity

The interplay between demographic characteristics and the ability of people and groups to manage heat stress determines social susceptibility to urban heat. The physiological sensitivity to heat is increased by factors like senior age, chronic illness, disability, and economic dependency, but the capacity to adapt is diminished by factors like low income, energy poverty, and substandard housing. These circumstances frequently coexist with limited mobility and a dependence on public services, which increases exposure during periods of intense heat.

Through an integrated risk lens, the Handbook for Livable and Resilient Cities conceptualizes vulnerability, highlighting the fact that exposure, sensitivity, and adaptive capacity interact to produce hazard impacts rather than just environmental factors. This reasoning is ingrained in risk-informed urban design paradigms, which emphasize how crucial institutional capacity, governance, and resource accessibility are in determining population resilience.

In order to show how planning systems, institutional coordination, and climate-responsive policies influence adaptive capacity, this figure places social vulnerability within the larger integration of urban planning, disaster risk management (DRM), and climate risk management (CRM).

The enabling context in which urban planning functions further strengthens—or limits—adaptive potential. Cities' ability to convert risk awareness into protective action depends on a number of factors, including institutional coordination, political commitment, legal frameworks, and data accessibility. As a result, populations living in places with inadequate planning capabilities or governance frameworks are more likely to be permanently vulnerable to heat exposure.

Figure 10. Risk-Informed Urban Planning Primary Concept. Adapted from World Bank & GFDRR (2021, Figure 1.4, p. 24).

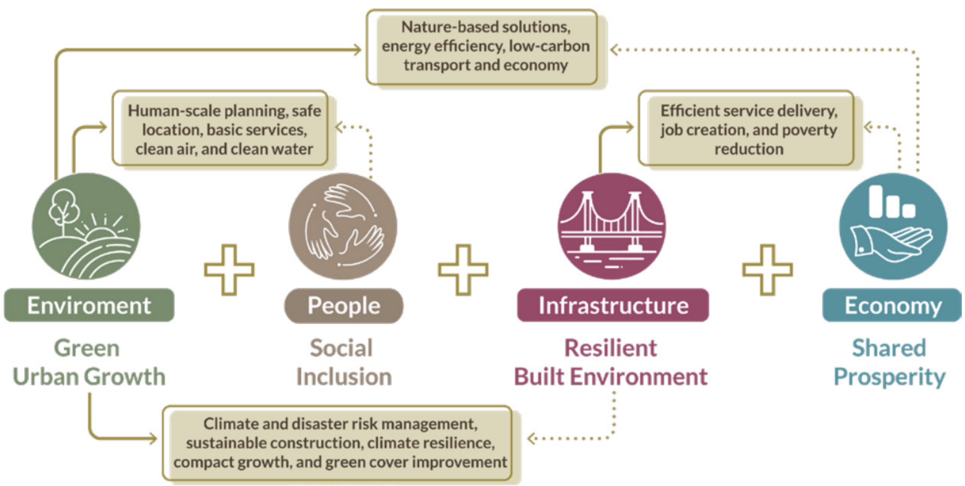


Figure 11. Risk-informed Urban Planning: Interconnected Goals. Adapted from World Bank & GFDRR (2021, Figure 1.7, p. 29).

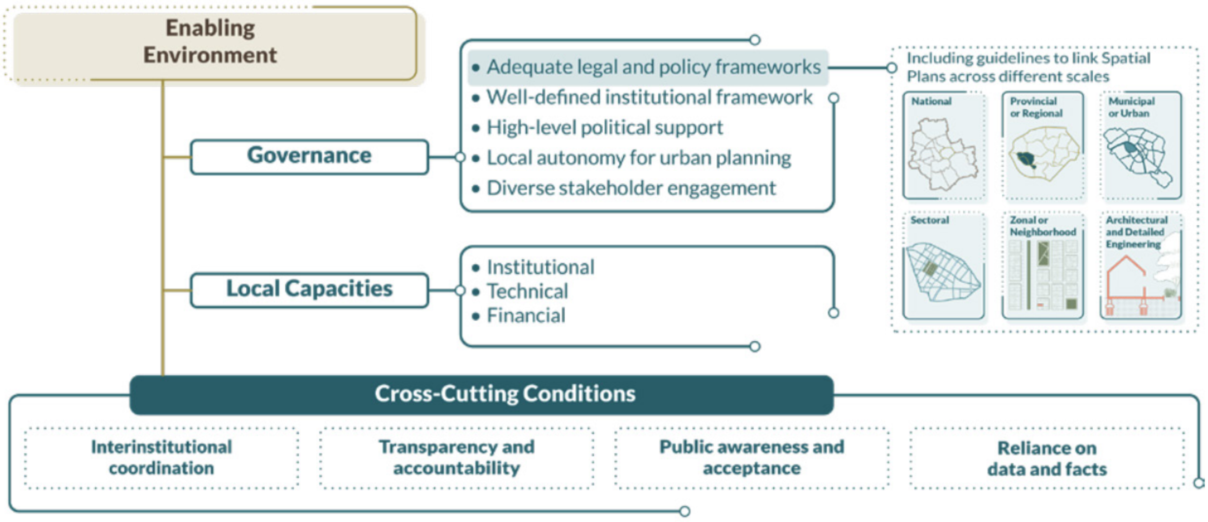


Figure 12. Enabling Environment for Risk-Informed Urban Planning Adapted from World Bank & GFDRR (2021, Figure 1.4, p. 24).

The governance, local capacities, and intersecting factors like openness, public awareness, and data dependence that have a direct impact on adaptive ability at the community level are highlighted in this image.

When taken as a whole, these frameworks highlight the fact that vulnerability is a state created by institutional decisions, planning processes, and unequal access to resources that determine who is best equipped to deal with urban heat.

2.4.2 Redlined Neighborhoods and Heat Burden

Due to historical and systemic inequalities, redlined districts are a spatial concentration of compounded heat risk, where environmental exposure and social vulnerability meet. Discriminatory investment and housing policies have resulted in metropolitan regions that are characterized by limited access to cooling supplies, aged housing stock, disinvestment, and diminished green infrastructure. These spatial factors limit locals' ability to adjust while also escalating the effects of urban heat islands.

Such neighborhoods frequently find themselves in situations where risk cannot be sufficiently controlled without focused intervention, according to risk-informed planning frameworks. The combination of socioeconomic fragility, heat exposure, and infrastructure deficiencies puts these regions in a cycle of increased risk that conventional planning techniques might overlook.

Depending on the viability of risk reduction, figure 12 highlights the necessity of restriction, conditioning, or promotion strategies in decision paths where hazards above acceptable risk thresholds.

Risk-informed planning moves away from completely blocking development and toward addressing current vulnerabilities in developed urban contexts, such as previously redlined areas. Integrated approaches that lower exposure, improve resilience, and stop risk from being reproduced through unmanaged densification or neglect are needed in these places.

In order to manage compounded hazards, figure 13 highlights infrastructure investment, development controls, and preparedness measures as planning solutions when risks are manageable but persistent.

The restrict–condition–promote paradigm offers a logical way to address heat burden in neighborhoods that are at risk, which helps operationalize these solutions.

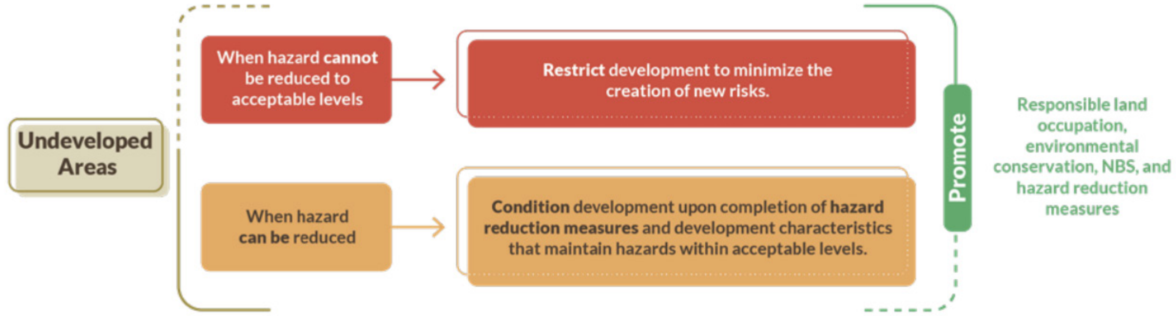


Figure 13. Hazard-Based Planning in Undeveloped Areas. Adapted from World Bank & GFDRR (2021, Figure 1.11, p. 41).

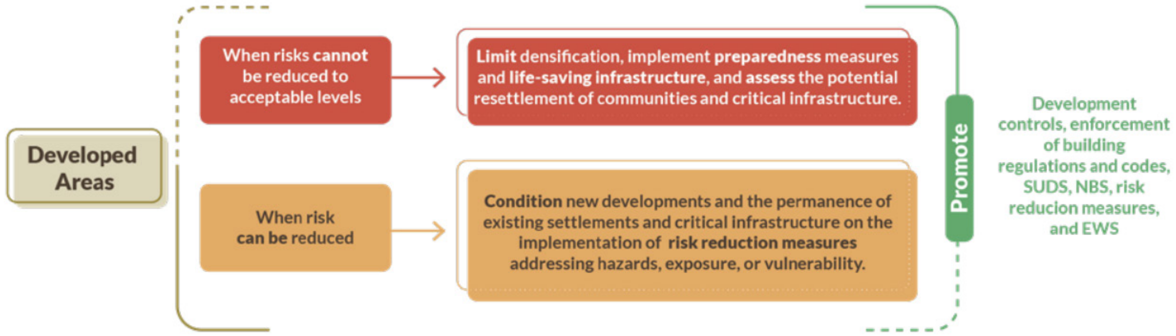


Figure 14. Hazard-Based Planning in Developed Areas. Adapted from World Bank & GFDRR (2021, Figure 1.12, p. 42).

Figure 15. Restrict, Condition, and Promote Measures. Adapted from World Bank & GFDRR (2021, Figure 1.13, p. 43).

Figure 15 provides a conceptual foundation for focused interventions in heat-stricken communities by tying hazard severity to suitable planning measures, thereby synthesizing risk-based decision-making.

When taken as a whole, these numbers lend credence to the idea that redlined communities are areas of layered risk, where past design choices have resulted in long-lasting social and environmental effects. Therefore, urban heat exposure in these regions is not a standalone climate problem but rather an expression of systemic inequity that has an immediate impact on mobility, health, and quality of life. Planning strategies that specifically include risk, vulnerability, and equity into analytical and design-based solutions are necessary to address this load.

2.5. Mobility, Accessibility, and Heat as a Spatial Barrier

2.5.1. Mobility and Accessibility in Risk-Informed Planning

People's perceptions and reactions to climate-related hazards are greatly influenced by urban mobility and accessibility. As metropolitan temperatures rise, it becomes more difficult for people to travel around the city in a safe and comfortable manner, especially for pedestrians. Severe heat changes how people travel on a daily basis, restricts access to necessary services, and changes the way cities function geographically. Heat should therefore be viewed as a spatial barrier that influences who can move, where they can move, and under what circumstances, in addition to being an environmental concern.

From the standpoint of risk-informed planning, accessibility in the face of heat stress turns into an issue of equality and resilience. When heat limits mobility, populations who depend on walking or public transportation which frequently overlap with socially vulnerable groups are disproportionately impacted. Therefore, it is essential to incorporate heat exposure into mobility and accessibility frameworks in order to comprehend how climate risk results in less urban access and unequal daily experiences.

Accessibility is increasingly positioned as a fundamental aspect of resilience rather than a byproduct of transportation provision in risk-informed urban development. In addition to being able to endure environmental risks, resilient cities are able to preserve access to opportunities, social networks, and necessary services even in times of stress. According to recent research, lowering susceptibility and promoting adaptive capacity in the face of climate-related threats requires access to emergency services, public space, food, healthcare, and work (Meerow et al., 2019; Sharifi, 2020).

However, accessibility is not a spatially fixed criterion. It depends on the environment in which movement takes place as well as on the infrastructure. Because it reduces walking pace, shortens acceptable travel distances, and discourages excursions along exposed routes, extreme heat raises the physiological cost of travel, especially for pedestrians. Therefore, even when physical distance and network connectivity are unaffected, the effective service regions of facilities may shrink during heat events (Khosla et al., 2021; Park et al., 2023). This phenomena draws attention to the shortcomings of traditional accessibility measurements that do not take climate factors into consideration.

It is becoming more widely recognized in risk-informed planning frameworks that mobility systems as opposed to typical ones. Planners can determine which people and locations are most likely to experience access issues during periods of excessive heat by incorporating environmental exposure into accessibility studies. In this way, accessibility serves as a resilience mechanism: susceptibility is decreased when access is maintained under thermal stress, while heat risk is increased when it is damaged. Planning objectives are shifted by this viewpoint in favor of human-centered mobility systems that continue to be safe, inclusive, and operational even in the face of climate stress.

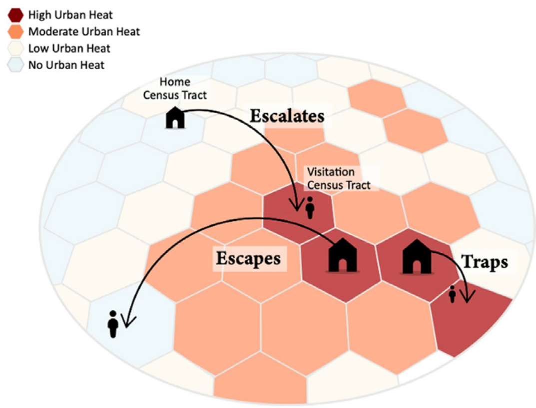


Figure 16. Conceptual diagram of Urban Heat traps

2.5.2. Heat Stress and Pedestrian Experience

Heat stress has a profound impact on pedestrian experiences and daily mobility choices at the human level. Air temperature, sun radiation, humidity, wind, surface materials, and urban shape all affect thermal comfort. Walking becomes physically demanding and, in severe situations, hazardous when these factors come together negatively. The risk of heat exhaustion and heat stroke is increased by prolonged exposure to high temperatures, especially for children, older adults, and people with underlying medical disorders (Matzarakis et al., 2020; Mora et al., 2022).

Crucially, pedestrians' experiences of heat vary throughout the urban landscape. Highly localized variances in heat exposure are caused by microclimatic variables at the street level, including the presence of shade, vegetation, building orientation, and surface materials. According to recent research, walkers actively adapt to these changes by changing their walking habits, travel schedules, and routes; they frequently choose cooler or shaded paths over longer or less direct ones (Middel et al., 2021; Erell et al., 2022). These adaptive responses show how pedestrian mobility is significantly influenced by perceived thermal risk.

Heat stress creates limitations beyond discomfort from the standpoint of danger. Particularly in districts with little shade, no green infrastructure, or great distances between destinations, high temperatures can produce conditions where pedestrians are effectively “trapped” within hot areas. On the other hand, pedestrians can reduce exposure and preserve mobility when they have access to cooler microclimates, such as parks, tree-lined streets, or shaded corridors. This dynamic illustrates how heat changes the city into a unique mobility environment where not all routes provide the same level of accessibility or safety.

The significance of comprehending everyday exposure to dangers is emphasized by risk-informed planning frameworks, especially for groups whose routines need frequent outdoor activity. Planners can spot areas of increased exposure, mobility obstacles, and thermal bottlenecks that are not obvious in network or aggregate climate evaluations by concentrating on pedestrian experience. Therefore, it is crucial to include human-scale heat exposure in pedestrian planning in order to increase walkability, guarantee fair access, and lessen mobility disparities brought on by climate change in urban settings.

The sections above show how urban heat significantly changes pedestrian movement, accessibility, and the daily urban experience, especially for vulnerable groups. Although these effects are frequently discussed conceptually, an operational framework that can integrate hazard assessment, social vulnerability, and spatial decision-making is necessary to translate heat-related risk into planning and design action.

By incorporating climate and catastrophe risk factors into every step of the planning process from diagnosis and visioning to implementation and monitoring risk-informed urban planning offers such a framework. This method places thermal exposure into urban systems, governance frameworks, and planning tools rather than considering heat as an external environmental factor. In this setting, accessibility issues and mobility limitations under heat stress are not merely theoretical results but rather practical planning inputs.

The three stages of risk-informed urban planning context assessment and diagnosis, formulation, and implementation with monitoring and evaluation are depicted in Figure17. This approach places a strong emphasis on the iterative integration of risk mapping, hazard screening, and stakeholder engagement before planning decisions and implementation tools are developed.

The design of implementation tools like climate-responsive street design, cooling infrastructure, and mobility interventions (Phase 3), as well as hazard and risk screening (Phase 1), spatial analysis, and scenario development (Phase 2), can all take into account urban heat exposure and pedestrian mobility constraints. Thus, the framework offers a precise scientific basis for converting accessibility issues and heat exposure at the human scale into risk-informed, spatially focused planning measures.

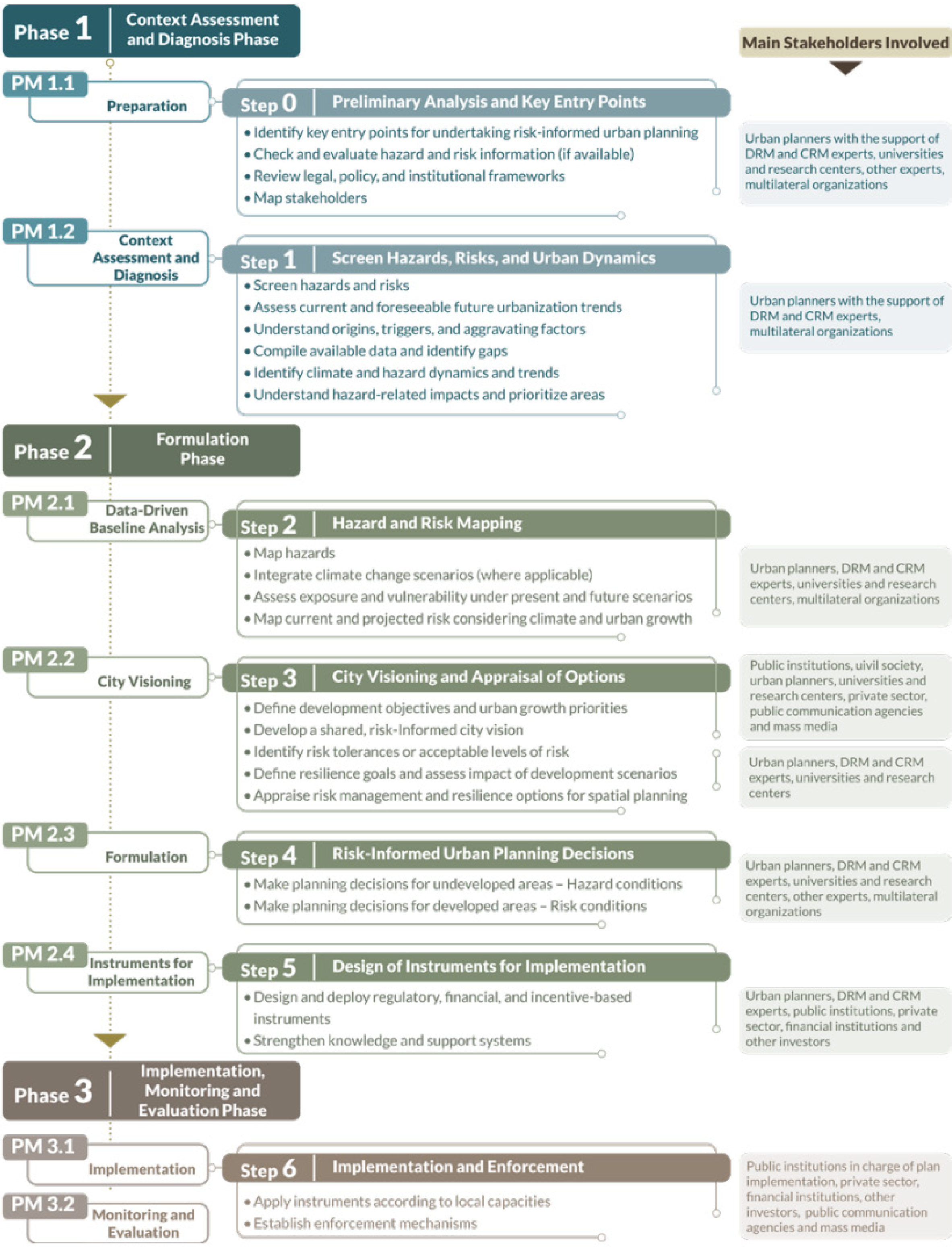


Figure 17. Operational Framework for Risk-informed Urban Planning. Adapted from World Bank & GFDRR (2021, Figure 3.1, p. 76).

2.6. Vacancy and Opportunity

2.6.1. Vacancy as a Legacy of Disinvestment

Urban vacancy is a spatial expression of long-term structural and systemic shortcomings in urban planning, governance, and investment, rather than just a land-use condition. Uneven public and private investment, population loss, economic restructuring, and discriminatory housing regulations all contribute to the amount of vacant land in many post-industrial towns. Communities that are already at risk are disproportionately impacted by the fragmented urban landscapes created by these processes. From the standpoint of risk-informed planning, vacancy serves as both a latent opportunity for focused intervention and proof of systemic failure, especially when it comes to mitigating climate-related hazards like urban heat.

Areas that are more vulnerable to environmental stressors, have lower adaptive ability, and have less access to services are frequently found near vacant properties. Therefore, vacancy offers a crucial spatial layer for comprehending how past underinvestment results in vulnerability in the present. However, because unoccupied ground is relatively flexible and does not have many of the restrictions that come with built-up regions, it presents special chances for climate-responsive measures that can improve neighborhood resilience, pedestrian mobility, and thermal comfort.

Discriminatory housing rules, selective reinvestment, and long-term economic restructuring have all influenced historical patterns of abandonment and unequal development, which are directly linked to urban vacancy. Decades of redlining, industrial decline, and disinvestment in primarily low-income and minority communities have resulted in highly spatialized vacancy in places like Chicago. Discontinuous urban fabrics with unused parcels, deteriorating infrastructure, and limited access to public services are the result of these processes.

Unoccupied properties degrade walkability, break up street continuity, and threaten social cohesiveness at the local level. A block or corridor with several unoccupied plots disrupts daily mobility and adds to feelings of insecurity and neglect. From a systems standpoint, vacancies indicate a breakdown in the way long-term planning plans, housing policy, infrastructure provision, and land markets are coordinated. Clusters of undeveloped property show the long-term effects of institutional and economic choices rather than individual failings.

From a risk perspective, vacancy-created fragmented landscapes are more vulnerable to climate stressors. Urban heat island impacts are made worse by the loss of active land use and tree cover, and these places' ability to adapt is diminished by poor upkeep and investment. Therefore, vacancy actively adds to current environmental risk in addition to reflecting historical disinvestment.

According to the Handbook for Livable and Resilient Cities, vacancy results from a combination of risk and inadequate coordination between catastrophe risk reduction, urban design, and climate adaptation measures. Unused land becomes a persistent condition that feeds cycles of degradation where socioeconomic fragility, environmental exposure, and governance shortcomings come together.

When combined, risk-informed frameworks and empirical vacancy patterns show that unoccupied land is fundamentally created rather than incidental or transient. Therefore, evaluating urban vulnerability and determining where assistance is most urgently needed require an understanding of vacancy as a legacy of disinvestment.

2.6.2. Vacancy-Led Interventions for Heat Reduc-

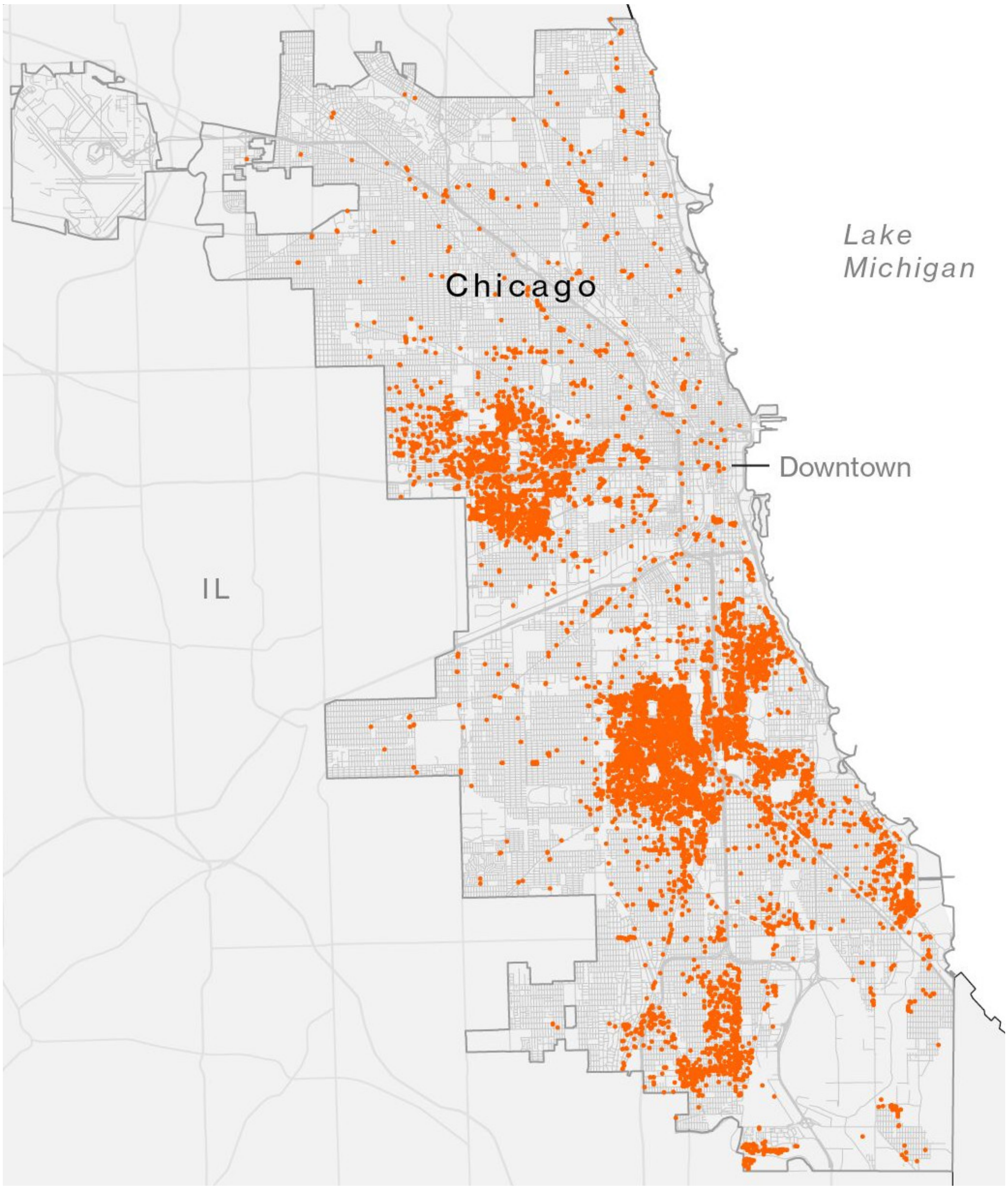
In addition to reflecting systemic failure, vacancy offers a crucial chance for climate-responsive intervention. Particularly in areas where traditional redevelopment has been sluggish or uneven, vacant parcels provide flexible, low-conflict areas for putting heat mitigation methods into practice. The potential of undeveloped land to support nature-based solutions that directly lower heat exposure while providing social and ecological co-benefits is highlighted in recent urban climate and planning literature.

Turning empty lands into green or semi-green areas can greatly enhance local thermal conditions from a microclimatic standpoint. Permeable surfaces decrease heat storage, whereas vegetation increases evapotranspiration, lowers air and surface temperatures, and offers shade. Such interventions, when placed appropriately, can create networks of cooling areas that encourage pedestrian traffic and lessen the total amount of heat exposure along daily routes.

Effective interventions should be responsive to local capability, scalable, and context-sensitive, according to risk-informed planning frameworks. These ideas are supported by vacancy-led initiatives, which permit community input, experimentation, and gradual implementation. Because they allow for the quick deployment of cooling infrastructure without necessitating a permanent change in land use, temporary and modular solutions are especially beneficial in uncertain planning environments.

In addition to having positive effects on the environment, vacancy-led cooling solutions directly affect accessibility and mobility. By creating cooler microclimates, rest areas, and shaded pathways, these areas can lessen the walking restrictions caused by heat and increase the functional accessibility of communities. In this way, instead of remaining a passive vestige of decline, unoccupied land becomes an active part of climate-responsive mobility networks.

By redefining vacancy as a diagnostic sign and a chance for action, planners can manage urban heat through localized, human-centered methods in addition to large-scale infrastructure. Therefore, vacancy-led interventions are a crucial tool for improving thermal comfort, walkability, and resilience in neighborhoods most impacted by climate stress within the larger framework of risk-informed urban planning.



• City-owned vacant lots

Figure 18. Vacant .lots owned by the City of Chicago. Source: Chicago Data Portal and Bloomberg (2025)

2.7. Integrating Risk into Urban Planning, Design, and Policy

Converting knowledge about hazards and vulnerabilities into practical planning, design, and policy tools is necessary to include climate and catastrophe risk into urban planning. Risk-informed planning frameworks place more emphasis on concrete decision logics that direct how cities manage land use, condition development, and encourage resilience-oriented investments than they do on risk as an abstract analytical layer. This strategy is especially pertinent when it comes to climate-related risks like excessive heat, which call for varied approaches based on exposure, sensitivity, and the viability of risk mitigation.

This integration is operationalized by the Handbook for Livable and Resilient Cities using a Restrict-Condition-Promote (RCP) framework that associates risk levels with certain planning actions. The RCP rationale ensures that solutions are appropriate, context-sensitive, and in line with long-term resilience goals by offering a methodical yet adaptable way to incorporate climate risk considerations into statutory planning, urban design, and public investment decisions.

2.7.1. Risk-Informed Urban Planning Frameworks

Frameworks for risk-informed urban planning are intended to direct choices at different degrees of hazard intensity and unpredictability. The understanding that not all risks can be handled in the same manner is at the heart of this strategy. While certain risks necessitate stringent development restrictions, others call for adaptable design techniques, and still others profit from the proactive promotion of actions that increase resilience.

Three distinct categories of planning action are used by the RCP framework to express this logic:

- Restrict, applied where risks are unacceptably high and cannot be reduced to acceptable levels through feasible measures;
- Condition, applied where risks are present but can be mitigated through appropriate planning, design, and construction practices; and
- Promote, applied where proactive interventions can enhance resilience, reduce long-term risk, and deliver co-benefits.

Restrict: Planning Responses to Unacceptable Risk

When risks provide serious and possibly irreversible risks to people's health, safety, or vital systems, restrictive measures are implemented. Restrictive planning measures aim to avoid land-use choices that would increase exposure or compromise natural cooling mechanisms in the context of excessive heat and urban heat island effects.

These steps include minimizing the extensive use of heat-absorbing materials, preventing the loss of green spaces in heat-prone locations, and reducing densification along important ventilation corridors. From the standpoint of planning, restriction acts as a safeguard to make sure that cities are not locked into increased risk in the future as a result of development paths.

Condition: Adaptive Design and Regulatory Measures

In many urban settings, risk avoidance is neither desired nor practical, especially in places that have already undergone development. The development of conditioning through adaptive design, regulatory standards, and technology interventions that lessen exposure and susceptibility to dangers is the focus of risk-informed planning instead.

The use of reflective and permeable materials, improved building regulations to promote ventilation and insulation, and energy-efficient technologies that minimize infrastructure overload while reducing indoor heat stress are all examples of conditioning solutions for intense heat. These actions actively lessen risk and increase adaptive capacity while enabling development to continue.

Promotive measures actively encourage planning and design strategies that improve long-term resilience and provide numerous co-benefits, which is a complement to constraints and conditioning. Promotive measures aim to change urban systems so they can more resiliently face and adjust to climatic stressors, rather than only lowering risk.

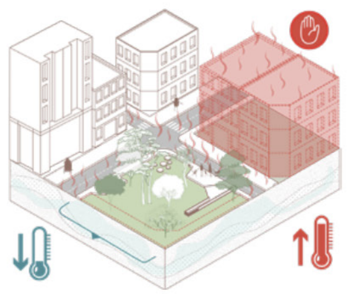
Promotive measures for urban heat include heat action plans, urban cooling networks, sustainable urban drainage systems, the growth of nature-based solutions, and thermal mapping. These tactics enhance ecological services, energy efficiency, and public space quality in addition to lowering temperatures.

The framework of Restrict–Condition–Promote shows how risk-informed planning proceeds from identifying hazards to developing unique, implementable planning solutions that can be incorporated into investment priorities, design guidelines, and statutory plans.

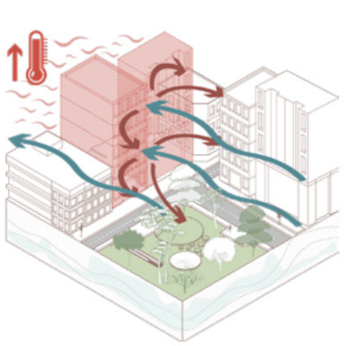
Restrict: Applies when hazard and risk levels are unacceptably high and cannot be reduced to acceptable levels through feasible, cost-effective measures.

Extreme heat, heat waves, and urban heat islands

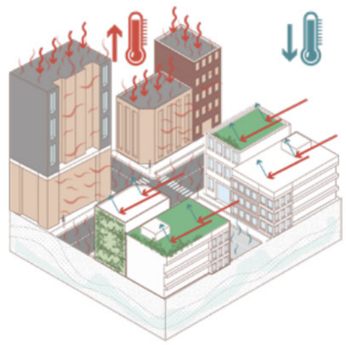
Reduce depletion of green spaces in areas prone to heat hazards.



Prohibit densification along wind corridors.

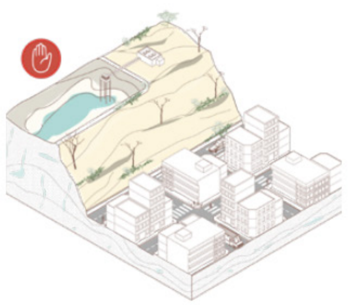


Limit undue use of heat-absorbing materials.



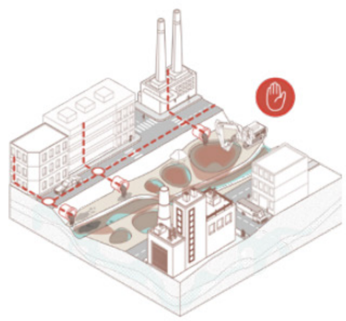
Urban droughts

Restrict deforestation and large impervious surfaces in high-infiltration areas.



Restrict overextraction, unregulated well drilling, and excessive damming.

Restrict activities that trigger water pollution risks, such as mining, landfills, and untreated wastewater discharge near basins.



Wildfires

Restrict development in areas with high wildfire susceptibility.

Figure 19. Restrict: Planning Responses to Unacceptable Risk. Adapted from World Bank & GFDRR (2021, Table 7.4, p. 205-206).

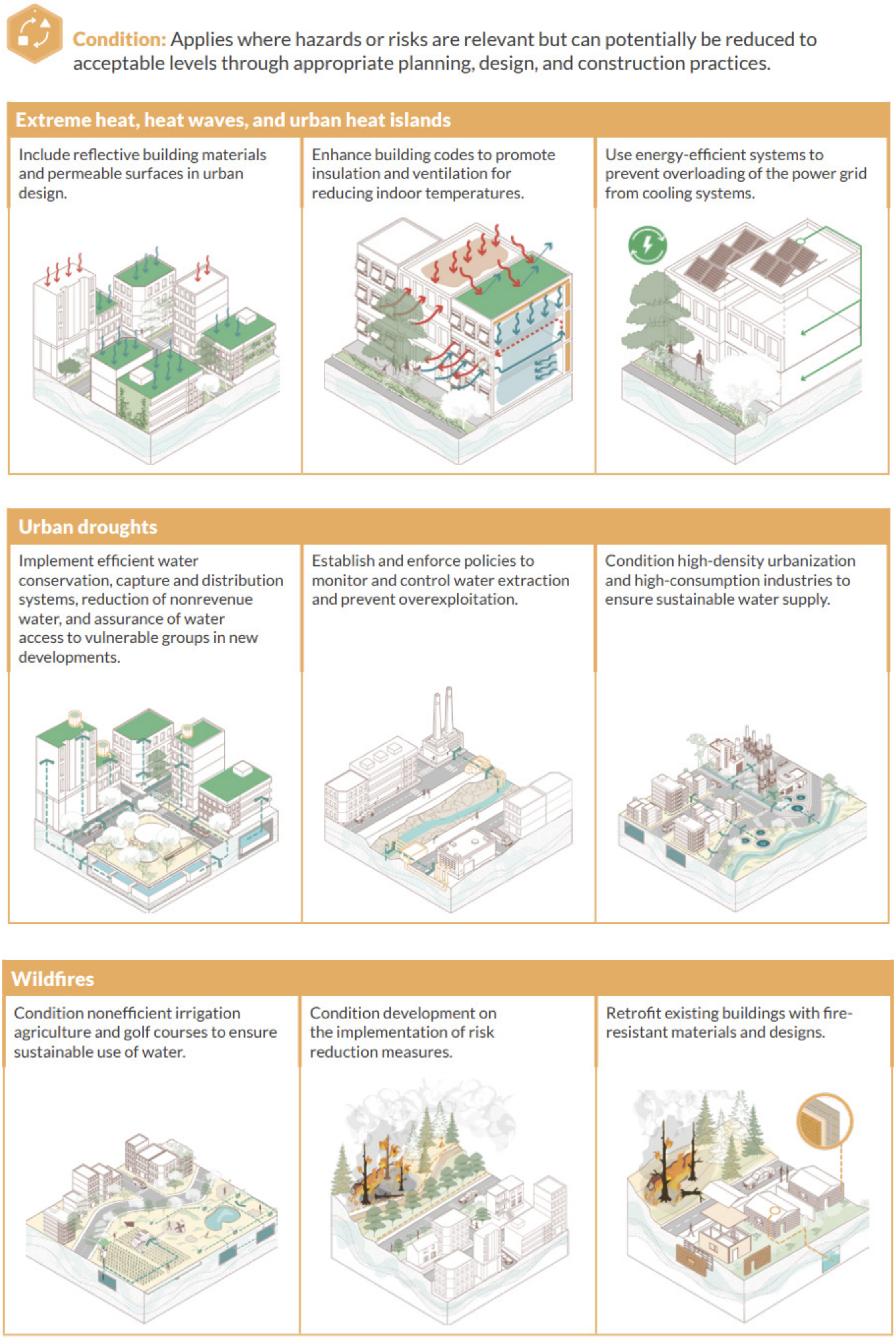


Figure 20. Condition: Adaptive Design and Regulatory Measures. Adapted from World Bank & GFDRR (2021, Table 7.5, p. 207-208).

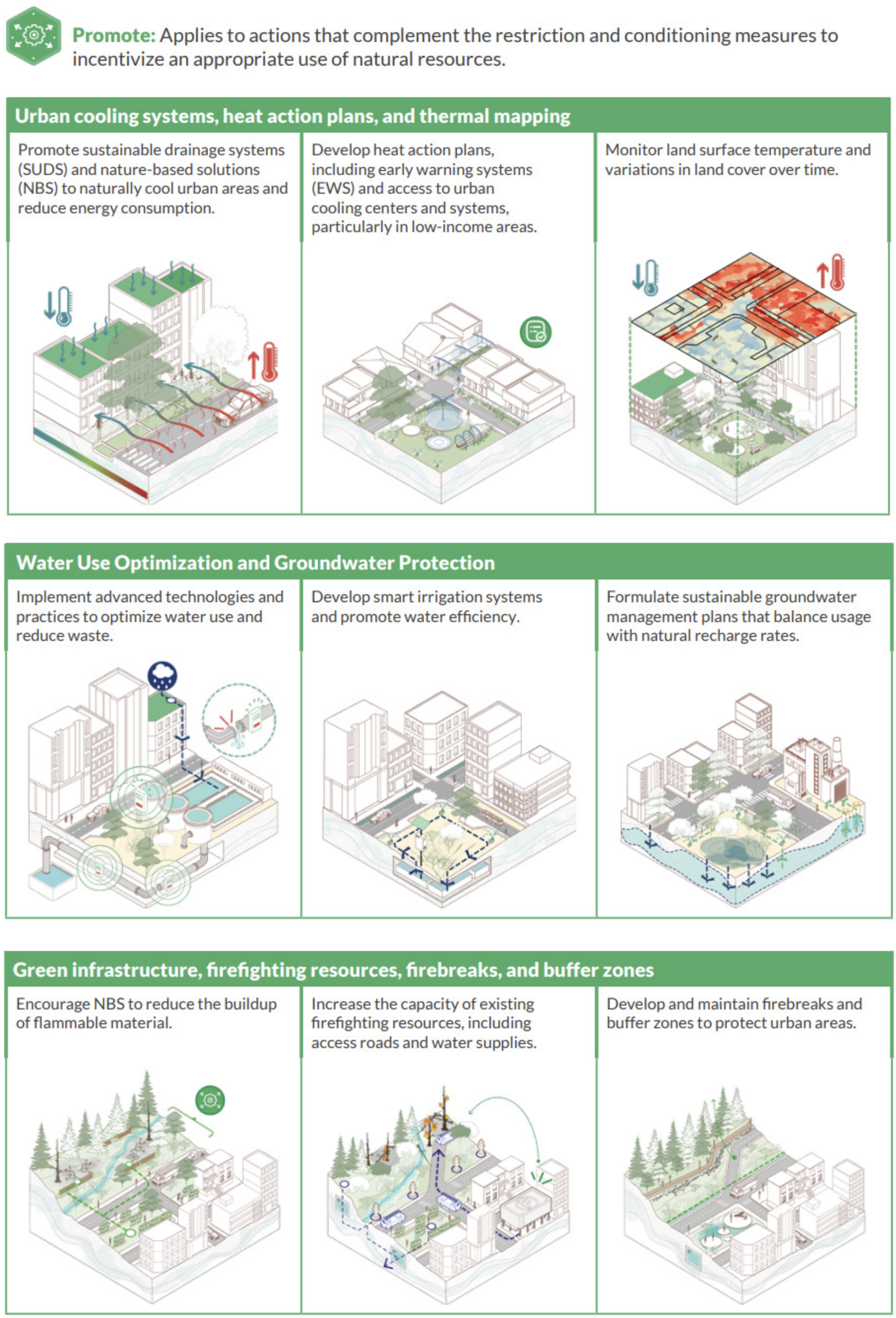


Figure 21. Promote: Proactive and Resilience-Building Interventions. Adapted from World Bank & GFDRR (2021, Table 7.6, p. 209-210).

2.8. Research Gaps and Conceptual Framework

Even while the literature on climate vulnerability, urban heat islands, and equitable design is expanding, there are still a lot of unanswered questions about how these topics are combined, especially when it comes to historical injustices in planning and daily mobility. Fewer studies specifically link these trends to the legacy of redlining and its effects on accessibility and pedestrian movement, even as research is beginning to recognize the disproportionate burden of heat exposure on underprivileged communities. The conceptual framework that underpins this investigation is presented in this part, along with important gaps in the body of previous material.

This part lays the analytical and methodological groundwork for the next chapter by identifying these gaps and situating the research within a risk-informed and equity-oriented planning paradigm.

2.8.1 Gaps in Linking Redlining, Heat, and Mobility

Research on urban heat as a socio-spatial hazard as well as a meteorological hazard has made significant progress, especially in identifying the connection between historically underdeveloped communities and high land surface temperatures. Research continuously demonstrates that **regions influenced by redlining and segregationist planning are more vulnerable to excessive heat and have higher levels of social vulnerability** because of differences in health, age, and income. Urban climatology, social vulnerability, and planning history are three areas of study that are frequently analytically isolated from one another. Fewer studies incorporate the well-established links between historical underinvestment and current thermal disparities into frameworks for spatial design that specifically address accessibility and mobility.

A second gap lies in the limited consideration of pedestrian experience within urban heat research. The **majority of the literature currently in publication uses aggregated temperature averages to assess exposure at the residential or neighborhood level, ignoring the dynamic way that heat is experienced through daily movement**. In particular, for people who rely on walking or public transportation, pedestrian mobility is rarely investigated as a mechanism through which heat risk is accumulated, alleviated, or amplified. Because of this, **planning systems often view heat as a static climatic state rather than as a lived**, human-scale phenomenon influenced by network connection, infrastructure quality, and route selection.

Lastly, there is still a gap between practical spatial planning and risk assessment. While risk-informed frameworks are excellent in conceptualizing hazard, exposure, and vulnerability, they frequently fall short in converting these dimensions into network-based choices on cooling infrastructure placement, walkability, and route optimization. As a result, less focus is placed on how heat danger modifies patterns of accessibility in urban systems. To close this gap, **analytical methods must take into consideration climate risk, historical injustice, and the spatial logic of everyday mobility all at once**. This means going beyond descriptive mapping and toward predictive and intervention-focused urban planning models.

2.8.2. Conceptual Framework of the Study

This study uses an integrated conceptual framework that connects historical redlining, urban heat exposure, and pedestrian mobility from a risk-informed planning viewpoint in order to fill the gaps that have been discovered. In order to investigate how structural inequality influences current heat risk and accessibility outcomes, the framework integrates essential components from mobility-oriented urban analysis, social vulnerability theory, and climate risk management.

Fundamentally, the paradigm views urban heat as a socially constructed spatial barrier as opposed to an exclusively natural phenomenon. Historical planning decisions have influenced the built environment, land-use patterns, and sociodemographic vulnerability, all of which interact to produce heat exposure. Redlined areas are situated as crucial locations where these factors converge, creating heightened danger that impacts everyday mobility as well as living circumstances.

The framework integrates four primary components:

1. **Historical and Structural Context**, capturing the legacy of redlining and disinvestment as determinants of present-day urban form and infrastructure;
2. **Climate Hazard and Exposure**, represented by spatial patterns of urban heat intensity and thermal stress;
3. **Social Vulnerability and Adaptive Capacity**, reflecting demographic sensitivity, resource access, and governance conditions; and
4. **Pedestrian Mobility and Accessibility**, emphasizing movement, route choice, and exposure during everyday journeys.

A risk-informed planning lens connects these elements by emphasizing diverse responses, such as conditioning, encouragement of actions, and limitation, depending on the degree and manageability of risk. The paradigm strategically incorporates vacant and underutilized land as markers of systemic failure and as opportunities for climate-responsive change.

The paradigm makes two significant contributions to the body of current literature by placing pedestrian mobility at the core of climate risk analysis. First, instead of framing heat exposure as a static residential state, it presents it as a dynamic process experienced through movement. Second, it offers a foundation for modeling how design and planning interventions, such shaded paths, cooling nodes, and vacancy-led green infrastructure, might change exposure patterns and increase accessibility for populations that are more susceptible. The study's methodological approach is directly influenced by this conceptual framework, which directs the simulation logic, spatial analysis, and variable selection discussed in the next chapter. By doing this, it creates a logical link between theory, empirical research, and results that are focused on planning.

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Conceptual framework

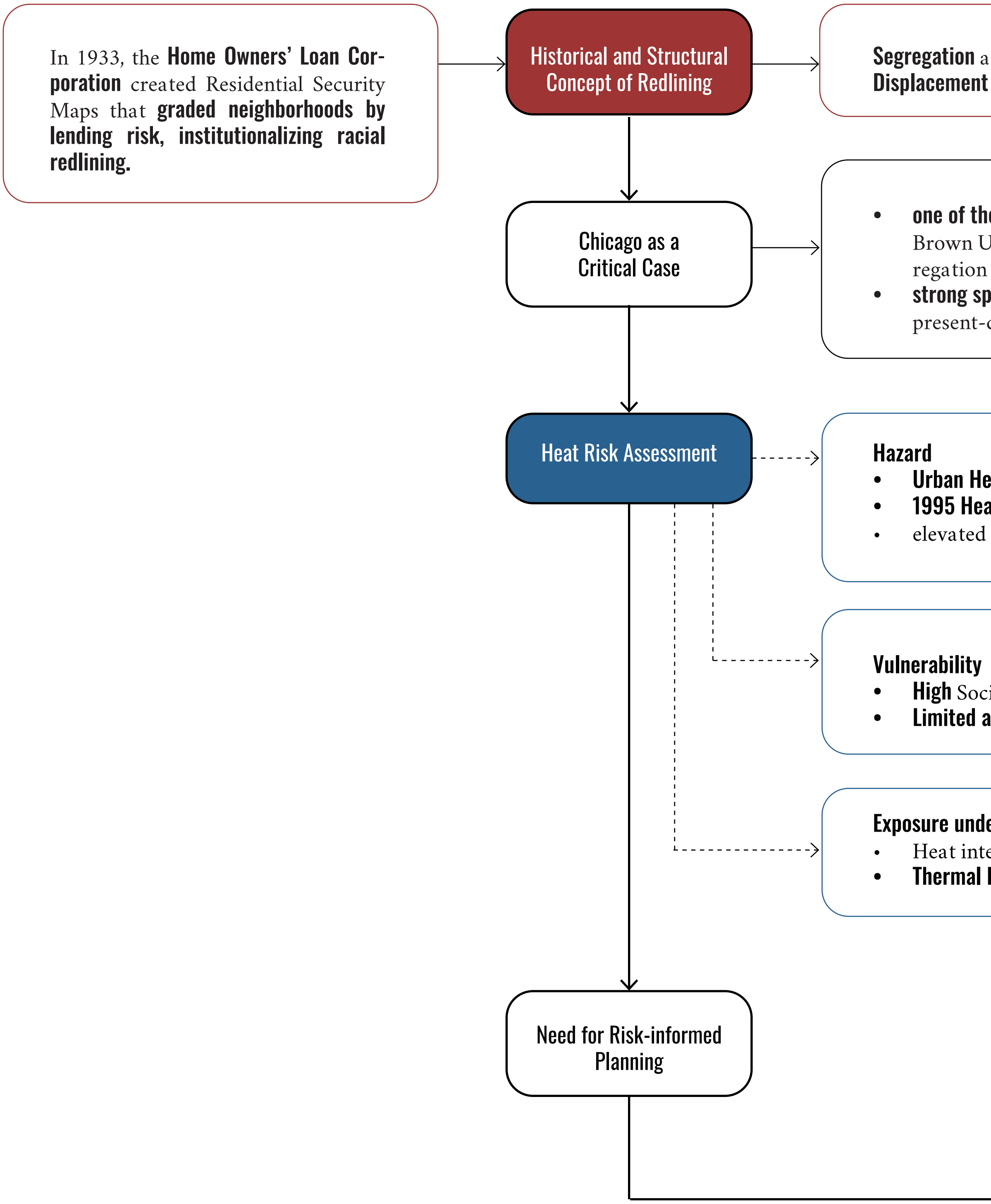
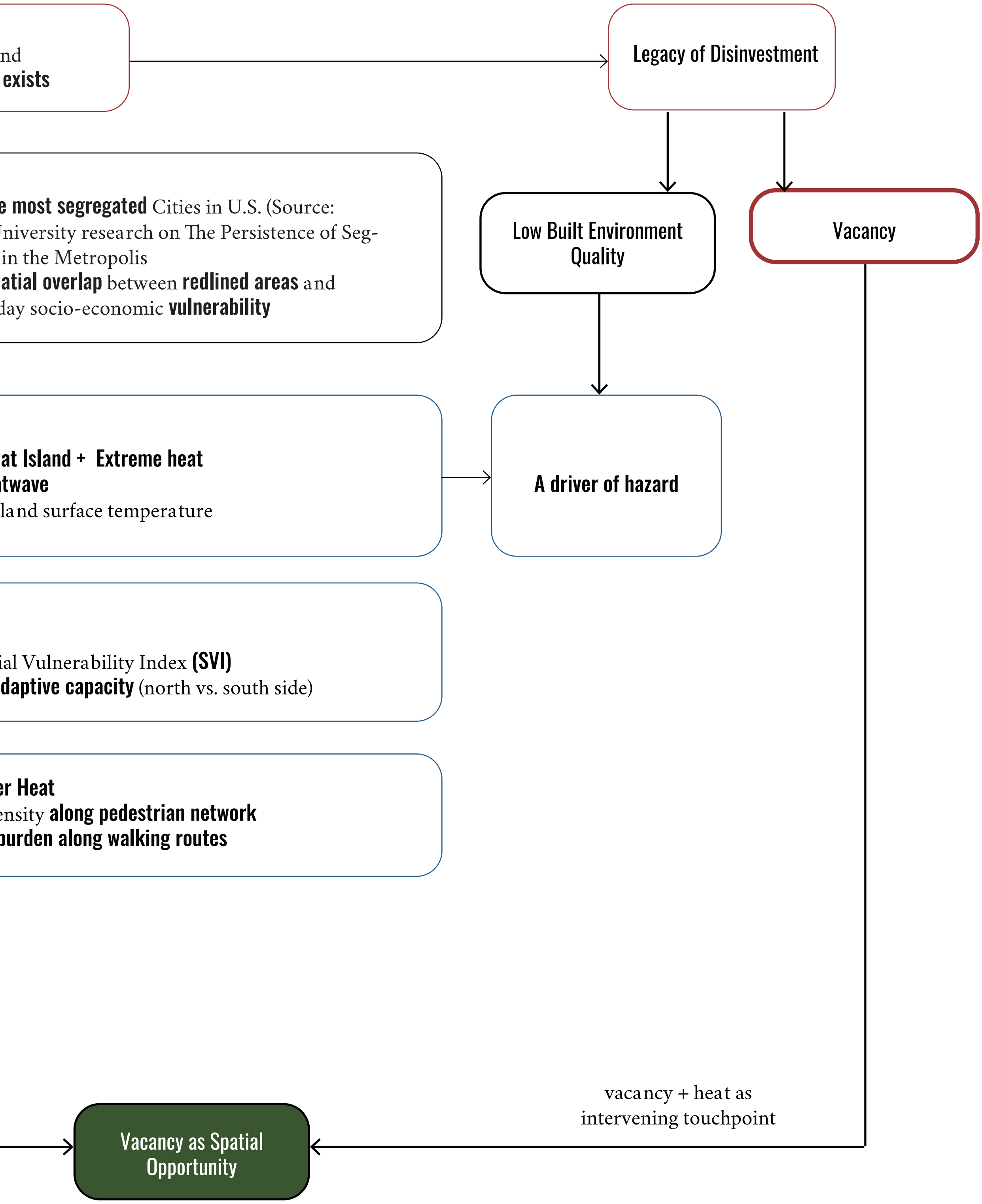


Figure 22. Conceptual Framework. Source: Author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Legacy of Disinvestment
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niversity research on The Persistence of Seg-
in the Metropolis
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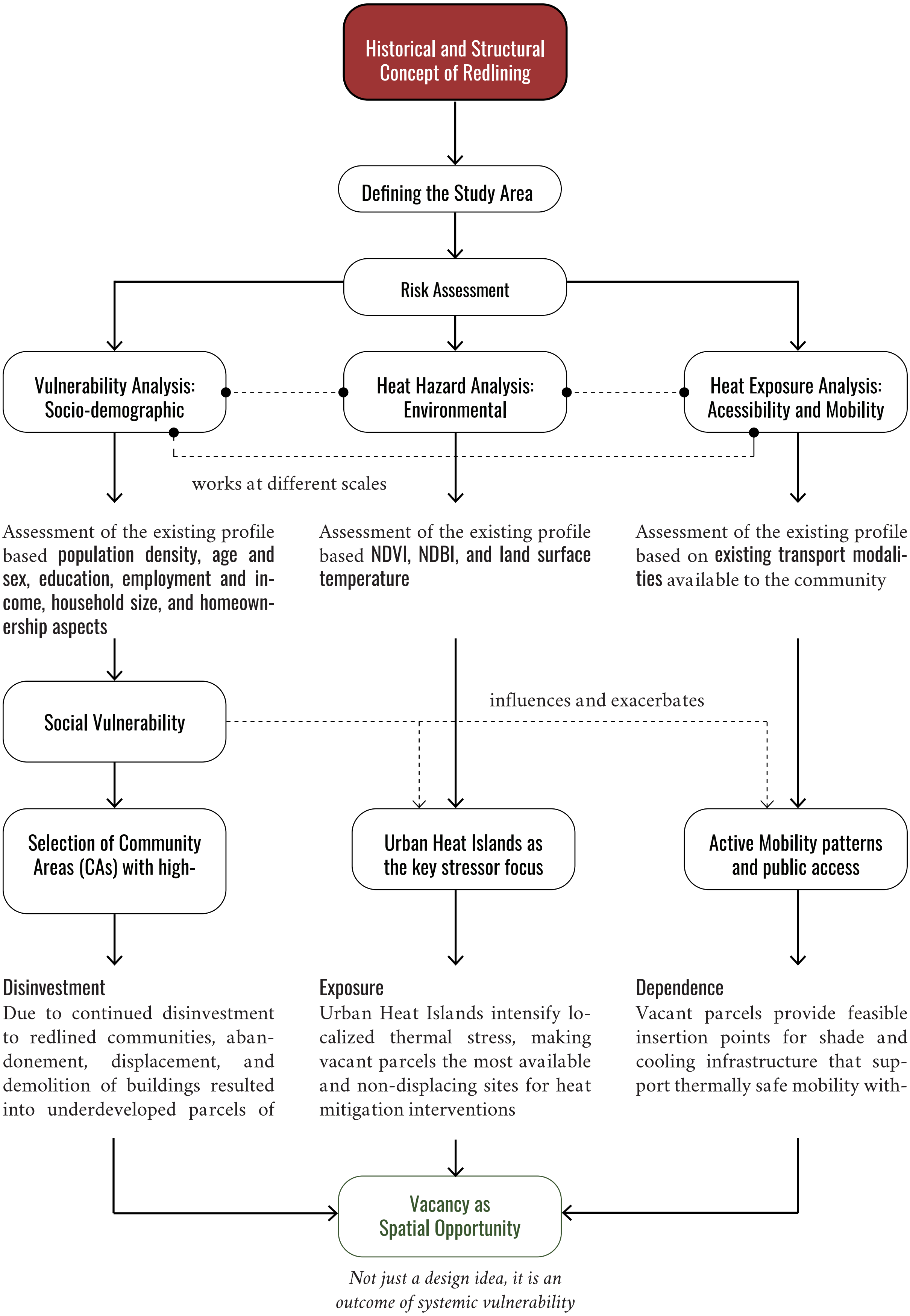
day socio-economic vulnerability
Low Built Environment Quality
Vacancy
at Island + Extreme heat
twave
land surface temperature
A driver of hazard
ial Vulnerability Index (SVI)
daptive capacity (north vs. south side)
r Heat
ensity along pedestrian network
burden along walking routes
vacancy + heat as intervening touchpoint
Vacancy as Spatial Opportunity

Problem Space



Opportunity Space

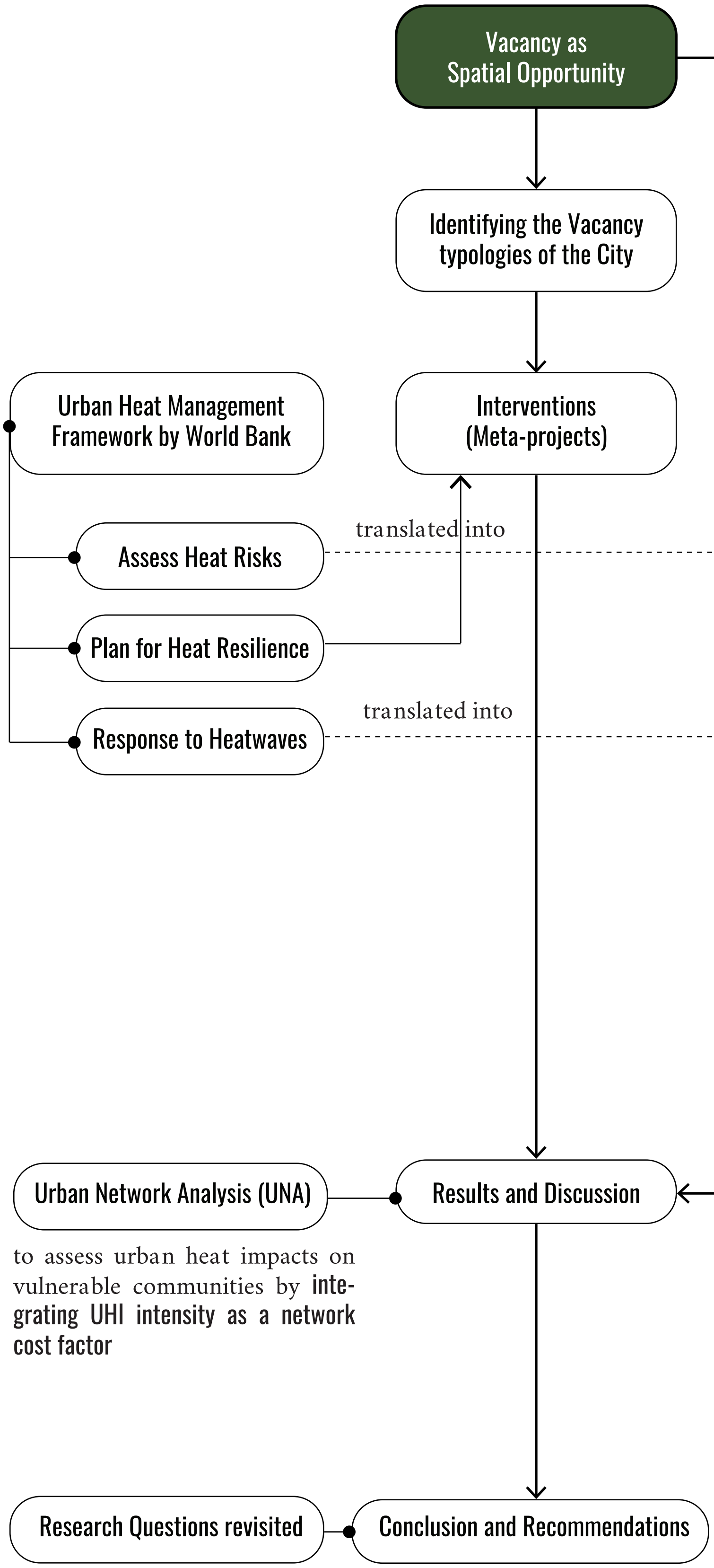


Figure 23. Problem and Opportunity Framework. Source: Author

CHAPTER III

Methodology

Chapter III: Methodology

3.1. Conceptual and Analytical Framework

3.1.1. Introduction

This study uses an integrated socio-spatial and environmental analytical framework to investigate how the City of Chicago's current urban heat exposure, social vulnerability, and pedestrian mobility are still influenced by past design choices. The framework is based on the idea that current climate risks, especially those caused by Urban Heat Island (UHI), are not dispersed equally throughout the urban landscape but rather result from long-standing structural disparities ingrained in investment, land-use regulation, and planning practices.

The foundation of this paradigm is redlining, which is defined as a historically institutionalized financial and planning practice that systematically limited environmental quality, infrastructure provision, and investment in neighborhoods that were primarily racially and economically marginalized. This study views redlining as a structural force whose material and geographical effects endure through urban design, land-use patterns, and environmental exposure rather than an entirely historical occurrence.

The framework proceeds through a causal and sequential logic composed of five interrelated dimensions:

1. **historical structuring of inequality,**
2. **spatial and urban form outcomes,**
3. **socio-demographic vulnerability,**
4. **environmental exposure and access constraints, and**
5. **spatial opportunity and intervention.**

3.1.2. Redlining and Urban Form

Redlining is regarded as the primary factor influencing how the study areas are physically laid out. Redlining-induced disinvestment affected infrastructure quality, building typologies, land-use intensity, and the unequal distribution of open and green spaces. By examining these spatial features, it is shown how historically underserved communities have more impervious surface covering, dispersed green infrastructure, and less environmental buffersall of which exacerbate urban heat accumulation.

3.1.3. Socio-Demographic Vulnerability

By looking at the sociodemographic traits of the inhabitants living in these historically underinvested areas, the framework builds on the urban form analysis and puts people above exposure. Age, income, work, housing tenure, education, and segregation patterns are some of the factors that generate vulnerability, which is viewed as a multifaceted condition. To combine these indications and pinpoint groups who are less able to adjust to environmental stressors like intense heat, the Social Vulnerability Index (SVI) is utilized.

The methodology highlights that heat exposure affects populations that are already structurally disadvantaged rather than all people equally by placing sociodemographic vulnerability before environmental heat analysis.

3.1.4. Urban Heat as Environmental Inequality

Urban heat is viewed as a spatial expression of environmental injustice rather than just a climatic occurrence. Through the use of metrics including Land Surface Temperature (LST), vegetation cover, and built-up intensity, the methodology evaluates how historically redlined and socially vulnerable districts are disproportionately affected by urban heat. To illustrate the compounding nature of environmental risk, other environmental stressors are included, such as air quality and flood susceptibility.

3.1.5. Access, Mobility, and Everyday Exposure

By including access and active mobility as essential components of lived experience, the framework goes beyond static exposure. People who depend on walking as their main form of transportation are disproportionately affected by heat, which is viewed as a barrier that alters pedestrian flow and restricts access to important locations. The approach establishes a clear connection between environmental exposure and everyday mobility limitations by analyzing pedestrian networks and walking catchments under heat stress conditions.

3.1.6. Vacancy as Spatial Opportunity

The paradigm only presents vacant land as an emergent spatial option after establishing the combined effects of redlining, urban form, vulnerability, heat, and access constraints. The study views vacant lands, especially those owned by the government, as latent urban infrastructure that can enable interventions that reduce heat and improve mobility, rather than viewing vacancy as blight. Thus, in places where typical large-scale redevelopment is constrained, vacant space provides a critical entry point for climate-responsive urban transformation.

3.2. Study Area: City of Chicago

3.2.1. Introduction

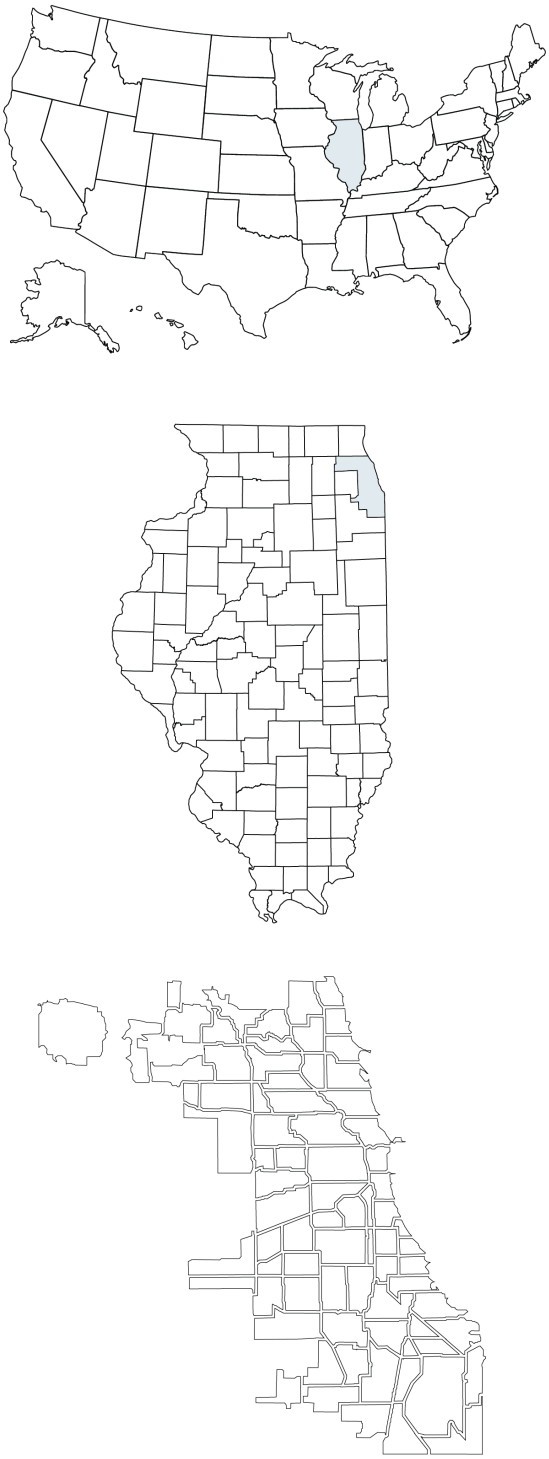
The **City of Chicago, Illinois, is the primary research location for the purpose of this study.** It lies geographically **along the southwestern shoreline of Lake Michigan** at approximately 41.8781° N latitude and 87.6298° W longitude and covers approximately 606.1 km² (234.5 mi²) of land area. With a population of about 2.7 million residents within the city and over 9.4 million within the metro area, Chicago is the third most populous city in the U.S. (U.S. Census Bureau, 2023). The city has **77 community areas and over 230 neighborhoods**, which are administrative and planning divisions and provide the structural framework for data collection and analysis in the current study.

Climatically, Chicago falls in the humid continental climate zone, which features notable seasonal variation in cold winters, moderate springs and autumns, and hot and humid summers. Average summer temperatures range from 29–32°C (85–90°F), but **severe heatwaves capture readings above 37°C (100°F)** (NOAA, 2022). They are aggravated by the influence of urban heat island (UHI), particularly for intensive, hard, and highly urbanized areas with inadequate cover of vegetation. These heat extremes are accountable for high risks to public health, livability, and active mobility.

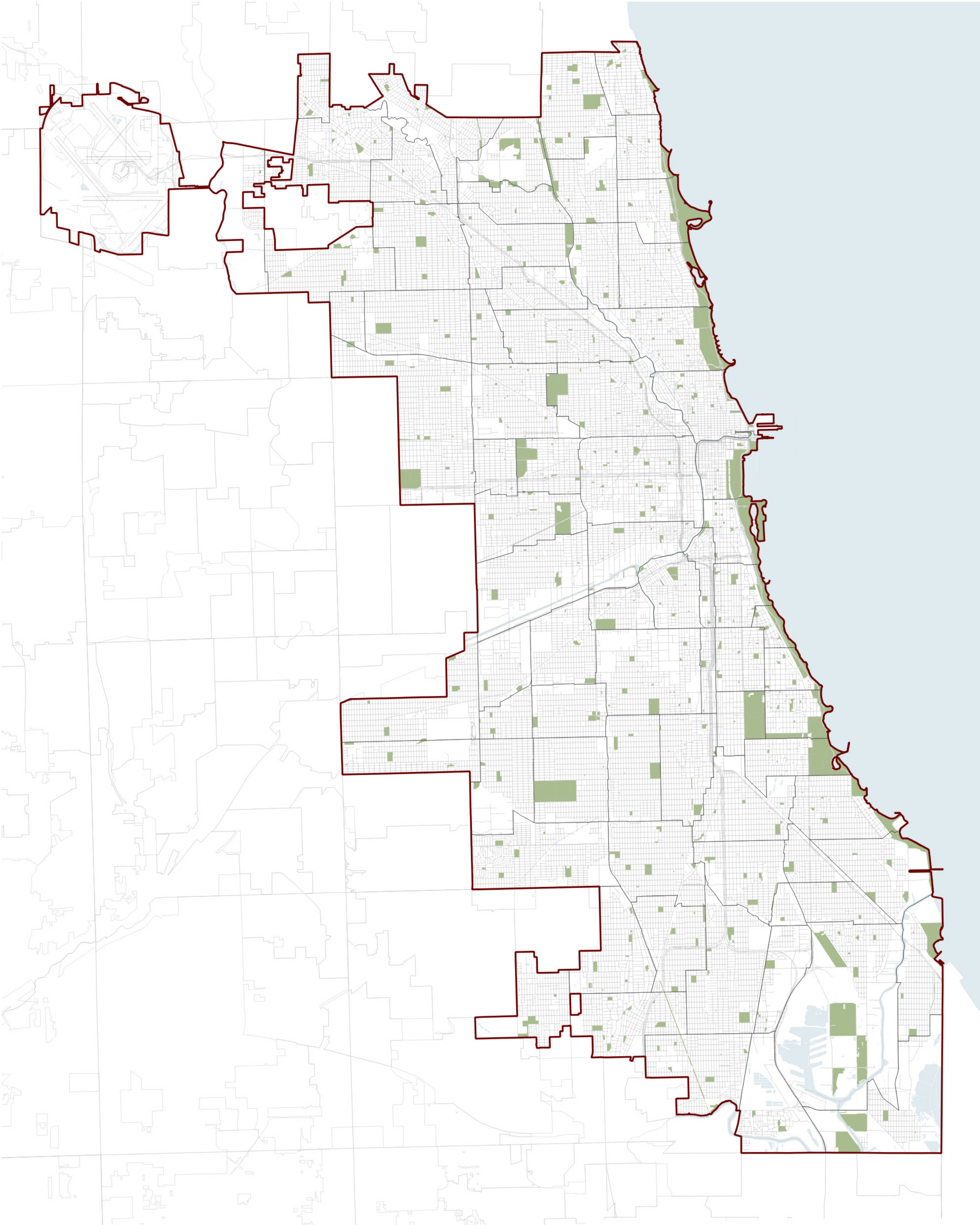
Urban morphologically, Chicago features a gridiron street pattern, a dense CBD in the Loop surrounded by progressively less dense residential and industrial districts. For all this coordinated structural form, there are stark contrasts between neighborhoods. Although wealthier, forested lakefront communities are protected from lesser heat exposure, long-time redlined South and West Side communities have substantially higher land surface temperatures (LST) with contrast up to 5–12°F (≈3–7°C) on days of intense summer heat (Hoffman et al., 2020; Ettinger et al., 2024). These are further support for the strong interlink between urban form, socioeconomic disadvantage, and environmental risk.

Geographically, **Chicago is located in Cook County in northeastern Illinois,** bounded by Lake Michigan to the east. Having the lake influence local climatic conditions, it provides moderating breezes at times that scatter urban heat. It is not uniformly distributed, however, and primarily alleviates northern and eastern lakefront neighborhoods, while inland and southern areas continue to endure disproportionately high UHI intensities. This spatial separation serves to perpetuate patterns of environmental disadvantage and produces differentiated degrees of exposure to climatic hazard across the city.

In combination, Chicago's physical characteristics, climate, and demographics render it a crucial site for exploring the interrelationship between walkability, urban heat, and inclusive mobility planning. The city experiences both the challenges of a dense metropolitan center and environmental risk inequity, offering a compelling case study for examining practices that mitigate UHI effects while promoting climate-resilient and equitable urban planning.



Map 1. State, County, and City of Chicago. Source: Chicago Data Portal



Map 2. Urban Fabric of Chicago. Source: Chicago Data Portal

Legends

- City of Chicago
- Community Areas
- Green Infrastructure
- Blue Infrastructure
- Road Network

0 2.5 5 km

3.2.2. Administrative Boundaries

The official city boundary encompasses an **area of approximately 606 km² (234 mi²) surrounding the southwestern shore of Lake Michigan**. This boundary delineates city government and public services' jurisdiction and forms the outer limit of analysis for this study. By invoking the municipal boundary, the research ensures that both climatic impacts at a macro scale and urban planning issues are framed within the legally defined limits of Chicago.

Within the city boundaries of this municipality, Chicago is **segmented into 77 community areas mapped in the 1920s by the Social Science Research Committee of the University of Chicago** and unchanged since then. These neighborhoods are widely utilized for studies at the academic level, public health analyses, and planning since they provide consistent geographic units over time, unlike neighborhood boundaries that may shift. These community areas consolidate census data, land use data, and environmental observations in a single unit, and therefore are most appropriately used as the level of analysis in which to investigate citywide trends in urban heat, travel, and demographic risk. Community areas are thus the macro-level unit of observation for the needs of this research.

On a finer scale, Chicago contains **more than 230 documented neighborhoods that are smaller and more culturally defined units nested within community areas**. Neighborhoods are more likely to derive from long-term settlement patterns, cultural identity, and experience than from official planning declarations. For instance, the Logan Square community area consists of Logan Square, Palmer Square, and Kosciuszko Park, while the Near West Side community area consists of Greektown and Little Italy. Neighborhoods are socially meaningful and meaningful to area-level planning and community outreach, yet not as statistically reliable as community areas. Neighborhoods will be used in this study at the micro-scale or local frame level, particularly in descriptions of experienced states of heat stress, walkability, and accessibility.

The distinctions between these administrative and cultural borders are critical to methodology. The city boundary frames the overall study area and scope. Community areas provide the most uniform and strongest spatial units for quantitative analysis of exposure to heat, population, and mobility. Finally, the neighborhoods offer a locally based and socially situated perspective that captures inequities at the scale most relevant.

Table 1. Boundaries in the City

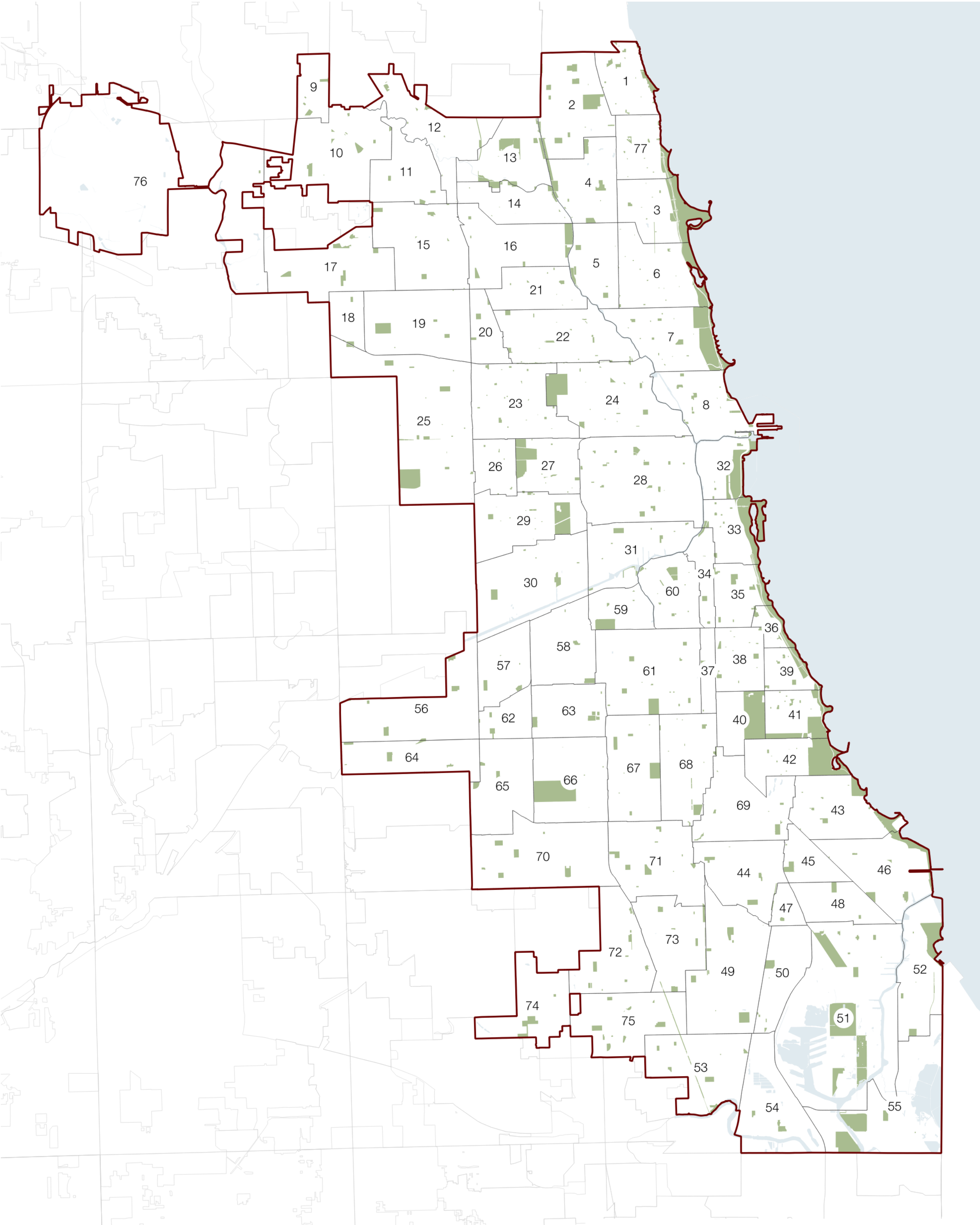
Boundary	Number
Community Areas	77
Neighborhood	230+
ZIP codes	~60

Table 2. Community Number and Name

Number	Community Name
1	Rogers Park
2	West Ridge
3	Uptown
4	Lincoln Square
5	North Center
6	Lake View
7	Lincoln Park
8	Near North Side
9	Edison Park
10	Norwood Park
11	Jefferson Park
12	Forest Glen
13	North Park
14	Albany Park
15	Portage Park
16	Irving Park
17	Dunning
18	Monthclare
19	Belmont Cragin
20	Hermosa
21	Avondale

Number	Community Name
22	Logan Square
23	Humboldt Park
24	West Town
25	Austin
26	West Garfield Park
27	East Garfield Park
28	Near West Side
29	North Lawndale
30	South Lawndale
31	Lower West Side
32	Loop
33	New South Side
34	Armour Square
35	Douglas
36	Oakland
37	Fuller Park
38	Grand Boulevard
39	Kenwood
40	Washington Park
41	Hyde Park
42	Woodlawn
43	South Shore
44	Chatham
45	Avalon Park
46	South Chicago
47	Burnside
48	Calumet Heights
49	Roseland

Number	Community Name
50	Pullman
51	South Deering
52	East Side
53	West Pullman
54	Riverdale
55	Hegewisch
56	Garfield Ridge
57	Archer Heights
58	Brighton Park
59	McKinley Park
60	Bridgeport
61	New City
62	West Elsdon
63	Gage Park
64	Clearing
65	West Lawn
66	Chicago Lawn
67	West Englewood
68	Englewood
69	Greater Gramd Crossing
70	Ashburn
71	Auburn Gresham
72	Beverly
73	Washington Heights
74	Mount Greenwood
75	Morgan Park
76	O'Hare
77	Edgewater



Map 3. Community Areas of Chicago. Source: Chicago Data Portal

Legends

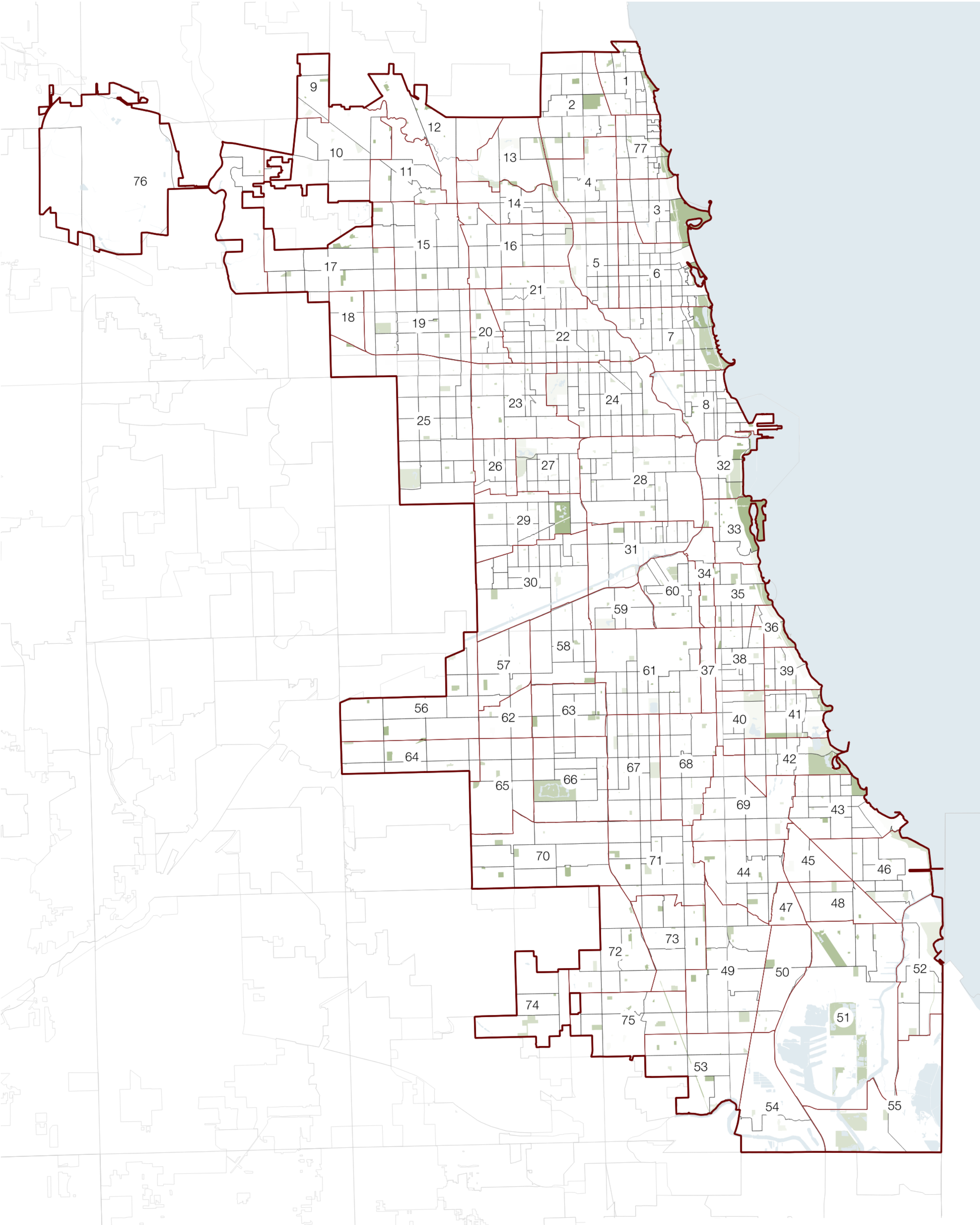
City of Chicago

Community Areas

Green Infrastructure

Blue Infrastructure

0 2.5 5 km



Map 4. Census Tracts of Chicago. Source: Chicago Data Portal

Legends

City of Chicago

Community Areas

Green Infrastructure

Blue Infrastructure

0 2.5 5 km

3.2.3. Land Use and Zoning

Chicago's zoning and land-use plan is evidence of the city's unique history of urbanization, industrialization, and transportation-based growth. Nearly 39.1% of the city is utilized for transportation and infrastructure. This immense share speaks to **Chicago's heritage as a transportation center in the past, with its extensive highway network, rail system, airport system, and waterway system** that not only connect the city to the rest of America but also shape the spatial configuration of neighborhoods.

Residential use of land is the second-largest category, covering 31.4% of the city's total area when single-family (19.9%) and multi-family (11.5%) residential uses are combined. Single-family residences dominate much of Chicago's outer neighborhoods, the historical patterns of suburbanization, with multi-family dwellings in more highly settled inner-city neighborhoods and along transit corridors.

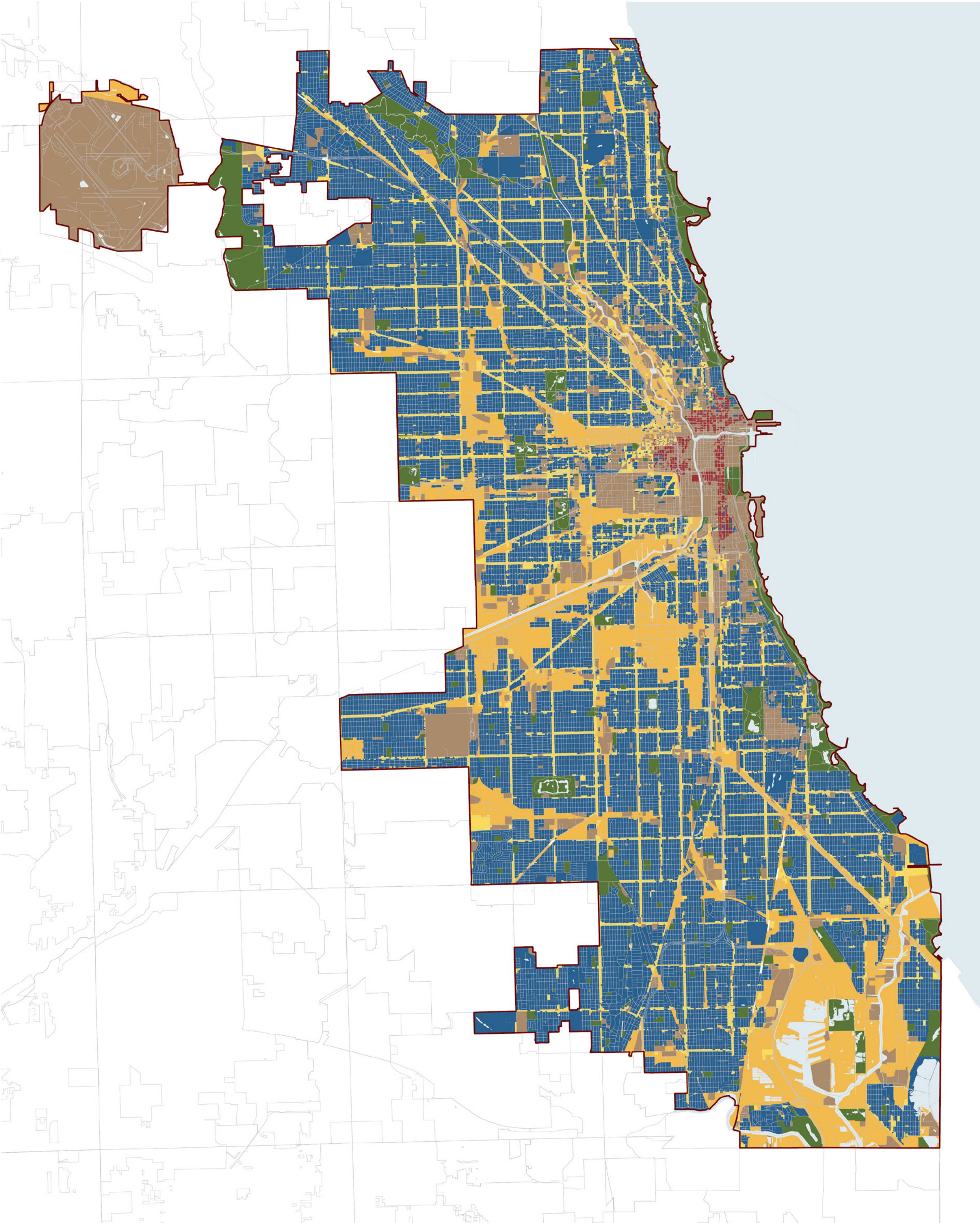
Commercial and industrial purposes need a combined smaller but not insignificant portion of Chicago's total area. Industrial occupies 5.6%, given the city's industrial heritage, and commercial occupies 4.8%. These purposes tend to cluster in corridors, riverfronts, and previously industrial areas that have experienced changes because of deindustrialization. Some of the city's older industrial districts have been redeveloped as mixed-use or residential projects, leaving scattered remnants of manufacturing and logistics space in place to continue serving the local economy. These shifts are indicative of ongoing conflicts between economic revitalization, gentrification, and preserving industrial employment opportunities.

Institutional land uses, including schools, hospitals, government buildings, and other civic facilities, account for 5.9% of Chicago's territory. 7.2% of parks and open space are occupied, which is an important percentage within a city where green infrastructure plays an increasingly important role in addressing livability and climate resilience.

4.8% of the city is vacant land, representing trends of disinvestment, including in neighborhoods that have previously suffered depopulation, economic decline, or structural disadvantage. Vacant parcels are problematic and provide challenges to planners and policymakers. On the one hand, vacant land can represent abandonment, underdevelopment, and lost economic potential. Alternatively, it presents possibilities for redevelopments, grassroots initiatives, or the creation of green space.

Table 3. Land Use in Percentage

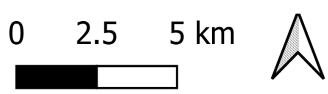
Land Use Category	% of Total Land
Transportation & Infrastructure	39.1%
Single-Family Residential	19.9%
Multi-Family Residential	11.5%
Commercial	4.8%
Industrial	5.6%
Institutional (schools, hospitals, govt.)	5.9%
Open Space / Parks	7.2%
Vacant Land	4.8%
Agricultural	~0%
Total	100%



Map 5. Zoning Plan of Chicago. Source: Chicago Data Portal

Legends

- City of Chicago
- Residential blocks
- Commercial blocks
- Industrial blocks
- City Center blocks
- Green blocks
- Planned Development blocks
- Road network



3.2.4. Urban Typologies

Residential Typologies
Chicago's residential topography is highly diverse, reflecting its multilayered history of urbanization. Single-family homes, typically located in the outlying neighborhoods, provide low-density living conditions with single-family dwellings and freestanding garages. Two-flats, one of Chicago's typical housing types, house multiple apartments stacked one atop the other in a single building, which offers affordability and density without compromising neighborhood identity. Multi-family apartments from low-rise walk-ups to mid-rise apartments are clustered along primary corridors and transit nodes to meet the need of greater populations. Finally, downtown high-rise condominiums and apartments that punctuate the skyline house professionals who want to be close to the central amenities of the city.

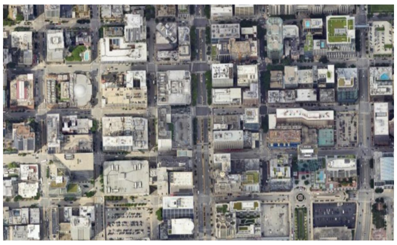
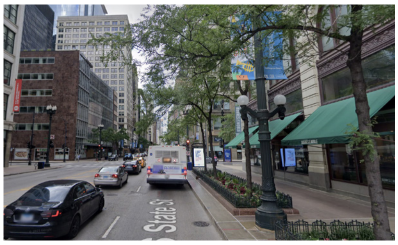
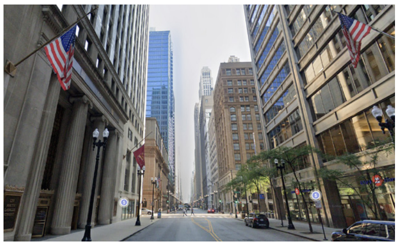
Commercial Typologies
Chicago commercial typologies concentrate shopping, eating, and services into coordinated corridors and centers. They range from low-rise store fronts inserted into neighborhood districts to mid- and high-rise office towers in the city center. The photographs concentrate on commercial intensity at the block scale and street-level energy, where retail on the ground floor animates pedestrian life. These venues are the epicenter of economic life, attracting consumption and employment hubs dispersed across the city.

Industrial Typologies
Industrial areas of Chicago include manufacturing districts and Planned Manufacturing Districts (PMDs), established to preserve industrial employment. Traditional manufacturing districts are located along the Chicago River and rail corridors where older structures continue to operate or are being redeveloped for mixed use. PMDs, by contrast, are constitutionally defined spaces where industrial growth has priority over residential encroachment and allows space for warehousing, logistics, and manufacturing. This typology is a reflection of the industrial legacy and ongoing pressures to balance employment retention with redevelopment in the city.

Downtown Typologies
Downtown zoning offers specialist categories that respond to the high density of Chicago's central core. Mixed-use downtown districts promote the conjoining of offices, residential high-rises, hotels, and shopping to keep a flow of activity around the clock. The Downtown Core (DC) district, located at the very center of the Loop, aims at office skyscrapers, financial hubs, and civic buildings, thus reinforcing Chicago's role as an international business hub. Downtown Service (DS) zones provide for facilitating infrastructure, including parking buildings, utilities, and logistics to enable the functioning of the city's dense core. Together, the sub-typologies establish the layering of Chicago's downtown development complexity.

Business Typologies
Business typologies are distinct from commercial zoning in that they focus on neighborhood-scale professional services and smaller retail enterprises. Examples of these are local business offices, smaller stores, and neighborhood-serving activities without the intensity of commercial or downtown zoning. The example presented illustrates how they often segue into mixed-use corridors presenting accessible services to proximate residents. They accommodate Chicago's polycentric economic base where employment and amenities are distributed outside the central core.

Table 4. Building typologies in Plan and Street View. Source: Google Earth

Building typologies	Plan View	Street View
Residential • Residential single-family • Residential two-flat • Residential multi-family • Downtown residential		
Commercial • Commercial buildings		
Industrial • Manufacturing • Planned Manufacturing District		
Downtown • Downtown mixed-use • Downtown core • Downtown service		
Business • Business		

Neighborhood Parks
Neighborhood parks are mid-sized public open spaces that are mostly accessible by foot and are situated inside residential blocks. They are visible in plan view as distinct green spaces that are incorporated into the street grid and frequently have playgrounds, sports fields, lawns, and tree canopies. At street level, these parks typically include pedestrian pathways, seating areas, and recreational amenities that support daily social and physical activities. In heat-vulnerable neighborhoods, they function as critical micro-climate regulators by providing shade, evapotranspiration cooling, and accessible respite during extreme heat events.

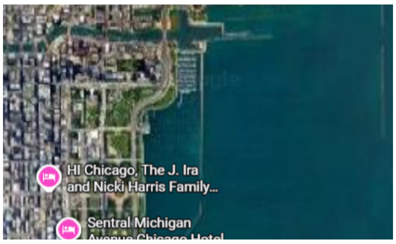
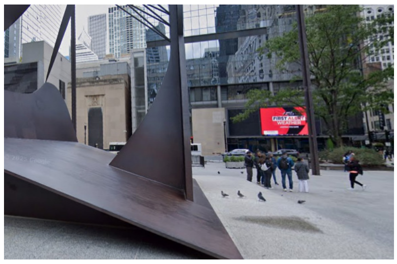
Regional / Lakefront Parks
Large-scale landscape systems that cater to city dwellers and frequently link to larger ecological or waterfront corridors are known as regional or lakefront parks. They look as vast green or open landscapes when viewed from a satellite, usually next to Lake Michigan and framed by formal promenades, beaches, or sports fields. Wide pedestrian walkways, open lawns, and considerable exposure to wind and sun are all visible at street level, however these are mitigated by tree clusters and the presence of water. In addition to drawing large numbers of pedestrians, these parks serve as important urban cooling infrastructures and mobility corridors, making significant contributions to the city's thermal management.

Urban Plazas / Civic Squares
The majority of urban plazas and municipal squares are hardscaped public areas found in crowded business or institutional areas. They are frequently incorporated into city blocks and look as geometric pavement surfaces framed by nearby buildings when viewed in plan. In street-level settings, there is usually a lot of pedestrian traffic, especially during business hours, fixed seating, sculptures, and a small tree canopy. These areas are crucial for researching heat exposure in pedestrian networks because of their impermeable materials and decreased greenery, which can exacerbate surface heat accumulation.

Linear Greenways / Multi-Use Trails
Multi-use trails and linear greenways are long public pathways that encourage bicycling, walking, and other forms of transportation. Often repurposed from old rail lines or infrastructure corridors, they show up as continuous, thin strips of vegetation or roads in satellite images. When viewed from the street, buffered routes with varied tree canopy, manicured margins, and connections to nearby neighborhoods are visible. These corridors serve as connecting cooling pathways that disperse shaded paths throughout the urban fabric and improve thermal comfort along active mobility networks in addition to their recreational use.

Community Gardens / Small Pocket Parks
Pocket parks and community gardens are small-scale open areas that are frequently made by adaptively repurposing underutilized or deserted properties. They look like little, asymmetrical parcels tucked away in crowded areas when viewed in plan view. Fencing, raised planting beds, limited tree cover, and community-managed amenities are frequently visible from street level observations. Despite their small size, these micro-open spaces support environmental stewardship, social bonding, and localized cooling, especially in historically underdeveloped communities without broader green infrastructure.

Table 5. Public Open Space typologies in Plan and Street View. Source: Google Earth

Public Space typologies	Plan View	Street View
• Neighborhood Parks		
• Regional / Lakefront Parks		
• Urban Plazas / Civic Squares		
• Linear Greenways / Multi-Use Trails		
• Community Gardens / Small Pocket parks		

3.3. Historical Structuring of Inequality: Redlining

3.3.1. Home Owners' Loan Corporation (HOLC) Redlining Maps

Chicago's racial and ethnic landscape cannot be separated from the city's history of redlining and structural racism. Beginning in the 1930s, the Home Owners' Loan Corporation (HOLC) and other federal institutions created maps that **graded neighborhoods as to their suitability for mortgage investment**. Those **with high concentrations of Black or immigrant populations were systematically color-coded red, labeled as "hazardous,"** and written out of investment. These redlined neighborhoods were **not labeled according to stock housing but according to their racial composition** making demographic segregation the dominant determiner of their classification.

Consequently, segregation patterns that can be seen today are both a cause and effect of these historical practices. Predominantly Black South and West Side neighborhoods, for instance, were largely redlined, cutting off access to mortgages and keeping down property values for generations. Predominantly White areas particularly in the **North Side were instead showered with investment**, facilitating upward mobility, higher-quality housing, and upgraded urban infrastructure. These contrasting paths cemented inequalities that continue to characterize Chicago's urban landscape.

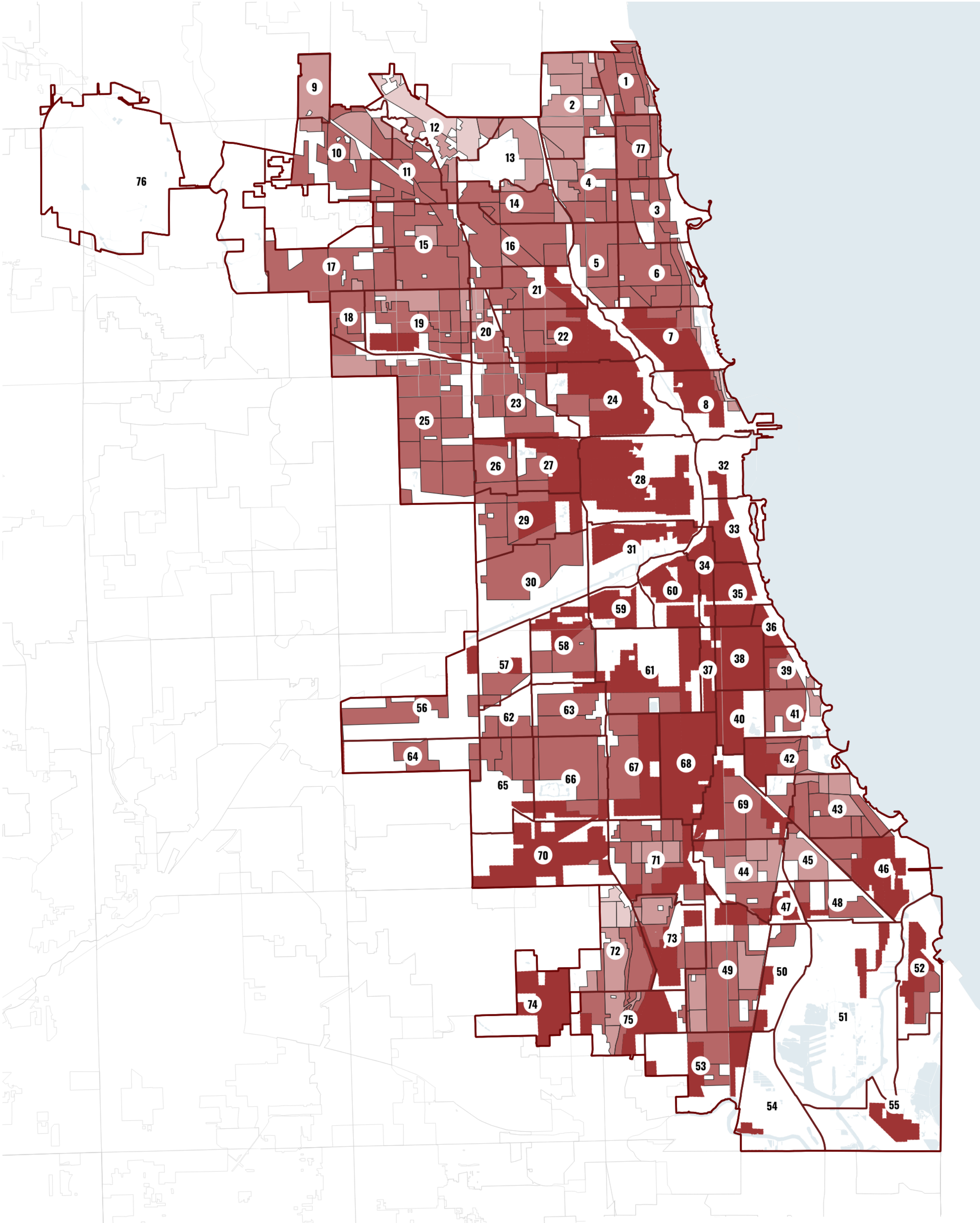
The Hispanic population, which grew exponentially in the postwar era, also suffered from these structural cracks. Hispanic neighborhoods were often situated next to Black neighborhoods or industrial strips, so they were routinely on maps as "declining" or "hazardous." **This created cycles of exclusion**, limiting Latino households from accessing secure homeownership and concentrating them in disinvested areas. The present-day clustering of Hispanic neighborhoods on the West and Southwest Sides attests to this pattern.

Chicago's Asian populations, though numerically smaller, were similarly spatially marginalized. Although not always specifically targeted by redlining, they were often excluded through restrictive covenants or less obvious barriers to housing in more highly graded neighborhoods. As such, Asian enclaves were located in restricted zones, often adjacent to underinvested neighborhoods. These processes illustrate how demographic segregation teamed up with discriminatory policies to produce unequal geographies of opportunity.

The long-term consequence of these racialized housing policies can be seen in modern typologies of displacement. **Redlined neighborhoods did not just suffer disinvestment but also faced structural vulnerabilities such as degrading housing stock, lack of green infrastructure, and cut-off municipal services.** When the same neighborhoods now face market reinvestment, residents are displaced by gentrification. Alternatively, when they face climate stressors like heatwaves or flooding, residents endure environmental displacement, since aging infrastructure cannot buffer against danger.

This intersection of demographic segregation across redlined neighborhoods produces vulnerability as a multi-faceted factor. For example, historically redlined communities will likely be intensified with more urban heat island effect because they lack more trees and have more impervious surfaces. The same communities also have lower-income, predominantly Black and Hispanic populations who already face barriers to access to healthcare and mobility. Demographic segregation thus amplifies the physical risks outlined by historical redlining, adding displacement pressures.

The lasting impact of redlining in shaping Chicago's neighborhoods also challenges the conceptualization of resilience and mobility. Walkability and active mobility practices are not evenly distributed across the city; rather, they occur in concentrations among reinstated but never redlined or gentrified neighborhoods. Conversely, dwellers in historically marginalized neighborhoods face hazardous or inhospitable environments for walking coupled with urban heat island phenomena and substandard infrastructure. Population segregation there directly structures access to social and environmental injustices.



Map 6. Redlined Neighborhoods in Chicago. Source: Home Owners' Loan Corporation (1939), digitized by the University of Richmond Digital Scholarship Lab, Mapping Inequality Project

Legends

- City of Chicago
- Community Areas
- Census tracts
- Blue Infrastructure
- D - Hazardous
- C - Definitely declining
- B - Still desirable
- A - Best

0 2.5 5 km

3.3.2. Displacement Typologies

The spatial distribution of displacement typologies throughout the City of Chicago is depicted on the map, demonstrating the **unequal patterns of neighborhood change and housing instability throughout the city**. Instead of being the result of a single process, displacement in Chicago arises from a variety of paths, **from gentrification-driven exclusion to long-term disinvestment and population loss**. These typologies provide a comprehensive knowledge of how various regions experience urban development by reflecting unique combinations of market pressure, planning dynamics, and socioeconomic vulnerability.

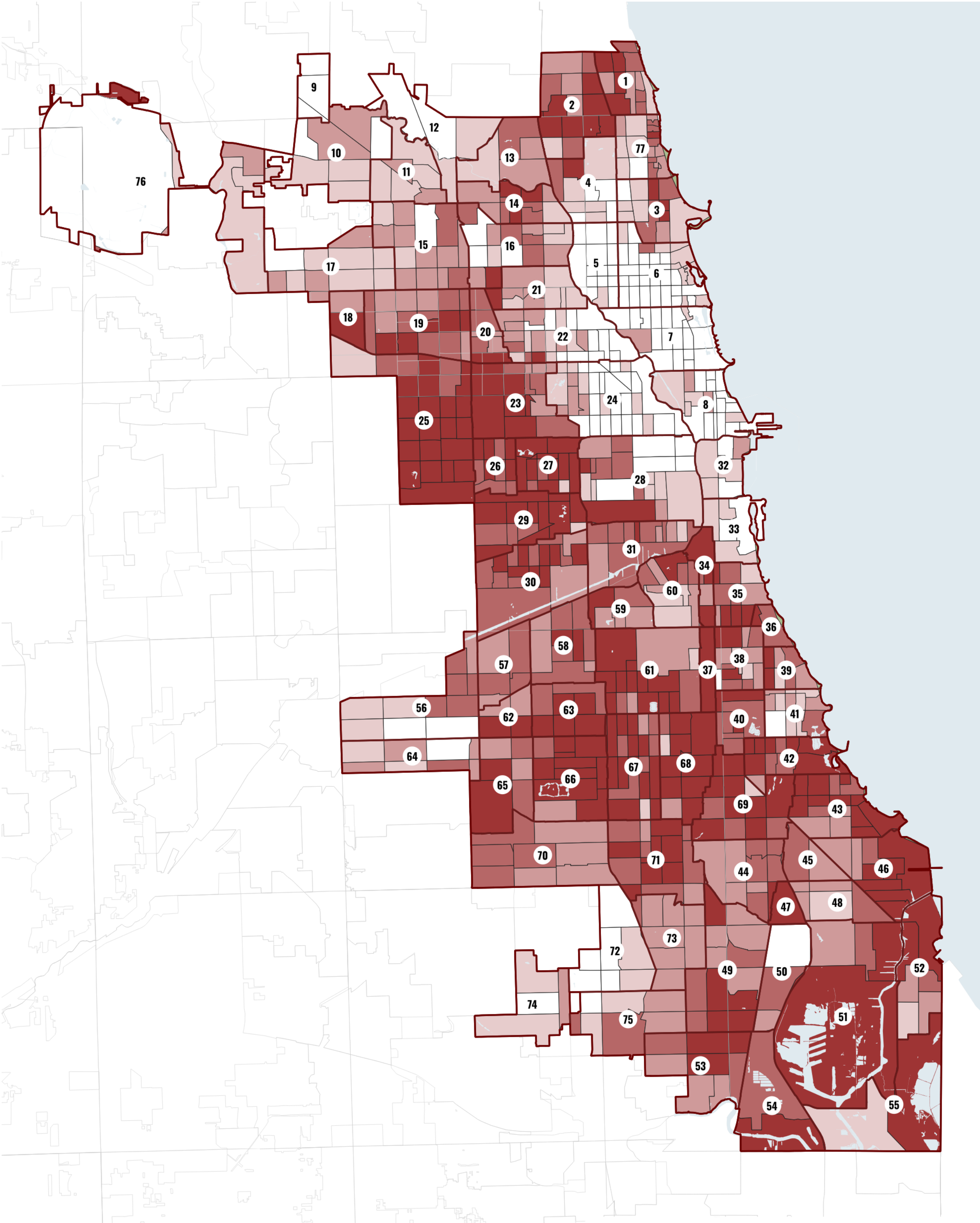
Areas undergoing continuous displacement, as well as **large sections of the South and West Sides, are categorized as low-income or vulnerable to displacement.** Due to redlining, industrial decline, and persistent underinvestment, these communities have historically had lower property prices, an aged housing stock, and less access to both public and private resources. In these situations, displacement frequently manifests as involuntary mobility brought on by foreclosure, home degradation, or service termination rather than just an increase in rent. These typologies' geographical concentration demonstrates how Chicago's residential instability is still shaped by structural inequality.

On the other hand, neighborhoods in the vicinity of the city center, along transportation routes, and close to lakefront or redevelopment zones are more frequently found to be at risk of gentrification or to be experiencing early or ongoing gentrification. Increasing investment, rising property values, and demographic shifts bringing in new, wealthier inhabitants are usually characteristics of these areas. Although these changes are frequently presented as revival, the map emphasizes how they might cause pressure on current inhabitants to relocate due to cultural marginalization, property tax burdens, and rent increases.

The districts where market pressures are increasing but have not yet completely displaced lower-income inhabitants are home to the majority of the categories that are at risk of becoming exclusive. These regions serve as transitional areas where future results can be greatly impacted by zoning changes, infrastructure investments, and policy decisions. According to the map, these areas might follow paths toward exclusivity in the absence of focused protections and affordability measures, which would further limit housing availability for vulnerable groups.

Neighborhoods where displacement pressures are currently reduced or where exclusion has already been solidified are represented by areas designated as stable or moderate/mixed income and stable/advanced exclusive. Advanced exclusive neighborhoods, which are typically found along the North Side and lakefront, are distinguished by high property costs and long-standing obstacles to entrance, whereas stable mixed-income neighborhoods typically enjoy the advantages of greater housing safeguards, community cohesion, or less speculative pressure. Because of different market histories and planning, these patterns show how exclusivity and stability can coexist in the same city.

When considered together, the displacement typologies map shows that displacement is not a discrete housing issue but rather a profoundly geographical and structural process. The necessity of interpreting displacement in conjunction with other urban dangers, such as environmental exposure and restricted mobility, is highlighted by the concentration of vulnerable and displacement-prone neighborhoods in historically disenfranchised districts of Chicago. The map reinforces the significance of equity-oriented, risk-informed design interventions by offering crucial spatial context for comprehending the intersections of displacement risk, urban heat exposure, and pedestrian accessibility within the framework of this study.



Map 7. Displacement typologies in Chicago. Source: Institute for Housing Studies at DePaul University (IHS), Chicago Neighborhood Displacement and Gentrification Typology Dataset

Legends

- City of Chicago
- Community Areas
- Census tracts
- Blue Infrastructure
- Low-income/susceptible to displacement
- Ongoing displacement
- At risk of Gentrification
- Early/ongoing gentrification
- Stable/moderate/mixed income
- At risk of becoming exclusove
- Becoming exclusive
- Stable/advanced exclusive
- Unavailable data

0 2.5 5 km

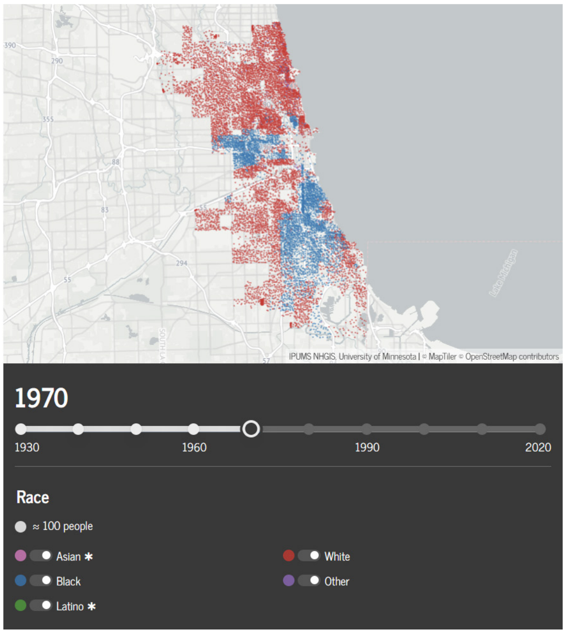
3.3.3. Persistence of Spatial Inequality over time

Racial and socioeconomic segregation have shown remarkable continuity over time, and spatial disparity has persisted in the City of Chicago since the 1970s. The series of segregation maps **from 1970 to 2020 shows that Black inhabitants are still concentrated on the South Side and large swaths of the West Side, while White numbers have remained concentrated in the city's northern, northwest, and parts southwest regions**. Reflecting the long-term effects of segregated housing markets, unequal public investment, and exclusionary planning practices, these spatial patterns have remained resistant to change even after discriminatory housing laws were formally abolished.

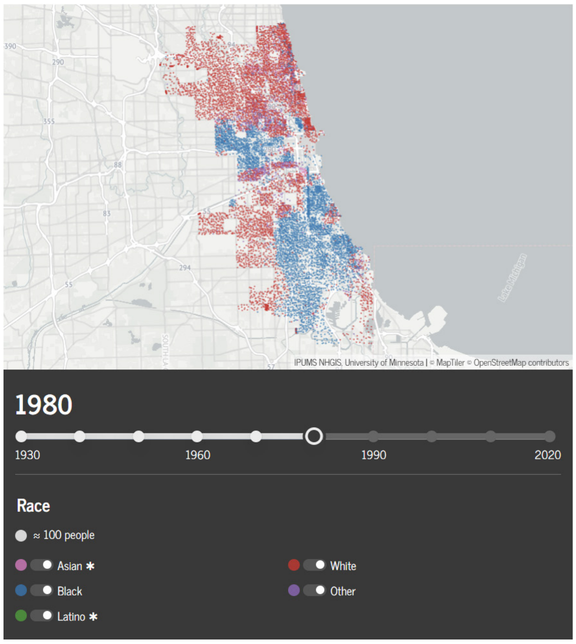
Suburbanization and deindustrialization in the latter half of the 20th century served to further solidify these divisions. South and West Side neighborhoods were disproportionately impacted by the loss of manufacturing jobs, which accelerated house abandonment, population reduction, and financial strain. The city's basic segregation structure remained largely unaffected by the selective investing that took place in certain regions. Rather, the 1980 and 1990 maps show how economic restructuring exacerbated geographic polarization, with opportunity increasingly concentrated elsewhere and disadvantage concentrated within previously marginalized regions.

Localized demographic shifts were brought about in the 2000s and 2010s by gentrification and reinvestment patterns, especially in the vicinity of the North Side and urban center. The maps from 2000 to 2020, however, show that these modifications were only spatially restricted and did not result in more widespread integration. The fact that a sizable chunk of the South and West Sides remained economically limited and racially homogeneous suggests that reinvestment procedures frequently shifted money without addressing systemic injustices. Segregation consequently grew more geographically concentrated as opposed to diffused, strengthening established neighborhood boundaries.

Inequality in infrastructure and the environment are significantly impacted by the continuation of segregation. Older infrastructure, a lack of green space, and exposure to environmental stresses like urban heat are all more common in neighborhoods that have been separated for decades. These circumstances are not accidental; rather, they are the result of years of uneven planning decisions in space. Therefore, it is crucial to comprehend how long these segregation patterns have persisted in order to evaluate current differences in pedestrian accessibility and exposure to urban heat islands, which still closely correspond with Chicago's historically underprivileged districts.

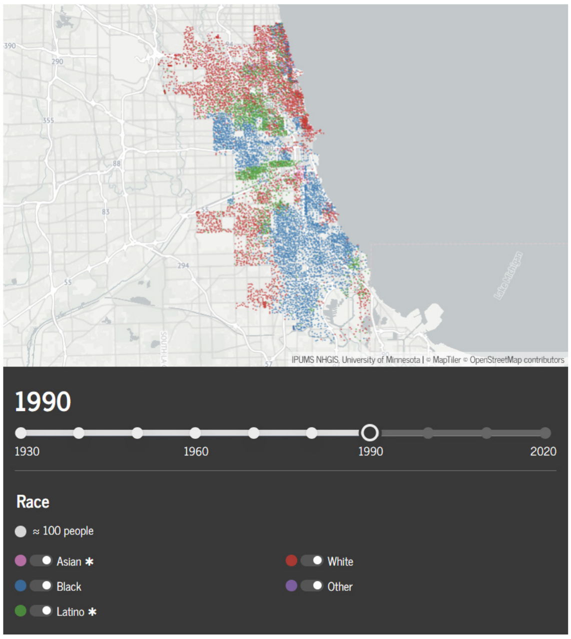


Map 8. 1970 Segregation Patterns in Chicago. Source: South Side Weekly by Charmaine Runes and Pat Sier

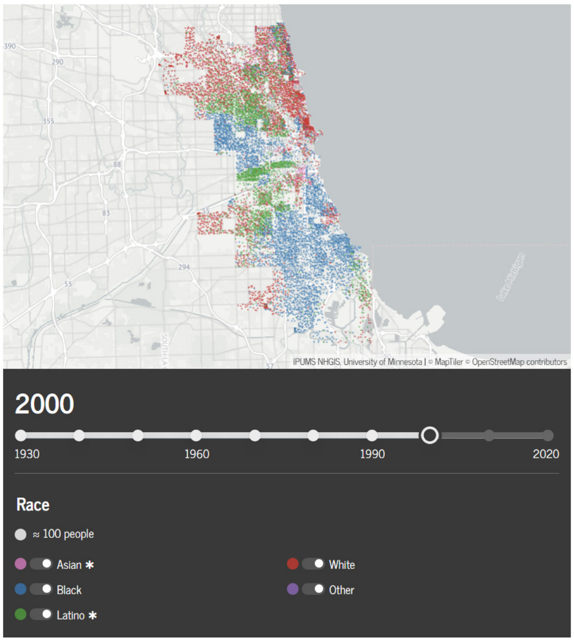


Map 9. 1980 Segregation Patterns in Chicago. Source: South Side Weekly by Charmaine Runes and Pat Sier

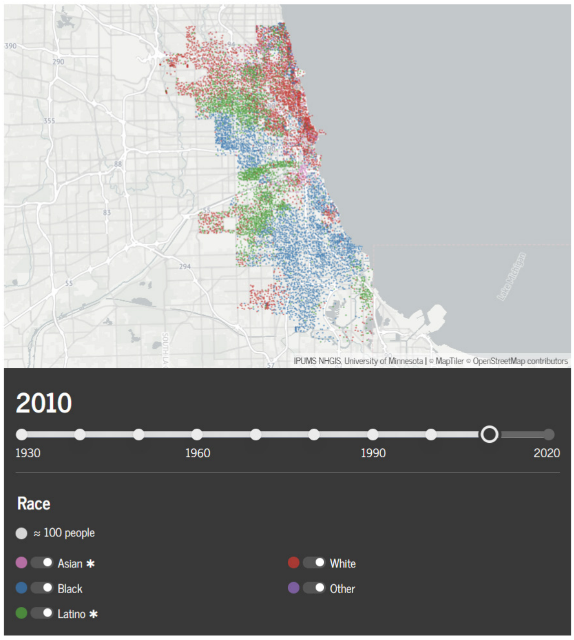
Note/s: The Census did not track Asian population prior to 1970 and Latino population prior to 1990



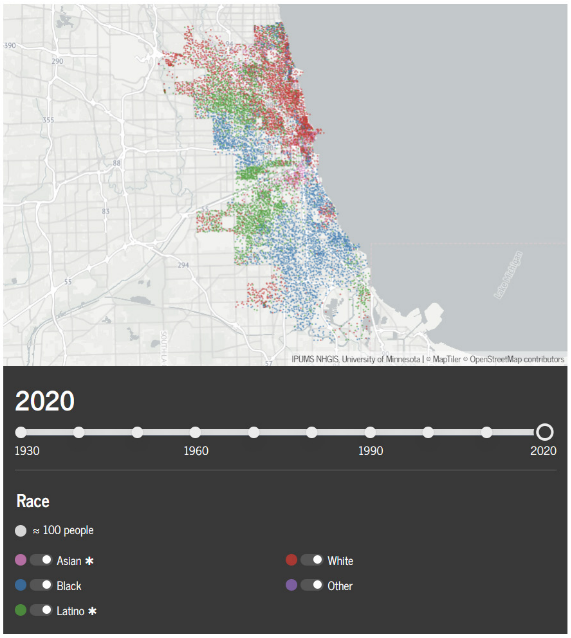
Map 10. 1990 Segregation Patterns in Chicago. Source: South Side Weekly by Charmaine Runes and Pat Sier



Map 11. 2000 Segregation Patterns in Chicago. Source: South Side Weekly by Charmaine Runes and Pat Sier



Map 12. 2010 Segregation Patterns in Chicago. Source: South Side Weekly by Charmaine Runes and Pat Sier



Map 13. 2020 Segregation Patterns in Chicago. Source: South Side Weekly by Charmaine Runes and Pat Sier

3.3.4. Long-Term Disinvestment and Urban Segregation

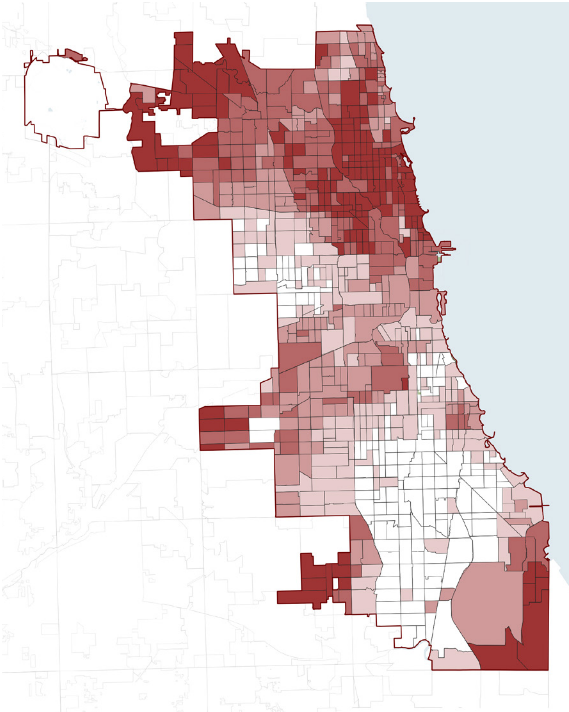
Chicago remains the **nation's most segregated metro, with White populations concentrated in the northern, northwestern, and parts of the southwestern wards, while Black populations are concentrated on the South Side and broad areas of the West Side**. Such geographic segregation reflects persistent patterns of racialized mortgage markets, redlining, exclusionary zoning, and unequal public investment whose configuration sorted out housing access and neighborhood opportunity over decades.

Demographically, Chicago contains around 986,280 Whites and 801,195 Blacks with very segregated patterns of settlement in space. **White tracts overlap more and more with higher-quality public services and facilities, and large numbers of Black tracts are found in neighborhoods of outdated infrastructure and weaker private investment.** This results in differential access to schools, health care, job centers, parks, and environmental quality in the long term.

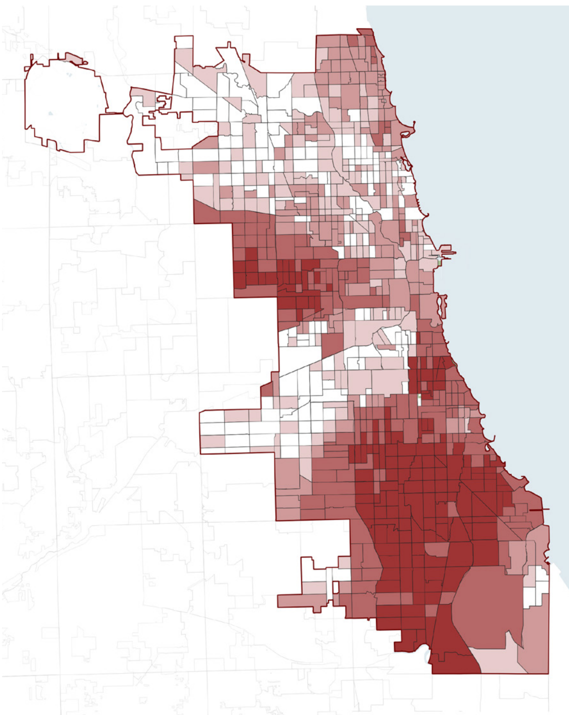
Economic inequality carries the trend forward. **South and West Side majority-Black communities experience higher poverty, joblessness, and housing insecurity than majority-White communities**. These translate into environmental inequity: residents are more likely to be further from large parks or in wards with diminishing tree canopy and extensive hardscape, putting them at greater exposure to urban heat island and heat-related health risk.

Segregation is in the form of mobility and access disparities as well. The **majority of Black neighborhoods are limited to distant access to high-frequency transit, deteriorated sidewalks, fewer shade trees on pedestrian routes, and poorer-quality public space**. These aspects reduce access to work and services and increase exposure during adverse weather heat waves and heavy precipitation illustrating how racialized space and climate threat intersect in daily travel.

Other broad groups enrich the mosaic. The Asian (~192,586) and Hispanic/Latino (~819,518) populations are both smaller in number but widespread across nodes such as Chinatown and the North Side enclaves neighborhoods that balance strong community bonds with gentrification pressures and infrastructure deficits. Hispanic/Latino residents are concentrated in Pilsen, Little Village, and parts of the Northwest and Southwest Sides, where density, aging housing, and limited green space add to heat and flood hazard. Other races who answer as "Some Other Race" (434,452) or "Two or More Races" (296,245) typically reside in hybrid or transition neighborhoods that face socioeconomic risk and environmental peril.



Map 14. White Population Density distribution. Source: Chicago Data Portal

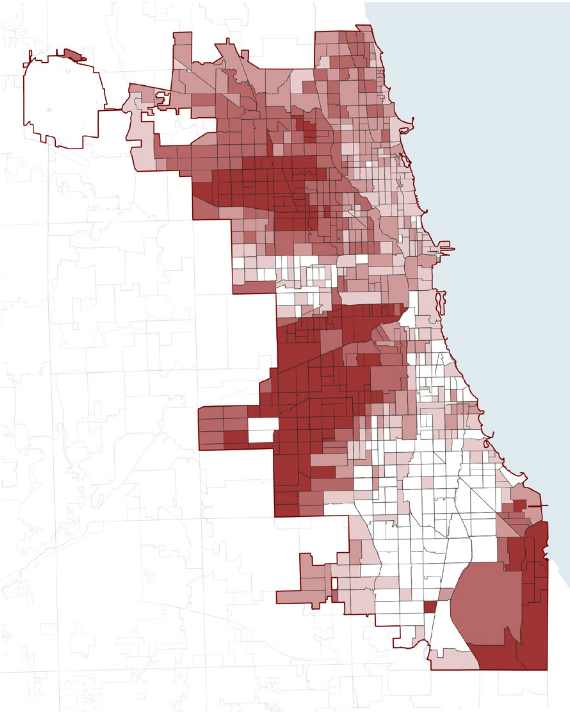


Map 15. Black Population Density distribution. Source: Chicago Data Portal

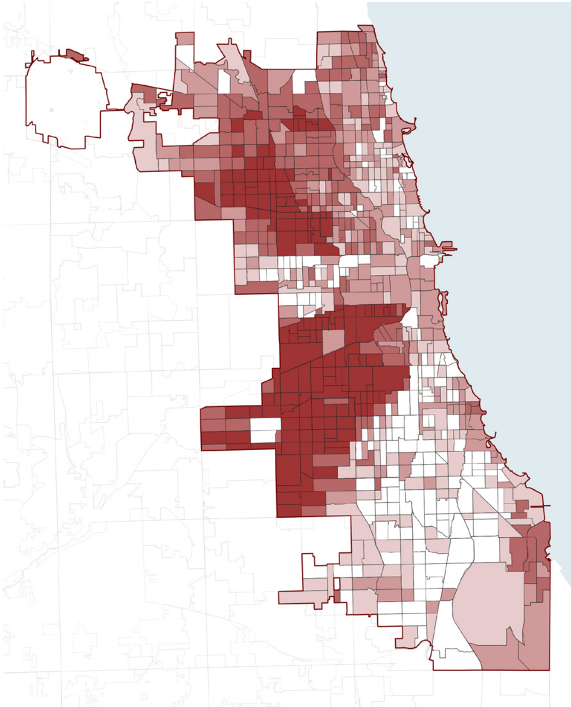
Legends

- City of Chicago
- Community Areas
- Census tracts
- Blue Infrastructure
- Low concentration
- Moderate concentration
- High concentration

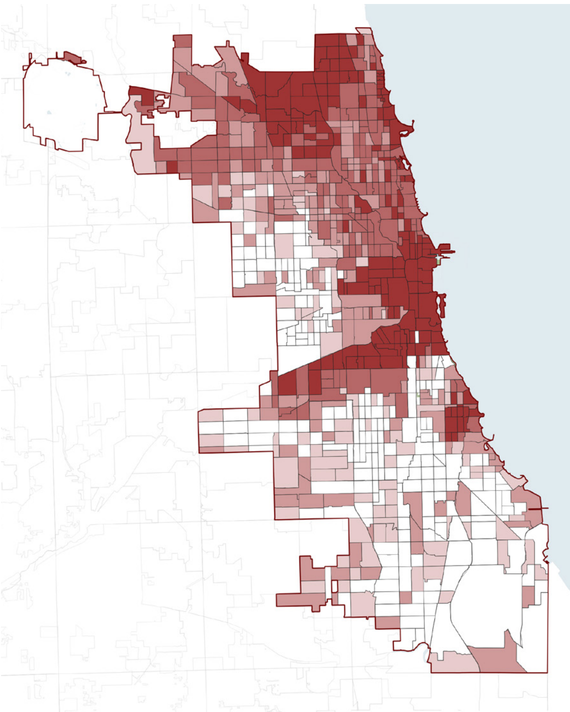
0 2.5 5 km



Map 16. Hispanic Population Density distribution. Source: Chicago Data Portal

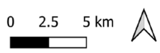


Map 18. Other Population Density distribution. Source: Chicago Data Portal



Map 17. Asian Population Density distribution. Source: Chicago Data Portal

City of Chicago
Community Areas
Census tracts
Blue Infrastructure
Low concentration
Moderate concentration
High concentration



3.4. Contextualizing the Risk Framework

3.4.1. Integration of Urban Heat Stress

Hazard, exposure, and vulnerability come together to form risk, according to the original "Factors of Disaster Risk" paradigm. This study adapts that core model to investigate the geographical development of urban heat risk in Chicago communities that have historically been redlined. The modified **paradigm reframes risk as a socio-spatial state influenced by urban form, transportation systems, and structural inequality rather than as a simply environmental or natural occurrence**. The main hazard is the intensity of the urban heat island (UHI); exposure is the movement of pedestrians along the street network; and susceptibility is operationalized by the CDC 2022 Social susceptibility Index (SVI). The approach converts a general disaster-risk model into an urban analysis focused on climate justice by placing each component within the context of Chicago's redlining history and current geographical disparities.

It is **crucial to include "amplified by" and "reduced by" components since they demonstrate how risk is dynamic rather than constant**. Amplification processes show how social vulnerability, concentration of impermeable surfaces, and structural disinvestment increase the probability of heat-related events in certain community regions. On the other hand, reduction mechanisms show that spatially focused interventions, such as investments in high-SVI neighborhoods and vacancy-integrated cooling corridors, might reduce risk. This dual logic highlights the fact that risk is not unavoidable and may be both created and perhaps decreased by choices about design, planning, and policy. In this way, the approach bolsters the concept that mobility disparities and urban heat exposure are spatially mediated circumstances that may be proactively addressed rather than being unintended consequences.

Vulnerability is a measure of the social awareness and adaptability of the people who live in these hot conditions. Concentrated high CDC 2022 SVI scores, which represent socioeconomic deprivation, health inequities, and restricted access to services, amplify it. These elements weaken a person's ability to handle intense heat events and make them more vulnerable to heat-related stress. However, by making targeted investments in high-SVI community areas, vulnerability can be decreased. Examples of these investments include better access to public facilities, mobility resources, and cooling infrastructure. This framing serves to emphasize that vulnerability is a social construct that may be changed by fair policy actions.

Hazard refers to the physical intensity of urban heat. It is influenced by regional heat trends and climate change intensification, situating Chicago within broader climatic shifts. However, at the local scale, hazard is amplified by impervious surface concentration in historically redlined areas, where decades of disinvestment have resulted in limited tree canopy and heat-retentive urban materials. This demonstrates that UHI intensity is not evenly distributed but spatially concentrated in neighborhoods shaped by past discriminatory planning practices. Hazard, therefore, becomes both a climatic and a structural phenomenon.

Exposure is defined as the thermal exposure of pedestrians along the network of metropolitan streets. Structural disparities that influence pedestrian movement, such as disjointed roadway networks, a lack of covered pathways, and a dependence on outdoor mobility in underprivileged areas, exacerbate it. The length and severity of the heat encountered during everyday travel are increased by these factors. By deliberately converting unused property into shaded, climate-responsive routes that reroute pedestrian circulation away from high-heat zones, vacancy-integrated cooling corridors can mitigate exposure. The framework establishes a direct connection between urban design initiatives and environmental circumstances by addressing the spatial layout of mobility itself.

In redlined community areas, heat risk is spatially concentrated due to the intersection of hazard, exposure, and susceptibility. Risk increases where high UHI intensity coexists with high SVI scores and extended pedestrian exposure. On the other hand, treatments that enhance adaptive capacity, lessen heat intensity, and reorganize mobility networks can all work together to lower risk. Thus, **this modified framework offers an operational framework as well as an analytical lens for comprehending and reducing urban heat disparities in Chicago.**

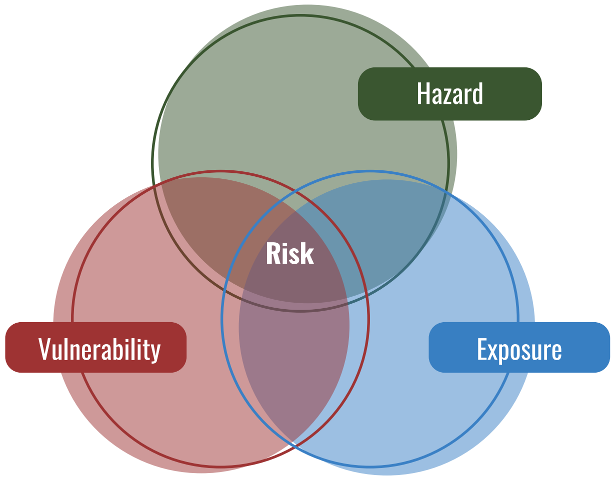


Figure 24. Factors of Disaster Risk. Source: Handbook for Livable and Resilient Cities by City Resilience Program, GFDRR, and World Bank

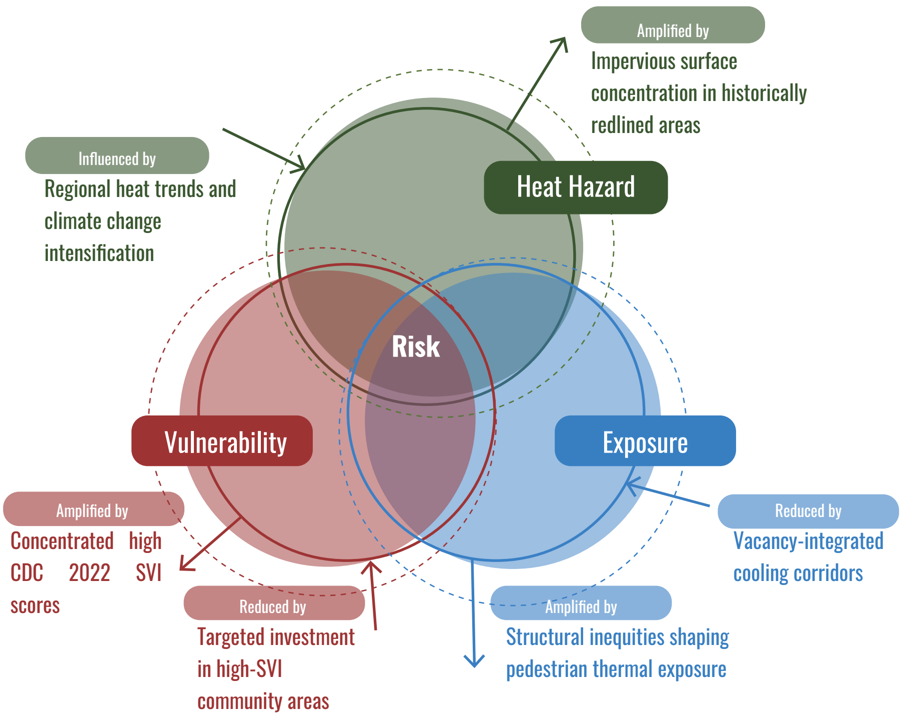


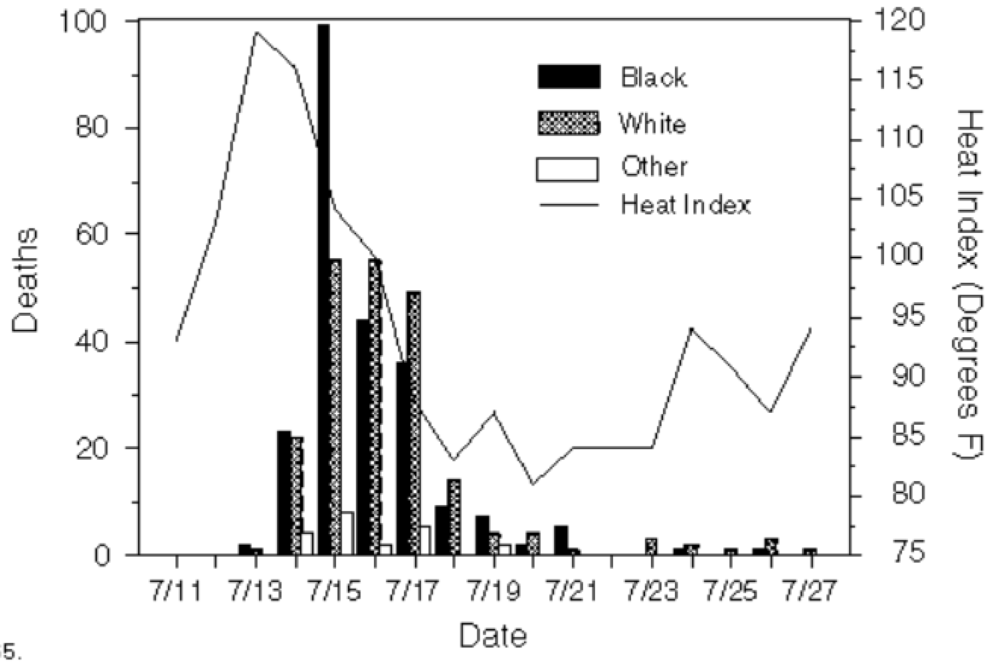
Figure 25. Interplay between Factors of Disaster Risk and the conceptual framework. Source: Author

3.4.2. Why Heat? 1995 Chicago Heatwave

In just one week, the Chicago Heatwave of 1995 caused nearly 700 excess deaths, with the South and West Sides of the city bearing a disproportionate share of the mortality. Black inhabitants made up the majority of those who perished, and many of them were in historically redlined districts with high rates of poverty, outdated housing stock, little tree cover, and restricted access to cooling facilities or air conditioning. Since then, studies have revealed that patterns of long-standing racial segregation and disinvestment were closely reflected in the geography of death.

Simultaneously, newspaper headlines show a changing public narrative that found it difficult to balance official assurances with the rising number of fatalities. While city officials stressed that emergency systems were operational and that conditions were "under control," early stories frequently presented the incident as temporary or manageable. Nevertheless, headlines became increasingly alarming as the death toll rose into the hundreds, indicating a rising public realization that the crisis was much worse than first thought. A disconnect between governmental confidence and lived experience was implied by the difference between official messaging and the visual reality, which included pictures of bodies being transported in refrigerated trucks and overcrowded morgues. This conflict serves as an example of how political framing might initially reduce structural risk before the magnitude of the tragedy reveals systemic inadequacy.

There are significant ramifications for modern-day Chicago when considering the 1995 heatwave. Due to segregation, underfunding, and unequal access to green infrastructure, many of the same districts that saw the highest fatality rates are still among the most heat-vulnerable today. The **lessons learned in 1995 highlight the need for proactive, equity-centered planning as opposed to reactive crisis management, as climate change increases the frequency and severity of extreme heat events**. Extreme heat is not only an environmental hazard but also a **social risk amplifier that continues to imprint onto Chicago's persistent patterns of inequality**, making the event both a historical warning and a basis for analysis.



*n=465.
†The Cook County Medical Examiner's Office categorizes race of decedents as black, white, or other.

Figure 26. Chicago Sun-times headline (top); Deathbeds cargo from trucks (bottom) Heatwave. Source: Google images

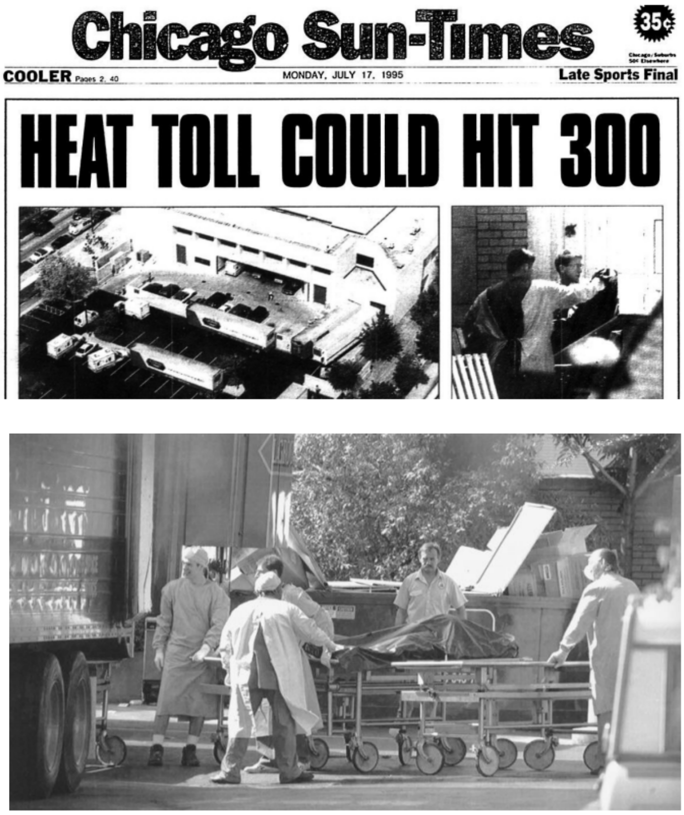


Figure 27. Chicago Sun-times headline (top); Deathbeds cargo from trucks (bottom) Heatwave. Source: Chicago Sun-times

Figure 28. Chicagoans at Park during Heatwaves. Source: Chicago Sun-times

3.5. Vulnerability

3.5.1. Overview of Vulnerability Framework

The idea of vulnerability in relation to urban heat risk in the City of Chicago is operationalized through the Vulnerability Analysis Framework. The framework, which is based on the IPCC's (2022) definition of vulnerability as "the propensity or predisposition to be adversely affected," converts a theoretical idea of climate risk into a quantifiable, locally explicit technique. Finding community regions that are at risk of being disproportionately impacted by Urban Heat Island (UHI) effects is the main goal. Instead than taking a limited or anecdotal approach, the analysis looks at all 77 officially recognized Chicago Community Areas to accomplish this. Instead of being viewed as an abstract state, vulnerability is viewed as a spatially distributed and measurable trait that varies among communities.

The CDC 2022 Social Vulnerability Index (SVI), which was first computed at the census tract level and then aggregated to the Community Area scale to correspond with the study's spatial unit of analysis, is used operationally to quantify vulnerability. The CDC 2022 RPL Overall percentile scores, which account for relative social vulnerability across socioeconomic, demographic, and housing-related characteristics, are then used to score and rank Community Areas. The top 10 Community Areas with the highest vulnerability can be transparently and reproducibly chosen thanks to this ranking, and they serve as the focal points for further exposure and hazard analyses. **The framework maintains compatibility with existing climate risk theory and public health vulnerability measurements while guaranteeing methodological rigor by organizing the process from definition to spatial aggregation and ranking.**

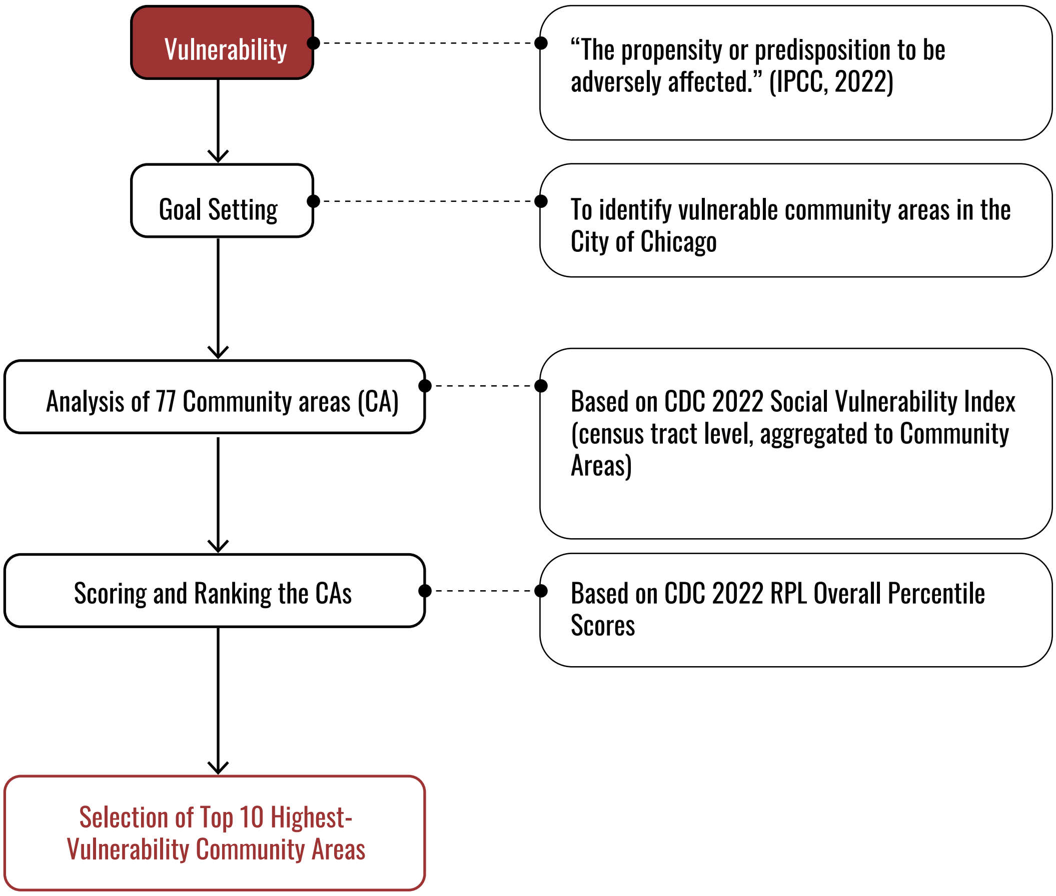


Figure 29. Vulnerability Analysis Framework. Source: Author

3.5.2. Analysis of Community Areas (Vulnerability)

The vulnerability scoring of each Community Area (CA) is **based on the CDC 2022 Social Vulnerability Index (SVI) percentile values at the census tract level.** For each of the four criteria (C1–C4), all census tracts belonging to a given Community Area were identified using a tract-to-community crosswalk. The **percentile values (ranging from 0 to 1) for each theme were then averaged (mean) across all tracts within that Community Area**. This produced one representative score per theme (C1, C2, C3, and C4) for each CA. Higher values indicate higher relative vulnerability.

The **Total score for each Community Area was computed by taking the mean of the CDC Overall Percentile Ranking (RPL_Overall)** of all census tracts within that Community Area. The Total score therefore reflects the aggregated overall social vulnerability of the CA, rather than an average of C1–C4. Community Areas were then ranked in descending order based on this Total score, where **Rank 1 represents the highest vulnerability.**

VC1

Socioeconomic Status

This subject illustrates the vulnerability brought on by economic disadvantage as determined by low income, unemployment, poverty rates, and educational achievement.

Indicators: Poverty rate, unemployment rate, median income, and education level (people without a highschool diploma)

Scoring (Range)

0 Least Vulnerable — 1.00 Highly Vulnerable

VC2

Household Characteristics

This subject highlights the vulnerability of demographic groups that are more likely to need assistance during emergencies, such as single-parent households, older adults over 65, children under the age of 18, and people with disabilities.

Indicators: Indicators: Elderly population (65+), children under 18, people with disability, and single-parent households

Scoring (Range)

0 Least Vulnerable — 1.00 Highly Vulnerable

VC3

Racial and Language

It calculates the percentage of residents who are members of minority groups and who speak little or no English, both of which have an impact on the availability of vital information, resources, and institutional help during emergencies.

Indicators: Percentage of minority population and percentage of people who speak English "less than very well"

Scoring (Range)

0 Least Vulnerable — 1.00 Highly Vulnerable

VC4

Housing and Transport

This theme evaluates the vulnerability related to mobility access and physical housing circumstances. Multi-unit housing, overcrowding, restricted access for private vehicles, and living in communal quarters are some of its signs.

Indicators: Multi-unit housing, mobile homes, crowded households, no vehicle access, and people living in group quarters

Scoring (Range)

0 Least Vulnerable — 1.00 Highly Vulnerable

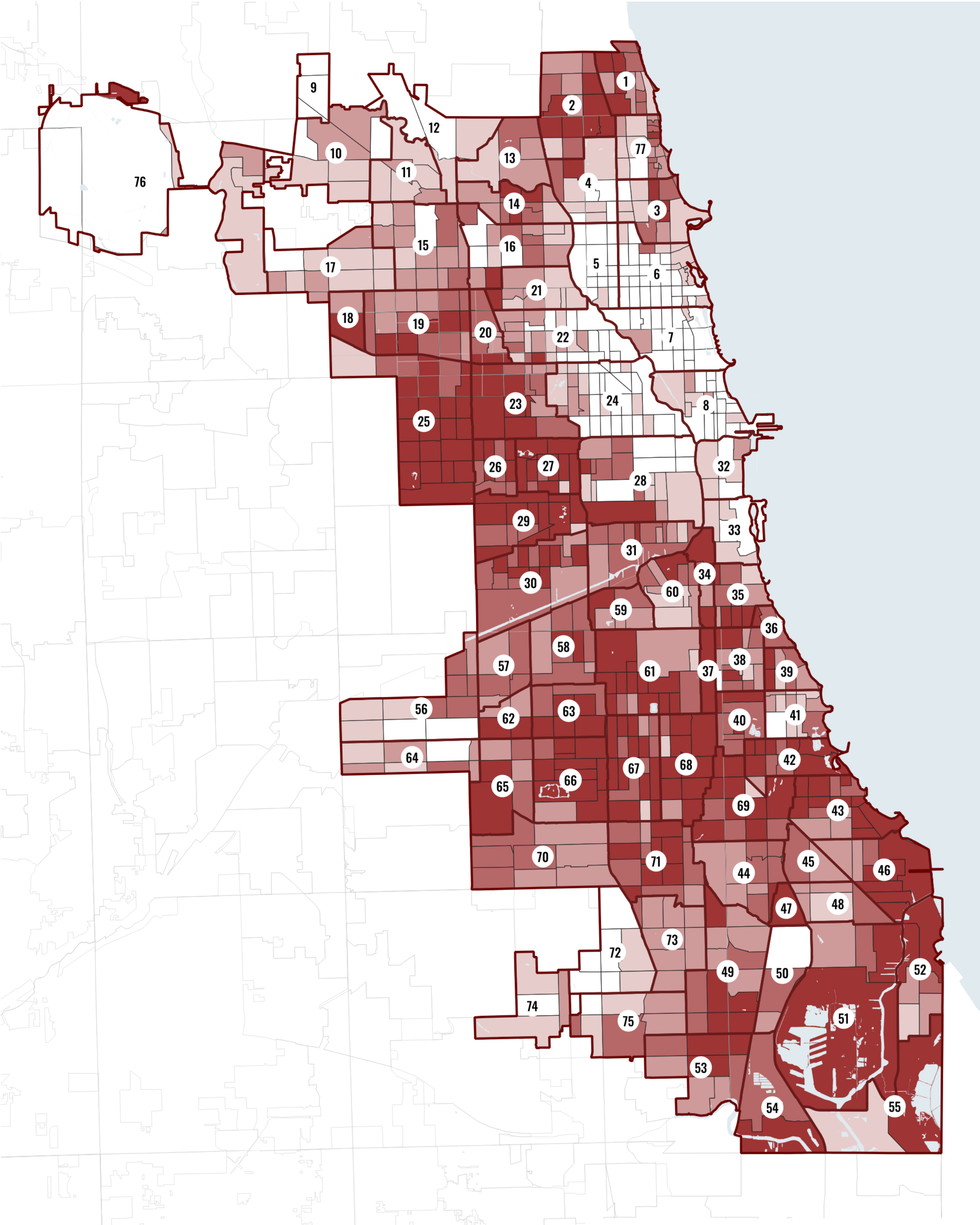
3.5.3. Analytical Maps: Social Vulnerability Map

A composite indicator of a community's ability to foresee, address, and recover from environmental, economic, and public health stressors is the Social Vulnerability Index (SVI). In order to represent the multifaceted character of vulnerability across census tracts in the City of Chicago, the overall SVI incorporates four thematic dimensions: socioeconomic status; household composition and disability; racial and language status; and housing and transportation. The SVI **emphasizes how overlapping socioeconomic, demographic, and infrastructure factors increase risk at the neighborhood level rather than highlighting a single disadvantage.**

The socioeconomic theme includes factors like educational attainment, work status, and income levels, all of which have a significant impact on a household's capacity to adjust to environmental stressors like intense heat. High socioeconomic vulnerability census tracts in Chicago are geographically concentrated in historically underinvested neighborhoods, where access to adaptable infrastructure, healthcare, and cooling services is hampered by ongoing unemployment and poverty. Vulnerability in these places is further exacerbated by the household composition theme, especially in areas with larger numbers of elderly persons, children, single-parent households, and people with impairments, which limit mobility during extreme weather events and increase sensitivity to heat exposure.

The structural aspects of vulnerability associated with minority status and low English proficiency are reflected in the racial and linguistic theme. Racialized patterns of settlement continue to influence access to resources, political representation, and information, as evidenced by the close alignment of historically segregated neighborhoods in Chicago with high vulnerability scores under this subject. Last but not least, the issue of housing and transportation highlights the vulnerabilities brought on by overcrowding, reliance on public transportation or walking, rental dependency, housing instability, and restricted automobile access. Because they have a direct impact on exposure to outside heat and the capacity to move through cities safely during hot weather, these variables are especially pertinent to this study.

When combined, the entire SVI **shows a clear social resilience disparity in Chicago from north to south.** Census tracts with high SVI values are those where several vulnerabilities converge, lowering adaptive capacity and increasing susceptibility to environmental shocks. Conversely, low SVI values reflect areas with greater socioeconomic stability, stronger infrastructure, and enhanced capacity to mitigate climate-related risks.



Map 19. Social Vulnerability Index (SVI) Map. Source: U.S. Centers for Disease Control and Prevention (CDC) 2022 Social Vulnerability Index (SVI)

Legends

- City of Chicago
- Community Areas
- Census tracts
- Blue Infrastructure
- Highly vulnerable
- Moderately-high vulnerable
- Moderately vulnerable
- Less vulnerable
- Least vulnerable

0 2.5 5 km

3.5.4. Scoring of CAs (Vulnerability)

Table 6. Scoring of CAs (Vulnerability)

Number	Community Name	VC1	VC2	VC3	VC4	Total	Ranking
1	Rogers Park	0.76	0.32	0.65	0.9	0.77	36
2	West Ridge	0.77	0.65	0.69	0.8	0.82	24
3	Uptown	0.59	0.24	0.6	0.88	0.62	52
4	Lincoln Square	0.44	0.16	0.5	0.6	0.37	68
5	North Center	0.13	0.14	0.42	0.32	0.12	76
6	Lake View	0.24	0.08	0.39	0.6	0.21	73
7	Lincoln Park	0.15	0.05	0.34	0.66	0.17	74
8	Near North Side	0.19	0.09	0.46	0.73	0.25	71
9	Edison Park	0.16	0.15	0.31	0.21	0.1	77
10	Norwood Park	0.3	0.54	0.43	0.44	0.38	67
11	Jefferson Park	0.54	0.44	0.6	0.38	0.49	63
12	Forest Glen	0.3	0.43	0.41	0.19	0.24	72
13	North Park	0.56	0.71	0.67	0.66	0.68	46
14	Albany Park	0.79	0.5	0.76	0.67	0.76	37
15	Portage Park	0.65	0.51	0.68	0.51	0.63	51
16	Irving Park	0.58	0.37	0.66	0.64	0.58	57
17	Dunning	0.59	0.46	0.59	0.4	0.52	61
18	Monthclare	0.7	0.86	0.76	0.72	0.81	29
19	Belmont Cragin	0.83	0.71	0.85	0.55	0.81	30
20	Hermosa	0.83	0.69	0.86	0.6	0.81	27
21	Avondale	0.67	0.24	0.74	0.5	0.56	58
22	Logan Square	0.47	0.16	0.62	0.58	0.42	65
23	Humboldt Park	0.84	0.72	0.86	0.66	0.83	23
24	West Town	0.3	0.1	0.54	0.57	0.28	70
25	Austin	0.91	0.83	0.93	0.67	0.92	3

Number	Community Name	VC1	VC2	VC3	VC4	Total	Ranking
26	West Garfield Park	0.94	0.74	0.95	0.58	0.89	8
27	East Garfield Park	0.91	0.64	0.91	0.74	0.88	9
28	Near West Side	0.56	0.29	0.73	0.74	0.56	59
29	North Lawndale	0.94	0.68	0.91	0.67	0.89	7
30	South Lawndale	0.93	0.71	0.91	0.52	0.86	17
31	Lower West Side	0.81	0.41	0.81	0.66	0.74	38
32	Loop	0.34	0.02	0.62	0.93	0.39	66
33	New South Side	0.33	0.49	0.73	0.56	0.48	64
34	Armour Square	0.85	0.87	0.82	0.72	0.89	6
35	Douglas	0.78	0.57	0.88	0.76	0.81	28
36	Oakland	0.84	0.7	0.92	0.62	0.83	22
37	Fuller Park	0.89	0.93	0.95	0.8	0.95	1
38	Grand Boulevard	0.79	0.49	0.92	0.51	0.72	44
39	Kenwood	0.67	0.67	0.82	0.68	0.74	40
40	Washington Park	0.88	0.61	0.94	0.66	0.85	18
41	Hyde Park	0.5	0.14	0.68	0.81	0.51	62
42	Woodlawn	0.88	0.58	0.89	0.75	0.87	13
43	South Shore	0.84	0.66	0.94	0.73	0.86	16
44	Chatham	0.85	0.6	0.96	0.44	0.77	35
45	Avalon Park	0.83	0.86	0.97	0.37	0.78	34
46	South Chicago	0.89	0.72	0.92	0.65	0.86	15
47	Burnside	0.87	0.72	0.94	0.8	0.9	5
48	Calumet Heights	0.55	0.71	0.98	0.33	0.61	55
49	Roseland	0.87	0.67	0.95	0.53	0.81	26
50	Pullman	0.76	0.48	0.86	0.24	0.58	56

Number	Community Name	VC1	VC2	VC3	VC4	Total	Ranking
51	South Deering	0.87	0.82	0.92	0.49	0.84	21
52	East Side	0.79	0.76	0.87	0.42	0.74	39
53	West Pullman	0.82	0.77	0.96	0.44	0.78	33
54	Riverdale	0.91	0.37	0.98	0.75	0.85	19
55	Hegewisch	0.72	0.75	0.75	0.5	0.71	45
56	Garfield Ridge	0.61	0.65	0.77	0.41	0.61	54
57	Archer Heights	0.8	0.53	0.84	0.47	0.72	43
58	Brighton Park	0.9	0.7	0.89	0.41	0.8	31
59	McKinley Park	0.82	0.49	0.84	0.52	0.73	41
60	Bridgeport	0.72	0.5	0.76	0.47	0.65	48
61	New City	0.93	0.78	0.89	0.61	0.88	10
62	West Elsdon	0.8	0.86	0.84	0.41	0.78	32
63	Gage Park	0.92	0.73	0.93	0.79	0.92	2
64	Clearing	0.68	0.52	0.75	0.39	0.61	53
65	West Lawn	0.86	0.68	0.86	0.56	0.82	25
66	Chicago Lawn	0.96	0.78	0.94	0.6	0.9	4
67	West Englewood	0.96	0.83	0.96	0.42	0.88	11
68	Englewood	0.92	0.8	0.96	0.52	0.86	14
69	Greater Gramd Crossing	0.86	0.75	0.96	0.65	0.87	12
70	Ashburn	0.76	0.68	0.89	0.43	0.73	42
71	Auburn Gresham	0.87	0.78	0.96	0.52	0.85	20
72	Beverly	0.21	0.21	0.52	0.18	0.17	75
73	Washington Heights	0.74	0.62	0.96	0.33	0.68	47
74	Mount Greenwood	0.25	0.4	0.26	0.53	0.33	69
75	Morgan Park	0.54	0.54	0.71	0.41	0.53	60
76	O'Hare	0.66	0.48	0.5	0.64	0.64	50
77	Edgewater	0.64	0.29	0.63	0.81	0.64	49

Table 7. Ranking of CAs (Vulnerability)

Ranking	Community Name	Total
1	Fuller Park	0.95
2	Gage Park	0.92
3	Austin	0.92
4	Chicago Lawn	0.9
5	Burnside	0.9
6	Armour Square	0.89
7	North Lawndale	0.89
8	West Garfield Park	0.89
9	East Garfield Park	0.88
10	New City	0.88

3.5.5. Ranking of CAs and Insights (Vulnerability)

1. **Strong South and West Side Concentration**
   The Top 10 most vulnerable areas are overwhelmingly located in Chicago's South and West Sides. These are historically redlined zones that were systematically denied mortgage access and investment in the 1930s HOLC maps. The spatial clustering directly mirrors the geography of historic "hazardous" (Grade D) districts.

2. **Persistent Socioeconomic Disadvantage**
   High poverty rates, unemployment, and lower educational attainment dominate these areas. Redlining restricted wealth accumulation, homeownership, and intergenerational asset-building, effects that continue to shape present-day socioeconomic vulnerability. The data reflects this long-term structural disinvestment.

3. **Demographic Sensitivity and Segregation**
   Many of the Top 10 communities have high proportions of elderly residents, single-parent households, and racial minorities. Redlining institutionalized racial segregation, concentrating marginalized populations in under-resourced neighborhoods. Today's vulnerability patterns still follow those segregated settlement structures.

4. **Housing and Built Environment Constraints**
   These neighborhoods often have older housing stock, overcrowding, and limited private vehicle access. Decades of underinvestment have led to poorer infrastructure quality and fewer adaptive resources during heat events. Redlining shaped not only who lives there, but the physical resilience capacity of the built environment.

5. **Structural not Random Vulnerability**
   The **alignment between high vulnerability scores and historically redlined areas demonstrates that climate vulnerability is structurally produced**. It is not simply about present-day demographics, but about accumulated policy decisions and unequal urban development. The findings reinforce that **heat risk and social vulnerability are deeply tied to historical planning injustice.**

Notes: Please refer to the Appendix for the raw datasets utilized in computing the scores for each set of criteria.

3.6. Heat Hazard

3.6.1. Overview of Hazard Framework

Urban heat is operationalized by the Hazard Analysis Framework as a quantifiable climatic stressor in the larger disaster risk model. According to this study, the main hazard affecting Chicago is the intensity of the Urban Heat Island (UHI), which is based on the IPCC's (2022) definition of hazard as the possibility of a physical event or trend that could cause harm. The goal is to determine which localities within the city are experiencing high levels of urban heat stress. A systematic comparison of heat intensity across the urban landscape is made possible by the analysis of all 77 Community Areas rather than just a few chosen neighborhoods in order to guarantee thorough spatial coverage.

Land Surface Temperature (LST), obtained from Landsat satellite data processed in Google Earth Engine, is used to quantify the amount of hazard. Through zonal statistical analysis, mean LST values are calculated for every Community Area, allowing for uniform comparisons across neighborhoods. The Community Areas are ranked and scored based on relative heat severity using these mean temperature values. In order to create a spatially specific list of high-heat zones that guide further exposure and vulnerability assessments within the overall risk analysis, the framework next determines the ten regions with the highest average LST values.

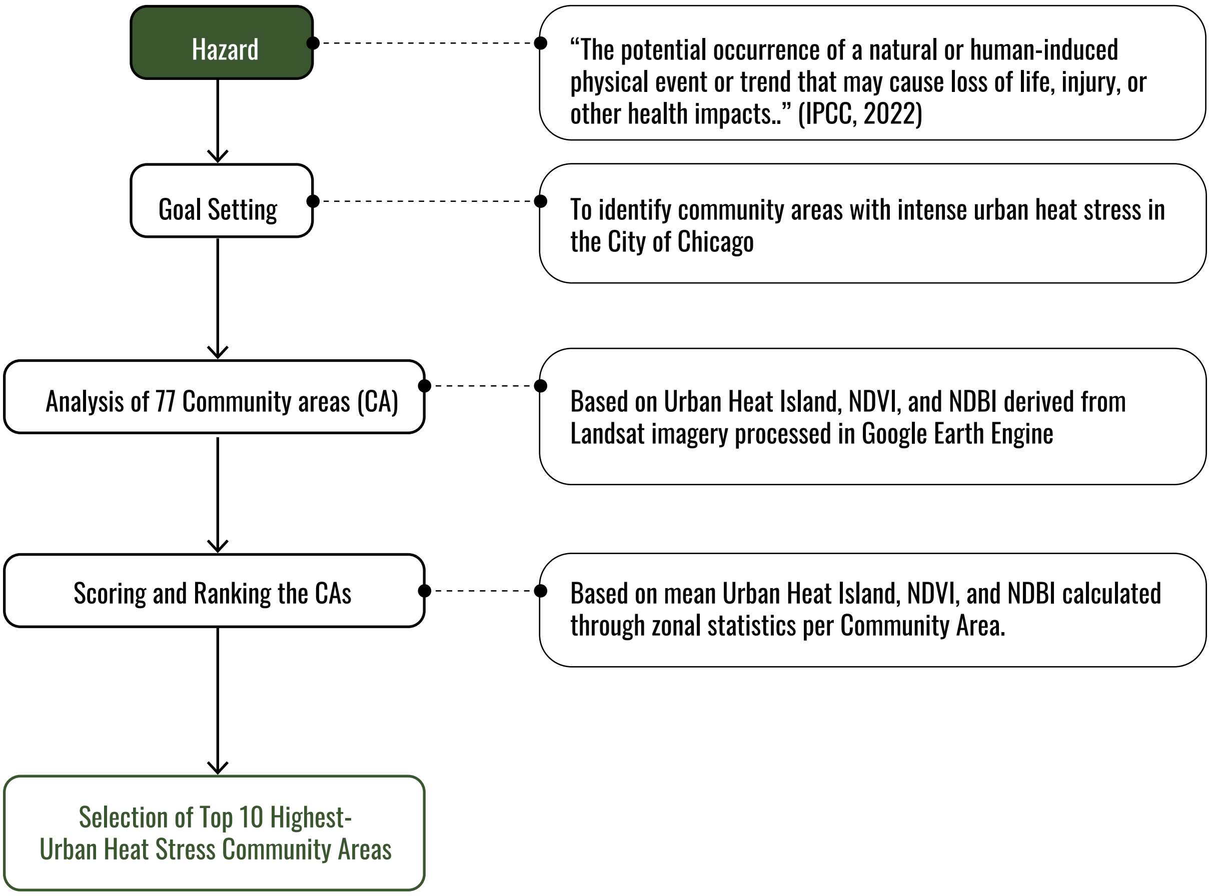


Figure 30. Hazard Analysis Framework. Source: Author

3.6.2. Analysis of Community Areas (Heat Hazard)

All environmental indicators were derived from satellite imagery **processed in Google Earth Engine (GEE) and summarized at the Community Area level using zonal statistics**. The mean values extracted for each of the 77 Community Areas were normalized using min–max scaling to a standardized 0–1 range, ensuring comparability across variables with different measurement units. In this scaling, **0 represents the lowest relative contribution to heat hazard and 1 represents the highest.** The three indicators: **NDVI (inverted), NDBI, and UHI were assigned equal weights and averaged** to compute a composite Environmental Heat Hazard Index, where higher values indicate greater heat hazard intensity.

HC1

Normalized Difference Vegetation Index (NDVI)

The mean NDVI value for each Community Area was extracted through zonal statistics, normalized to a 0–1 range using min-max scaling, and inverted so that lower vegetation levels correspond to higher heat hazard scores.

Scoring (Range)

0 High NDVI (0.80)	1 Low NDVI (0/-)

HC2

Normalized Difference Built-up Index (NDBI)

The mean NDBI per Community Area was calculated through zonal statistics and normalized to a 0–1 scale using min–max transformation, where higher values indicate greater built-up intensity and increased heat hazard.

Scoring (Range)

0 Low Built-up (0/-)	1.00 High Built-up (0.8)

HC3

Urban Heat Islands (UHI)

The Urban Heat Island layer was originally derived by the author using August 2024 Land Surface Temperature data representing peak annual heat conditions where a buffered rural baseline (20–50 km sensitivity test) was used to calculate relative urban heat intensity, and the resulting Community Area means were normalized to a 0–1 scale to represent increasing thermal hazard.

Scoring (Range)

0 Low Temperature	1.00 High Temperature

3.6.3. Analytical Maps: NDVI Map

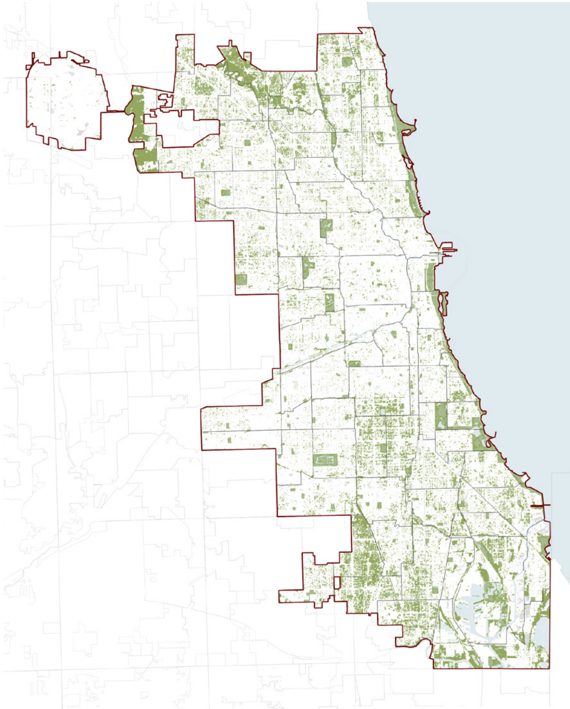
The Normalized Difference Vegetation Index (NDVI), which is **based on Landsat 8/9 Level-2 surface reflectance, is shown on the map for the City of Chicago in August 2024**. QA flags were used to cloud-masked the red and near-infrared bands, which were then composited as a monthly median and translated to an index with a resolution of about 30 m. Denser and healthier green vegetation is indicated by higher numbers in the legend, which typically range from -0.09 to +0.52.

The NDVI is a **dimensionless indicator of "greenness"** that stands in for the density and vigor of vegetation. Water or bare substrates usually have values at or below zero; paved and constructed sites often have values between 0.05 and 0.25; while actively vegetated surfaces (such as planting beds, turf, and tree canopy) register at ~0.30. The layer approximates the cooling and shading capacity available at peak heat because it summarizes August, the hottest month in the city.

At the city level, Chicago's extensive park and open-space system is where the highest NDVI patches are located. Large cemeteries that serve as de facto urban forests, Humboldt and Garfield Parks on the West Side, Jackson and Washington Parks on the South Side, and Lincoln Park along the lakefront all exhibit distinctive clusters of cool colors. Continuous strips of possible evaporative cooling are indicated by the emergence of vegetated corridors along sections of the Chicago River and lagoon systems.

In contrast, the **Southwest and West Sides' industrial and logistical belt which includes rail yards, warehouse areas, large parking lots, and highway rights-of-way is dominated by low-NDVI fabric**. Due to the high amount of impermeable surface and limited tree canopy, the key commercial areas and the area surrounding Midway Airport likewise show a depressed NDVI. These trends support the vegetation–temperature relationship by aligning with regions that have been previously recognized as LST hotspots.

Variation at the neighborhood level is revealed by the ~30 m granularity. Even in generally low-green regions, residential blocks with mature street trees and backyard greenery report a reasonable NDVI, while superblocks with asphalt and connected rooftops look like abrupt depressions. Therefore, the layer aids in identifying micro-deficits in certain corridors where targeted greening would have a significant positive impact, such as lengthy arterial segments, expansive paved complexes, or unsheltered transit approaches.



Map 20. Tree Canopy Cover. Source: Google Earth Engine Satellite, adapted by the Author

Legends

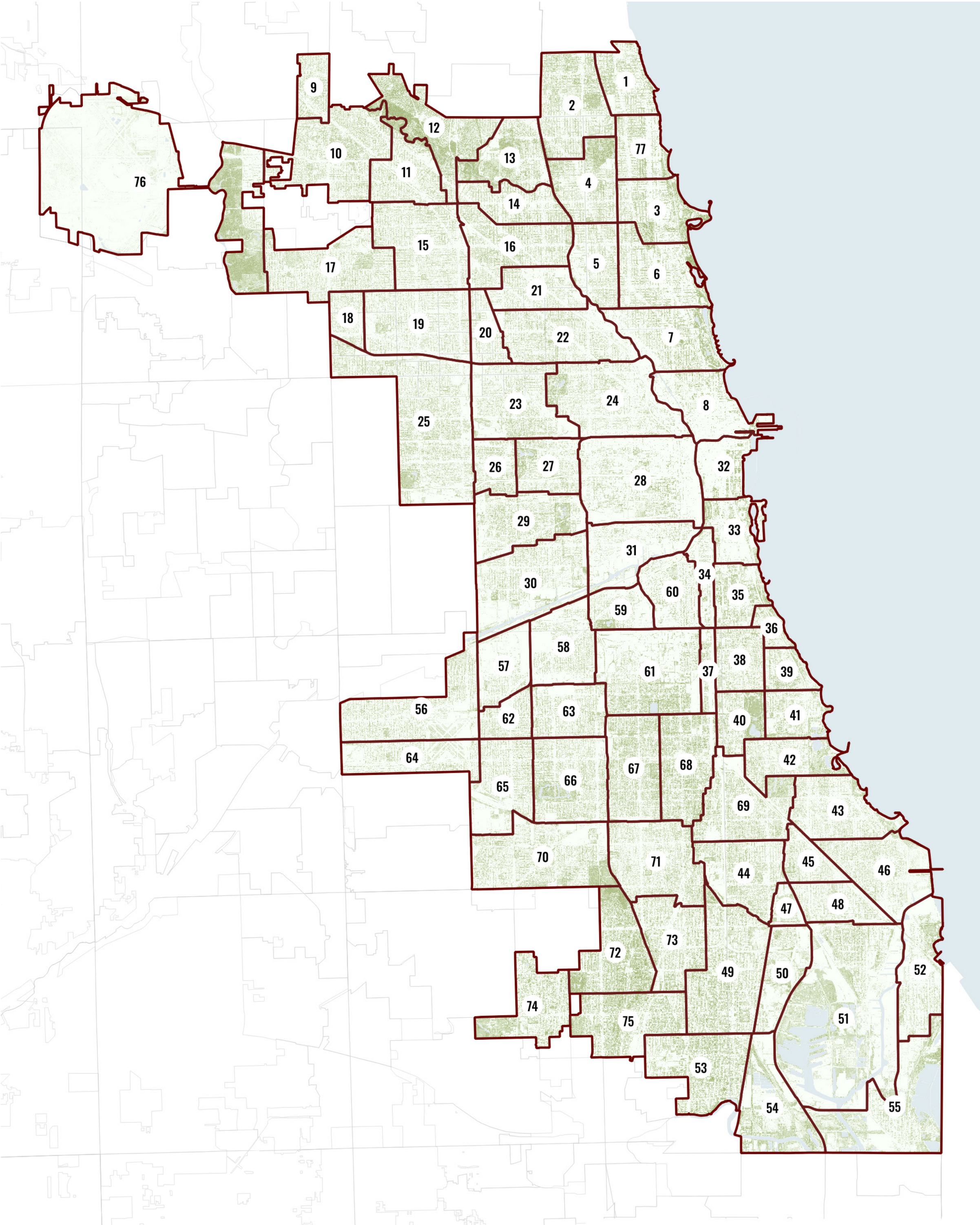
City of Chicago

Community Areas

Blue Infrastructure

Tree cover

Green Infrastructure



Map 21. Normalized Difference Vegetation Index (NDVI). Source: Google Earth Engine Satellite, adapted by the Author

Legends

- City of Chicago
- Community Areas
- Blue Infrastructure
- Low NDVI (0/negative)
- Moderate NDVI (~0.4)
- High NDVI (0.8)

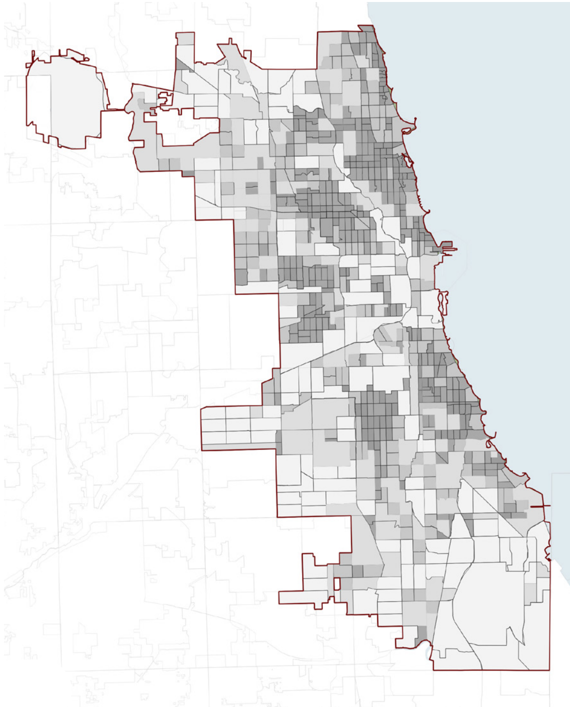
3.6.4. Analytical Maps: NDBI Map

The Difference Normalized The Built-up Index (NDBI) provides information about the spatial structure and level of urbanization of a city by measuring the amount and intensity of built-up surfaces within an urban area. The index, which separates impervious surfaces like buildings and roads from vegetated or open regions, is **derived from satellite data utilizing the difference between shortwave infrared (SWIR) and near-infrared (NIR) reflectance.** The NDBI in Chicago shows distinct spatial differences between the less consolidated, outlying areas in the south and west and the dense, developed zones in the city center and northern districts. These differences reflect patterns of urban expansion and socio-spatial inequality.

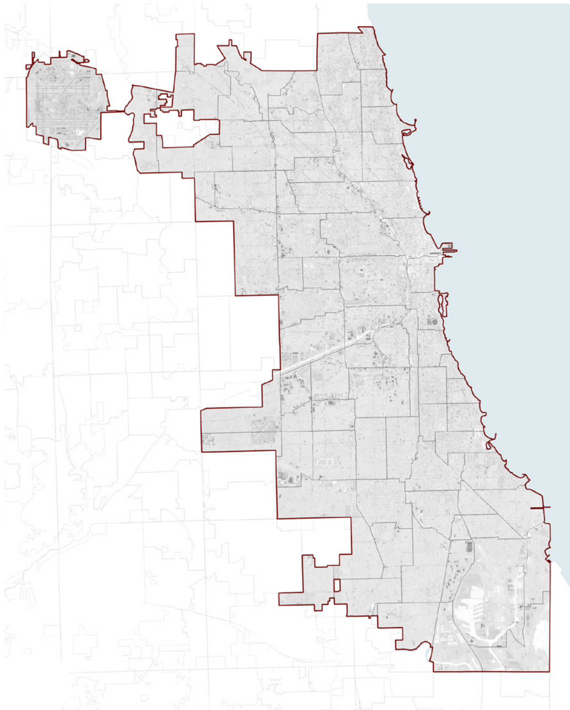
High NDBI values are located in regions where building materials like concrete and asphalt predominate and there is a lot of impermeable covering. The **urban heat island effect is exacerbated by these surfaces' increased heat retention and decreased natural permeability.** On the other hand, regions with lower NDBI values usually residential or mixed-use areas with more vegetation and open spaces show better ecological balance and thermal performance. These regional differences demonstrate the direct effects of land-use intensity and material composition on the environmental resilience and livability of the metropolis.

The link between built-up intensity and heat accumulation is also influenced by surface reflectivity, or albedo. While neighborhoods with lighter, reflecting materials are better equipped to dissipate heat, those with darker, low-albedo surfaces typically collect more solar radiation, leading to higher surface temperatures. This distinction shows how design decisions and material quality affect energy efficiency and urban comfort. Furthermore, differences in built-up density and albedo frequently correspond with socioeconomic inequalities, with lower-income neighborhoods having worse infrastructure and being more vulnerable to heat stress.

In general, Chicago's NDBI geographical distribution highlights the connection between socioeconomic fairness, environmental vulnerability, and urban form. Areas with **increased heat exposure and little vegetation conditions more prevalent in the South and West Sides correspond with the most densely populated areas**. On the other hand, although being just as packed, the northern and lakefront districts use more reflective materials and green areas that reduce heat buildup. In order to guide urban design and climate adaptation measures that support thermal resilience and equitable livability throughout the city, it is imperative to comprehend these built-up patterns.



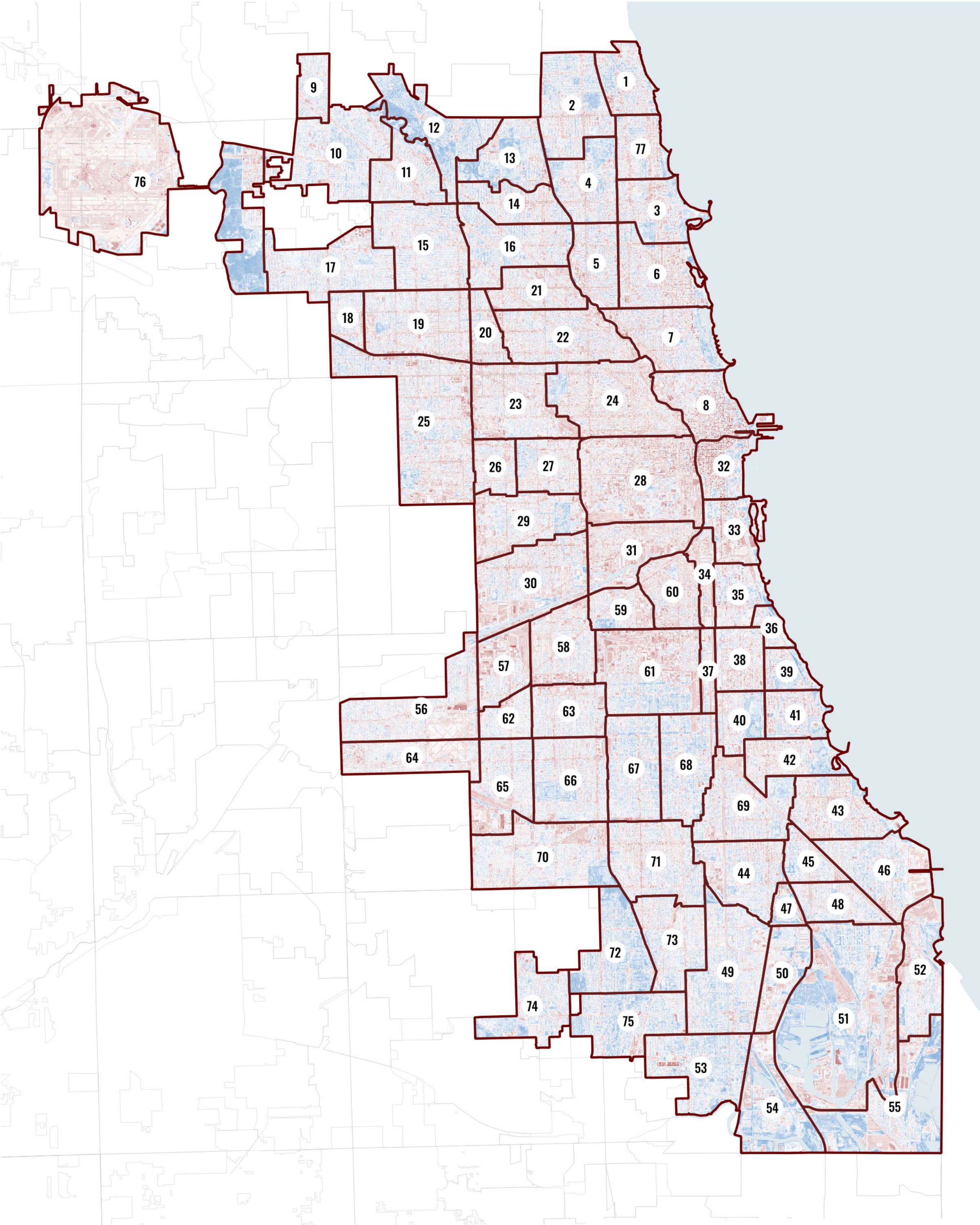
Map 22. Imperviousness of Surface. Source: Google Earth Engine Satellite, adapted by the Author



Map 23. Albedo Surface. Source: Google Earth Engine Satellite, adapted by the Author

Legends

- City of Chicago
- Community Areas
- Blue Infrastructure
- Low Imperviousness
- Moderate Imperviousness
- High Imperviousness
- Low Albedo
- Moderate Albedo
- High Albedo



Map 24. Normalized Difference Built-up Index (NDBI) in Chicago. Source: Google Earth Engine Satellite, adapted by the Author

Legends

City of Chicago

Community Areas

Blue Infrastructure

High built-up

Moderate built up

Low built-up

0 2.5 5 km

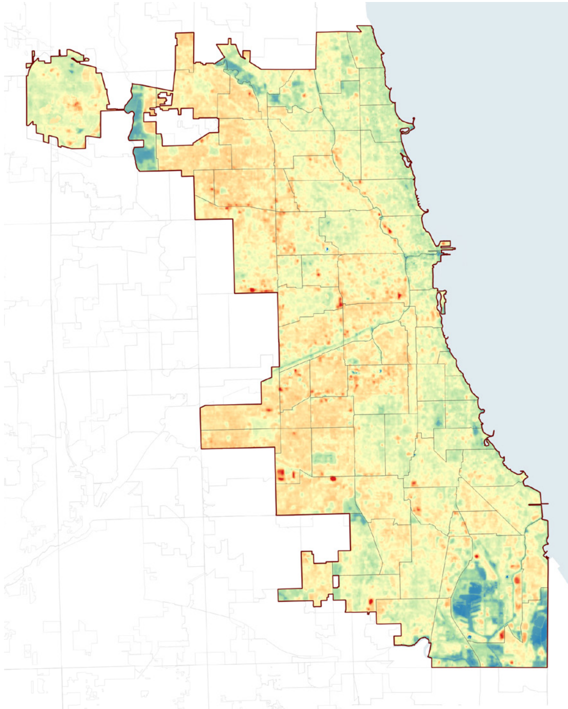
3.6.5. Analytical Maps: Land Surface Temperature

The **August 2024 LST map is used as the baseline for calculating the intensity of the Urban Heat Island (UHI)** in relation to a rural reference, assessing sensitivity to various rural buffers, and connecting heat patterns to walkability and equity outcomes in the environmental profile of Chapter 3 of this study. As a result, it serves as the foundation for further hotspot rankings as well as the selection of street design and greening scenarios that will be assessed for their capacity to cool Chicago's key corridors.

In August 2024, the map shows the intensity of the Urban Heat Island (UHI) in the City of Chicago, measured in degrees Celsius in comparison to a nearby rural baseline. Here, UHI is calculated by subtracting the mean surface temperature of non-urban, non-water areas in a buffer outside the city from the surface temperature of each pixel. **Surfaces with positive values (yellow–red) are hotter than the rural reference; those with negative values (teal–blue) are cooler**. In order to create a citywide, block-scale map of heat surplus, the layer was created using Landsat 8/9 Level-2 thermal data at ~30 m resolution, cloud-masked, and composited as a monthly median. The result was then compared to the rural mean.

There is a clear cooling signal from the shoreline. Lower UHI is seen along parts of the eastern neighborhoods and major park frontages as a result of the moderating influence of Lake Michigan and nearby water bodies, which record the most negative UHI values. Additionally, large green areas seem cooler than their surroundings, illustrating how shade and evapotranspiration work together to reduce heat excess during the hottest month.

This UHI surface serves as a prioritizing layer inside the environmental profile. It enables a Heat–Mobility Vulnerability ranking of streets and nodes when layered with NDVI/Tree Canopy, imperviousness, sidewalk and crossing characteristics, transit stop locations and shelter presence, and demographic vulnerability. High UHI, high foot traffic, and little shade make corridors ideal for interventions including planting strips and street trees, reduced or shaded crossings, cool materials, and covered transit stops.



Map 25. Land Surface temperature (LST) in Chicago. Source: Google Earth Engine Satellite, adapted by the Author

Legends

City of Chicago

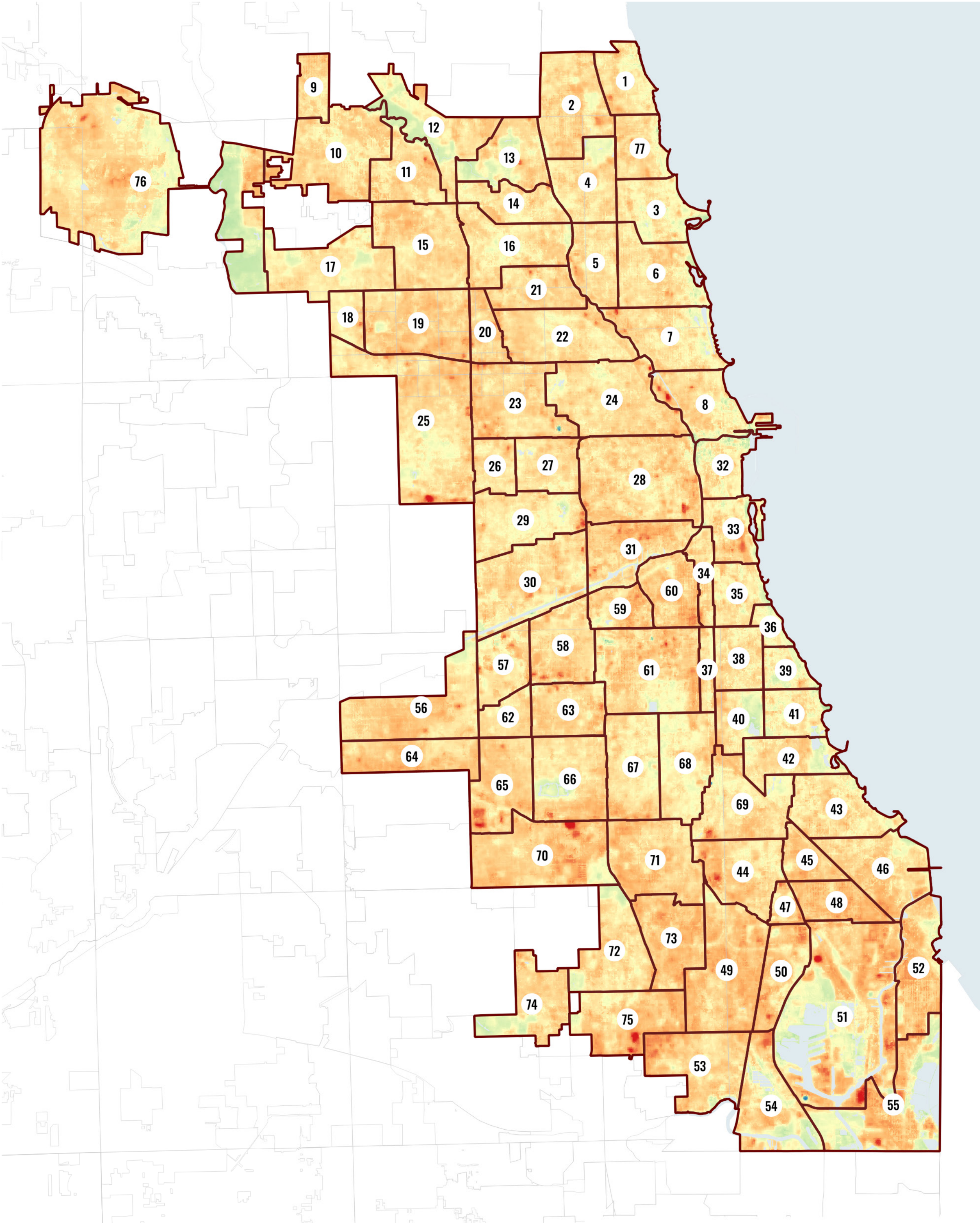
Community Areas

Blue Infrastructure

High temperature (46.4 C)

Moderate temperature (30 C)

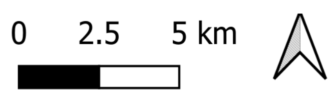
Low temperature (23.5 C)



Map 26. Urban Heat Islands in Chicago. Source: Google Earth Engine Satellite, adapted by the Author

Legends

- City of Chicago
- Community Areas
- Blue Infrastructure
- High temperature
- Moderate temperature
- Low temperature



3.5.6. Scoring of CAs (Heat Hazard)

Table 8. Scoring of CAs (Heat Hazard)

Number	Community Name	HC1	HC2	HC3	Total	Ranking
1	Rogers Park	0.5	0.63	0.34	0.49	58
2	West Ridge	0.4	0.52	0.5	0.47	61
3	Uptown	0.41	0.62	0.15	0.39	67
4	Lincoln Square	0.32	0.46	0.31	0.36	70
5	North Center	0.59	0.71	0.46	0.59	40
6	Lake View	0.6	0.79	0.36	0.58	41
7	Lincoln Park	0.57	0.71	0.33	0.54	48
8	Near North Side	0.9	0.91	0.34	0.72	16
9	Edison Park	0.59	0.53	0.49	0.54	47
10	Norwood Park	0.57	0.49	0.49	0.52	53
11	Jefferson Park	0.58	0.52	0.43	0.51	55
12	Forest Glen	0	0	0.08	0.03	77
13	North Park	0.23	0.29	0.17	0.23	75
14	Albany Park	0.6	0.64	0.33	0.52	51
15	Portage Park	0.7	0.61	0.53	0.61	32
16	Irving Park	0.57	0.58	0.35	0.5	56
17	Dunning	0.68	0.59	0.23	0.5	56
18	Monthclare	0.79	0.64	0.3	0.58	43
19	Belmont Cragin	0.81	0.75	0.7	0.75	9
20	Hermosa	0.78	0.8	0.7	0.76	8
21	Avondale	0.8	0.87	0.55	0.74	10
22	Logan Square	0.71	0.81	0.47	0.66	21
23	Humboldt Park	0.7	0.86	0.63	0.73	13
24	West Town	0.73	0.87	0.45	0.68	18
25	Austin	0.64	0.72	0.46	0.61	35

Number	Community Name	HC1	HC2	HC3	Total	Ranking
26	West Garfield Park	0.6	0.78	0.42	0.6	37
27	East Garfield Park	0.56	0.71	0.43	0.57	45
28	Near West Side	0.81	0.98	0.55	0.78	5
29	North Lawndale	0.54	0.73	0.28	0.52	53
30	South Lawndale	0.72	0.81	0.42	0.65	30
31	Lower West Side	0.89	1	0.66	0.85	1
32	Loop	0.89	0.93	0.01	0.61	34
33	New South Side	0.68	0.77	0.34	0.6	38
34	Armour Square	0.83	0.98	0.48	0.76	6
35	Douglas	0.45	0.67	0.25	0.46	63
36	Oakland	0.52	0.5	0	0.34	72
37	Fuller Park	0.73	0.84	0.39	0.65	27
38	Grand Boulevard	0.55	0.82	0.39	0.59	39
39	Kenwood	0.54	0.49	0.02	0.35	71
40	Washington Park	0.23	0.43	0.13	0.26	74
41	Hyde Park	0.62	0.54	0.11	0.42	64
42	Woodlawn	0.6	0.61	0.24	0.48	59
43	South Shore	0.86	0.7	0.33	0.63	31
44	Chatham	0.61	0.63	0.6	0.61	33
45	Avalon Park	0.82	0.59	0.78	0.73	13
46	South Chicago	0.82	0.61	0.53	0.65	27
47	Burnside	0.75	0.55	0.67	0.66	24
48	Calumet Heights	0.88	0.57	1	0.82	3
49	Roseland	0.49	0.48	0.84	0.6	36
50	Pullman	0.69	0.6	0.74	0.68	19

Number	Community Name	HC1	HC2	HC3	Total	Ranking
51	South Deering	1	0.4	0.31	0.57	44
52	East Side	0.95	0.63	0.71	0.76	6
53	West Pullman	0.41	0.34	0.66	0.47	62
54	Riverdale	0.64	0.28	0.25	0.39	68
55	Hegewisch	0.97	0.16	0.14	0.42	65
56	Garfield Ridge	0.73	0.73	0.56	0.67	20
57	Archer Heights	0.86	0.95	0.36	0.72	15
58	Brighton Park	0.78	0.83	0.59	0.73	12
59	McKinley Park	0.68	0.75	0.66	0.7	17
60	Bridgeport	0.78	0.93	0.76	0.82	2
61	New City	0.63	0.81	0.54	0.66	23
62	West Elsdon	0.65	0.68	0.41	0.58	42
63	Gage Park	0.64	0.74	0.61	0.66	22
64	Clearing	0.81	0.8	0.78	0.8	4
65	West Lawn	0.72	0.76	0.74	0.74	10
66	Chicago Lawn	0.51	0.62	0.44	0.52	51
67	West Englewood	0.33	0.48	0.37	0.39	66
68	Englewood	0.32	0.47	0.23	0.34	72
69	Greater Gramd Crossing	0.58	0.66	0.4	0.55	46
70	Ashburn	0.56	0.65	0.76	0.66	26
71	Auburn Gresham	0.61	0.64	0.71	0.65	27
72	Beverly	0.02	0.09	0.35	0.15	76
73	Washington Heights	0.55	0.54	0.88	0.66	24
74	Mount Greenwood	0.39	0.43	0.35	0.39	68
75	Morgan Park	0.32	0.35	0.78	0.48	59
76	O’Hare	0.71	0.69	0.2	0.53	49
77	Edgewater	0.52	0.65	0.42	0.53	50

Table 9. Ranking of CAs (Hazard)

Ranking	Community Name	Total
1	Lower West Side	0.85
2	Bridgeport	0.82
3	Calumet Heights	0.82
4	Clearing	0.8
5	Near West Side	0.78
6	East Side	0.76
7	Hermosa	0.76
8	Belmont Cragin	0.75
9	Avondale	0.74
10	West Lawn	0.74

3.5.7. Ranking of CAs and Insights (Heat Hazard)

1. **Strong West–Southwest Spatial Concentration**
   The highest hazard scores cluster heavily in the West Side and Southwest Side, particularly Lower West Side, Bridgeport, Clearing, Hermosa, Belmont Cragin, and West Lawn. This indicates a spatially concentrated heat-risk corridor rather than a citywide random pattern. The clustering suggests structural land-use and built-form drivers.

2. **Built-Up Intensity is a Major Driver**
   Many of these areas are characterized by high built-up density and impervious surfaces, contributing to elevated heat retention. Industrial corridors (e.g., Lower West Side, Bridgeport) and tightly packed residential grids (e.g., Belmont Cragin, Hermosa) reinforce this condition. This confirms that NDBI and urban morphology are significantly influencing hazard totals.

3. **Limited Vegetation and NDVI Deficit**
   Several of the top-ranking areas exhibit relatively low NDVI values, meaning reduced tree canopy and green cover. This lack of vegetative cooling amplifies surface heat accumulation. The combination of low NDVI + high built-up index intensifies localized Urban Heat Island effects.

4. **Mixed Socio-Spatial Pattern (Not Only Traditionally Vulnerable Areas)**
   Interestingly, some areas like Bridgeport and Clearing are not historically among the most socially vulnerable communities, yet they rank high in hazard exposure. This shows that heat hazard (physical exposure) does not always align perfectly with social vulnerability, reinforcing the importance of separating hazard and vulnerability in your framework.

5. **Industrial and Transportation Corridors as Heat Amplifiers**
   Lower West Side, Bridgeport, and Calumet Heights are strongly influenced by rail yards, warehouses, freight corridors, and major road infrastructure. **Transportation and logistics landscapes significantly increase impervious cover and thermal mass**. These infrastructural heat contributors are key intervention targets.

Notes: Please refer to the Appendix for the raw datasets utilized in computing the scores for each set of criteria.

3.7. Heat Exposure

3.7.1. Overview of Heat Exposure Framework

According to the IPCC (2022) definition, exposure is defined by the Exposure Analysis Framework as the presence and mobility of individuals inside surroundings that may be negatively impacted by a hazard. Through the prism of urban access and pedestrian mobility in the City of Chicago, exposure is operationalized in this study. Finding community areas with high pedestrian activity concentrations within the current transportation and access network is the goal, especially in places that connect with high urban heat conditions. The framework guarantees a thorough citywide evaluation of how existing mobility mechanisms spatially situate inhabitants in relation to heat-prone settings by looking at all 77 Community Areas.

Operationally, exposure is assessed through the use of the current multimodal mobility network, which includes public transportation, bicycle facilities, and pedestrian infrastructure. By concentrating on the concentration of pedestrian and transit access within high-heat zones highlighted in the hazard assessment, accessibility intensity is quantified using network-based analysis. By combining these accessibility measures at the Community Area level, neighborhoods are ranked and scored based on how much heat exposure they experience as pedestrians. The approach **provides a geographical foundation for comprehending how mobility patterns interact with urban heat to influence overall risk by identifying the ten Community Areas with the highest network-based pedestrian heat exposure.**

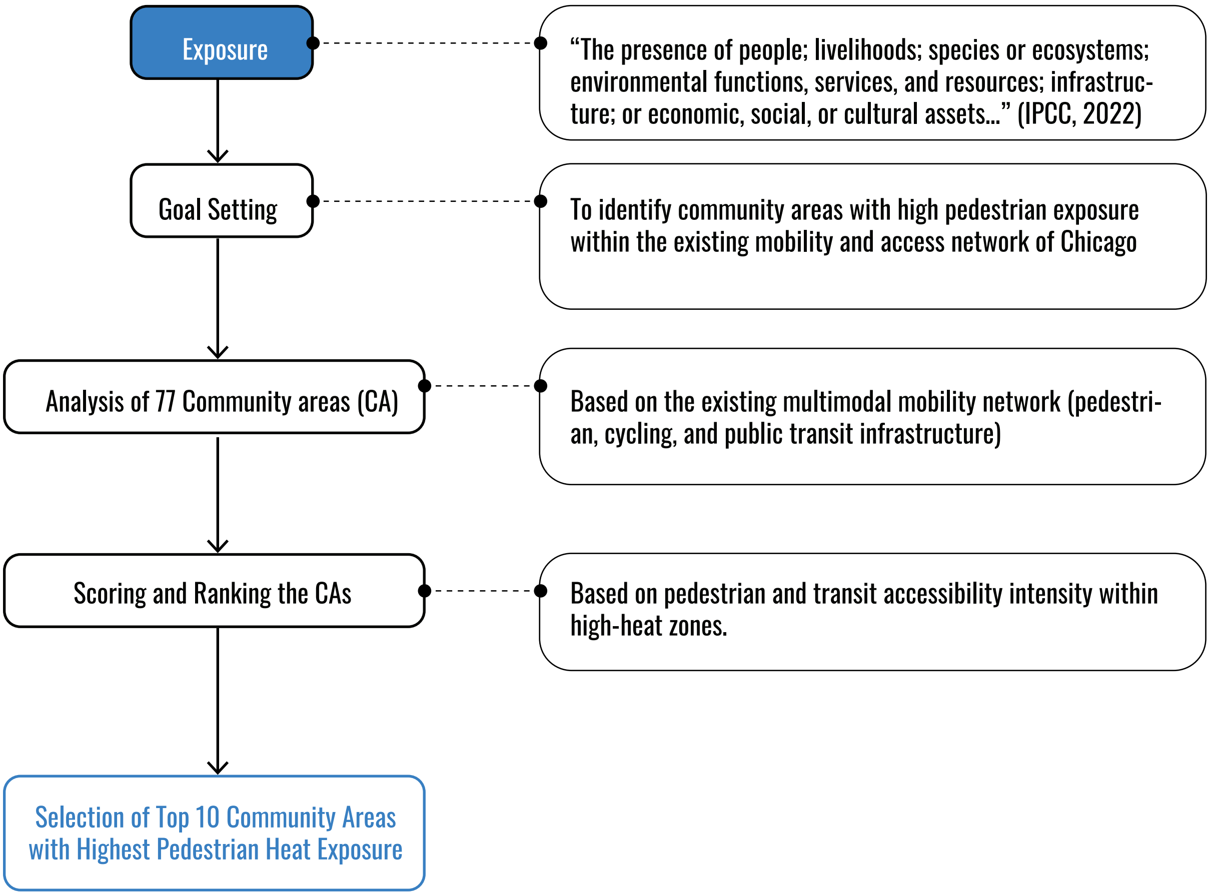


Figure 31. Exposure Analysis Framework. Source: Author

3.7.2. Analysis of Community Areas (Heat Exposure)

Criteria 1 and 2 **define exposure through the condition of mobility infrastructure and spatial access rather than environmental heat alone**. C1 (Active and Transit Mobility Deficit) measures the structural provision of bus, rail, and cycling networks within each Community Area. After normalization and inversion, higher scores indicate areas with limited or fragmented transport infrastructure. **In this framework, exposure reflects infrastructural insufficiency communities with weaker networks are more exposed to mobility constraints and reduced adaptive capacity under heat.**

C2 (Rail Accessibility Deficit) shifts the focus from infrastructure quantity to effective reach. Using 15-minute walking isochrones from rail stations, it measures how much of each Community Area is realistically accessible by foot to high-capacity transit. Once normalized and inverted, higher scores represent lower coverage and greater accessibility deficit. Together, these criteria **position exposure as a mobility condition, where limited infrastructure and restricted transit reach intensify vulnerability in high-heat contexts**.

EC1

Active and Transit Mobility Deficit

The Mobility Network Deficit Index (C1) was calculated by aggregating the length and count of bus routes, rail lines, and cycling infrastructure within each community area, then normalizing the values using min–max scaling to a 0–1 range and inverting the results so that 1 represents the highest mobility deficit (lowest infrastructure provision) and 0 represents the lowest deficit.

Scoring (Range)

0 Low Mobility Deficit	1.00 High Mobility Deficit

EC2

Rail Accessibility Deficit (15-Minute Isochrone Reach)

C2 was calculated by summing the total 15-minute walking isochrone coverage from rail stations within each Community Area, normalizing the values using min–max scaling (0–1), and inverting the scores so that 1 represents the lowest rail accessibility (highest deficit) and 0 represents the highest accessibility (lowest deficit).

Scoring:

0 Low Built-up (0/-)	1.00 High Built-up (0.8)

3.7.3. Analytical Maps: Public Transportation Network

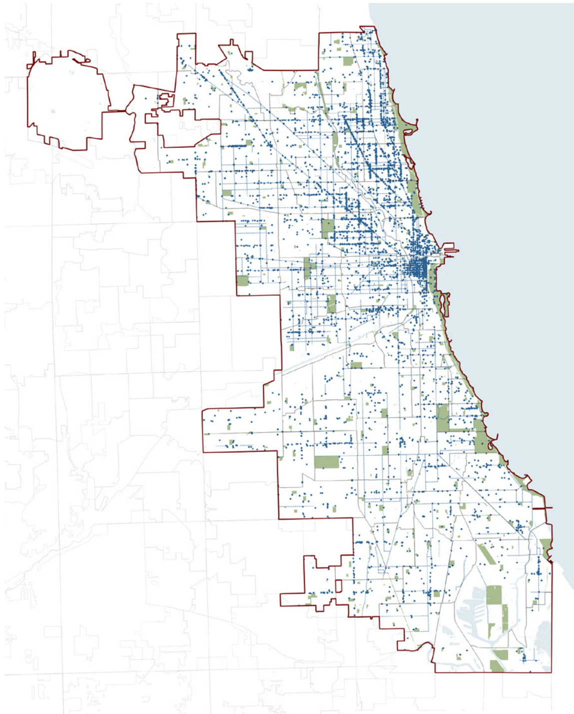
Chicago's transit system is one of the most comprehensive in the United States, structured on a radial and grid pattern that connects neighborhoods to the central downtown (the Loop) and regionally. Anchored by the Chicago Transit Authority (CTA) rail system, the system incorporates bus corridors, commuter rail lines, and regional connections. The multi-modal system is necessary for preserving day-to-day mobility across the city, linking residential neighborhoods to employment, schools, and fundamental services.

The CTA "L" train system is perhaps the most symbolic feature, with multiple color-coded lines radiating from the central downtown core. The rail lines form convenience patterns, with neighborhoods near stops enjoying greater connectivity and more reliable travel. The extensive network of rail is supplemented by an equally vital network of buses that provide last-mile connectivity to areas not served by rail. The two form the backbone of mass mobility in the city.

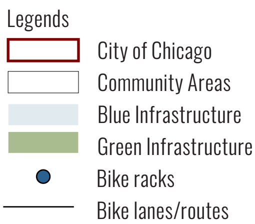
Accessibility is not, nevertheless, equally spread. Northern and downtown areas have high-density transit coverage, short headways, and overlapping modes, generating robust accessibility for their residents. In contrast, a few **South and West Side communities have gaps in coverage or longer travel times, a legacy of past disinvestment and disproportionate infrastructure construction.**

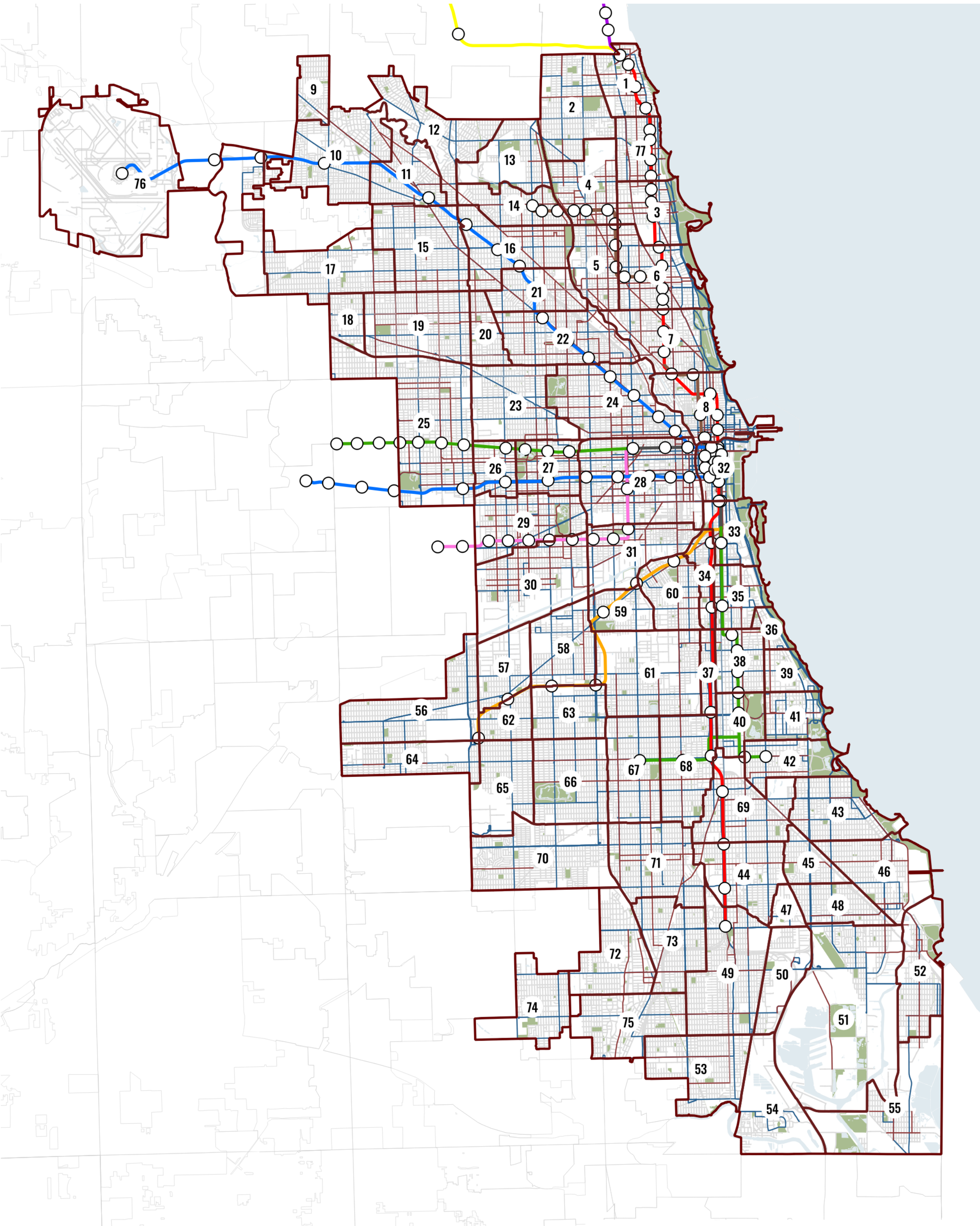
Of the city's most prominent active mobility corridors, none is as iconic as the 18.5-mile shared-use Chicago Lakefront Trail. On peak summer days, it can accommodate as many as 70,000 users (Chicago Park District, 2024). With regard to recreation, the trail is a safe, car-free route connecting north and south neighborhoods along Lake Michigan.

However, many issues persist in Chicago's overall "bikeability." Per PeopleForBikes, the city fared terribly, with a score of 7 out of 100, and highlighted gaps in protected lanes, poor street connectivity, and traffic speed is excessive (PeopleForBikes, 2023). Nevertheless, with over 425 miles of bikeways, many of them lack protection or are substantially fragmented or concentrated in wealthier central zones. **Reflective of systemic imbalances in the distribution of active mobility infrastructure, lower-income neighborhoods and historically marginalized communities are not only underserved but are also more vulnerable to traffic-related risks.**



Map 27. Bike Routes and racks in Chicago. Source: Chicago Data Portal





Map 28. Transportation network in Chicago. Source: Chicago Data Portal and CTA

Legends
- City of Chicago
- Community Areas
- Blue Infrastructure
- Green Infrastructure
- Railway Stations
- Bus Lines/routes
- Cycling lanes

0 2.5 5 km

3.7.4. Analytical Maps: Isochrones Access Map

The 15-minute city has become a dominant concept in urban planning as a paradigm of accessibility, equity, and livability. By tracing 15-minute walking isochrones around public transportation stops in Chicago, neighborhoods can be mapped where citizens are in easy walking distance of fast transit. This spatial plan privileges the critical interconnection between urban form, transportation systems, and active mobility, making it clear what areas are well linked to transit and what are not.

The isochrone map shows that much of Chicago's rapid transit system provides walkable access concentrated along the major rail lines. Stations on the Red, Blue, and Green Lines, for instance, display closely spaced overlapping isochrones, particularly in central and north-side neighborhoods. These areas are the strongest correspondence between public transit and pedestrian accessibility, where residents have a reliable choice of sustainable, carless transportation.

Closer to the city center, intersecting isochrones give extensive walkable coverage, with the majority of residents of these neighborhoods within a short walking distance of multiple stations. However, as one moves outward to peripheral areas, the isochrones break apart, with great expanses of territory beyond the 15-minute boundary. This shows a spatial mismatch in walkable transit coverage: downtown and inner neighborhoods are well-served, but suburban and outer neighborhoods are often car-dependent or use lengthy feeder trips to reach rail stations.

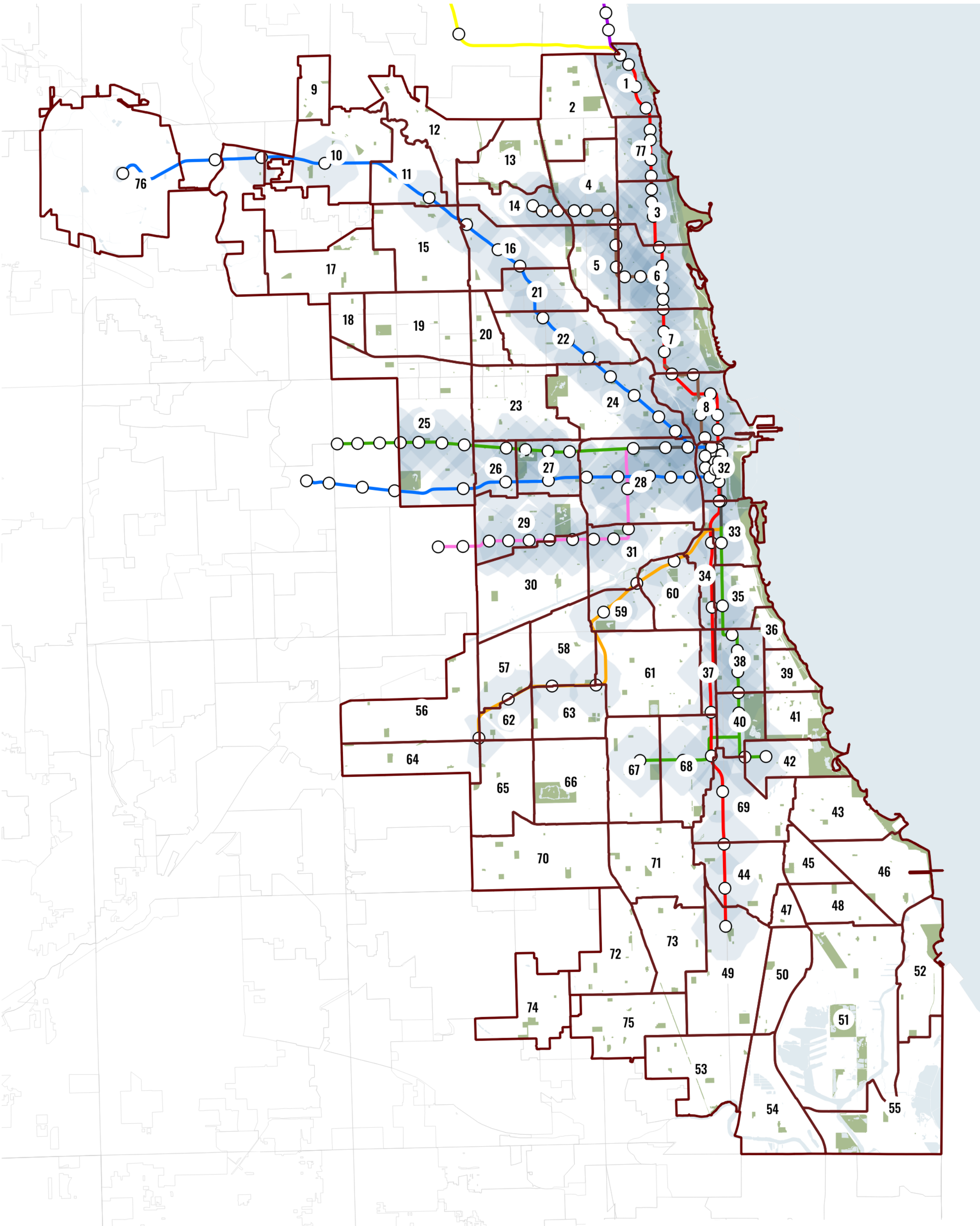
The **isochrone map primarily indicates how walking can be integrated as the primary feeder mode to transit.** Where isochrones meet within a neighborhood, there exist diverse walking alternatives, and active mobility becomes the default choice. These conditions reduce the necessity for cars, promote healthier lifestyles, and lower emissions from short-distance trips. Further, promoting walking to transit stations ensures last-mile connections are not barriers but opportunities for increased physical activity.

In terms of equity, the **isochrones also map unequal access to mobility between communities**. Historically marginalized communities particularly on Chicago's south and west sides show less expansive walking catchments to stations. These lacunae also overlap with disinvested communities, where transit coverage and pedestrian infrastructure are less comprehensive. Addressing these gaps requires not only expanding transit coverage but also investing in sidewalks, crossings, and pedestrian-safe routes so that walking to transit is feasible and safe for all.

Pedestrian isochrones also coincide with broader concerns of urban heat vulnerability. While 15-minute walk access may be hypothetically available, the discomfort of walking in extreme heat can discourage active mobility. Areas without tree canopy cover or with little infrastructure that is shaded can anticipate reduced walking to transit even when they are geographically close. The inclusion of cooling strategies such as climate-responsive urban design, tree planting, and shaded sidewalks is therefore paramount to making walkability a viable and equitable mode in Chicago.

The **isochrone analysis informs the allocation of transit-oriented development (TOD) priority**. By locating new housing, services, and amenities in close proximity to transit by walking, Chicago can strengthen its system of active mobility and reduce dependency on automobiles. The city's recent efforts to push TOD boundaries to non-traditional higher-income neighborhoods are a positive development, yet the isochrone data shows that focused efforts are still needed in marginalized neighborhoods where walking access to stations remains low.

Overall, the 15-minute isochrone data is an eye-opening look at how well Chicago's transit system supports active mobility via walking. **Core neighborhoods are well-served, but inequities persist at the periphery and in historically disinvested neighborhoods.** Improving pedestrian infrastructure, expanding shaded and safe walking corridors, and aligning urban development with the principles of the 15-minute city can help make walking an equitable connection to transit for all. In doing so, Chicago can continue towards a more sustainable, equitable, and climate-resilient transportation network.



Map 29. 15 Minutes Walking Isochrones to Rail Stations in Chicago. Source: Chicago Data Portal and CTA

Legends

- City of Chicago
- Community Areas
- Blue Infrastructure
- Green Infrastructure
- 15 Minutes isochrones
- Railway Stations

0 2.5 5 km

3.7.5. Scoring of CAs (Heat Exposure)

Table 10. Scoring of CAs (Heat Exposure)

Number	Community Name	EC1	EC2	Total	Ranking
1	Rogers Park	0.36	0.67	0.52	42
2	West Ridge	0.52	0.67	0.59	32
3	Uptown	0.28	0.44	0.36	60
4	Lincoln Square	0.47	0.11	0.29	68
5	North Center	0.22	0.33	0.28	70
6	Lake View	0.18	0.44	0.31	67
7	Lincoln Park	0.14	0.44	0.29	69
8	Near North Side	0.05	0.44	0.24	72
9	Edison Park	0.67	1	0.83	14
10	Norwood Park	0.61	0.78	0.7	22
11	Jefferson Park	0.49	0.67	0.58	33
12	Forest Glen	0.72	0.44	0.58	34
13	North Park	0.63	0.67	0.65	25
14	Albany Park	0.46	0.22	0.34	63
15	Portage Park	0.55	0.44	0.49	46
16	Irving Park	0.51	0.22	0.36	61
17	Dunning	0.69	1	0.84	12
18	Monthclare	0.74	1	0.87	7
19	Belmont Cragin	0.58	1	0.79	18
20	Hermosa	0.6	1	0.8	17
21	Avondale	0.4	0.67	0.54	39
22	Logan Square	0.3	0.44	0.37	59
23	Humboldt Park	0.42	0.33	0.38	57
24	West Town	0.21	0.22	0.21	74
25	Austin	0.66	0.56	0.61	28

Number	Community Name	EC1	EC2	Total	Ranking
26	West Garfield Park	0.71	0.44	0.57	36
27	East Garfield Park	0.62	0.33	0.47	48
28	Near West Side	0.17	0	0.09	77
29	North Lawndale	0.68	0.22	0.45	50
30	South Lawndale	0.53	0.67	0.6	30
31	Lower West Side	0.29	0.11	0.2	76
32	Loop	0	0.56	0.28	71
33	New South Side	0.08	0.33	0.21	75
34	Armour Square	0.35	0.11	0.23	73
35	Douglas	0.38	0.44	0.41	54
36	Oakland	0.44	0.56	0.5	45
37	Fuller Park	0.76	0.22	0.49	47
38	Grand Boulevard	0.59	0.11	0.35	62
39	Kenwood	0.33	0.44	0.39	55
40	Washington Park	0.64	0.11	0.38	58
41	Hyde Park	0.25	0.44	0.34	64
42	Woodlawn	0.48	0.56	0.52	43
43	South Shore	0.57	1	0.78	21
44	Chatham	0.65	0.56	0.6	31
45	Avalon Park	0.7	1	0.85	11
46	South Chicago	0.73	1	0.86	9
47	Burnside	0.75	1	0.88	6
48	Calumet Heights	0.77	1	0.89	4
49	Roseland	0.67	0.56	0.61	29
50	Pullman	0.72	1	0.86	10

Number	Community Name	EC1	EC2	Total	Ranking
51	South Deering	0.8	1	0.9	3
52	East Side	0.78	1	0.89	5
53	West Pullman	0.74	1	0.87	8
54	Riverdale	0.83	1	0.92	1
55	Hegewisch	0.82	1	0.91	2
56	Garfield Ridge	0.63	0.44	0.54	40
57	Archer Heights	0.58	0.56	0.57	37
58	Brighton Park	0.54	0.33	0.44	51
59	McKinley Park	0.43	0.44	0.43	52
60	Bridgeport	0.31	0.33	0.32	66
61	New City	0.45	0.22	0.34	65
62	West Elsdon	0.62	0.22	0.42	53
63	Gage Park	0.56	0.56	0.56	38
64	Clearing	0.69	0.56	0.62	27
65	West Lawn	0.61	0.56	0.58	35
66	Chicago Lawn	0.52	0.78	0.65	26
67	West Englewood	0.73	0.67	0.7	23
68	Englewood	0.71	0.33	0.52	44
69	Greater Gramd Crossing	0.6	0.33	0.46	49
70	Ashburn	0.66	1	0.83	15
71	Auburn Gresham	0.64	0.44	0.54	41
72	Beverly	0.59	1	0.79	19
73	Washington Heights	0.67	0.67	0.67	24
74	Mount Greenwood	0.68	1	0.84	13
75	Morgan Park	0.63	1	0.81	16
76	O'Hare	0.79	0.78	0.79	20
77	Edgewater	0.34	0.44	0.39	56

Table 11. Ranking of CAs (Heat Exposure)

Ranking	Community Name	Total
1	Riverdale	0.92
2	Hegewisch	0.91
3	South Deering	0.9
4	Calumet Heights	0.89
5	East Side	0.89
6	Burnside	0.88
7	Montclare	0.87
8	West Pullman	0.87
9	South Chicago	0.86
10	Pullman	0.86

3.7.6. Ranking of CAs and Insights (Heat Exposure)

1. **Southern and Far-South Community Areas Dominate the Top 10**
   Riverdale, Hegewisch, South Deering, Calumet Heights, South Chicago, and Pullman are all located in the far South/Southeast side, indicating a clear spatial concentration of exposure risk in peripheral areas of Chicago.

2. **High Exposure Is Linked to Limited Rail Reach**
   Many of the top-ranked areas score high due to low rail isochrone coverage (C2), meaning residents have limited 15-minute walking access to transit, reinforcing infrastructural isolation.

3. **Infrastructure Deficit and Accessibility Gap Overlap**
   The highest-ranking CAs reflect a combination of weak active mobility networks (C1) and poor transit reach (C2), showing that exposure is not only environmental but strongly tied to structural mobility limitations.

4. **Exposure Is Not Limited to High-Density Urban Cores**
   Unlike hazard rankings that highlighted central areas (e.g., Lower West Side), the exposure results emphasize peripheral neighborhoods, suggesting that mobility-based exposure operates differently than heat intensity alone.

5. **Reinforcement of Spatial Inequality Patterns**
   Several of the top 10 areas have **historically experienced disinvestment and infrastructural neglect, implying that mobility exposure aligns with long-standing socio-spatial inequities**.

Notes: Please refer to the Appendix for the raw datasets utilized in computing the scores for each set of criteria.

CHAPTER IV

Results and Discussion

Chapter IV: Results and Discussion

4.1. Heat Risk Assessment

4.1.1. Top 10 High-Risk communities

Vulnerability, hazard, and exposure are the three main dimensions that are **integrated to create the composite assessment of urban heat risk** that is shown in Table. The study integrates environmental intensity (heat hazard), infrastructure-based accessible conditions (exposure), and sociodemographic sensitivity (vulnerability) rather than depending on a single indicator. Research-based criteria were used to operationalize each dimension: exposure through deficiencies in mobility and train accessibility; danger through environmental measures including heat intensity and vegetation shortage; and vulnerability through demographic and socioeconomic factors. Instead of capturing isolated disadvantage, **the final ranking measures cumulative risk by allocating equal weight and summing the normalized values (0–1).**

The top-ranked communities: Riverdale, Calumet Heights, South Deering, Burnside, and South Chicago showcase the geographical emergence of compounded risk. These regions routinely score highly on a number of parameters rather than just having high danger or high vulnerability. For example, great heat hazard intensity is combined with strong socioeconomic vulnerability in some regions, while exposure deficiencies are extremely high (low accessible reach) in others. Thus, **multidimensional stress is reflected in the total scores, which show the intersections of social fragility, infrastructure constraint, and environmental heat risk.**

In terms of methodology, this strategy improves the study's analytical robustness. The scoring system makes sure that variables with different units and scales are comparable by normalizing each indicator and, if needed, inverting deficit-based measurements. **As risk is defined as the interplay of hazard, exposure, and vulnerability, this avoids placing undue emphasis on any one metric and is consistent with risk assessment frameworks seen in the literature on climate adaptation.** Transparency, reproducibility, and justification based on earlier studies on urban heat islands, environmental justice, and mobility disparities are made possible by the structured criteria-based grading.

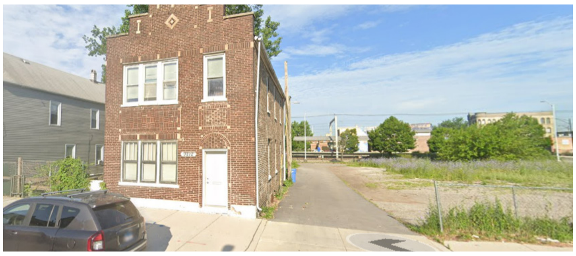
Table 12. Ranking of Top 10 High-Risk CAs

Ranking	Community Name	Vulnerability Score	Heat Hazard Score	Heat Exposure Score	Total Score	Final Rankin
1	Burnside	0.9	0.66	0.88	2.44	1
2	South Chicago	0.86	0.65	0.86	2.37	2
3	Calumet Heights	0.61	0.82	0.89	2.32	3
4	South Deering	0.84	0.57	0.9	2.31	4
5	Riverdale	0.85	0.39	0.92	2.16	5
6	Austin	0.92	0.61	0.61	2.14	6
7	Gage Park	0.92	0.66	0.56	2.14	7
8	Pullman	0.58	0.68	0.86	2.12	8
9	Fuller Park	0.95	0.65	0.49	2.09	9
10	Chicago Lawn	0.9	0.52	0.65	2.07	10

4.1.2. Built Environment Quality of High-Risk Areas

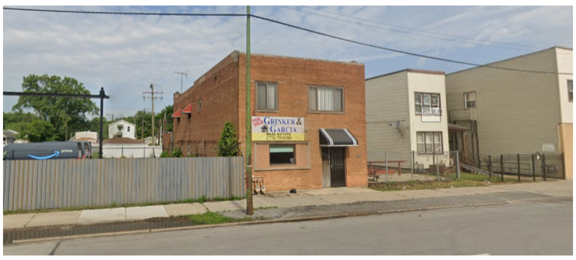
1 Burnside

2 South Chicago



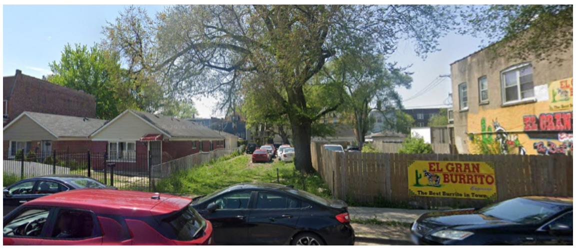
3 Calumet Heights

4 South Deering



5 Riverdale

6 Austin



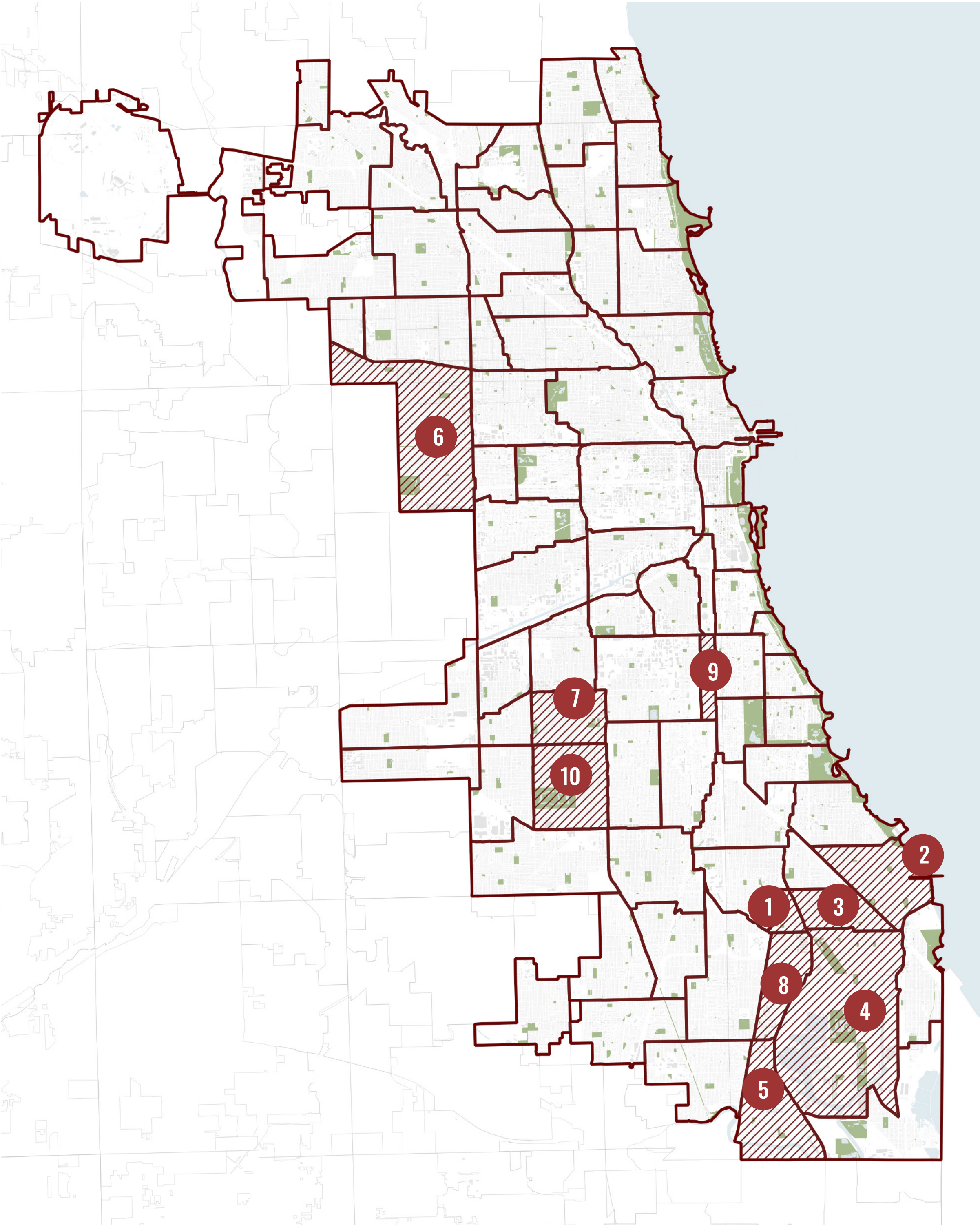
7 Gage Park

8 Pullman

9 Fuller Park

10 Chicago Lawn

Figure 32. Street view of 10 High risk community areas. Source: Google Earth Street View



Map 30. 10 Highly at risk Community Areas. Source: Author

Legends

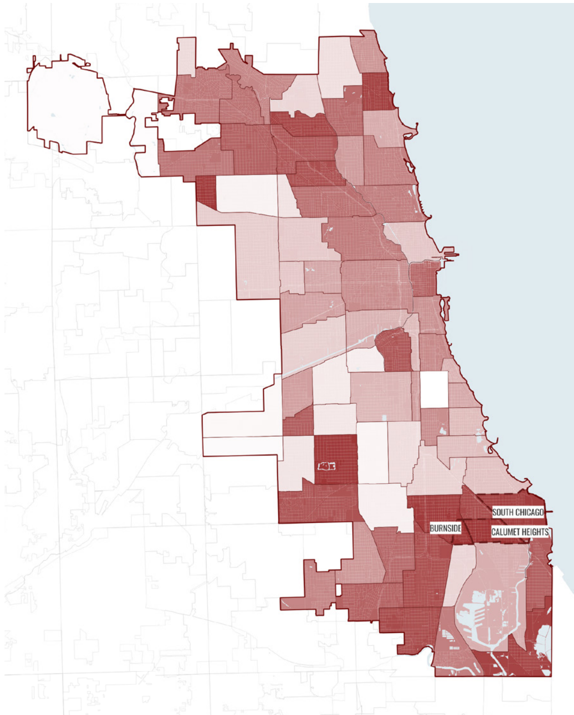
- City of Chicago
- Community Areas
- Blue Infrastructure
- Green Infrastructure
- High Risk community areas

4.2. High Heat Risk Community Areas

4.2.1. Vulnerability Comparative Analysis

Together, the three chosen community areas show a concentrated geography of increased social vulnerability that is both territorially vast and physically continuous rather than dispersed. Instead of representing isolated pockets of poverty, the darkest SVI categories in each instance form sizable, continuous clusters that reflect ongoing socioeconomic hardship at the local level. These top-ranked zones show reduced internal variance and higher overall intensity when compared to other community areas citywide, indicating that vulnerability is not limited to certain tracts but rather is widely dispersed throughout the area. Given that environmental risks can have a greater impact when there is widespread vulnerability, this trend supports their designation as priority zones within the heat-risk paradigm.

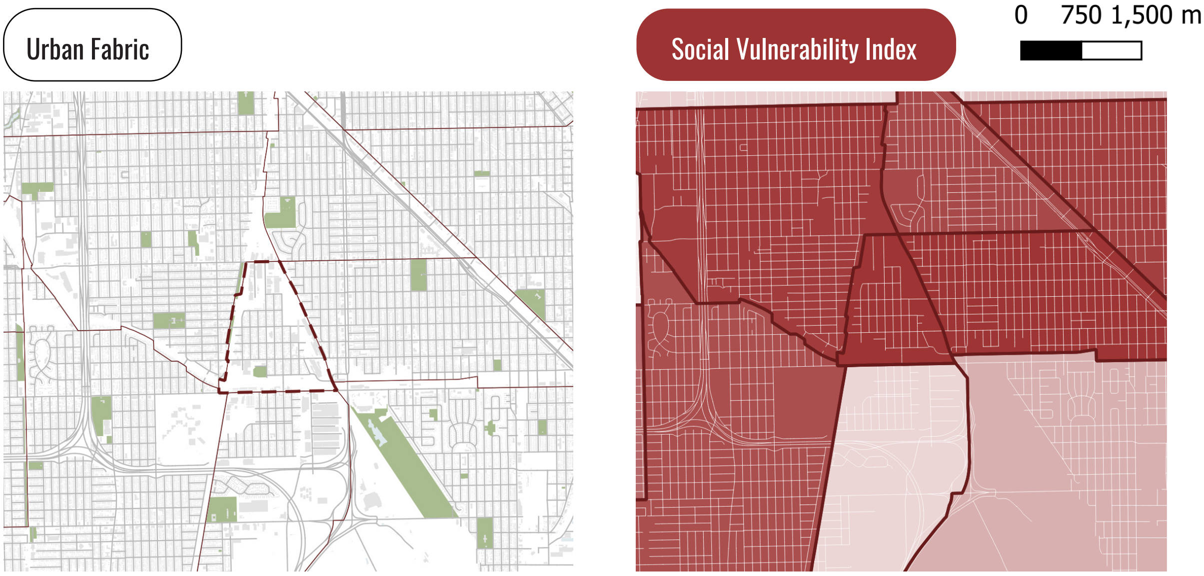
There is a noticeable geographical difference when compared to several North Side community areas. Stronger adaptation capacity and more stable socio-economic situations are suggested by the generally lighter SVI classifications and more scattered and discontinuous vulnerable areas found in northern neighborhoods. A more diverse socio-spatial structure is seen in the North Side, where even areas of intermediate susceptibility are frequently separated by lower-risk areas. However, vulnerability seems to be entrenched and systemic in the top three sectors, creating coherent high-risk landscapes that mirror accumulated structural injustices. This distinction is crucial: the top three community areas chosen represent structurally concentrated disadvantage, **rendering them disproportionately vulnerable when combined with environmental stresses and heat exposure, whereas northern areas may experience episodic or isolated vulnerability**.



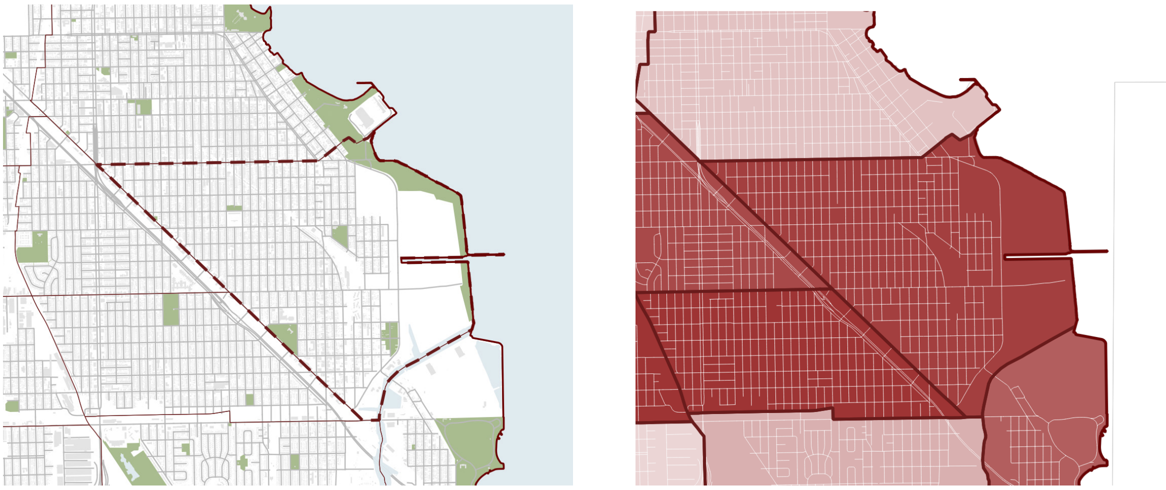
Map 31. SVI of 3 Selected CAs. Source: Author

Legends

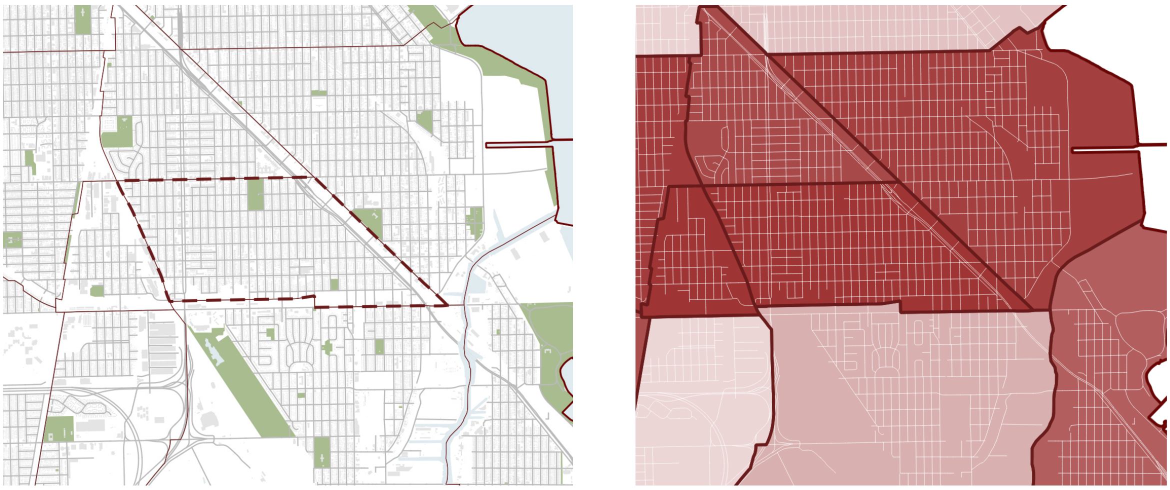
- City of Chicago
- Blue Infrastructure
- Highly vulnerable
- Moderately-high vulnerable
- Moderately vulnerable
- Less vulnerable
- Least vulnerable
- City of Chicago
- Green Infrastructure
- Blue Infrastructure



Burnside: Long-standing structural injustices ingrained in Burnside's urban fabric are demonstrated by concentrated zones of moderate to high social vulnerability that physically correspond with previously redlined districts.



South Chicago: Disinvestment has persisted over generations in South Chicago, as seen by the clear overlap between historically "hazardous" redlined districts and present high SVI clusters. Its industrial adjacency and uneven distribution of environmental amenities amplify exposure and compound socioeconomic vulnerability.

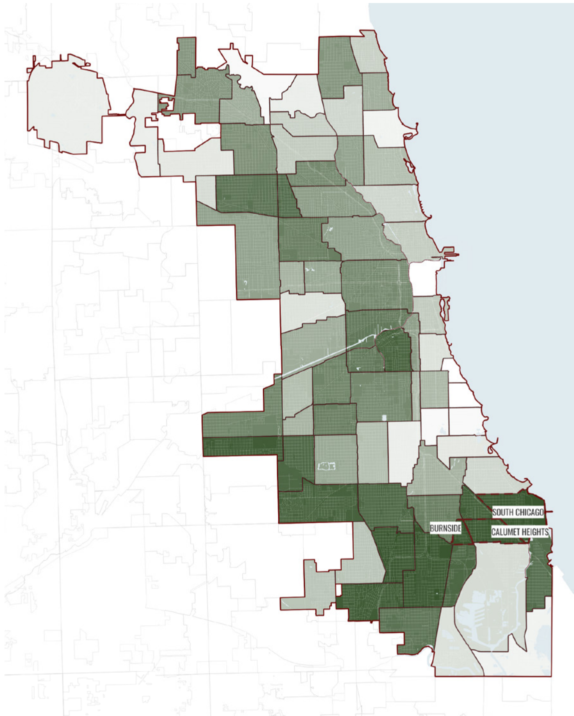


Calumet Heights: In comparison to nearby communities, Calumet Heights exhibits relatively lower and more geographically diverse vulnerability levels, with certain sections showing better home stability.

4.2.2. Heat Hazard Comparative Analysis

Instead of isolated hotspots, the geographical distribution of Urban Heat Island (UHI) intensity throughout the three community areas that were chosen shows a pattern of continuous and concentrated thermal stress. Heat hazard appears to be fundamentally integrated in the urban landscape, as seen by the large clusters of high and moderately-high UHI zones that span several interior blocks. The chosen regions have more wide and internally persistent heat signatures than typical North Side neighborhood areas, where high temperatures are frequently edge-based, fractured, or offset by proximity to greater green corridors or lakefront cooling effects. Darker classes predominate because they show persistent surface heat accumulation, which supports their designation as priority hazard zones in the larger risk framework.

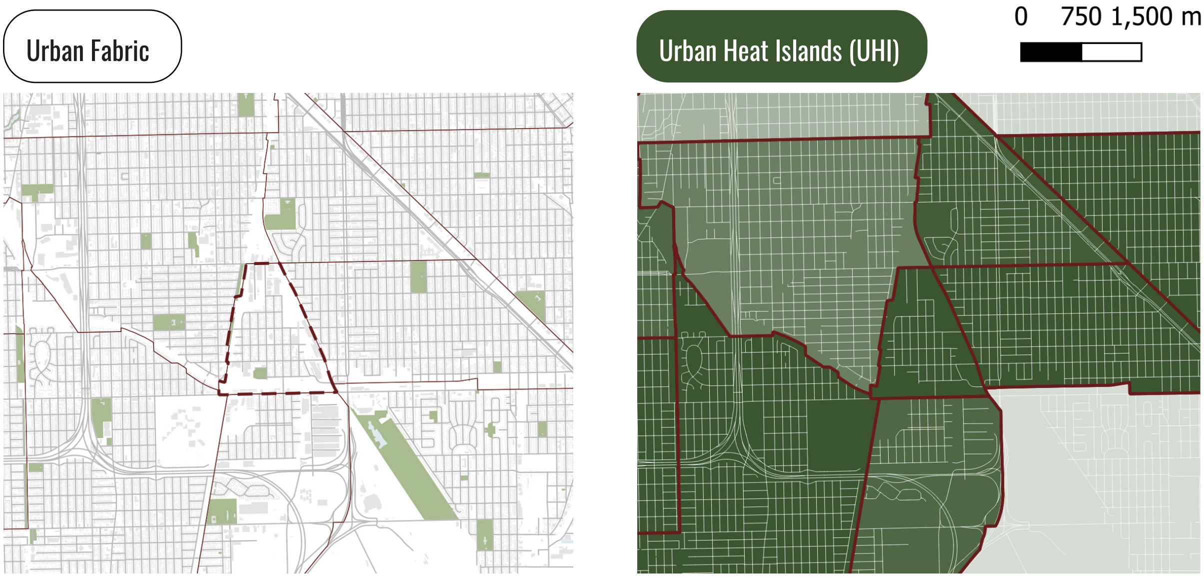
A more thorough analysis of the data indicates that the thermal intensity in these regions is **influenced by cumulative built-up density and little vegetative buffering across adjacent residential grids rather than just isolated industrial lots**. The chosen neighborhoods have a sharper spatial concentration of high-heat zones than northern areas, where UHI gradients often transition between moderate and low classes more gradually. This suggests that there is less microclimatic relief within short walking distances. Pedestrians are more likely to be exposed for extended periods of time due to the spatial continuity of high surface temperatures, especially during periods of intense heat. Because of this, the danger profile of these three regions is not only larger but also more spatially concentrated, which, when paired with increased social vulnerability and limited mobility networks, can have more significant effects.



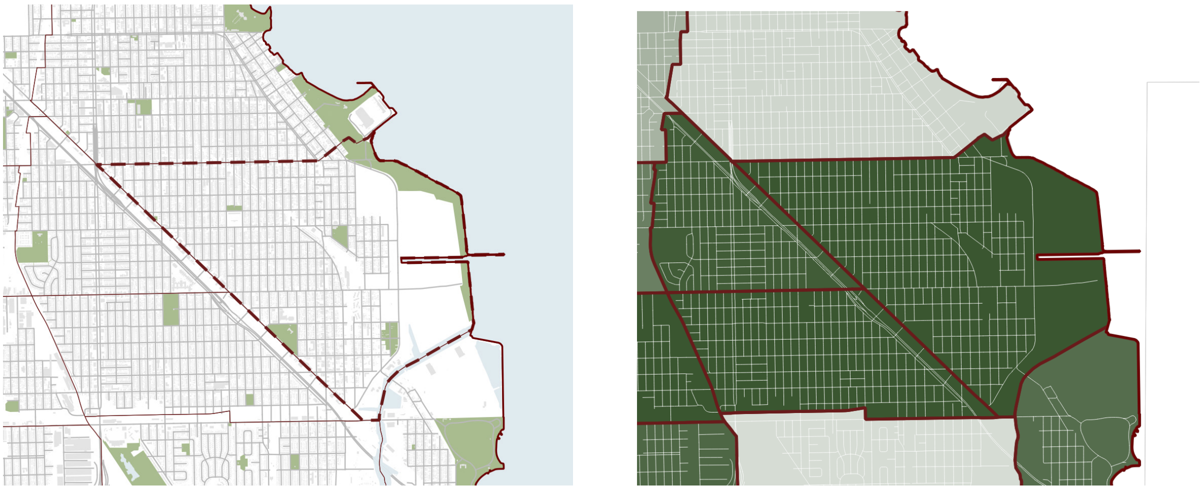
Map 32. UHI of 3 Selected CAs. Source: Author

Legends

- City of Chicago
- Blue Infrastructure
- High UHI
- Moderately-high UHI
- Moderately UHI
- Low-Mod UHI
- Low UHI
- City of Chicago
- Green Infrastructure
- Blue Infrastructure



Burnside: Burnside has concentrated areas of greater NDBI and a relatively low NDVI, which correlates with localized UHI hotspots, especially near industrial boundaries and built-up corridors.



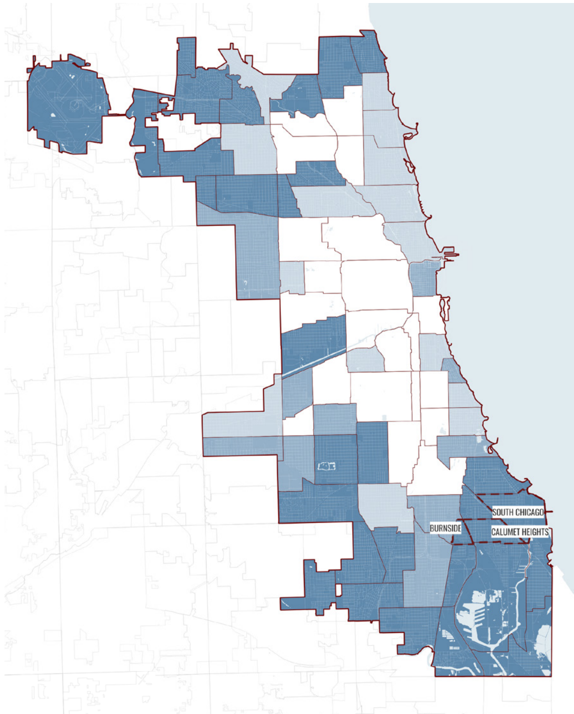
South Chicago: South Chicago exhibits more extensive and ongoing UHI exposure throughout the community due to its wider zones of moderate-to-high built-up intensity (NDBI) and uneven vegetation distribution. Heat concentrations are especially noticeable close to industrial and waterfront locations.

Calumet Heights: Surface temperatures in a number of residential zones are moderated by Calumet Heights' more widely dispersed green cover and relatively greater NDVI.

4.2.3. Heat Exposure Comparative Analysis

Across the three selected community areas, the access deficit maps reveal a spatially persistent pattern of mobility constraint rather than evenly distributed connectivity. Since everyday destinations, transit nodes, and mobility-supportive infrastructure are not fairly accessible in short trip times, a sizable component of each area is classified as having a moderate to high access deficit. The deficiency indicates structural gaps in network integration because it is not limited to the periphery but rather spans within residential blocks. Systemic mobility disadvantage is reinforced by the chosen areas' wider and more continuous zones of poor accessibility, which contrast with numerous North Side neighborhood areas where transit density, multimodal choices, and finer-grained connectedness typically reduce lengthy trip distances.

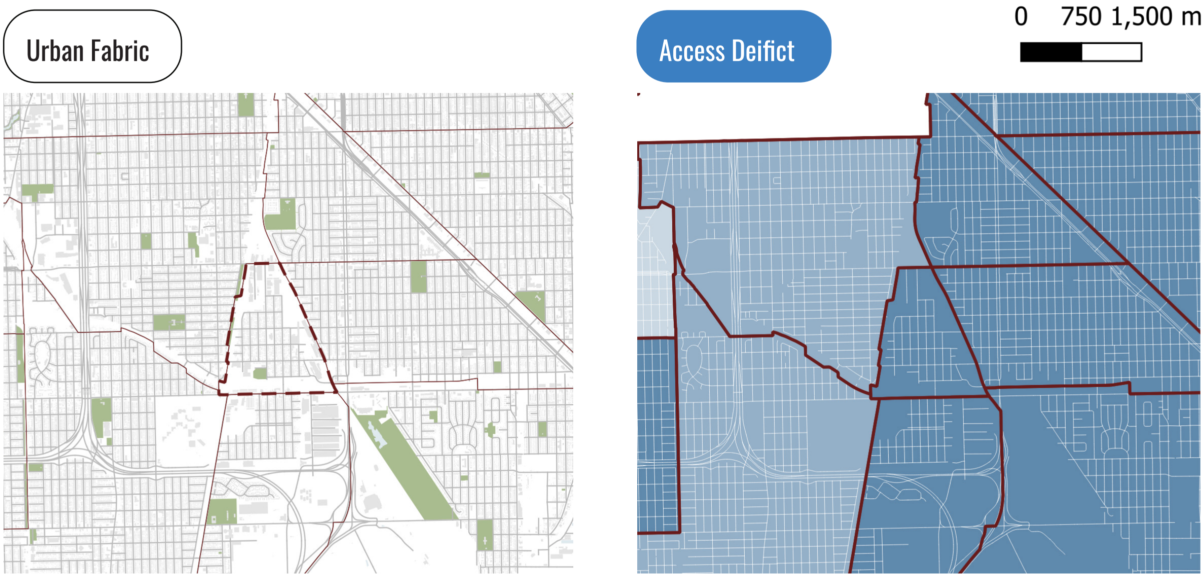
A more accurate interpretation posits that rather than equally distributed networks, access issues in these communities are linked to corridor-dependent mobility systems. Internal grids include longer walking distances, fewer modal options, and a greater reliance on bus corridors because connectivity seems to be concentrated over a few main routes. Because residents are forced to travel long distances without reliable microclimatic relief or multimodal redundancy, this arrangement increases pedestrian exposure during situations of intense heat. In contrast, northern neighborhoods often benefit from overlapping transit services, denser rail access, and shorter average block-to-destination distances, which diffuse mobility pressure. The **spatial continuity of access deficit in the selected areas therefore compounds both vulnerability and hazard**: limited network resilience reduces adaptive capacity, heightening the cumulative heat risk for residents who depend on active mobility for daily needs.



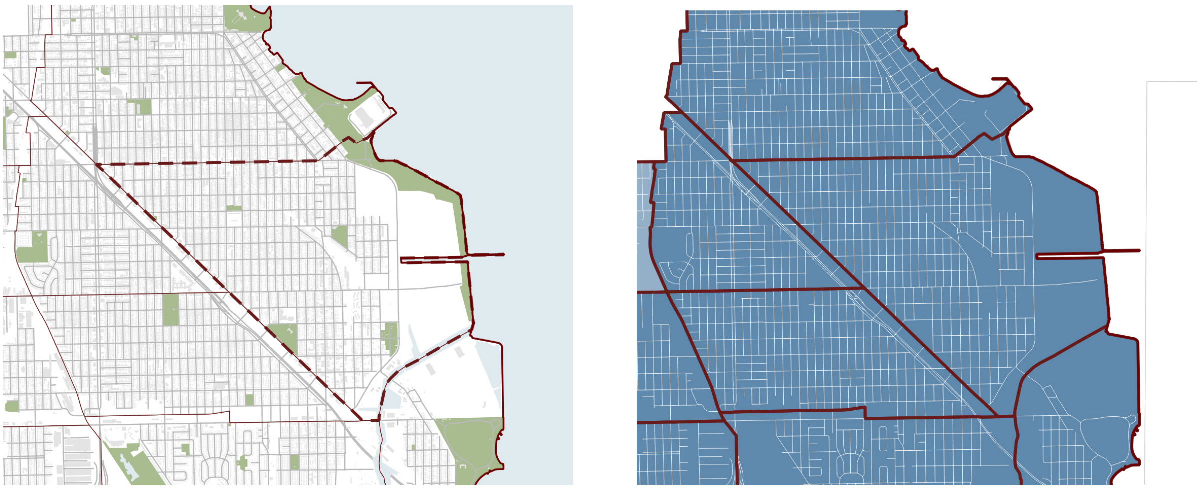
Map 33. Access deficit of 3 Selected CAs. Source: Author

Legends

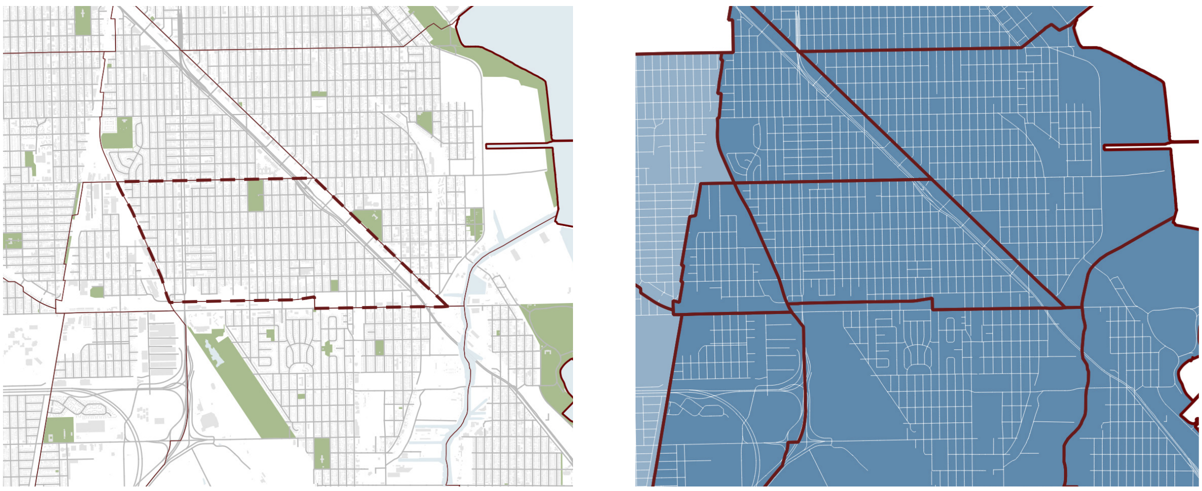
- City of Chicago
- Blue Infrastructure
- High Acess deficit
- Moderately-high Acess deficit
- Moderately Acess deficit
- Low-Mod Acess deficit
- Low Acess deficit
- City of Chicago
- Green Infrastructure
- Blue Infrastructure



Burnside: A limited mobility network shapes Burnside's exposure: transit service is focused along outer corridors, leaving the interior relatively underserved, while bike facilities and routes appear scant and irregular. Residents are more likely to have to endure longer, hotter walks to get to dependable transit during periods of excessive heat.



South Chicago: Major bus corridors provide better coverage in South Chicago, but active mobility assistance (bike racks and routes) is still dispersed and grouped, creating a "patchwork" of access rather than a seamless network.



Calumet Heights: Compared to the other two neighborhoods, Calumet Heights has a somewhat better baseline of daily connectedness due to its relatively wider isochrone reach and more readable street grid.

4.3. Vacancy as Spatial Opportunity

4.3.1. Introduction of the Toolkit

The Infrastructure for Transitions - Chicago Climate Adaptation Toolkit expands on previous studies that reframe vacancy as an active mechanism in the land transformation lifecycle rather than as an urban failure. This approach views unoccupied parcels as temporally flexible areas that can host temporary uses that create social, spatial, and economic value before long-term reconstruction, as opposed to perceiving them as static by-products of disinvestment.

This adaption places the transitional land-use logic in the context of the City of Chicago's unique socio-spatial, governance, and environmental circumstances. This toolbox places vacancy at the nexus of urban heat exposure, past redlining, fragmented mobility networks, and uneven municipal investment, which sets it apart from approaches that primarily concentrate on economic regeneration. In this situation, undeveloped property becomes both a possible source of short-term climate infrastructure for towns that are at risk and an economic asset in waiting.

Fundamentally, the toolkit suggests an impermanent, reversible, and modular system of interventions that can be used on parcels that are administered by land banks as well as those that are owned by municipalities. Intentionally lightweight and flexible, these interventions are made to work during times of regulatory change without sacrificing the possibility of future rebuilding. The technology converts unused space into climate-responsive infrastructure while preserving administrative viability by combining shade systems, cooling nodes, permeable surfaces, urban greening modules, and pedestrian-supportive features.

Crucially, the toolkit functions inside, as opposed to outside, the city's official land disposition and governance framework. It makes short-term activation a valid stage of the redevelopment cycle, enabling parcels to create community and environmental value in times of transition. By doing this, it reinterprets vacancy as a beneficial urban state that encourages experimentation, community stewardship, and spatial fairness.

The transitional land framework is advanced into a realm that is focused on mobility and climate risk by this Chicago adaption. The toolkit positions vacancy as a strategic platform for adaptive urban infrastructure by coordinating temporary land activation with pedestrian network resilience and heat mitigation. This allows for flexibility in responding to immediate environmental pressures while maintaining a coexistence with long-term planning goals.

4.3.2. Case of Impernence in Rust Belt cities

In the middle to late 20th century, the Midwest and Northeastern cities underwent significant deindustrialization, which resulted in the formation of the Rust Belt. With the fall of manufacturing and the globalization of production, industrial centers like Detroit, Cleveland, and Buffalo faced factory closures, job losses, suburban outmigration, and dwindling tax bases. Due to this economic restructuring, there are significant concentrations of undeveloped parcels because of the excess housing, unused industrial land, and fragmented property ownership that were left behind. As a result of deteriorating public services, weaker municipal capacity, and little investments in already vulnerable districts, vacancy has shifted from being a transient market occurrence to a structural state ingrained in post-industrial urban economies.

The South and West Sides of Chicago, whose industrial routes formerly supported local employment, exhibit many of the same characteristics as the Rust Belt. But the legacy of redlining and racialized planning, which routinely denied Black areas access to financing and investment, is also inextricably linked to Chicago's vacancy rate. Already shut out of capital flows, these communities were disproportionately vulnerable to long-term land disinvestment, foreclosure, and abandonment when deindustrialization took place. **The socioeconomic restructuring of the Rust Belt and the spatialized injustices created by historical redlining are thus reflected in Chicago's vacant lot topography.** Collectively, these dynamics have solidified unequal patterns of development that still influence the current concentration of vulnerability and emptiness.

Map 34. Rust belt. Source: Cato Institute

4.3.3. Governance Context and Land Banking

In Rust Belt cities, vacant property is frequently handled through land banking schemes, where lots are purchased to be stabilized, held, and subsequently transferred whenever market and policy conditions coincide rather than for immediate redevelopment. According to this theory, vacancy is a natural part of the land lifecycle rather than an exception. This issue is addressed by impermanent or transient use, which turns the holding period from idle downtime into a productive transitional phase. Between purchase and permanent transfer, modular, reversible interventions can create community and environmental value while maintaining flexibility for future redevelopment. Temporary activation thus reinforces rather than undermines the fundamental principles of land banking, which include managing uncertainty, stabilizing land, and preparing parcels for more equitable long-term usage.

Land banks are in a good administrative position to facilitate short-term use since they:

- **Allow for temporary activation without giving up long-term authority by maintaining centralized ownership and regulatory control.**
- **Oversee parcels that aren't yet ready for development so they can be used temporarily during holding periods.**
- **Can use low-commitment, reversible measures that don't interfere with future redevelopment ambitions to lessen maintenance loads and neighborhood risk.**

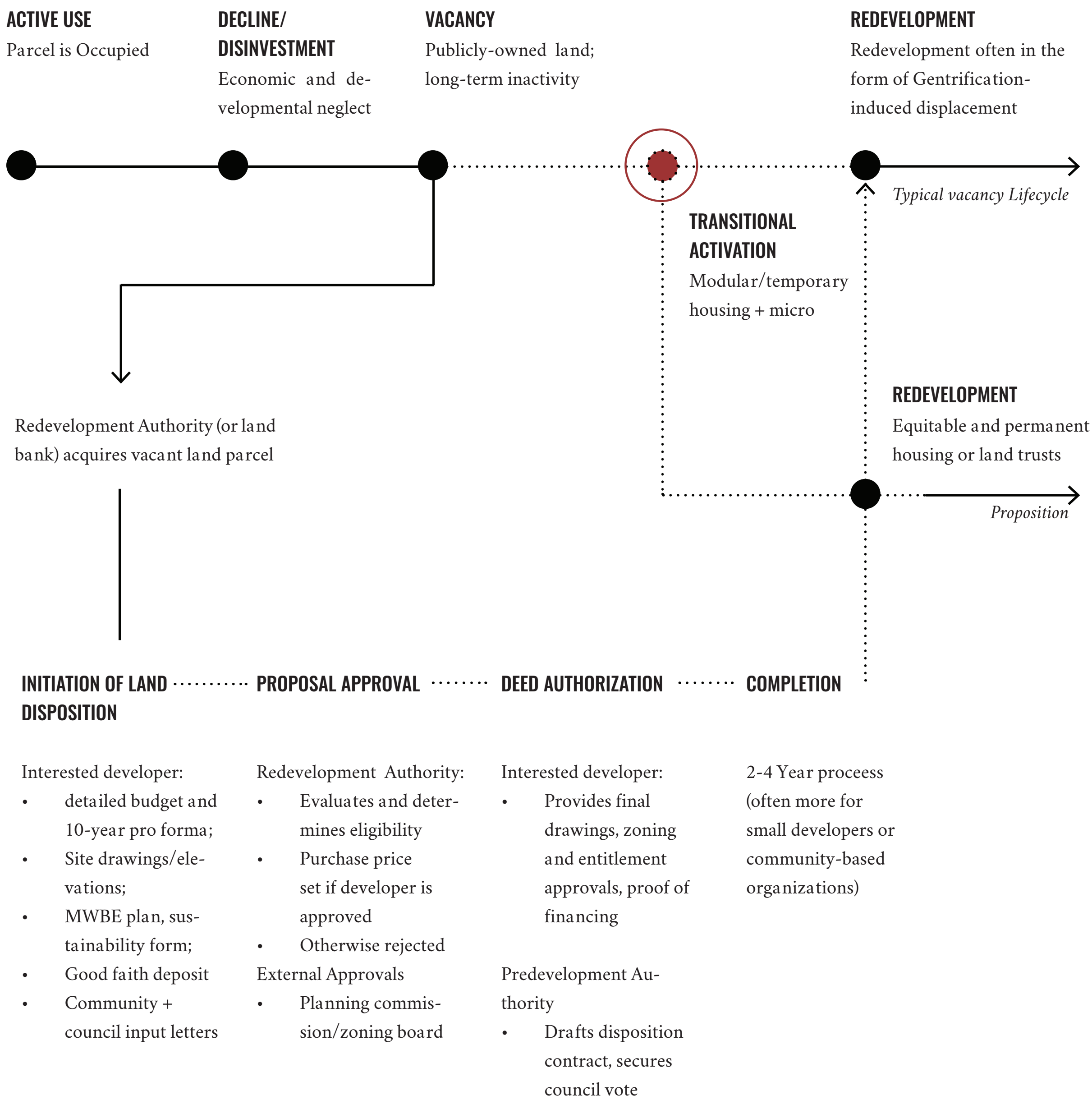


Figure 33. Working with the Land Banking System. Source: Lauren Jasper, adapted by the Author

4.3.4. Distribution of Vacant Lots in Chicago

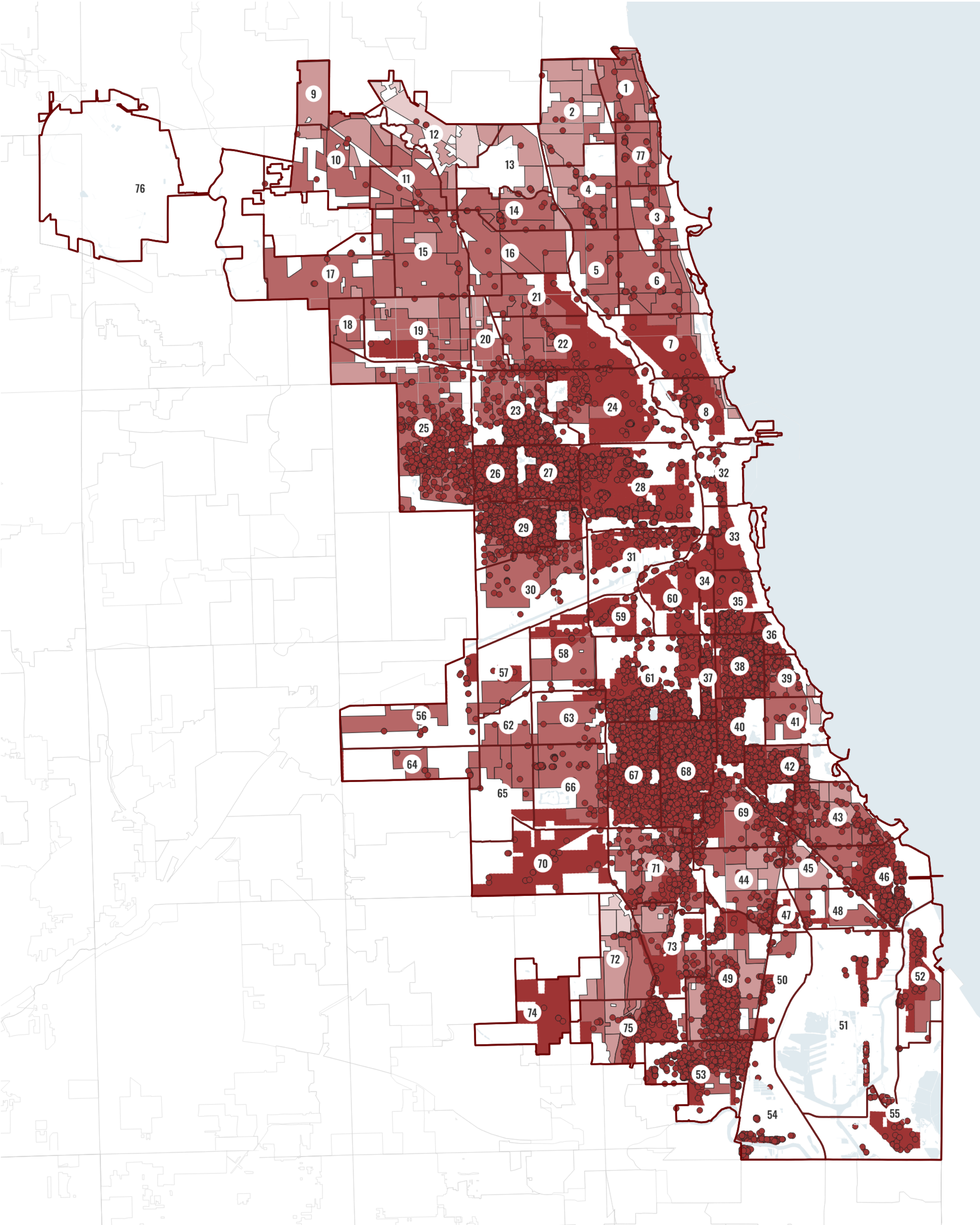
The City of Chicago's vacant lots **show a clear regional disparity in land use conditions around the city**. The figure illustrates that while there are **relatively few city-owned parcels in the North Side and lakefront districts, vacancies are concentrated in the South and West Sides.** Long-standing patterns of investment and neglect are reflected in this unequal distribution, whereby certain communities have amassed excess land as private markets withered and populations decreased. **The resulting landscape serves as an example of how past urban policy decisions have left a spatial legacy.**

These **vacancy clusters are not random; rather, they are the result of structural injustices ingrained in Chicago's urban growth**. Among the most impacted neighborhoods are Englewood, West Englewood, North Lawndale, Greater Grand Crossing, and Austin, which have historically been molded by redlining, discriminatory lending practices, racially restrictive covenants, and industrial failure. The **city purchased numerous parcels as properties were foreclosed upon or abandoned, resulting in vast areas of underutilized property that represent decades of systematic disinvestment.**

The livability of the neighborhood is directly impacted by the significant quantity of abandoned parcels. **Unmaintained lots frequently turn into locations for criminal activity, uncontrolled vegetation, or illegal dumping, creating a chaotic environment that undermines locals' sense of security and sense of community.** Residents find it more difficult to rely on social networks, community surveillance, and informal control-factors that usually support safer, more resilient neighborhoods as a result of the visual and physical fragmentation caused by vacancy, which reduces neighborhood cohesion.

Vulnerable communities are disproportionately impacted by the intersections of vacant lots with environmental and public health issues. The urban heat island effect is exacerbated in areas with high densities of vacant land since these areas often lack sufficient green infrastructure and tree canopy. In the South and West Sides, where inhabitants already experience higher rates of heat vulnerability, restricted access to cooling services, and increased exposure to long-term environmental stressors, this is particularly alarming. The buildup of undeveloped land is a contributing factor to climate-related inequality as well as a lost chance for cooling solutions.

Figure 34. Vacant lot in Englewood. Source: Google Map street view



Map 35. Vacant lots owned by the City and Redlined Map of Chicago. Source: Chicago Data Portal

Legends

- City of Chicago
- Community Areas
- Green Infrastructure
- Blue Infrastructure
- Vacant lots owned by the City
- D - Hazardous
- C - Definitely declining
- B - Still desirable
- A - Best

0 2.5 5 km

4.3.5. Presence of Vacant lots in the Community Areas

Vacant lots are a recurrent spatial condition in all 10 of the top-risk community areas, indicating a pattern of persistent disinvestment ingrained in communities that are already highly vulnerable and hazardous. These parcels are frequently found in clusters rather than at random, especially in places that were previously designated as "hazardous" on redlining maps. Their concentration is a symptom of long-standing structural injustices that have hindered infrastructure improvements, reinvestment, and property stability for decades in addition to physical abandonment.

The fact that vacancy clusters and formerly redlined neighborhoods coincide geographically emphasizes how vacancy is a tangible result of discriminatory lending and housing practices. Poorly graded areas in the early to mid-20th century faced decreased property values, capital withdrawal, and limited loan availability; these factors eventually combined to create cycles of unused land, destruction, and population decline. In this way, vacant lots are more than just empty areas; they represent the tangible remnants of past segregation and unequal urban growth, which now show themselves as increased social vulnerability and decreased adaptability.

The **hazard, exposure, and vulnerability components of the heat risk paradigm are all intersected by unoccupied lots.** They frequently correspond with socioeconomic instability and diminished local cohesion when viewed through the lens of vulnerability. Unmanaged or impermeable unoccupied lots might worsen localized heat accumulation from a danger perspective. The thermal experience of mobility is shaped by their frequent placement in residential corridors that are regularly traversed by people. As a result, vacancy becomes a sign of heat risk as well as a factor in it.

However, **these parcels offer important "opportunity spaces" precisely because they are underutilized.** Unused lots could be strategically transformed into bioswales, pocket parks, tree canopy corridors, green infrastructure, or shaded mobility hubs to improve walkability and thermal comfort while directly reducing land surface temperatures. Their dispersed presence in high-risk regions provides a decentralized network of possible micro-interventions that can lessen the severity of UHI and protect susceptible groups from excessive heat.

The **narrative changes from one of deficit to one of opportunity when emptiness is reframed as adaptive infrastructure rather than deterioration.** These parcels offer one of the most practical and scalable strategies for reducing spatial heat risk in communities that have historically been severely impacted by redlining and increased climate sensitivity. They have the **potential to change from being emblems of systemic injustice to tools of environmental justice and climate-responsive urban renewal** when incorporated into a larger resilience plan.

Community Area

Burnside
Although Burnside's vacant lots are somewhat scattered, there is a discernible concentration in the blocks in the west and south of the city, especially close to important crossroads and the edges of transitional industries. This pattern points to pockets of localized disinvestment buried within residential grids that are otherwise intact, resulting in fragmented urban fabric conditions that may be used as nodes for strategic interventions.

47
Vacant Lots

7,268.49 square feet ≈ 675.28 square meters
average size of ONE vacant lot

South Chicago
Particularly in the southeast and waterfront-adjacent areas, where sizable, continuous clusters are visible, South Chicago has the largest concentration and spatial saturation of undeveloped lands. Both environmental vulnerability and redevelopment opportunities at the district level are reinforced by the density and aggregation of vacancy here, which point to deeper structural deterioration and land-use shift.

624
Vacant Lots

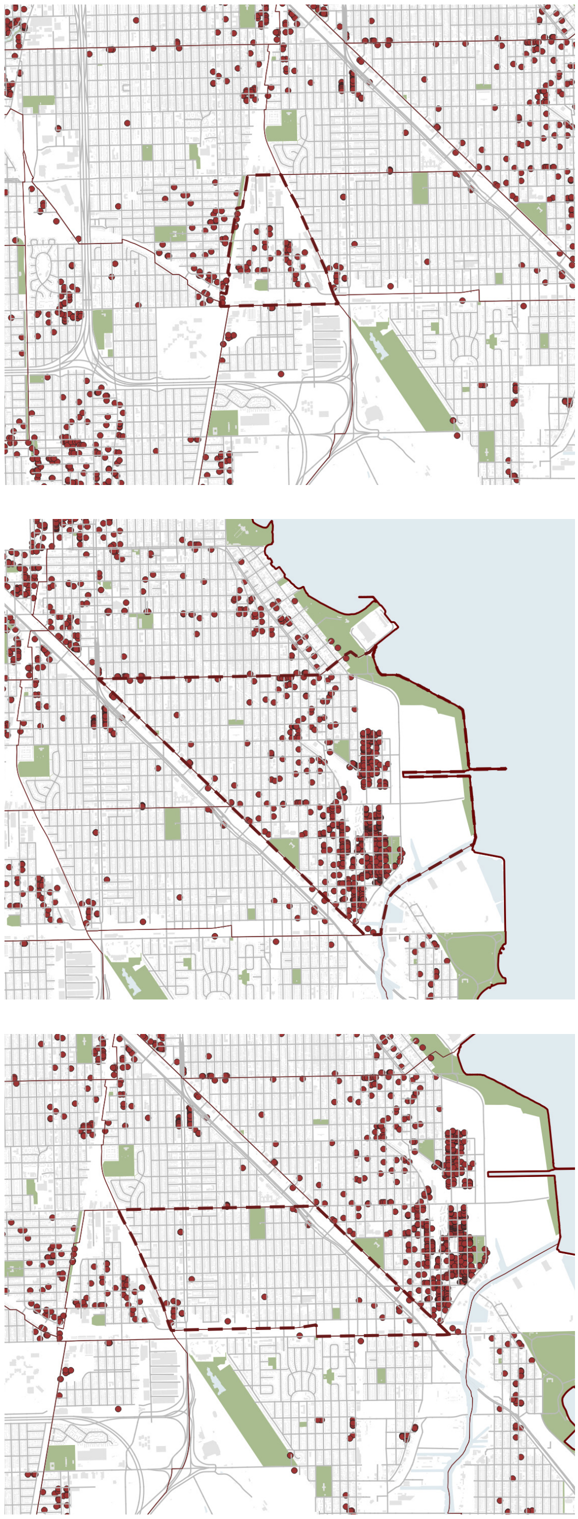
1,963.53 square feet ≈ 182.42 square meters
average size of ONE vacant lot

Calumet Heights
The northwest portion of Calumet Heights has a higher spatial concentration of vacant lots, creating dense clusters as opposed to uniformly spaced gaps. The clustering indicates specific areas of instability within an otherwise comparatively cohesive residential landscape, even though overall saturation is lower than in South Chicago.

31
Vacant Lots

3,715.46 square feet ≈ 345.18 square meters
average size of ONE vacant lot

Vacant Lots



Map 36. Presence of Vacant Lots of 3 Selected CAs. Source: Author

Legends
- City of Chicago
- Green Infrastructure
- Blue Infrastructure
- Vacant lots owned by the City

0 500 1,000 m

4.4. Package System

4.4.1. Overview of the System

The suggested method serves as the main framework for putting this theory into practice and provides a versatile way to activate unoccupied lots in Chicago's heat-vulnerable neighborhoods. It creates a kind of transitional infrastructure that functions during the holding phase of land banking or municipal ownership, as opposed to encouraging permanent or fixed development. Because of the framework's deliberate flexibility, it is possible to accommodate various parcels, community actors, and climatic circumstances without necessitating permanent construction or ownership transfers. By doing this, vacancy is no longer viewed as a static state of neglect but rather as an operational stage of the urban lifecycle.

Land availability, temporal governance, and the deployment of modular infrastructure are the three interdependent factors that are integrated into each activation package. Parcels can be temporarily designed to create social and environmental benefit through short-term agreements while long-term redevelopment is uncertain or ongoing. There is little site-specific adjustment needed because the technology is made to be scalable and reproducible over several empty locations. This makes it possible to deliberately implement transitional climate treatments inside pedestrian vulnerability and high heat exposure networks, strengthening spatial continuity as opposed to relying solely on site-based solutions.

Crucially, the framework does not mandate a specific building type or strict program. Rather, it creates an administratively feasible and consistent governance and design logic for arranging short-term climate-responsive usage. In order to provide iterative testing of heat mitigation measures without limiting future redevelopment pathways, the system prioritizes accessibility, experimentation, and reversibility over technical permanence. The focus is on developing flexible infrastructure that connects short-term environmental needs with long-term urban development in historically underinvested neighborhoods, rather than on architectural finality.

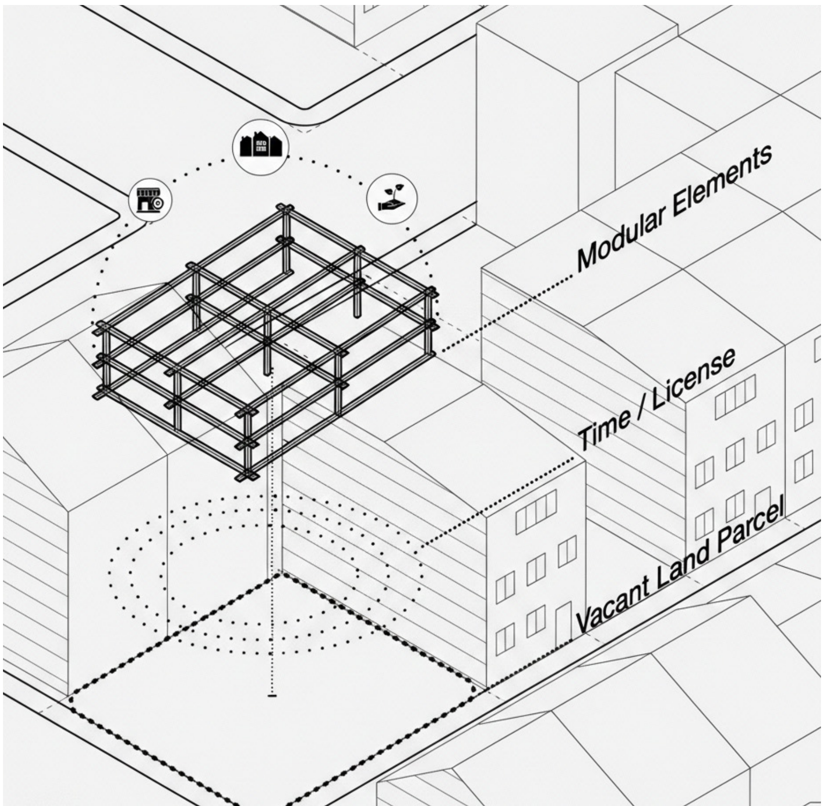
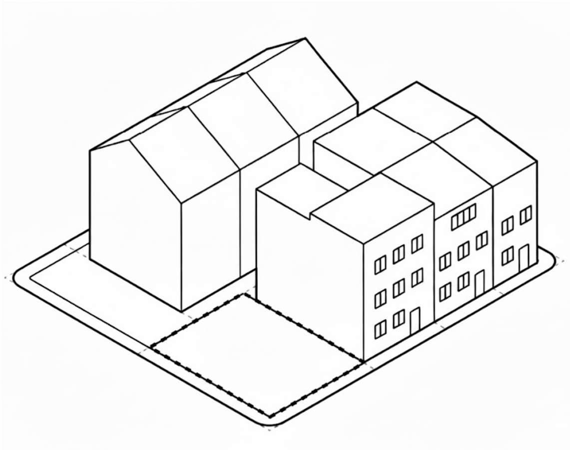


Figure 35. Package System. Source: Lauren Jasper, adapted by the Author

4.4.2. Components of the System

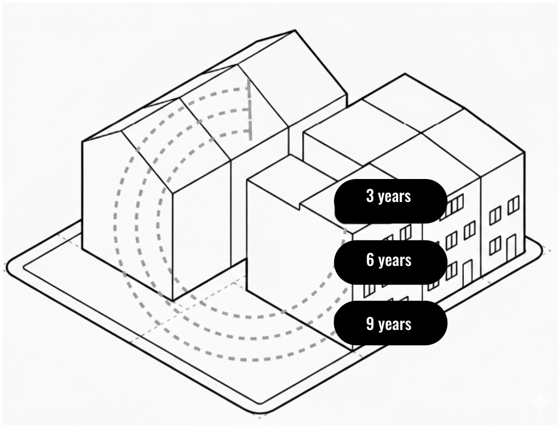


Land

The parcels designated for activation are those that are strategically situated within Chicago's high-heat, high-vulnerability zones and are reachable through temporary agreements with land bank authorities or municipal agencies.

Key Criteria:

- situated in areas with large overlaps for SVI and UHI
- accessible through short-term land bank or municipal control
- Not scheduled for immediate, long-term redevelopment
- Located near pedestrian walkways or areas with gaps in mobility

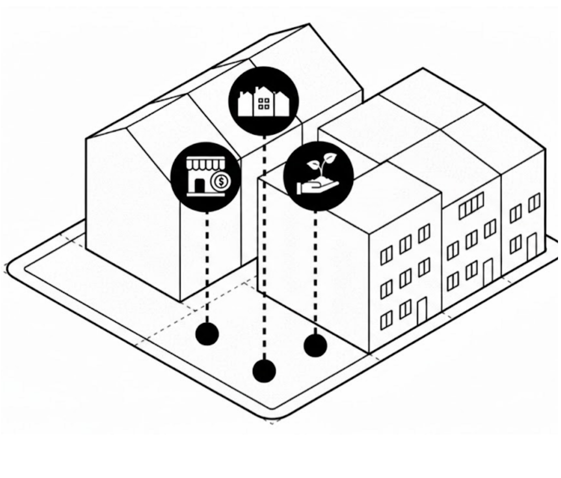


Time

Within the project, time serves as an adaptive governance tool. A strategic window for environmental testing, community involvement, and quantifiable heat reduction performance is created during the holding term of vacant land. The concept uses temporality to manage current climate risk while preserving flexibility for future land use transitions, as opposed to speeding up redevelopment.

Key principles:

- Short-term (seasonal) and multi-year activation are both possible.
- Duration associated with quantifiable impact on heat mitigation
- Extensions of agreements are possible provided performance is confirmed.
- Temporality connects short-term risk mitigation with long-term recovery.



Modular Activation System

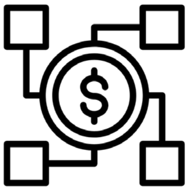
Lightweight and adaptable, these modules can be assembled, disassembled, and relocated without permanent structural alteration to the site. Interventions may include shade canopies, permeable cooling surfaces, greening units, water-mist systems, and pedestrian rest nodes integrated within urban networks

Core components:

- Infrastructure that is reversible, prefabricated, and modular
- Gradual implementation (one or more modules)
- Heat reduction and pedestrian assistance
- Adaptable to upcoming changes in redevelopment

Figure 36. Components of Package System. Source: Lauren Jasper, adapted by the Author

4.4.3. Logistics and Finance

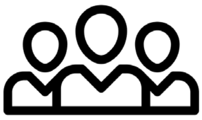


How is the Transitional Infrastructure System funded?
Large upfront capital investments or long-term land acquisition are not necessary for the system to function. The funding mechanism is incremental and hybrid, in line with the goals of local stabilization, environmental justice, and climate adaption. Because interventions are modular and reversible, they can be financed at small scales and expanded over time.

Key points:
- Federal, state, and local public funds for climate adaption
- Environmental justice and philanthropic grants
- Mission-driven small-scale finance, or CDFIs
- Limited income from interim programming that is compatible
- Model of incremental investment (scalable deployment)

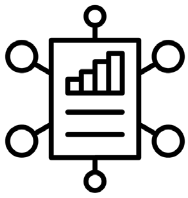
What incentives exist for public agencies and land banks?
By lowering holding costs, lowering risk, and enhancing neighborhood conditions without sacrificing redevelopment deadlines, transitional activation supports administration aims. Agencies can demonstrate quantifiable heat reduction results while retaining long-term planning authority by converting unoccupied parcels into climate-responsive assets.

Key points:
- Lower maintenance and security expenses
- Discourages illicit conduct and dumping
- enhances safety and neighborhood impression
- supports environmental justice and climate action initiatives.
- maintains the flexibility of future redevelopment



Who maintains activated parcels during the transitional phase?
In order to maintain long-term control and flexibility in redevelopment, ownership and regulatory authority remain with land bank institutions or municipal agencies. During the activation period, community organizations or appointed stewards are given operating and maintenance tasks under temporary activation agreements. This shared governance concept improves local engagement while lessening the load on municipalities.

Key points:
- The City or Land Bank retains ownership of the land.
- Daily operations are managed by temporary users.
- Well-defined maintenance contracts
- Infrastructure that is reversible prevents long-term burdens
- Accountability is strengthened by community stewardship.



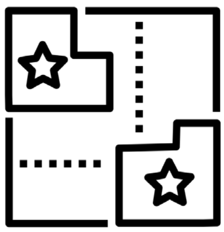
How does this align with zoning and regulatory frameworks?
The system is designed to function within current administrative tools for pilot projects, overlay provisions, or temporary use. The infrastructure reduces the need for intricate rezoning procedures because it is non-permanent and adaptable. Transitional use is not an exception to the redevelopment lifecycle, but rather a recognized step of it thanks to regulatory compatibility.

Key points:
- Compliant with provisions for temporary use
- Only minor zoning changes are needed.
- Designed as a pilot or demonstration project
- does not change the land's long-term classification
- acknowledges the vacancy as a period of transi-

4.4.4. Activation Process

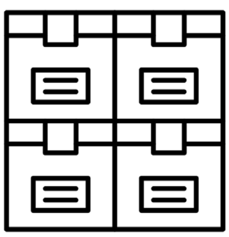
The Transitional Climate Infrastructure System is designed to make it easier to activate undeveloped land in Chicago's high-heat and high-vulnerability zones. The framework functions as a flexible governance and design guide that may adjust to different ownership arrangements, regulatory environments, and local priorities instead of dictating a strict procedural rulebook. Whether a parcel is owned by the municipality, administered by a land bank, or held under a temporary arrangement will affect how it is implemented, but the basic goal is always the same: to turn vacancy into a temporary platform for quantifiable heat mitigation and pedestrian support.

In the context of the transitional climate concept, the following is a tactical order for parcel activation.



Step 1: Identify Heat-Vulnerable and Eligible Parcels

The selection process gives preference to empty lots located in areas with high Urban Heat Island (UHI) intensity, high Social Vulnerability Index (SVI), and fragmented pedestrian networks. Administrative viability, redevelopment schedules, and ownership clarity are evaluated to make sure activation coincides with the holding stage of land governance.



Step 2: Define Activation Package

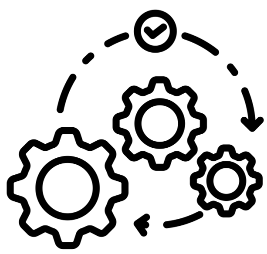
The duration of activation, module intensity, and location conditions are taken into consideration while choosing interventions. Cooling surfaces, rest nodes, greening modules, shade infrastructure, and water-mist systems are examples of programmatic components. The deployment's size and complexity match the intended time of use as well as the objectives for heat mitigation.

Step 3: Secure Temporary Use Agreement

Agreements for short-term activation are made with land bank officials or local organizations. Duration, maintenance obligations, liability limits, and exit requirements are all specified in agreements. Reversibility and maintaining long-term redevelopment flexibility continue to be prioritized.

Step 4: Deploy and Monitor Performance

Modular infrastructure is implemented gradually while its effects on the environment, space, and society are tracked. Surface temperature decrease, pedestrian dwell duration, user involvement, and maintenance effectiveness are a few examples of performance measures. Monitoring guarantees that activation continues to be responsive to community demands and climatic conditions.



Step 5: Transition, Scale, or Reintegrate

After the activation period ends, parcels may move toward long-term redevelopment, expand successful interventions, move modules to nearby locations, or remove installations without making structural changes. Instead of interfering with adaptive governance, the system is made to function smoothly throughout the vacancy lifecycle.

4.5. Meta-projects Framework for Heat Mitigation

4.5.1. Urban Heat Management Framework by World Bank

The catalog groups solutions into three complementary categories: Assess, Plan, and Respond in order to conform to the Handbook's more general guidelines.

Assess

This category focuses on analytical techniques and tools that help cities determine exposure levels, identify populations and regions most at risk, and comprehend the spatial distribution of urban heat. Assessment facilitates well-informed decision-making and intervention prioritization by building a solid evidence base.

Plan

The focus of planning solutions is on long-term, structural measures that incorporate heat adaptation and mitigation into infrastructure development, land-use planning, and urban regulations. By taking these steps, the urban environment's systemic resilience will be strengthened and future heat risks will be lessened.

Respond

Response solutions deal with short-term and immediate measures intended to safeguard public health during high heat events, especially heatwaves. In order to avoid heat-related disease and mortality, these strategies place a high priority on quick deployment, emergency preparedness, and focused assistance for vulnerable populations.

Scale

City: Interventions applied at a citywide level, spanning multiple neighborhoods and locations.

Neighborhood and community: Interventions implemented at an intermediate scale, concentrating on a specific neighborhood or community area.

Site and Household: Interventions applied at a localized scale, targeting an individual site, building, or household.

Ease of Implementation

Hard: Interventions that demand extensive resources and coordination and are typically complex to execute, often requiring long-term commitment (e.g., large-scale transit-oriented development).

Medium: Interventions that require considerable resources and planning effort and may pose implementation challenges over a moderate timeframe (e.g., early warning systems).

Easy: Interventions that involve minimal resources and can be deployed quickly and with relative ease (e.g., public awareness initiatives).

Benefits

People (health and equality): Interventions that positively affect public health, well-being, and social equity among residents, visitors, and workers.

Economy (productivity and livelihoods): Interventions that contribute to economic performance, employment, and income generation.

Infrastructure: Interventions that enhance the functionality, resilience, or provision of urban infrastructure systems.

Environment: Interventions that support environmental quality and strengthen natural and ecological systems.

Type of Solutions

Governance, policy, and plans: Interventions that address regulatory frameworks, planning instruments, and institutional arrangements.

Capacity development and behavior change: Interventions aimed at building skills, awareness, and behavioral shifts among individuals and institutions.

Data and technology: Interventions that leverage digital tools, data systems, or smart technologies.

Infrastructure (gray, green and blue): Interventions focused on physical investments, including built infrastructure (gray), nature-based solutions (green), and water-related systems (blue).

Level of Evidence

Pilots: Innovative or emerging interventions with limited to moderate empirical backing that have demonstrated early effectiveness and adaptability across contexts, indicating potential for broader application.

Established practices: Interventions that have been extensively tested and validated, supported by robust scientific or empirical evidence.

Figure 37. Catalogue of 25 solutions for urban heat resilience. Source: World bank handbook

01 Establishing an Early Warning System

Description
Urban heat early warning systems (EWS) are data-driven instruments that forecast, track, and disseminate times of increased heat risk, particularly during heatwaves. To evaluate heat intensity and predict possible health effects, they integrate meteorological data, satellite photography, and local environmental information. These tools assist in determining when and where threats are most serious by converting climatic data into useful knowledge. In order to safeguard vulnerable people, the outputs encourage prompt public actions including the opening of cooling centers, the issuance of heat alerts, and the dissemination of heat safety guidelines.

Scale
City

Type of Action
Data and technology

Ease of Implementation
Medium

Level of Evidence
Established practices

Suitability
This strategy works best in densely populated urban areas with substantial infrastructure, high levels of air pollution, and sizable susceptible populations, such as low-income inhabitants, older adults, and those with pre-existing medical issues. It is especially important in metropolitan areas where heat-related dangers are increasing as a result of urbanization, climate change, and more frequent or severe heatwaves. Health organizations, emergency services, and urban planners use the system to direct focused heat-response operations and service delivery, while local governments usually oversee implementation.

02 Data-driven assessment of urban heat risks

Description
Heat risk assessments can function as standalone tools or as part of an early warning system, using qualitative, data-driven, or combined approaches depending on local capacity and context. Data-driven assessments rely on geospatial methods, satellite imagery, GIS, and environmental data to map heat exposure, vulnerability, and high-risk populations. By integrating socioeconomic, infrastructure, and demographic information, these assessments support targeted heat action plans, guide urban development decisions, and strengthen emergency response strategies.

Scale
City

Type of Action
Data and technology

Ease of Implementation
Hard

Level of Evidence
Pilot project

Suitability
This approach is most suitable for cities with strong data and planning infrastructure, including weather monitoring, satellite data, and urban planning capacity, where heat exposure varies significantly across neighborhoods. It is particularly relevant in dense urban areas experiencing increasingly frequent and intense heatwaves, often intensified by the urban heat island effect and compounded by limited green space in disadvantaged communities. Local governments, urban planners, environmental agencies, public health organizations, and emergency services are the primary users, applying the insights to guide climate adaptation and heat mitigation strategies.

03 Participatory assessment of urban heat risks

Description
Heat risk assessments can operate independently or as part of an early warning system, using qualitative, data-driven, or combined approaches depending on local capacity. A participatory approach emphasizes community knowledge and lived experience, making it especially valuable in data-poor or underserved urban environments. Through methods such as participatory mapping, interviews, focus groups, and citizen-led data collection, this approach identifies localized heat risks, service gaps, and coping strategies while strengthening community resilience.

Scale
Neighborhood and community

Type of Action
Data and technology

Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
This solution is most appropriate for small cities, towns, or underserved neighborhoods within large urban areas where access to advanced data, cooling infrastructure, and public health resources is limited. It is particularly relevant in contexts experiencing rising temperatures and frequent heatwaves intensified by the urban heat island effect, with heightened health risks for low-income and marginalized communities. Primary users include residents of informal or vulnerable settlements, local governments, health organizations, urban planners, NGOs, and community groups working to reduce heat-related impacts.

04 Heat risk awareness campaign

Description
Heat awareness campaigns work best when they are launched prior to the hot season and can be used separately or in conjunction with an early warning system. They concentrate on teaching locals about the dangers of heat, how to avoid it, and useful cooling techniques like drinking plenty of water, finding shade, and using less energy. These efforts increase community resilience, lessen the strain on urban infrastructure during heatwaves, and lessen the negative effects of heat on health.

Scale
City

Type of Action
Capacity development and behavior change, Data and technology
Ease of Implementation
Easy

Level of Evidence
Established practies

Suitability
This strategy works effectively in crowded metropolitan areas where excessive heat creates major health hazards and many are still unaware of the effects of climate change, especially in neighborhoods or informal settlements with no access to cooling facilities. It works best in areas with high rates of heat-related sickness and mortality and frequent heatwaves, where it is crucial to schedule awareness campaigns around seasonal climate trends. In order to target susceptible groups and implement heat-awareness efforts, city governments, employers of outdoor workers, NGOs, community-based organizations, and public health agencies often take the lead in implementation.

05 Urban ventilation corridors

Description
By directing natural airflow through crowded urban areas, dispersing heat, and enhancing microclimates, urban ventilation corridors lower urban heat. They are usually in line with natural elements like rivers, transportation corridors, prevailing winds, and interconnected green areas, all of which improve cooling through evapotranspiration, shade, and ventilation. In order to prevent airflow obstruction, their efficacy depends on the careful regulation of surrounding development through the use of controls such setbacks, height limits, and limitations on huge podium constructions.

Scale
City

Type of Action
Governance, policy, and plans, Infrastructure (gray)
Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
This approach works well in densely populated or quickly expanding metropolitan regions where the urban heat island effect is exacerbated by heat retention and inadequate air circulation. In hot areas with little natural ventilation, seasonal heatwaves, or flood-prone circumstances, where ventilation corridors can also support green and blue infrastructure, this is especially important. Architects, developers, and community stakeholders participate in design, regulation, and feedback, while city governments and urban planners usually oversee implementation.

06 Urban heat design guidelines and regulations

Description
For planning, building, and development procedures to incorporate heat-resilient methods, urban heat design rules and regulations are crucial. To lessen heat absorption and improve natural cooling, they support strategies including the use of reflecting materials, the incorporation of vegetation, and climate-responsive building design. These recommendations strengthen long-term urban resilience, reduce emissions, and enhance thermal comfort by promoting energy efficiency, green infrastructure, and locally relevant behaviors.

Scale
City

Type of Action
Governance, policy, and plans

Ease of Implementation
Medium

Level of Evidence
Established practies

Suitability
This strategy works best in densely populated areas that are rapidly expanding or regenerating and where the risks associated with the urban heat island effect are growing. It is especially pertinent to cities that experience extended high temperatures as a result of climate change, including desert areas that gain from green and blue infrastructure to improve water efficiency and cooling. Planners, architects, and developers use the standards to design structures and urban areas that lower heat exposure and increase resistance; city governments usually take the lead in implementation.

07 Upgrading water supply networks

Description
In addition to enhancing public health, sanitation, and access to clean water particularly for vulnerable communities upgrading water supply networks helps lessen the effects of urban heat. Expanding and renovating infrastructure, lowering water loss through monitoring systems, boosting the supply of potable water, and incorporating storage, wastewater reuse, and rainwater harvesting are some examples of significant advances. These improvements promote cooling during heatwaves, enable green infrastructure, and enhance overall urban resilience when they are planned holistically and integrated with other infrastructure projects.

Scale
Neighborood and community

Type of Action
Infrastructure (gray)

Ease of Implementation
Hard

Level of Evidence
Pilot Project

Suitability
Cities with old or quickly expanding water infrastructure that has to be expanded or rehabilitated especially to reach underserved or informal areas are most suited for this approach. It is particularly important in hot areas with little rainfall or seasonal fluctuations, where consistent access to water promotes resilience, health, and cooling during heatwaves. In order to increase access, boost efficiency, and include regional water management techniques, implementation is usually spearheaded by city governments and utilities with assistance from business partners and neighborhood associations.

08 Blue infrastructure

Description
In addition to supporting more general water management objectives, blue infrastructure which includes ponds, rivers, wetlands, and water retention systems offers an efficient method of controlling urban heat. These characteristics create localized cooling zones that can greatly enhance thermal comfort in crowded metropolitan settings by lowering surrounding air temperatures through convection and evaporative cooling. Blue infrastructure also improves enjoyment, public space quality, and long-term urban resilience when properly maintained and shaded.

Scale
Neighborhood and community

Type of Action
Infrastructure (gray)

Ease of Implementation
Hard

Level of Evidence
Established practies

Suitability
This strategy works effectively in densely populated areas with little green space and rising interest in large-scale sustainable practices, especially in places where waterfronts are significant urban features. It is particularly important in areas that need efficient stormwater and flood management due to high temperatures, little rainfall, or significant seasonal change. At the city level, local governments are usually in charge of implementation, with smaller projects incorporated within residential, commercial, or mixed-use developments providing support from private players and community organizations.

09 Public water features

Description
By offering targeted cooling, boosting thermal comfort, and increasing the standard of public areas, public water features contribute to the reduction of urban heat. They are useful instruments for both urban livability and climate adaptation since they promote social engagement and communal well-being.

Scale
Neighborhood and community

Type of Action
Infrastructure (gray)

Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
Dense metropolitan locations with high urban heat island intensity and little green infrastructure, such as expanding or redeveloping neighborhoods and waterfront districts, are best suited for this strategy. Because evaporative cooling and stormwater management can lessen heat stress, it works especially well in areas with high temperatures, frequent heatwaves, or erratic rainfall. In order to increase thermal comfort and urban resilience, public water features are usually implemented under the direction of local governments, with participation from developers and community organizations.

10 Green space and tree planting

Description
Increasing the number of urban trees and green areas is a very efficient way to reduce urban heat through evapotranspiration and shade, especially in crowded, busy areas. A multifunctional climate adaptation strategy, strategically placed vegetation also enhances air quality, lowers stormwater runoff, and promotes physical and mental well-being. Long-term resilience, biodiversity support, and sustainable cooling effects are ensured by using native and climate-adapted plant species along streets and in public areas.

Scale
Neighborhood and community

Type of Action
Infrastructure (gray)

Ease of Implementation
Easy

Level of Evidence
Established practies

Suitability
This approach works best in crowded urban settings with plenty of concrete and asphalt, especially when there is little open space and a lot of pedestrian activity. It works effectively in hot and temperate areas by lowering ambient temperatures; in arid environments, drought-resistant plants and effective irrigation are particularly crucial. Urban centers and high-density neighborhoods with restricted access to natural areas are the main users and beneficiaries.

11 Cool roads and pavements

Description
By substituting reflective or permeable materials that minimize heat absorption and improve cooling for conventional asphalt and concrete, cool roads and pavements lower urban heat. While porous materials permit water infiltration and evaporative cooling, which lowers surface and ambient temperatures, high-albedo surfaces reflect solar energy. Beyond streets, these interventions can be used in parking lots, walkways, plazas, and sports fields to enhance pedestrian and surrounding building thermal comfort.

Scale
Neighborood and community

Type of Action
Infrastructure intervention (gray, green, or blue)

Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
This strategy works well in low-density cities with little traffic from cars and pedestrians. Permeable pavements are especially appropriate in regions with heavy rainfall, but high-albedo materials work well in most climates. City or local governments usually oversee implementation through public works initiatives or specifications found in contracts for the construction of roads and pavements.

12 Providing shade in public spaces

Description
Particularly in hot and muggy cities, offering shade in public areas is an affordable, passive way to lower urban heat, safeguard public health, and preserve economic productivity. While maintaining balanced solar exposure for daylight and seasonal warmth, shade enhances thermal comfort, lessens the urban heat island effect, and reduces heat exposure for outdoor workers and pedestrians. Trees, canopies, shelters, vertical shade, and solar-integrated buildings are effective options; these should ideally be customized utilizing indigenous and local methods to fit the urban environment and climate of the city.

Scale
Neighborhood and community

Type of Action
Infrastructure intervention (gray, green, or blue)

Ease of Implementation
Medium

Level of Evidence
Established practies

Suitability
This strategy works best in urban areas including informal settlements where there is little tree cover and a lot of foot traffic. By lowering temperatures, minimizing direct sun exposure, and enabling changeable shading to balance light and comfort, it works well in a variety of climates. Improved pedestrian safety, less heat stress for outdoor workers, and more useful and appealing public areas are the main advantages.

13 Resources efficiency measures

Description

By reducing the internal and external heat loads in buildings, energy efficiency methods lower ambient temperatures and waste heat. Reflective roofs, high-performance insulation, energy-efficient windows, and optimum ventilation are examples of strategies that lower cooling demand, relieve the strain on power systems, and minimize emissions during periods of extreme heat. These strategies enhance interior comfort and support more comprehensive urban cooling and climate resilience when paired with passive cooling.

Scale

Site and household

Type of Action

Data and technology, Infrastructure (gray)

Ease of Implementation

Medium

Level of Evidence

Pilot Project

Suitability

This strategy works best in densely populated places where energy-intensive cooling causes heat buildup and puts stress on power lines, especially during peak hours. It is particularly important in hot climes and areas that frequently experience heatwaves or water scarcity, as effective systems may lower interior temperatures while consuming fewer resources. In order to increase comfort and resilience, developers, companies, and families usually employ energy-efficient practices, which are implemented by city governments through construction codes and incentives.

14 High-performance building envelopes

Description

By restricting heat absorption from walls and roofs, high-performance building envelopes assist prevent heat buildup, especially in areas where heat-trapping materials are prevalent. Thermal comfort is enhanced in all climates by cool roofs, reflecting surfaces, and other low-carbon materials that lower interior temperatures and lessen the need for air conditioning. Additionally, by lowering emissions, lowering energy costs, and promoting better interior conditions, these tactics improve urban resistance to rising temperatures overall.

Scale

Site and household

Type of Action

Infrastructure (green)

Ease of Implementation

Medium

Level of Evidence

Pilot Project

Suitability

This method works effectively in densely populated areas where the urban heat island effect is exacerbated by building heat retention. It works in all temperatures, but it is especially useful in areas where typical building materials retain heat. Households looking to minimize energy expenses and lower indoor temperatures are the main beneficiaries.

15 Indoor cooling measures

Description
Indoor cooling techniques, which fall into two categories passive and active are essential for controlling urban heat. While active cooling employs mechanical systems like fans and air conditioning to reduce interior temperatures, passive cooling concentrates on building design elements like insulation, ventilation, reflective surfaces, and shading to increase comfort without using a lot of energy. By increasing the effectiveness of active systems and implementing district cooling, waste heat and energy consumption can be decreased, which will lessen their impact on the urban heat island effect.

Scale
Site and household

Type of Action
Data and technology, infrastructure (gray)

Ease of Implementation
Easy

Level of Evidence
Pilot Project

Suitability
This approach works best in crowded cities with little open space, because protecting vulnerable populations like children and the elderly depends on lowering indoor temperatures. It is especially crucial in areas where severe heat waves are occurring, as energy-efficient active cooling can offer crucial relief without raising outside temperatures. Access to reliable, reasonably priced electricity is essential for successful implementation, and local governments must assist adoption in low-income and informal areas.

16 Natural ventilation in buildings

Description
Natural ventilation is a cost-effective and sustainable strategy for reducing indoor heat by improving airflow through building design rather than relying on mechanical cooling. It uses pressure differences and buoyancy effects to circulate fresh air, lowering temperatures, improving air quality, and reducing energy use and waste heat. Common methods include single-sided, cross, stack, and chimney ventilation, each suited to different building layouts and climatic conditions.

Scale
Site and household

Type of Action
Infrastructure intervention (green)

Ease of Implementation
Easy

Level of Evidence
Established practies

Suitability
Dense urban environments that mostly rely on mechanical cooling are a good fit for this approach, especially high-rise structures where better ventilation can lessen heat accumulation. It works best in hot climates when natural ventilation may either replace or lessen energy-intensive cooling. Lower indoor temperatures and better indoor air quality in both residential and commercial buildings are the main advantages.

17 Facade screening and external shading elements

Description
By preventing direct solar radiation from reaching building surfaces, façade screening and external shade components lower surface and interior temperatures, hence reducing urban heat. Overhangs, louvers, brise-soleil, perforated screens, and green façades are examples of features that increase thermal comfort while lowering the need for air conditioning and the energy it uses. These components also improve architectural aesthetics, support sustainability objectives, and lessen localized heat buildup in densely populated places when they are designed with the local climate and materials in mind.

Scale
Site and household

Type of Action
Infrastructure (green)

Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
Buildings with high solar exposure are most suited for this solution, especially in crowded cities that want to encourage energy-efficient and climate-responsive architecture. It works particularly well in hot, dry, tropical, or heat-wave-prone regions where lowering solar heat gain can drastically reduce the need for cooling. In order to increase comfort and save energy costs, implementation is usually spearheaded by architects and developers, backed by municipal laws, and embraced by building owners.

18 Cool roofs

Description
By reflecting solar radiation, lowering indoor and roof surface temperatures, and minimizing contributions to the urban heat island effect, cool roofs are an efficient way to reduce urban heat. Reflective coatings, which offer energy savings, enhanced comfort, and comparatively quick payback periods, can be applied to both new and existing structures. Cool roofs are particularly useful in crowded or informal metropolitan settings where inexpensive cooling solutions are required. They can be integrated with solar technologies and are appropriate for the majority of climates and building types.

Scale
Site and household

Type of Action
Infrastructure (green)

Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
This method can be incorporated into construction rules and urban planning policies, and it works well in urban settings with large roof surfaces, such as informal settlements. It works best in warm and temperate climes, where it saves a lot of energy in hot weather and may be used in a variety of settings. Low-income homes, businesses, and public buildings stand to gain the most from cool roofs since they enhance thermal comfort, lessen heat stress, and save energy expenses.

19 Urban agriculture

Description
By boosting evapotranspiration, enhancing air quality, and controlling stormwater runoff, urban agriculture which includes community gardens, rooftop farms, and vertical systems helps reduce urban heat. Additionally, these areas promote social cohesion, create jobs, and increase food security, especially in low-income and unofficial neighborhoods. Urban agriculture is a sustainable land-use approach that helps cities cool and adapt to climate change while strengthening environmental resilience.

Scale
Site and household

Type of Action
Capacity development and behavior change, infrastructure (green)
Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
Dense cities with little green area and significant urban heat island effects are ideal for this technique. In hot, dry, or flood-prone areas, where cooling and water absorption offer extra advantages, it works especially well. Governments can lead implementation at the municipal and neighborhood levels through funding and policies, while citizens can take the lead through home and community gardens.

20 Integration of green infrastructure into buildings

Description
Through vegetation-driven shade and evapotranspiration, green walls and roofs effectively reduce surface and ambient temperatures. They can improve stormwater management, air quality, and building energy performance while also greatly reducing the effects of urban heat islands when implemented on a large scale. By lowering energy costs, cutting greenhouse gas emissions, and improving overall urban sustainability and resilience, these technologies provide extra advantages.

Scale
Site and household

Type of Action
Infrastructure intervention (green)

Ease of Implementation
Hard

Level of Evidence
Pilot project

Suitability
Dense urban settings with high-rise structures and little ground-level green space are best suited for this strategy. Public buildings can act as pilot projects to increase awareness, and it works especially well in warmer regions where mitigating the urban heat island effect is a top issue. In order to increase urban livability, the private sector and public institutions are driving implementation, including green infrastructure into both new and existing structures.

21 Integration of water feature within buildings

Description
By utilizing evaporative cooling to lower ambient air temperatures and enhance thermal comfort, incorporating water elements into buildings contributes to the reduction of urban heat. By regulating microclimates and lowering heat absorption on building surfaces, these systems also lessen the need for energy-intensive cooling. In addition to providing cooling, water features improve both indoor and outdoor spaces by lowering stress levels, enhancing air quality, and making densely populated regions more resilient and comfortable.

Scale
Site and household

Type of Action
Infrastructure (gray and blue)

Ease of Implementation
Medium

Level of Evidence
Pilot Project

Suitability
High-density urban structures with few external cooling choices, such as mixed-use, commercial, and residential projects, are a good fit for this approach. It works very well in hot, dry conditions, and when water features are carefully planned to prevent too much wetness, it can even help humid areas. To increase internal comfort and sustainability, implementation is usually spearheaded by architects and developers, backed by city incentives and legislation, and embraced by building owners.

22 Protective interventions during heatwaves

Description
Protective interventions during heatwaves reduce health risks by limiting exposure to extreme temperatures, particularly for outdoor workers and vulnerable populations. Measures such as shifting work hours, restricting outdoor activity during peak heat, closing schools, and encouraging indoor cooling help prevent heat-related illnesses. These actions also reduce peak energy demand and waste heat from cooling systems, indirectly lowering urban heat island impacts in dense cities.

Scale
City

Type of Action
Governance, policy and plans, Capacity development and behavior change

Ease of Implementation
Medium

Level of Evidence
Established practices

Suitability
This strategy works best in densely populated cities that frequently experience heatwaves, particularly in situations where vulnerable populations and informal settlements have little ability to adapt. Due to dense built environments and little natural cooling, it is especially pertinent in areas that experience prolonged high temperatures and strong urban heat island effects. Public awareness campaigns that promote adaptive behavior during extreme heat events support the implementation, which is spearheaded at the city level through policy enforcement and collaboration with businesses and communities.

23 Issuing heat warnings

Description
By facilitating early, preventive action, heat alerts are an essential response tool that helps safeguard cities during periods of high heat. As part of early warning systems, they are usually provided by national or local authorities and disseminated via a variety of media in plain, understandable language. In order to reach susceptible groups and direct preventative activity prior to heat impacts, effective heat warnings depend on coordinated dissemination and standardized protocols, like the Common Alerting Protocol.

Scale
Site and household

Type of Action
Capacity development and behavior change

Ease of Implementation
Easy

Level of Evidence
Pilot Project

Suitability
This solution can be implemented by any city with access to weather data and communication networks, using multiple channels such as SMS, broadcast media, and digital platforms. It is effective in both warm and temperate climates, provided warning accuracy and service quality are reliable. Successful implementation depends on coordination among authorities, weather services, emergency agencies, and telecommunications providers, as well as public education on how to respond to alerts.

24 Setting up heatb relief/cooling centers

Description

By providing air-conditioned places, cooling centers offer vital protection from excessive heat, particularly in urban areas where access to home cooling is scarce. In addition to lessening the strain on medical institutions during heatwaves, they are intended to assist vulnerable populations like outdoor laborers, low-income residents, older persons, and people with medical concerns. Cooling centers protect health, sustain productivity, and build community resilience during high heat events by combining social services, water access, and public health messaging.

Scale

Neighborhood and community

Type of Action

Response and health risk reduction

Ease of Implementation

Medium

Level of Evidence

Established practices

Suitability

This strategy works best in crowded cities with plenty of pedestrian traffic throughout the day and little access to air conditioning, especially in low-income areas. Cooling center design should take climate variables into account. For example, in humid areas, airtight windows and doors can increase efficiency. Usually, NGOs and community-based organizations that operate in public buildings and institutions collaborate with municipal or local governments to lead programs.

25 Distribution of drinking water

Description

During heatwaves, distributing drinking water can save lives, particularly for low-income areas and those who are exposed to extreme temperatures. In order to guarantee access for the most vulnerable, including those living in informal settlements, temporary water distribution stations are placed in busy public places and underserved areas. During extreme heat events, safe, dependable access to clean water is ensured by collaborating with public agencies, private suppliers, and community organizations and coordinating distribution with awareness efforts.

Scale

Neighborhood and community

Type of Action

Capacity development and behavior change

Ease of Implementation

Easy

Level of Evidence

Pilot Project

Suitability

This inexpensive solution can be used in any environment, but it works particularly well in urban areas with poor access to clean water or high temperatures. For low-income neighborhoods, informal settlements, and outside laborers who rely on daily pay and lack dependable access to water, it is especially crucial. Water safety must be guaranteed, and local organizations must be included to promote shared accountability and reduce health hazards.

4.5.2. Integration of Plan Framework to Interventions

The Plan for Heat Resilience was organized by the **conceptual framework as a series of interconnected steps, starting with the identification of vacancy as a spatial opportunity situated inside high-risk community regions.** The approach moved from risk assessment to resilience planning and response, placing vacant lots within a larger urban heat management logic developed from the World Bank's recommendations, rather than treating them as discrete land-use artifacts. In order to determine where actions would have the biggest spatial and social impact, the assessment phase combined hazard (UHI, NDVI, NDBI), vulnerability (SVI, redlining legacy), and exposure (mobility networks, isochrones), as the diagram makes clear.

The "Plan for Heat Resilience" phase **converts this multifaceted evaluation into meta-projects based on vacancy typologies.** The methodology operationalizes resilience by classifying empty lots based on factors like scale, clustering, and proximity to transit corridors, going beyond merely recommending policies. The assessment and response components are crucial because they go beyond surface temperature measurements to include urban form features like street hierarchy, block shape, imperviousness, and gaps in green infrastructure. **This ensures that interventions address structural heat causes rather than just symptoms. By incorporating long-term spatial reform into the resilience strategy, this crucial connection keeps the plan from becoming reactive.**

Last but not least, the response dimension links site-specific interventions to governance and city-scale policy procedures, reaffirming that institutional alignment rather than only physical redesign is necessary to create resilience. The flow diagram shows how zoning modifications, green infrastructure requirements, and heat emergency procedures are among the more general planning tools that are informed by localized vacancy-based interventions. The framework promotes a proactive and scalable model of heat resilience by combining assessment, planning, and response in a logical flow. This turns previously underinvested areas into infrastructure assets that can simultaneously decrease exposure, increase adaptive capacity, and lessen hazard intensity.

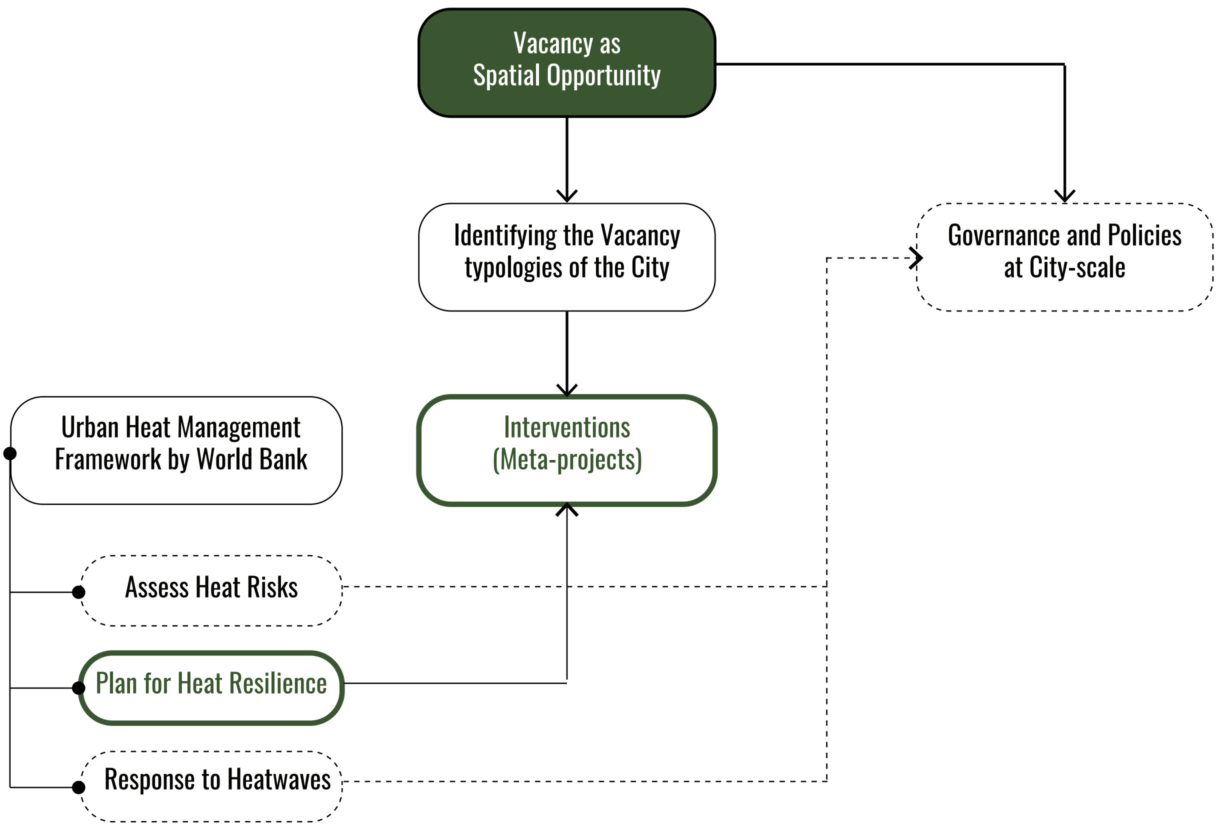


Figure 38. Conceptual Framework: Opportunity Space. Source: Author

Distribution of Proposed interventions to the PLAN FOR HEAT RESILIENCE Framework by World Bank

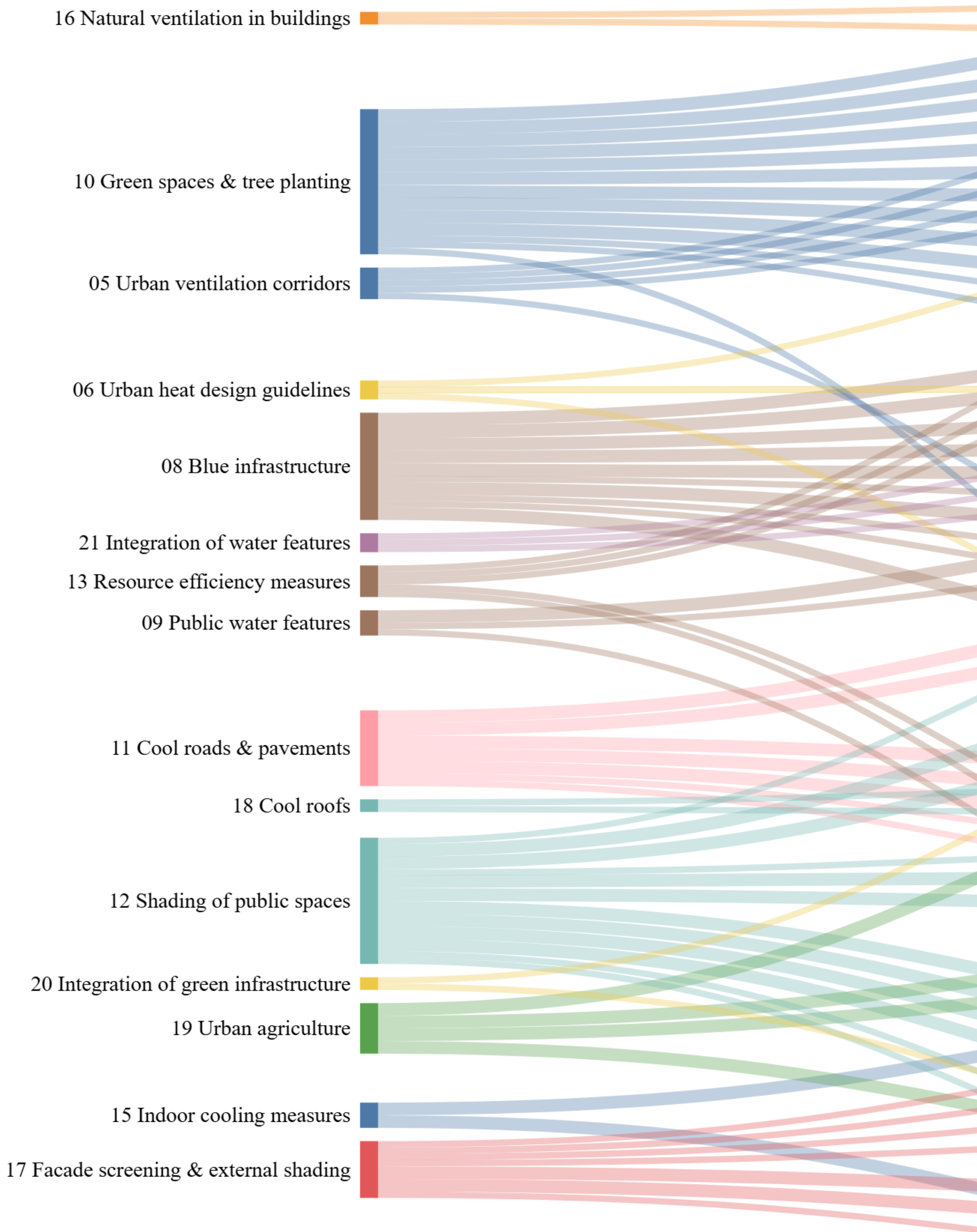
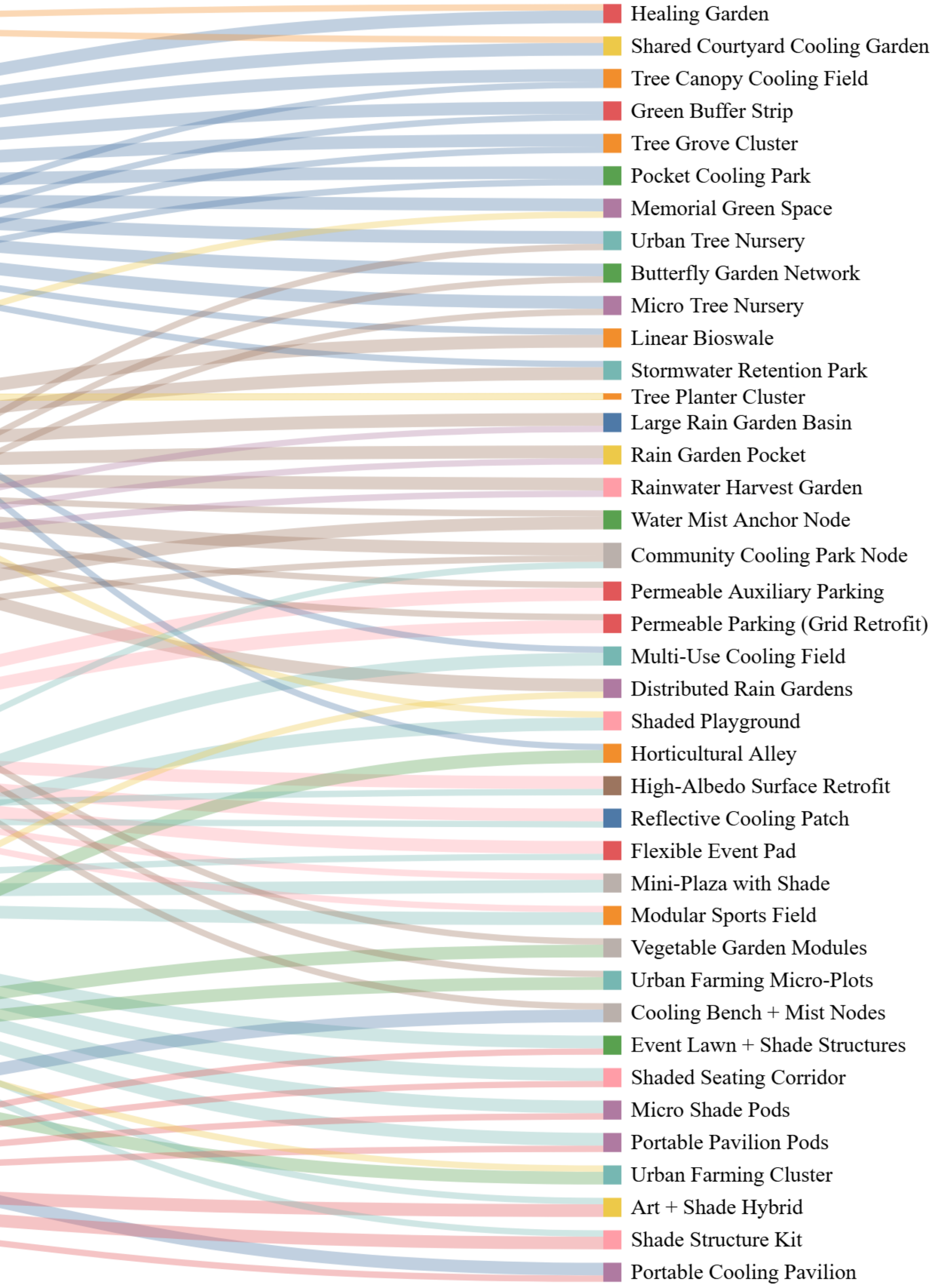
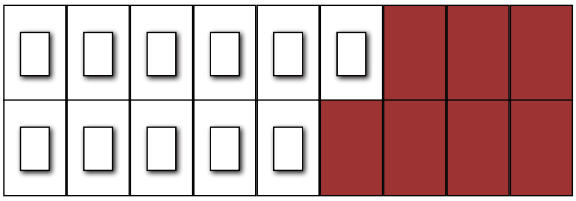


Figure 39. Distribution of Proposed interventions to the Plan for Heat Resilience Framework by World bank. Source: Author


Healing Garden
Shared Courtyard Cooling Garden
Tree Canopy Cooling Field
Green Buffer Strip
Tree Grove Cluster
Pocket Cooling Park
Memorial Green Space
Urban Tree Nursery
Butterfly Garden Network
Micro Tree Nursery
Linear Bioswale
Stormwater Retention Park
Tree Planter Cluster
Large Rain Garden Basin
Rain Garden Pocket
Rainwater Harvest Garden
Water Mist Anchor Node
Community Cooling Park Node
Permeable Auxiliary Parking
Permeable Parking (Grid Retrofit)
Multi-Use Cooling Field
Distributed Rain Gardens
Shaded Playground
Horticultural Alley
High-Albedo Surface Retrofit
Reflective Cooling Patch
Flexible Event Pad
Mini-Plaza with Shade
Modular Sports Field
Vegetable Garden Modules
Urban Farming Micro-Plots
Cooling Bench + Mist Nodes
Event Lawn + Shade Structures
Shaded Seating Corridor
Micro Shade Pods
Portable Pavilion Pods
Urban Farming Cluster
Art + Shade Hybrid
Shade Structure Kit
Portable Cooling Pavilion

4.5.3. Proposed Interventions: Mass Void



Mass Void
Large, continuous groups of empty lots brought about by extensive disinvestment or demolition. These holes provide chances for large-scale or phased changes and have a substantial impact on the microclimate and neighborhood organization.

Figure 40. Mass Void diagram and in Satellite and Street view. Source: Author and Google Earth images

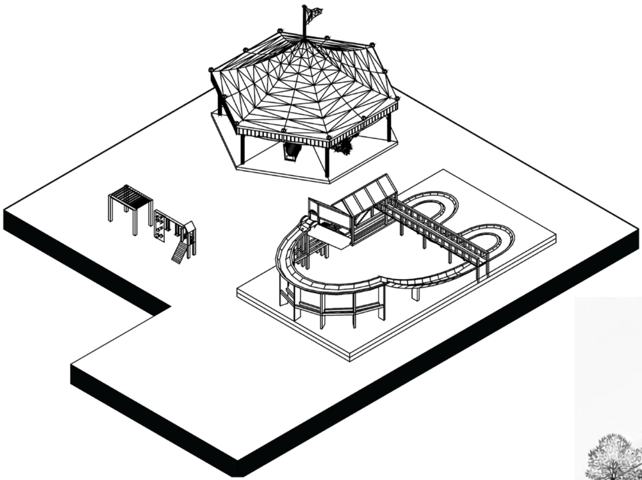
Table 13. Mass Void Implementation and Impacts

Mass Void	
Thermal Impact Capacity	High
Thermal reasoning (evidence-based logic)	Large exposed surface area; high solar absorption; strong canopy-based cooling return and measurable surface temperature reduction.
Network Position	Block-Level Anchor
Network Reasoning	Influences surrounding pedestrian flows; capable of functioning as neighborhood cooling hub.
Spatial Scale	Macro
Scale Justification	Supports large-scale canopy, permeable surfaces, and event-based adaptive uses.
Governance Feasibility	Moderate-High
Governance Justification	Often city or land bank owned; feasible under structured temporary agreements.
Feasible Interventions	1. Tree Canopy Cooling Field; 2. Event Lawn with Shade Structures; 3. Large Rain Garden Basin; 4. Memorial Green Space; 5. Community Cooling Park Node
Primary Climate Objective	Surface Temperature Reduction
Secondary co-benefits	Community gathering, stormwater management, social cohesion
Implementation Priority levels	High

Associated with PLAN FOR HEAT RESILIENCE Framework

EVENT LAWN WITH SHADE STRUCTURES 12 17

TERM: SHORT MEDIUM LONG

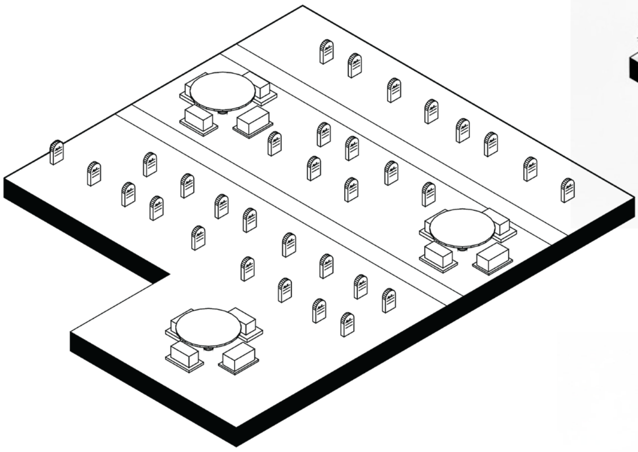


08 09 COMMUNITY COOLING PARK NODE

TERM: SHORT MEDIUM LONG

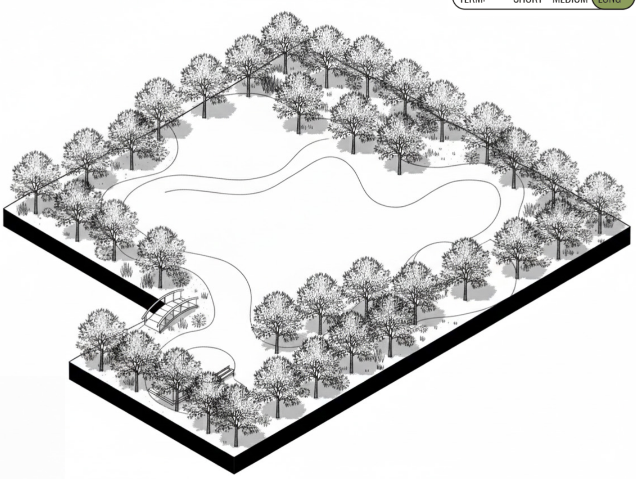
MEMORIAL GREEN SPACE 10 06

TERM: SHORT MEDIUM LONG



10 05 TREE CANOPY COOLING FIELD

TERM: SHORT MEDIUM LONG



LARGE RAIN GARDEN BASIN 08 21

TERM: SHORT MEDIUM LONG

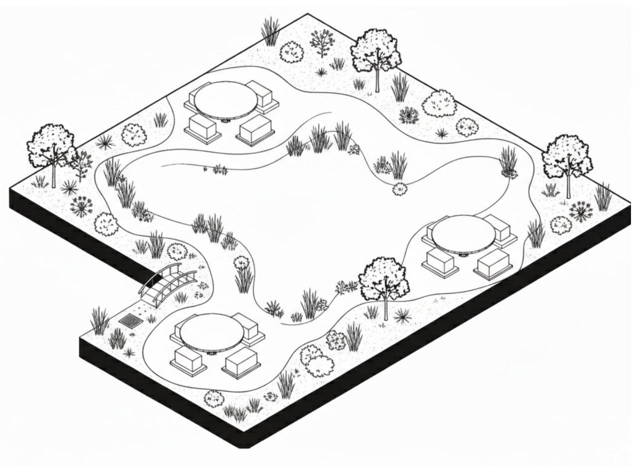
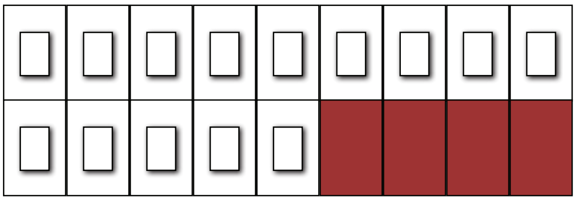


Figure 41. Mass Void interventions. Source: Author

4.5.4. Proposed Interventions: Contiguous Void



Contiguous Void
Collections of neighboring undeveloped lots that make up an internal space or block section. Without necessitating a whole block makeover, these areas can accommodate coordinated, medium-scale activation methods.

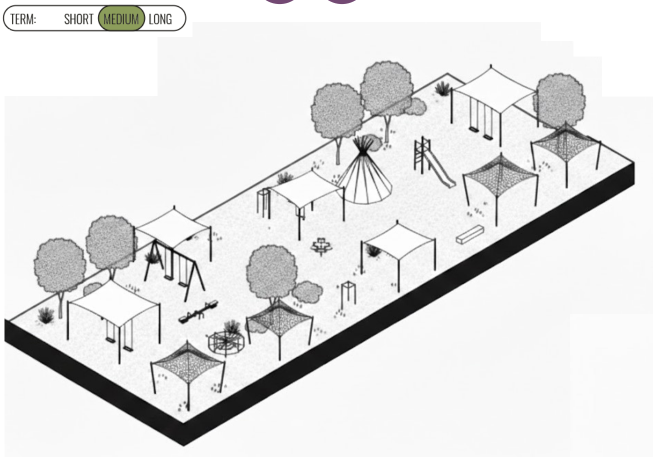
Figure 42. Contiguous Void diagram and in Satellite and Street view. Source: Author and Google Earth images

Table 14. Contiguous Void Implementation and Impacts

Contiguous Void	
Thermal Impact Capacity	High
Thermal reasoning (evidence-based logic)	Extended open parcel capable of supporting significant vegetation mass and continuous climate buffering.
Network Position	Neighborhood Connector
Network Reasoning	Links parcels; strengthens continuous cooling corridor.
Spatial Scale	Macro
Scale Justification	Accommodates playgrounds, healing gardens, and multi-use cooling fields.
Governance Feasibility	Moderate
Governance Justification	May require coordination across parcels but feasible under unified management.
Feasible Interventions	1. Shaded Playground; 2. Healing Garden; 3. Urban Tree Nursery; 4. Multi-Use Cooling Field; 5. Stormwater Retention Park
Primary Climate Objective	Microclimate Stabilization
Secondary co-benefits	Youth activity, mental health, ecological restoration
Implementation Priority levels	High

SHADED PLAYGROUND 06 12

TERM: SHORT MEDIUM LONG



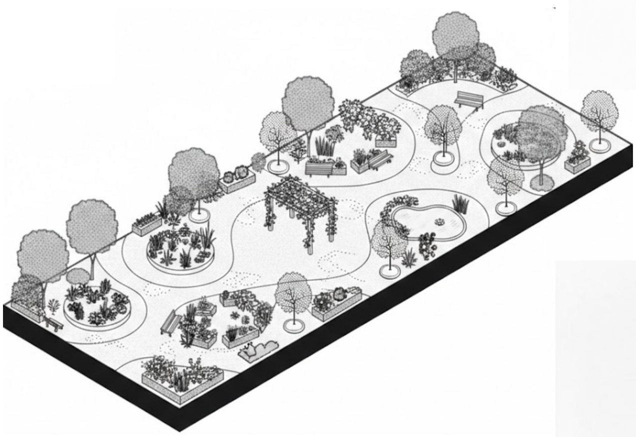
Associated with PLAN FOR HEAT RESILIENCE Framework

05 12 MULTI-USE COOLING FIELD

TERM: SHORT MEDIUM LONG

HEALING GARDEN 10 16

TERM: SHORT MEDIUM LONG



08 10 STORMWATER RETENTION PARK

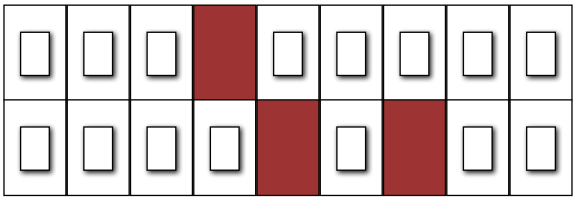
TERM: SHORT MEDIUM LONG

URBAN TREE NURSERY 10 13

TERM: SHORT MEDIUM LONG

Figure 43. Contiguous Void interventions. Source: Author

4.5.5. Proposed Interventions: Scattered Void



Scattered Void
Isolated unoccupied lots scattered erratically over a community. For this typology, lightweight and modular interventions work best since affects are localized

Figure 44. Scattered Void diagram and in Satellite and Street view. Source: Author and Google Earth images

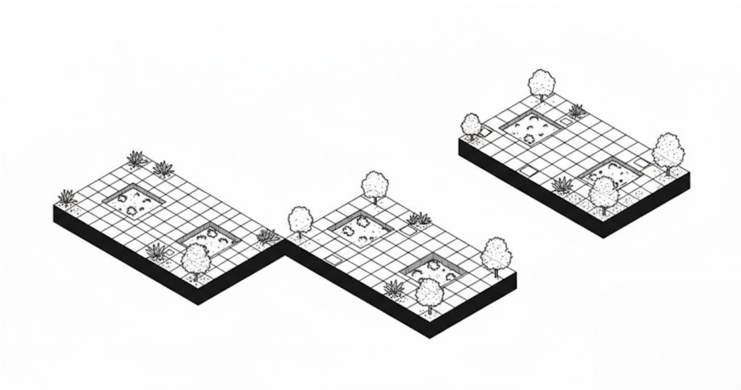
Table 15. Scattered Void Implementation and Impacts

Scattered Void	
Thermal Impact Capacity	Medium
Thermal reasoning (evidence-based logic)	Irregular geometry enables pocket cooling zones and flexible modular placement.
Network Position	Semi-Corridor
Network Reasoning	Supports secondary pedestrian comfort and local activity nodes.
Spatial Scale	Meso
Scale Justification	Supports sport fields, green clusters, and flexible event pads.
Governance Feasibility	Moderate
Governance Justification	Requires adaptive modular configuration but manageable.
Feasible Interventions	1. Modular Sports Field; 2. Urban Farming Cluster; 3. Pocket Cooling Park; 4. Rainwater Harvest Garden; 5. Flexible Event Pad
Primary Climate Objective	Localized Cooling + Activation
Secondary co-benefits	Youth engagement, food security, recreation
Implementation Priority levels	Medium

Associated with PLAN FOR HEAT RESILIENCE Framework

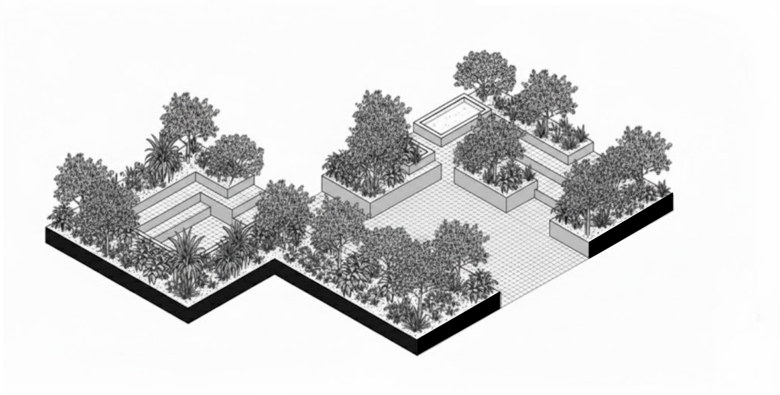
POCKET COOLING PARK 05 10

TERM: **SHORT** MEDIUM LONG



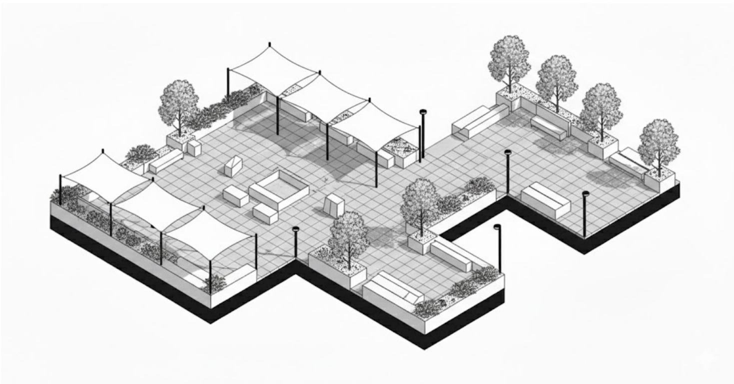
08 12 RAINWATER HARVEST GARDEN

TERM: **SHORT** MEDIUM LONG



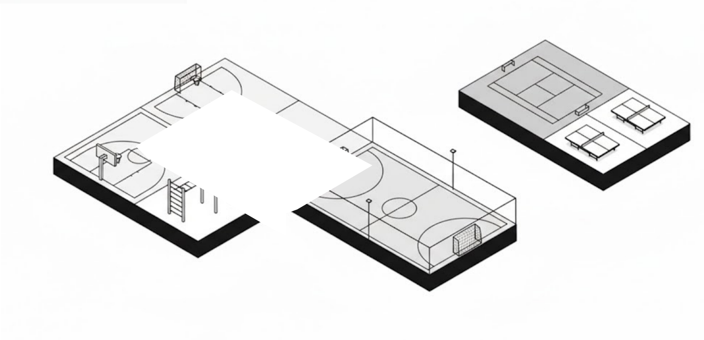
FLEXIBLE EVENT PAD 11 12

TERM: **SHORT** MEDIUM LONG



11 12 MODULAR SPORTS FIELD

TERM: SHORT **MEDIUM** LONG



URBAN FARMING CLUSTER 19 20

TERM: SHORT **MEDIUM** LONG

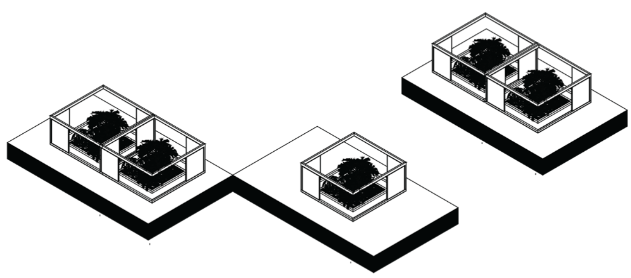
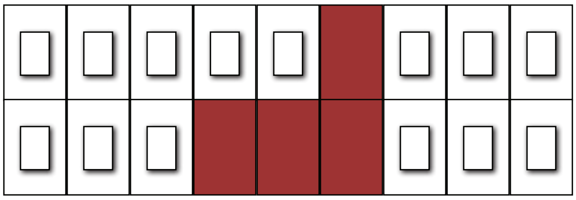


Figure 45. Scattered Void interventions. Source: Author

4.5.6. Proposed Interventions: Flagged Void



Flagged Void
Parcels that have little street frontage or shapes that extend inward, making them less accessible and visible. These spaces are frequently better suited for community-oriented or semi-private uses.

Figure 46. Flagged Void diagram and in Satellite and Street view. Source: Author and Google Earth images

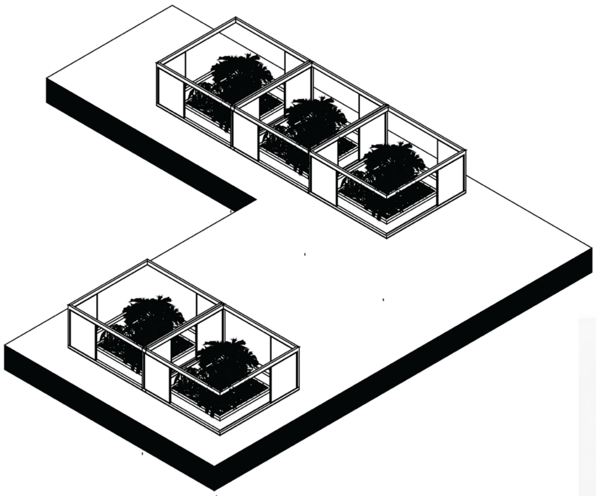
Table 16. Flagged Void Implementation and Impacts

Flagged Void	
Thermal Impact Capacity	Low-Medium
Thermal reasoning (evidence-based logic)	Dispersed parcels; limited individual cooling but strong cumulative network impact.
Network Position	Distributed Network
Network Reasoning	Creates multi-point cooling interventions.
Spatial Scale	Micro
Scale Justification	Best suited for modular and phased deployment.
Governance Feasibility	High
Governance Justification	Flexible, scalable, and easily reversible.
Feasible Interventions	1. Urban Farming Micro-Plots; 2. Permeable Auxiliary Parking; 3. Micro Tree Nursery; 4. Shade Structure Kit; 5. Reflective Cooling Patch
Primary Climate Objective	Distributed Cooling Support
Secondary co-benefits	Food security, land stewardship
Implementation Priority levels	Medium

Associated with PLAN FOR HEAT RESILIENCE Framework

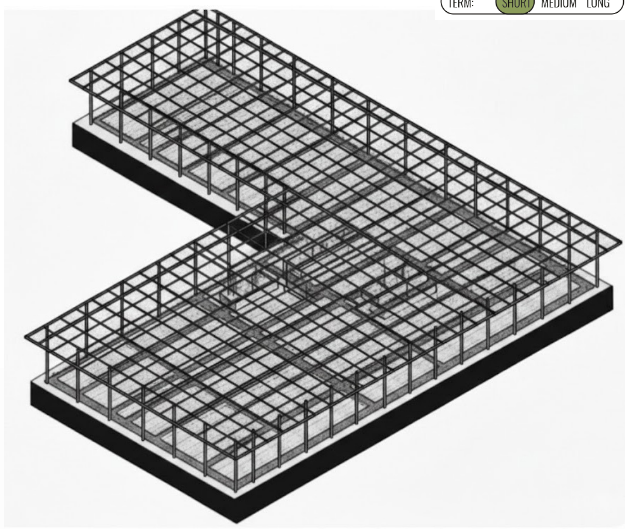
URBAN FARMING MICRO-PLOTS 13 19

TERM: SHORT MEDIUM LONG



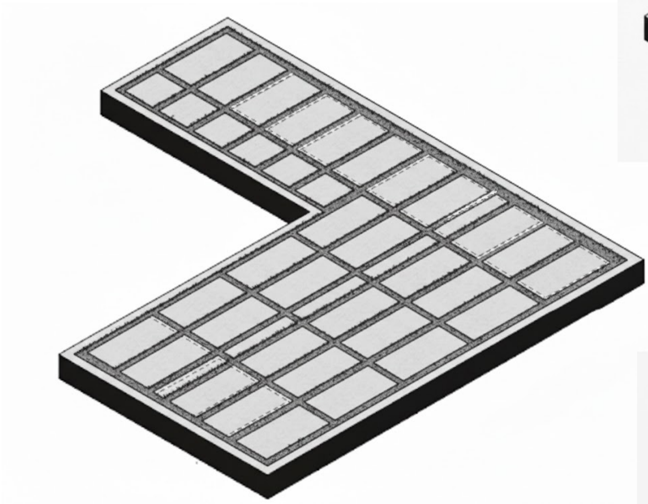
12 17 SHADE STRUCTURE KIT

TERM: SHORT MEDIUM LONG



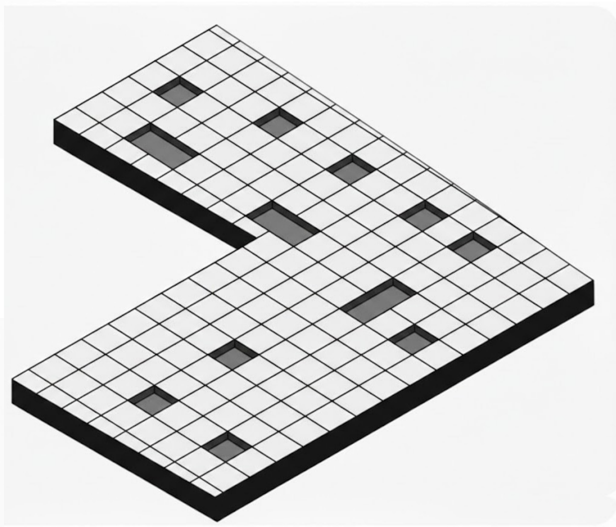
PERMEABLE AUXILIARY PARKING 11

TERM: SHORT MEDIUM LONG



11 REFLECTIVE COOLING PATCH

TERM: SHORT MEDIUM LONG



MICRO TREE NURSERY 10 13

TERM: SHORT MEDIUM LONG

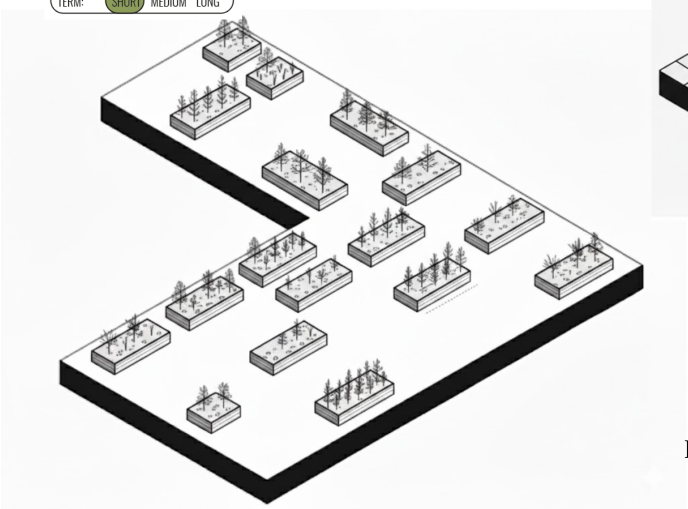
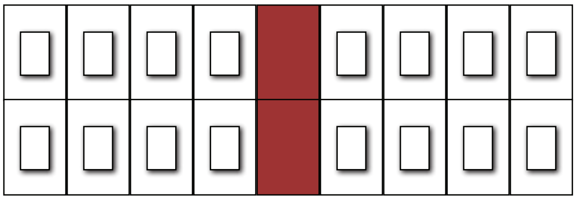
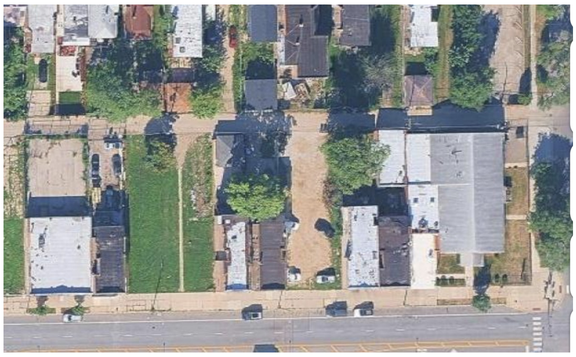


Figure 47. Flagged Void interventions. Source: Author

4.5.7. Proposed Interventions: Strip Void





Strip Void
Linear gaps that reduce pedestrian continuity and street activity along a corridor or street edge. Markets, green infrastructure, and shaded walkways are examples of linear activations that work well with this type.

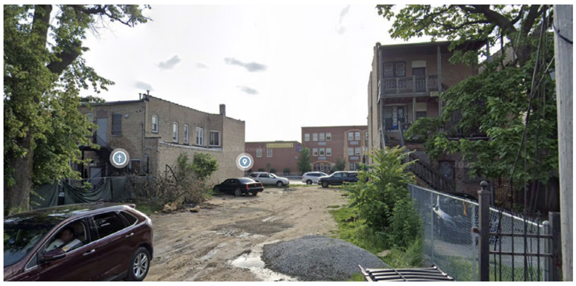


Figure 48. Strip Void diagram and in Satellite and Street view. Source: Author and Google Earth images

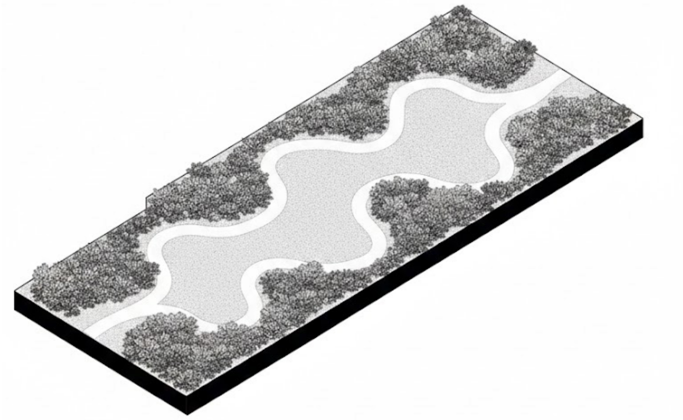
Table 17. Strip Void Implementation and Impacts

Strip Void	
Thermal Impact Capacity	Medium-High
Thermal reasoning (evidence-based logic)	Linear exposure allows shading corridors, bioswale integration, and edge cooling.
Network Position	Pedestrian Corridor
Network Reasoning	Direct adjacency to sidewalks; supports mobility cooling.
Spatial Scale	Meso
Scale Justification	Ideal for linear green buffers and horticultural corridors.
Governance Feasibility	High
Governance Justification	Narrow parcels; modular deployment is straightforward.
Feasible Interventions	1. Green Buffer Strip; 2. Linear Bioswale; 3. Horticultural Alley; 4. Shaded Seating Corridor; 5. High-Albedo Surface Retrofit
Primary Climate Objective	Pedestrian Heat Mitigation
Secondary co-benefits	Stormwater control, mobility comfort, biodiversity
Implementation Priority levels	High

Associated with PLAN FOR HEAT RESILIENCE Framework

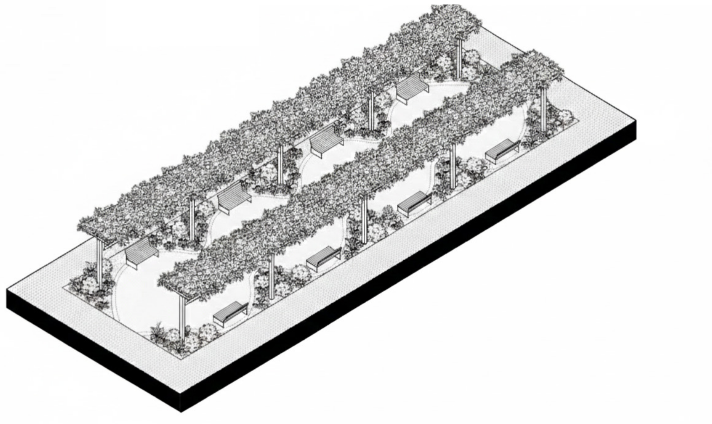
HIGH-ALBEDO SURFACE RETROFIT 11 18

TERM: SHORT MEDIUM LONG



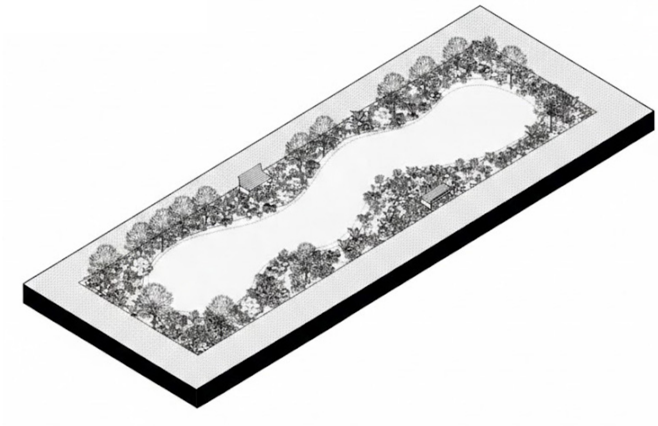
12 17 SHADED SEATING CORRIDOR

TERM: SHORT MEDIUM LONG



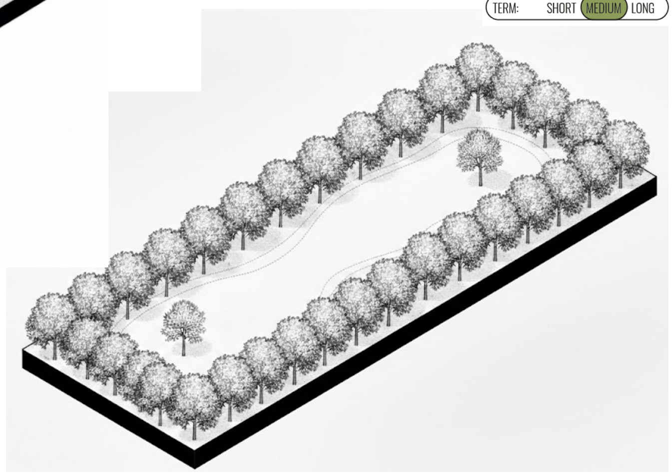
LINEAR BIOSWALE 08 10

TERM: SHORT MEDIUM LONG



10 05 GREEN BUFFER STRIP

TERM: SHORT MEDIUM LONG



HORTICULTURAL ALLEY 10 19

TERM: SHORT MEDIUM LONG

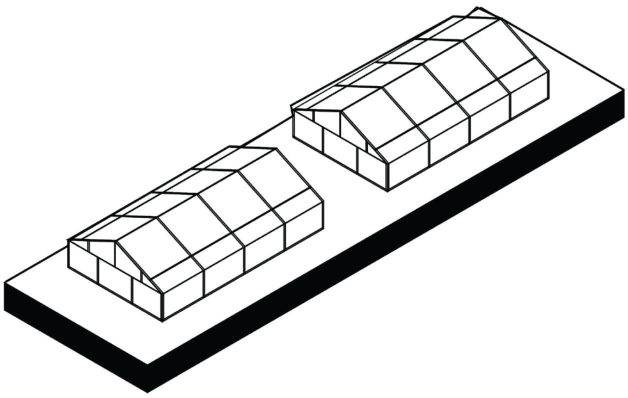
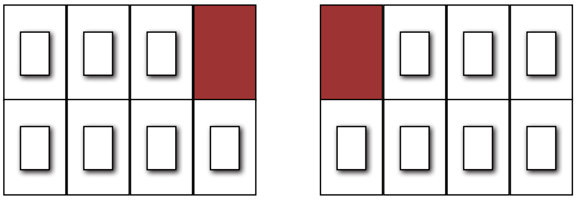


Figure 49. Strip Void interventions. Source: Author

4.5.8. Proposed Interventions: Corner Void



Corner Void
Block corners, where visibility and pedestrian traffic are greatest, are home to vacant lots. When engaged, corner voids can serve as neighborhood anchors or gates despite their small size.

Figure 50. Corner Void diagram and in Satellite and Street view. Source: Author and Google Earth images

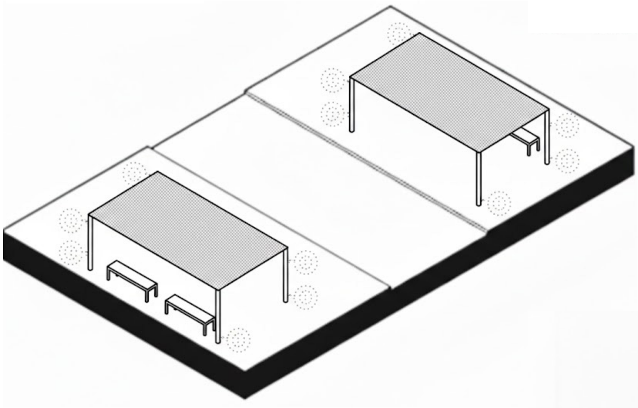
Table 18. Corner Void Implementation and Impacts

Corner Void	
Thermal Impact Capacity	Medium
Thermal reasoning (evidence-based logic)	High solar and wind exposure at intersections; strong shading return potential.
Network Position	Intersection Node
Network Reasoning	High pedestrian visibility and dwell potential.
Spatial Scale	Micro-Meso
Scale Justification	Supports small plazas and pavilion anchors.
Governance Feasibility	High
Governance Justification	Strategic visibility encourages community activation.
Feasible Interventions	1. Portable Cooling Pavilion; 2. Mini-Plaza with Shade; 3. Rain Garden Pocket; 4. Water Mist Anchor Node; 5. Art + Shade Hybrid
Primary Climate Objective	Intersection Heat Mitigation
Secondary co-benefits	Social activation, public visibility
Implementation Priority levels	High

Associated with PLAN FOR HEAT RESILIENCE Framework

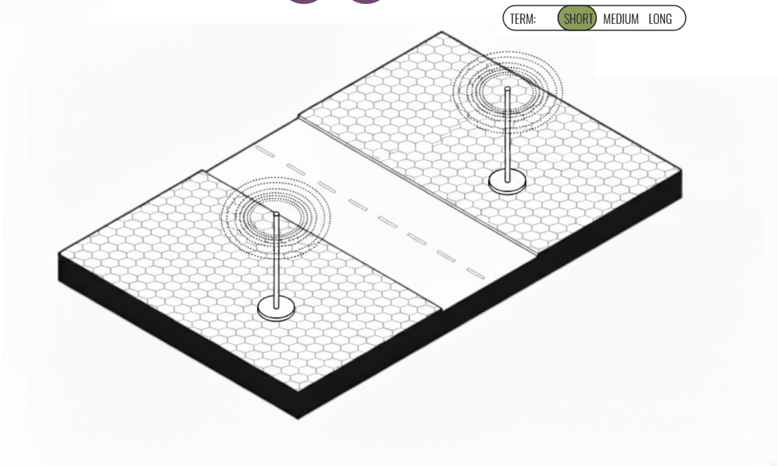
PORTABLE COOLING PAVILION 15 17

TERM: SHORT MEDIUM LONG



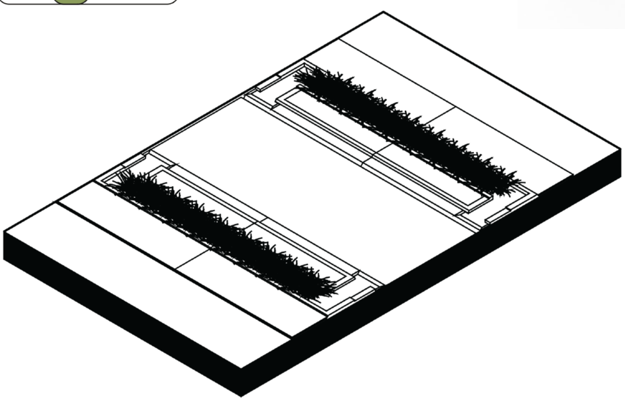
08 09 WATER MIST ANCHOR NODE

TERM: SHORT MEDIUM LONG



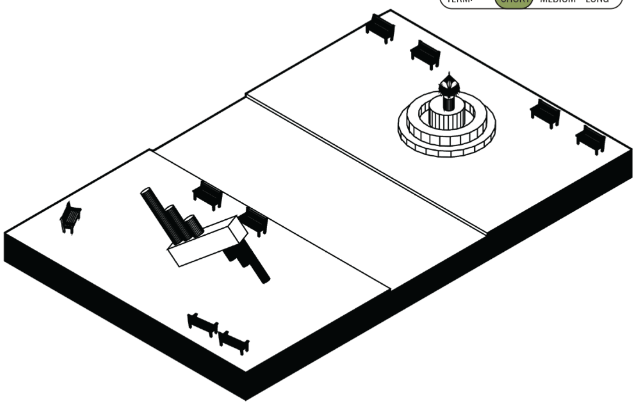
RAIN GARDEN POCKET 08 21

TERM: SHORT MEDIUM LONG



12 17 ART + SHADE HYBRID

TERM: SHORT MEDIUM LONG



MINI-PLAZA WITH SHADE 11 12

TERM: SHORT MEDIUM LONG

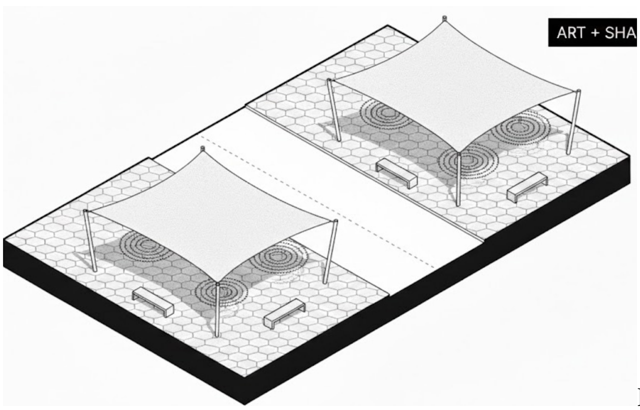
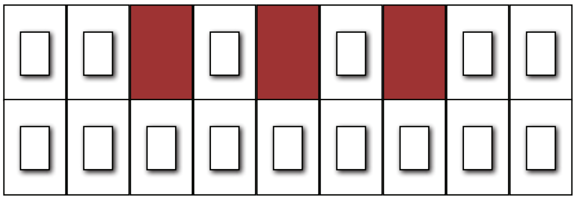


Figure 51. Corner Void interventions. Source: Author

4.5.9. Proposed Interventions: Interval Void



Interval Void
Frequent interruptions in enclosure and thermal comfort are caused by regularly spaced unoccupied plots between occupied structures. Pocket parks and rest areas are examples of tiny, repetitive interventions that work well at these locations.

Figure 52. Interval Void diagram and in Satellite and Street view. Source: Author and Google Earth images

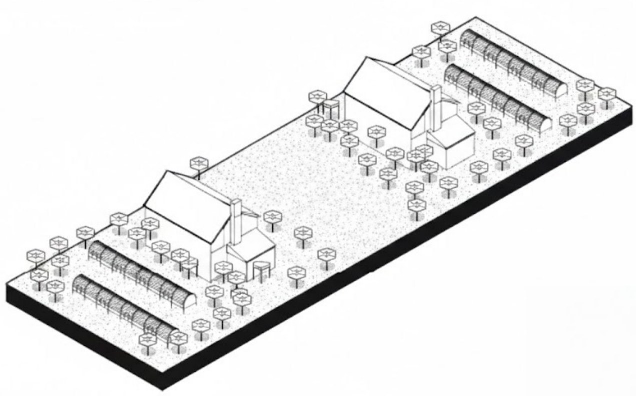
Table 19. Interval Void Implementation and Impacts

Interval Void	
Thermal Impact Capacity	Low-Medium
Thermal reasoning (evidence-based logic)	Smaller fragmented surfaces; suitable for micro shade deployment and cumulative cooling effect.
Network Position	Network Node
Network Reasoning	Repeated gaps create distributed cooling rhythm.
Spatial Scale	Micro
Scale Justification	Ideal for modular pods and permeable surfaces.
Governance Feasibility	High
Governance Justification	Low-cost, highly reversible.
Feasible Interventions	1. Micro Shade Pods; 2. Vegetable Garden Modules; 3. Permeable Auxiliary Parking; 4. Cooling Bench + Mist Node; 5. Tree Planter Cluster
Primary Climate Objective	Cumulative Heat Reduction
Secondary co-benefits	Food production, pedestrian rest
Implementation Priority levels	Medium

Associated with PLAN FOR HEAT RESILIENCE Framework

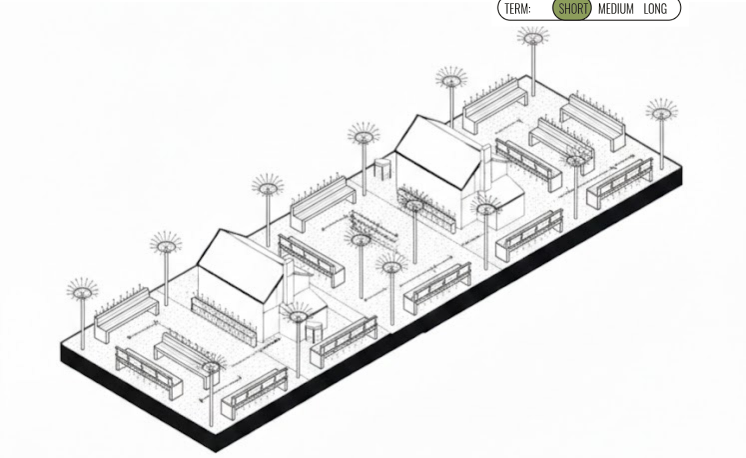
MICRO SHADE PODS 12 17

TERM: SHORT MEDIUM LONG



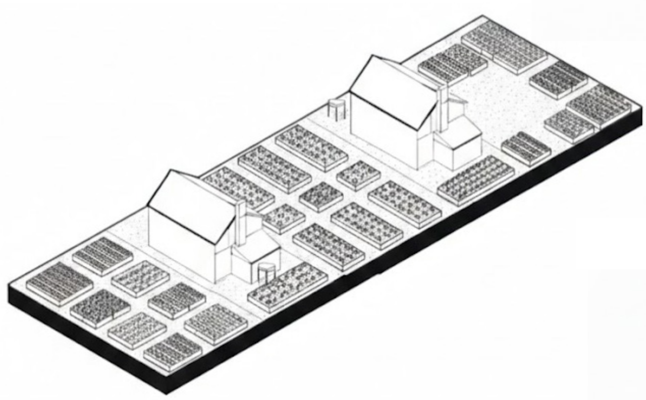
09 15 COOLING BENCH + MIST NODES

TERM: SHORT MEDIUM LONG



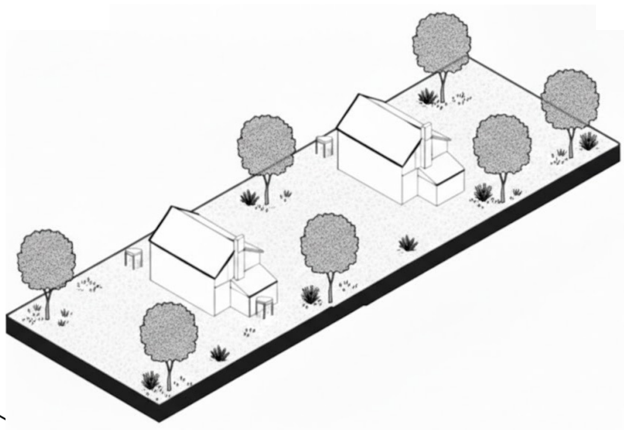
VEGETABLE GARDEN MODULES 13 19

TERM: SHORT MEDIUM LONG



06 10 TREE PLANTER CLUSTER

TERM: SHORT MEDIUM LONG



PERMEABLE AUXILIARY PAPRKING 11

TERM: SHORT MEDIUM LONG

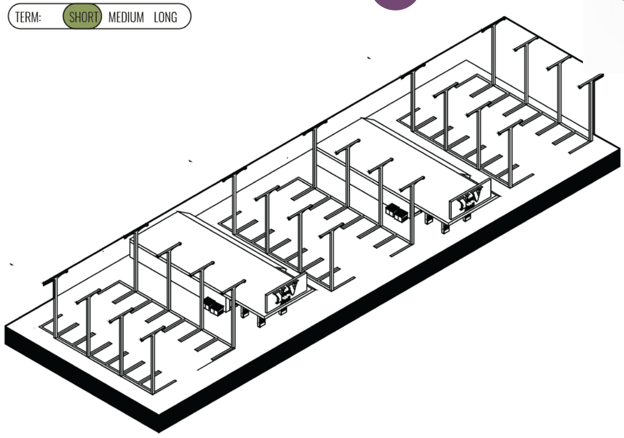
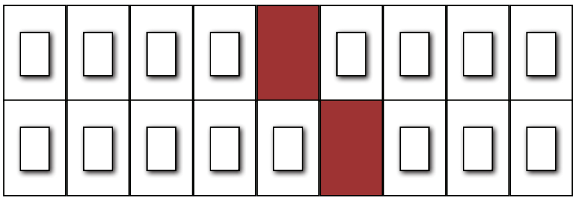


Figure 53. Interval Void interventions. Source: Author

4.5.10. Proposed Interventions: Offset Void



Offset Void
Vacancies that are dispersed or out of alignment throughout a block, causing the urban fabric to break apart. These deficiencies can be gradually filled by incremental, modular initiatives.

Figure 54. Offset Void diagram and in Satellite and Street view. Source: Author and Google Earth images

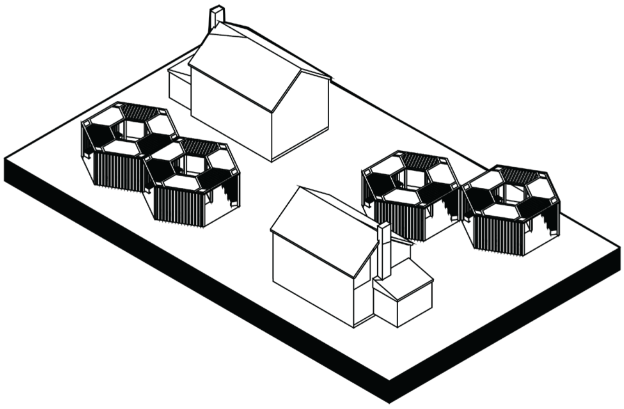
Table 20. Offset Void Implementation and Impacts

Offset Void	
Thermal Impact Capacity	Medium
Thermal reasoning (evidence-based logic)	Distributed staggered parcels enhance passive ventilation and interior block cooling.
Network Position	Distributed Block
Network Reasoning	Strengthens internal microclimate across blocks.
Spatial Scale	Meso
Scale Justification	Supports pavilion modules and pollinator gardens.
Governance Feasibility	High
Governance Justification	Independent parcels allow phased activation.
Feasible Interventions	1. Butterfly Garden Network; 2. Portable Pavilion Pods; 3. Tree Grove Cluster; 4. Shared Courtyard Cooling Garden; 5. Distributed Rain Gardens
Primary Climate Objective	Distributed Microclimate Enhancement
Secondary co-benefits	Biodiversity, community engagement
Implementation Priority levels	Medium

Associated with PLAN FOR HEAT RESILIENCE Framework

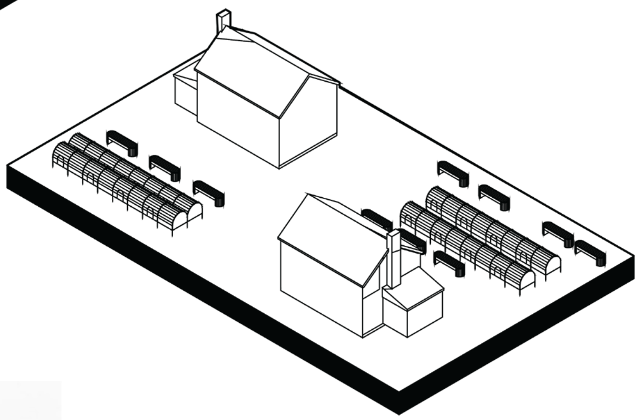
PORTABLE PAVILION PODS 12 17

TERM: SHORT MEDIUM LONG



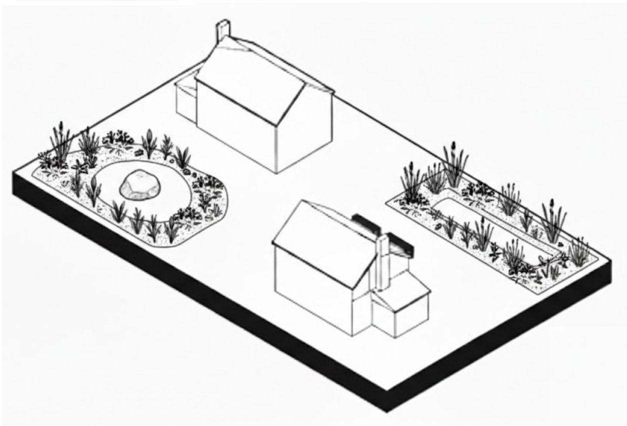
10 16 SHARED COURTYARD COOLING GARDEN

TERM: SHORT MEDIUM LONG



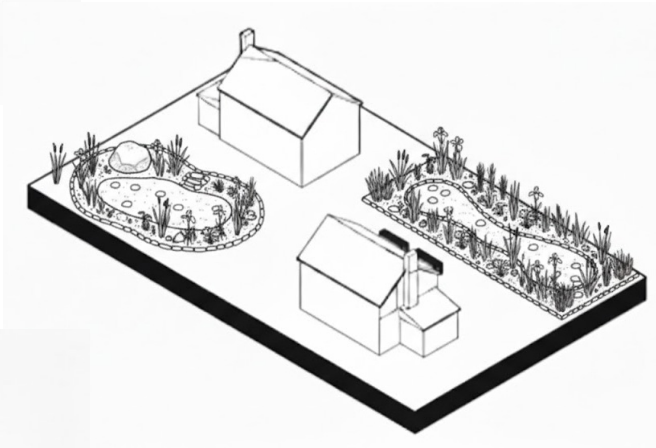
BUTTERFLY GARDEN NETWORK 10 13

TERM: SHORT MEDIUM LONG



08 20 DISTRIBUTED RAIN GARDENS

TERM: SHORT MEDIUM LONG



TREE GROVE CLUSTER 05 10

TERM: SHORT MEDIUM LONG

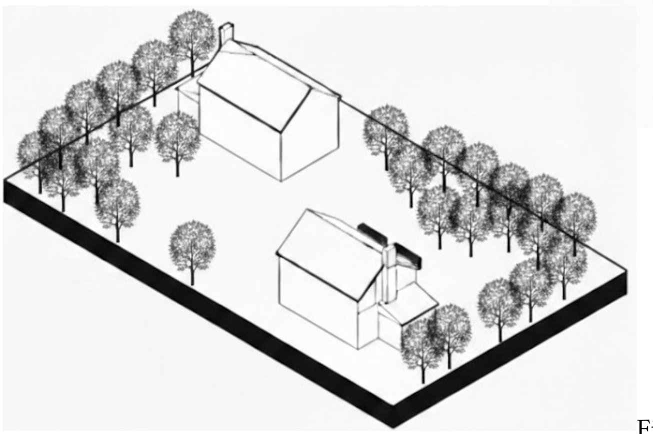


Figure 55. Offset Void interventions. Source: Author

4.5.11. Phasing the Infrastructure for Transitions

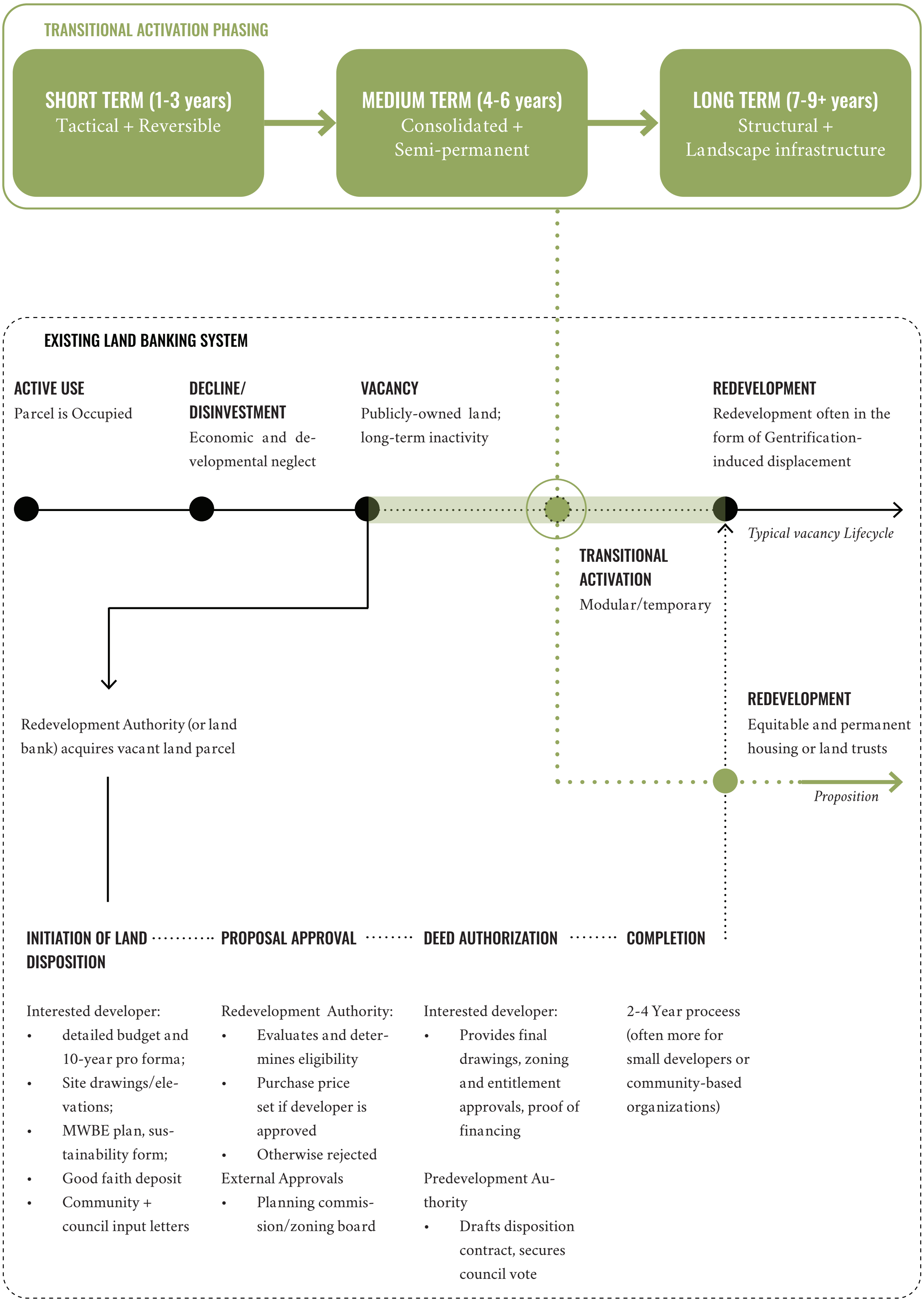


Figure 56. Phasing the Infrastructure for Transitions. Source: Author

Table 21. Phased Interventions per Void types

Void type	Short term (1-3 years)	Medium term (4-6 years)	Long Term (7-9 + years)
Mass Void	Shade Structure Kit; Reflective Cooling Patch; Portable Cooling Pavilion; Rain Garden Pocket	Event Lawn w/ Shade; Community Cooling Park Node; Memorial Green Space	Tree Canopy Cooling Field; Large Rain Garden Basin; Stormwater Retention Park; Urban Tree Nursery
Contiguous Void	Shade Structure Kit; High-Albedo Retrofit; Rain Garden Pocket	Shaded Playground; Healing Garden; Multi-Use Cooling Field	Urban Tree Nursery; Stormwater Retention Park; Tree Canopy Cooling Field
Scattered Void	Pocket Cooling Park; Rainwater Harvest Garden; Flexible Event Pad	Modular Sports Field; Urban Farming Cluster; Shared Courtyard Cooling Garden	Distributed Rain Garden Network; Tree Grove Cluster
Flagged Void	Urban Farming Micro-Plots; Permeable Auxiliary Parking; Shade Structure Kit; Reflective Cooling Patch	Healing Garden; Urban Farming Cluster	Tree Grove Cluster (if parcels consolidate)
Strip Void	Shaded Seating Corridor; High-Albedo Retrofit; Water Mist Anchor Node	Green Buffer Strip; Linear Bioswale; Horticultural Alley	Continuous Green Corridor Integration; Canopy-lined Pedestrian Corridor
Corner Void	Portable Cooling Pavilion; Water Mist Anchor Node; Rain Garden Pocket; Art + Shade Hybrid	Mini-Plaza with Shade; Memorial Green Space	Anchor Canopy Node integrated into network
Interval Void	Micro Shade Pods; Cooling Bench + Mist Nodes; Tree Planter Cluster; Vegetable Garden Modules	Clustered Micro-Cooling Rhythm	Integrated Distributed Cooling Layer across block
Offset Void	Portable Pavilion Pods; Shade Structure Kit; Rainwater Harvest Garden	Butterfly Garden Network; Shared Courtyard Cooling Garden; Tree Grove Cluster; Distributed Rain Gardens	Partial Canopy Integration; Block-scale Cooling Network

4.5.12. Matrix of Interventions

The Matrix of Interventions serves as a tool for strategic translation between climate-responsive design action and spatial typology. The matrix explains how each form of void Mass, Contiguous, Scattered, Flagged, Strip, Corner, Interval, and Offset has unique spatial capacities, constraints, and implementation logics rather than treating vacant land as a homogenous state. The matrix creates an organized framework for decision-making that matches suitable climate policies with scale, morphology, and governance feasibility by cross-referencing interventions with void typologies. In this sense, it transforms the project into a system-based planning tool rather than a proposal that is only driven by design.

The matrix's significance stems from its capacity to operationalize flexibility. Urban vacancy is dynamic; properties may become temporarily accessible, merge, subdivide, or change ownership. In such dynamic circumstances, a strict one-to-one assistance strategy would not work. Instead, the matrix shows how many interventions are flexible and scalable across various sorts of voids. For instance, modular cooling components, such planter clusters, mist nodes, shade structures, and permeable surfaces, can be integrated into larger macro-scale landscapes and strategically placed in micro voids. Phased implementation is made possible by this layered compatibility, which enables the city to react gradually to budget cycles, governance limitations, and community preparedness.

The matrix also makes hierarchy clear. Contiguous voids and mass act as structural cooling backbones that can sustain multipurpose cooling fields, retention parks, and long-term canopy systems. At the meso-scale, scattered and offset voids disperse thermal relief throughout neighborhoods and blocks. Micro-scale, quick-deployment solutions that improve cumulative cooling performance and pedestrian comfort are made possible by flagged and interval voids. The grid avoids resource misallocation by specifying these responsibilities, making sure that tiny tactical initiatives are not overwhelmed with systemic expectations and that large-scale infrastructure is not pushed into geographically dispersed locations.

Additionally, the matrix supports the robustness logic of the project. Redundancy, diversity, and distributed capacity are necessary for climate adaptation in urban settings. The system does not rely on a specific land condition or implementation pathway because various interventions can work across a variety of void types. Distributed Offset or Scattered methods can nevertheless produce cumulative cooling effects in the absence of a huge Mass vacuum. This redundancy enhances the framework's adaptability and is consistent with modern resilience planning concepts that prioritize networked systems and flexibility over single, massive solutions.

The matrix's governance component is equally significant. Various void forms suggest various time horizons, ownership patterns, and political viability. Through the integration of typological compatibility and short-, medium-, and long-term classifications, the matrix offers a realistic phasing structure. While bigger Mass or Contiguous reforms progress via lengthy planning cycles, tactical deployments in Flagged or Interval voids can be implemented quickly, creating tangible impact and community trust. Instead of just being visionary, this temporal layering guarantees that the idea will continue to be implementable.

Finally, by integrating flexibility at several levels spatial, temporal, and institutional the Matrix of Interventions enhances the project's adaptability. It turns vacancy from an absence-related issue into a calibrated network of opportunities, with each sort of void making a distinct contribution to urban activity and thermal mitigation. The matrix improves the overall coherence, viability, and resilience of the climate-responsive transportation strategy by methodically matching intervention scale with geographical morphology.

Table 22. Void Typology Capacity Definitions

Void type	Sub-void types (could be accommodated)	Can accommodate	Not Suitable for
Mass Void	Contiguous, Scattered, Offset (as phased or nested systems)	Large canopy systems, full parks, event lawns, retention basins, sports fields, cooling park anchors	Highly fragmented micro-only tactical uses as primary strategy (unless phased within larger plan)
Contiguous Void	Mass (scaled-down), Scattered, Offset	Coordinated medium–large landscape systems, nurseries, stormwater retention parks, multi-use cooling fields	Highly dispersed modular kits without spatial cohesion
Scattered Void	Flagged, Interval, Offset	Modular fields, pocket parks, farming clusters, distributed cooling nodes	Full-scale park anchors requiring continuous land mass
Flagged Void	Interval, Scattered (localized), Offset	Semi-private, modular, reversible uses, micro-farming plots, shade kits, permeable retrofits	Large public fields, sports complexes, basin-scale retention systems
Strip Void	Corner (nodes along corridor), Offset (partial), Scattered (edge conditions)	Linear cooling corridors, buffers, bioswales, shaded walkways, mobility-based heat mitigation	Block-based plaza systems, centralized anchor parks
Corner Void	Scattered, Flagged, Strip (intersection node), Interval	Anchor nodes, pavilions, mist nodes, mini-plazas, small rain gardens	Large retention basins or macro landscape systems
Interval Void	Flagged, Scattered, Offset	Repetitive modular cooling pods, micro shade systems, planter clusters, small-scale permeable surfaces	Large coordinated landscapes requiring land continuity
Offset Void	Mass (distributed form), Contiguous (scaled), Scattered, Flagged, Interval	Distributed block cooling, courtyard gardens, tree grove clusters, rain garden networks	Linear corridor-only systems or single-anchor park models

Table 23. Matrix of Interventions (Mass, Contiguous, Scattered, and Flagged Voids)

Interventions	Term	Mass Voids	Contiguous Voids	Scattered Voids	Flagged Voids
Tree Canopy Cooling Field	Long	Yes	Yes	No	No
Event Lawn with Shade Structures	Medium	Yes	Yes	No	No
Large Rain Garden Basin	Long	Yes	Yes	No	No
Memorial Green Space	Medium	Yes	Yes	No	No
Community Cooling Park Node	Medium	Yes	Yes	Yes	No
Shaded Playground	Medium	Yes	Yes	Yes	No
Healing Garden	Medium	Yes	Yes	Yes	Yes
Urban Tree Nursery	Long	Yes	Yes	No	Yes
Multi-Use Cooling Field	Medium	Yes	Yes	Yes	No
Stormwater Reten-tion Park	Long	Yes	Yes	No	No
Modular Sports Field	Medium	Yes	Yes	Yes	No
Urban Farming Cluster	Medium	Yes	Yes	Yes	Yes
Pocket Cooling Park	Short	Yes	Yes	Yes	Yes
Rainwater Harvest Garden	Short	Yes	Yes	Yes	Yes
Flexible Event Pad	Short	Yes	Yes	Yes	Yes
Urban Farming Mi-cro-Plots	Short	Yes	Yes	Yes	Yes
Permeable Auxiliary Parking	Short	Yes	Yes	Yes	Yes
Micro Tree Nursery	Short	Yes	Yes	Yes	Yes
Shade Structure Kit	Short	Yes	Yes	Yes	Yes
Reflective Cooling Patch	Short	Yes	Yes	Yes	Yes

Interventions	Term	Mass Voids	Contiguous Voids	Scattered Voids	Flagged Voids
Green Buffer Strip	Medium	Yes	Yes	No	No
Linear Bioswale	Medium	Yes	Yes	No	No
Horticultural Alley	Medium	Yes	Yes	Yes	No
Shaded Seating Corridor	Short	Yes	Yes	Yes	No
High-Albedo Surface Retrofit	Short	Yes	Yes	Yes	Yes
Portable Cooling Pavilion	Short	Yes	Yes	Yes	Yes
Mini-Plaza with Shade	Medium	Yes	Yes	Yes	No
Water Mist Anchor Node	Short	Yes	Yes	Yes	No
Rain Garden Pocket	Short	Yes	Yes	Yes	Yes
Art + Shade Hybrid	Short	Yes	Yes	Yes	Yes
Micro Shade Pods	Short	Yes	Yes	Yes	Yes
Cooling Bench + Mist Nodes	Short	Yes	Yes	Yes	Yes
Vegetable Garden Modules	Short	Yes	Yes	Yes	Yes
Tree Planter Cluster	Short	Yes	Yes	Yes	Yes
Butterfly Garden Network	Medium	Yes	Yes	Yes	Yes
Portable Pavilion Pods	Short	Yes	Yes	Yes	Yes
Tree Grove Cluster	Medium	Yes	Yes	Yes	No
Shared Courtyard Cooling Garden	Medium	Yes	Yes	Yes	Yes
Distributed Rain Gardens	Medium	Yes	Yes	Yes	Yes

Table 24. Matrix of Interventions (Strip, Corner, Interval, and Offset Voids)

Interventions	Term	Strip Voids	Corner Voids	Interval Voids	Offset Voids
Tree Canopy Cooling Field	Long	No	No	No	Yes
Event Lawn with Shade Structures	Medium	No	No	No	Yes
Large Rain Garden Basin	Long	No	No	No	Yes
Memorial Green Space	Medium	No	Yes	No	Yes
Community Cooling Park Node	Medium	No	Yes	No	Yes
Shaded Playground	Medium	No	Yes	No	Yes
Healing Garden	Medium	No	Yes	No	Yes
Urban Tree Nursery	Long	No	No	No	Yes
Multi-Use Cooling Field	Medium	No	No	No	Yes
Stormwater Reten-tion Park	Long	No	No	No	Yes
Modular Sports Field	Medium	No	No	No	Yes
Urban Farming Cluster	Medium	No	No	Yes	Yes
Pocket Cooling Park	Short	No	Yes	Yes	Yes
Rainwater Harvest Garden	Short	Yes	Yes	Yes	Yes
Flexible Event Pad	Short	No	Yes	No	Yes
Urban Farming Mi-cro-Plots	Short	No	No	Yes	Yes
Permeable Auxiliary Parking	Short	Yes	No	Yes	Yes
Micro Tree Nursery	Short	No	No	Yes	Yes
Shade Structure Kit	Short	Yes	Yes	Yes	Yes
Reflective Cooling Patch	Short	Yes	Yes	Yes	Yes

Interventions	Term	Strip Voids	Corner Voids	Interval Voids	Offset Voids
Green Buffer Strip	Medium	Yes	No	No	Yes
Linear Bioswale	Medium	Yes	No	No	Yes
Horticultural Alley	Medium	Yes	No	No	Yes
Shaded Seating Corridor	Short	Yes	Yes	No	Yes
High-Albedo Surface Retrofit	Short	Yes	Yes	Yes	Yes
Portable Cooling Pavilion	Short	Yes	Yes	Yes	Yes
Mini-Plaza with Shade	Medium	No	Yes	No	Yes
Water Mist Anchor Node	Short	Yes	Yes	Yes	Yes
Rain Garden Pocket	Short	Yes	Yes	Yes	Yes
Art + Shade Hybrid	Short	No	Yes	Yes	Yes
Micro Shade Pods	Short	Yes	Yes	Yes	Yes
Cooling Bench + Mist Nodes	Short	Yes	Yes	Yes	Yes
Vegetable Garden Modules	Short	No	No	Yes	Yes
Tree Planter Cluster	Short	Yes	Yes	Yes	Yes
Butterfly Garden Network	Medium	No	No	Yes	Yes
Portable Pavilion Pods	Short	No	Yes	Yes	Yes
Tree Grove Cluster	Medium	No	No	Yes	Yes
Shared Courtyard Cooling Garden	Medium	No	Yes	Yes	Yes
Distributed Rain Gardens	Medium	Yes	Yes	Yes	Yes

4.6. Strategic Map of Vacancy Interventions for the City of Chicago

4.6.1. Proposed Infrastructure for Transitions

A **spatial-morphological categorization framework was used to classify the vacant lots in order to better understand how vacancy restructures the urban fabric rather than just keeping track of empty parcels**. Individual unoccupied properties were categorized based on their spatial interactions with the surrounding street network and with each other using a density- and proximity-based approach. Concentrations of vacancies were found using clustering analysis, and corner and strip conditions were distinguished by proximity to intersections and linear alignment along corridors. The approach **reads emptiness as a pattern rather than as a single data point for each lot, indicating whether it forms dispersed fragments, linear interruptions, huge continuous fields, or strategically placed gaps within the block structure.**

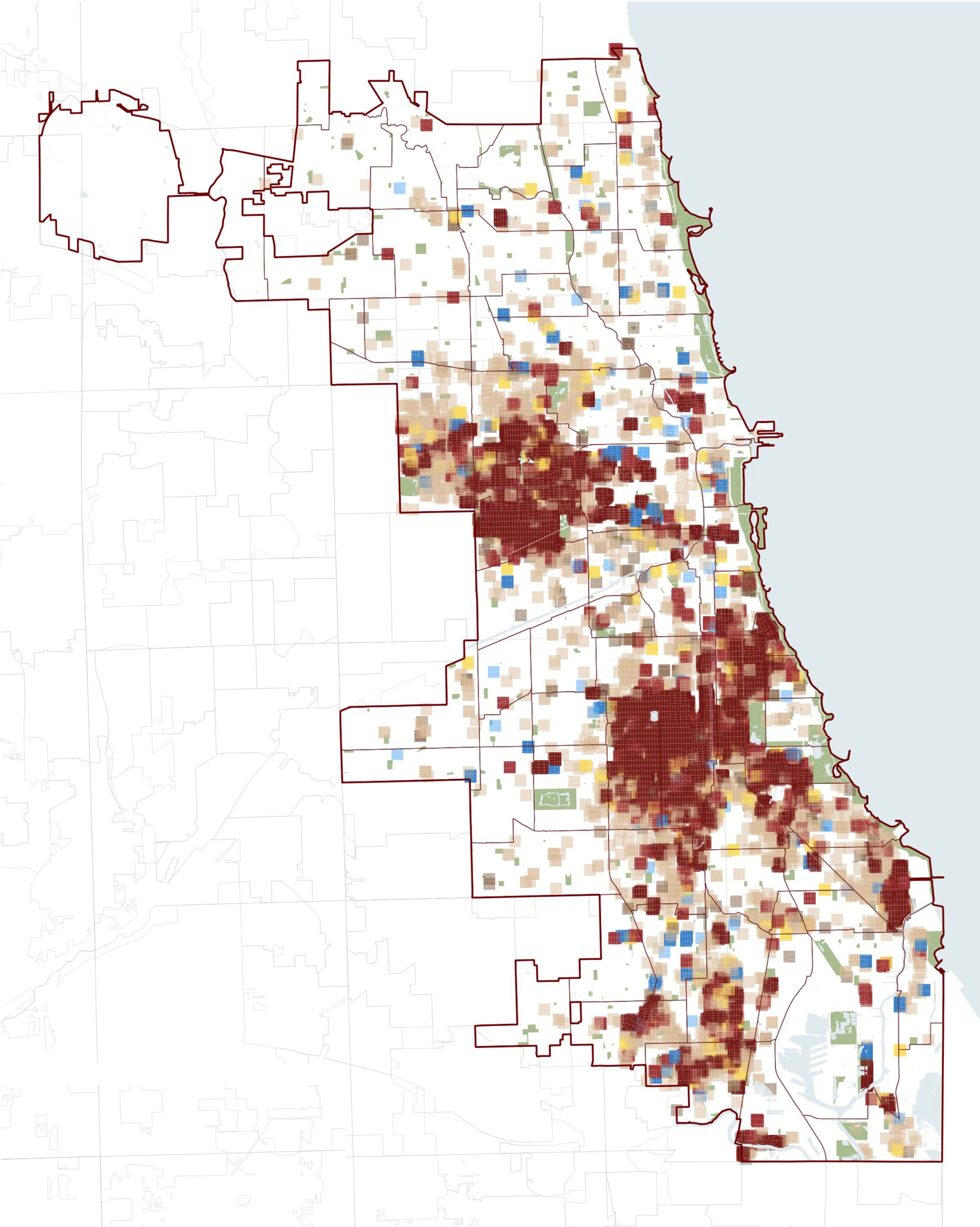
Areas where void is structurally dominant and spatially concentrated are represented by the first category, **Mass and Contiguous Voids.** These clusters frequently show patterns of long-term destruction or disinvestment that have altered entire blocks or sub-neighborhoods. These gaps present chances for revolutionary interventions due to their size, such as community land trusts, solar fields, stormwater landscaping, large-scale green infrastructure systems, or phased redevelopment plans. Their size allows for coordinated development strategies that can improve neighborhood circulation, increase canopy coverage, and considerably reduce the effects of urban heat islands.

On the other hand, vacancies included into circulation logic are reflected by **Strip and Corner Voids.** Corner voids are found in high-visibility, high-access junctions, whereas strip voids are found throughout corridors where pedestrian continuity is broken. Instead of complete rebuilding, these kinds respond well to programmatic and tactical interventions. Shaded walkways, bioswale corridors, micro-mobility lanes, or market infrastructure that reinstates street activity can all be supported by linear voids. Corner voids are ideal for cooling hubs, pocket plazas, tree clusters, or community anchors that strengthen local identity and enhance microclimatic comfort at crucial urban junctions because of their visibility and accessibility.

Lastly, smaller-scale and more distributed vacancy conditions are represented by **interval, offset, flagged, and scattered voids.** In addition to breaking up the urban fabric, these lots offer little chances for distributed resilience. They are suitable for modular interventions like tree planting, permeable surfaces, community gardens, cooling nodes, or auxiliary home infill because they are lighter in space and frequently integrated into residential settings. since of their dispersed character, they are especially useful in heat adaption techniques since localized heat exposure can be decreased by implementing cumulative micro-scale treatments across numerous tiny parcels. This **typological taxonomy reframes vacancy as a diverse spatial resource rather than just as absence**, with each morphology indicating a particular urban intervention method, scale, and intensity.

Table 25. Distribution of Vacancy typologies

Void Type	Count
Mass Void	11,997
Scattered Void	2,747
Contiguous Void	1,815
Offset Void	606
Strip Void	518
Flagged Void	243
Corner Void	72
Interval Void	36



Map 37. Vacant lot typologies and interventions. Source: Author

Legends

- City of Chicago
- Community Areas
- Green Infrastructure
- Blue Infrastructure
- Mass Void
- Contiguous Void
- Strip Void
- Corner Void
- Scattered Void
- Flagged Void
- Interval Void
- Offset Void

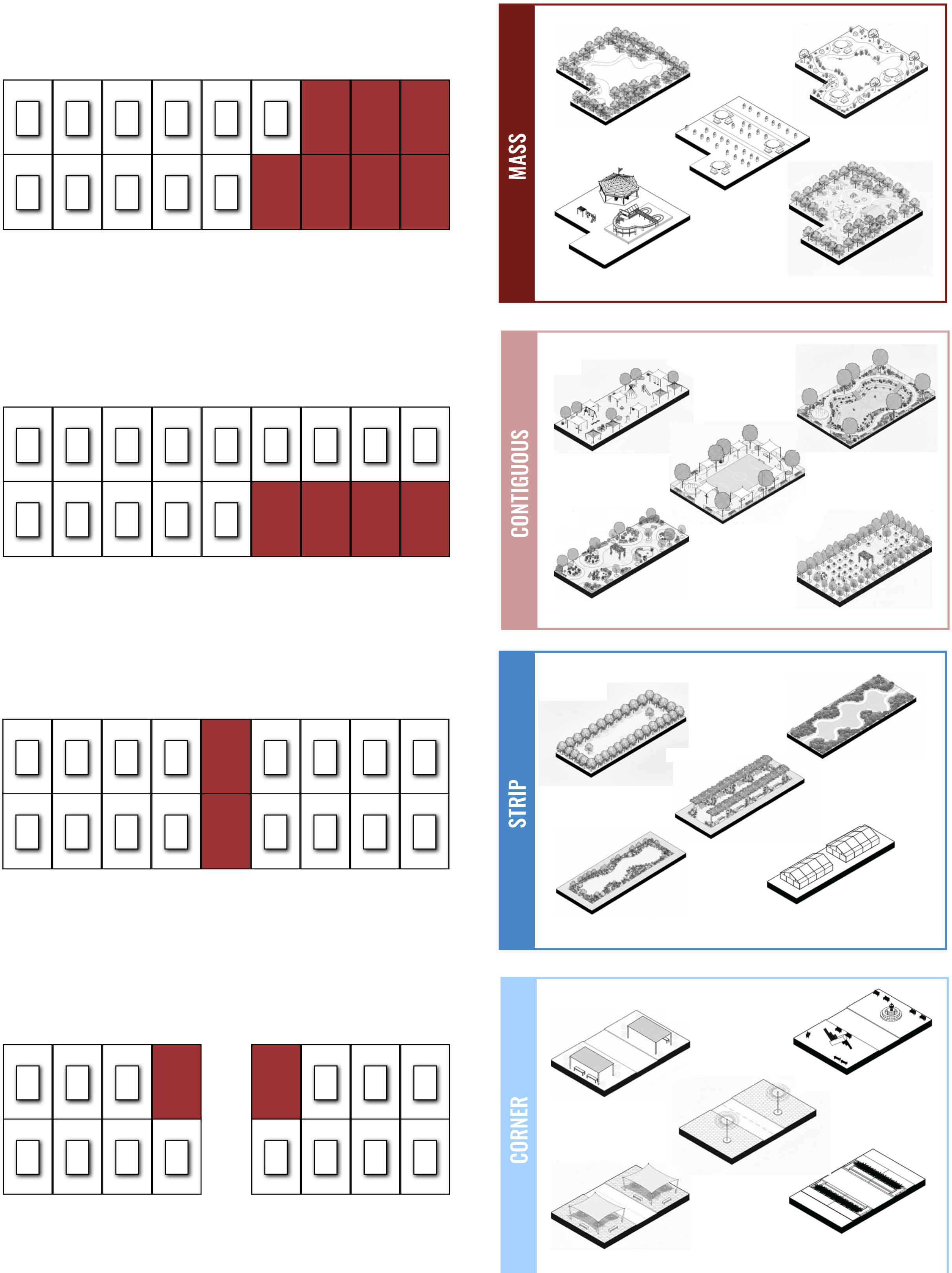


Figure 57. Void Types and interventions (Mass, Contiguous, Strip, and Corner). Source: Author

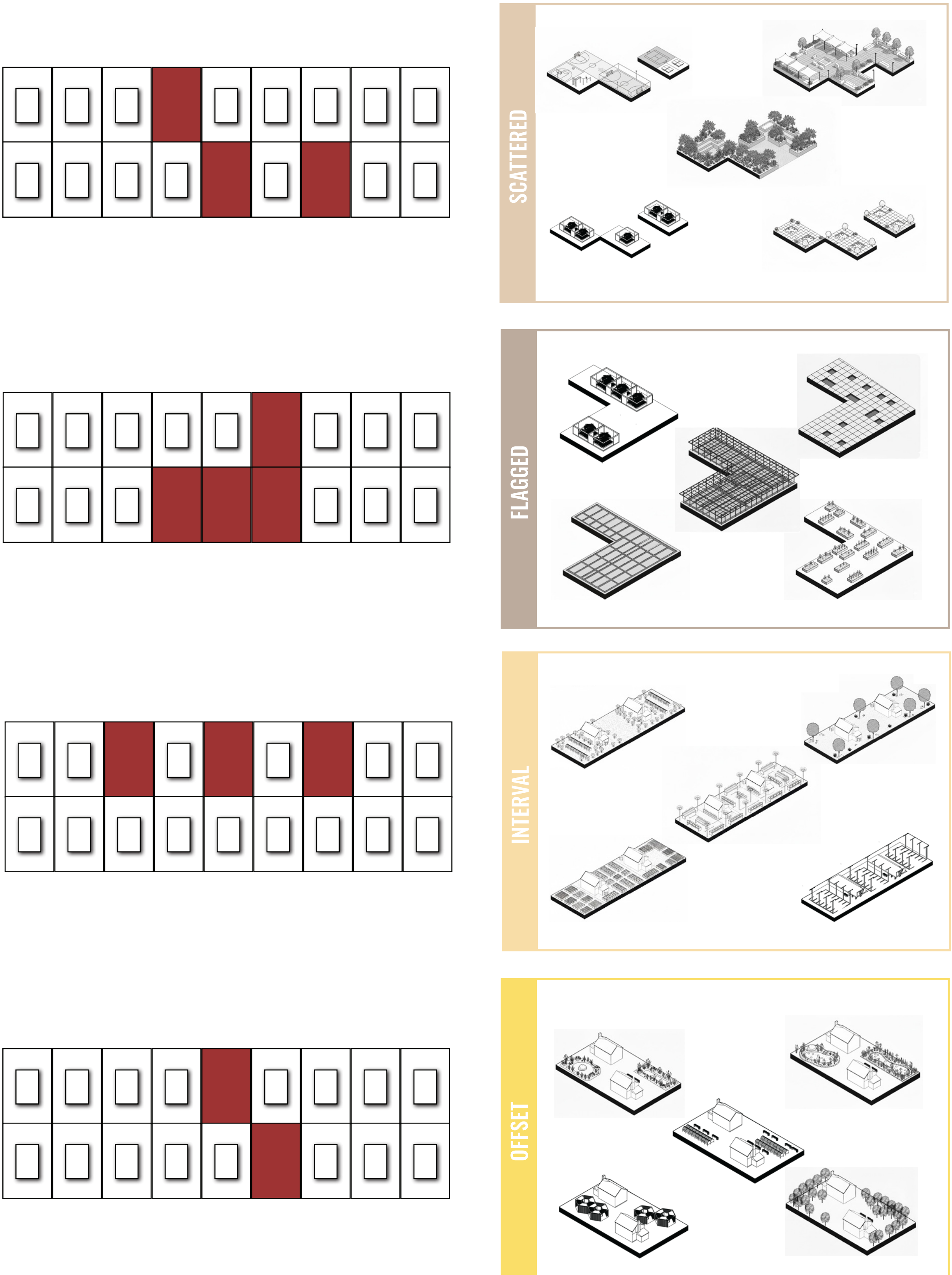
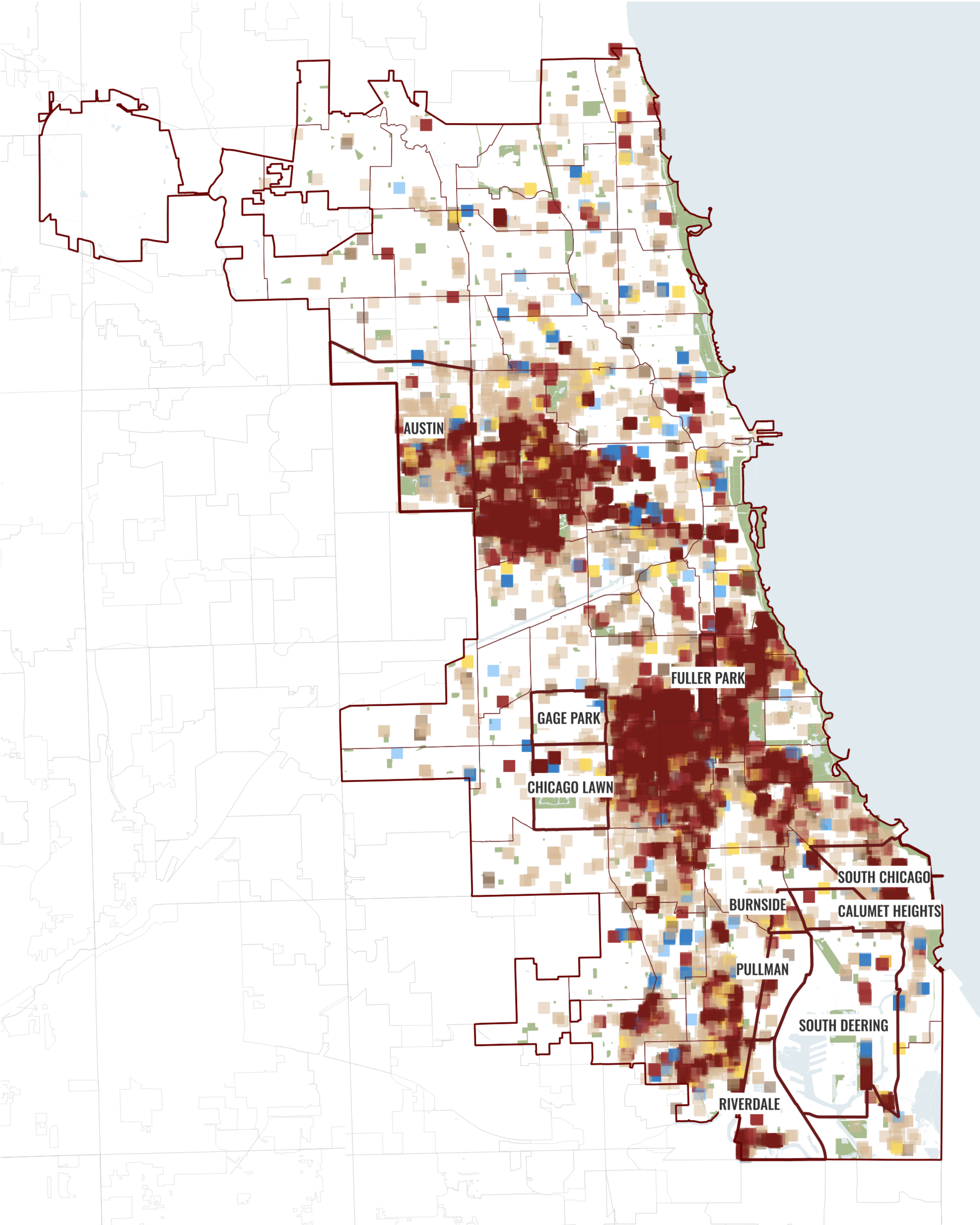
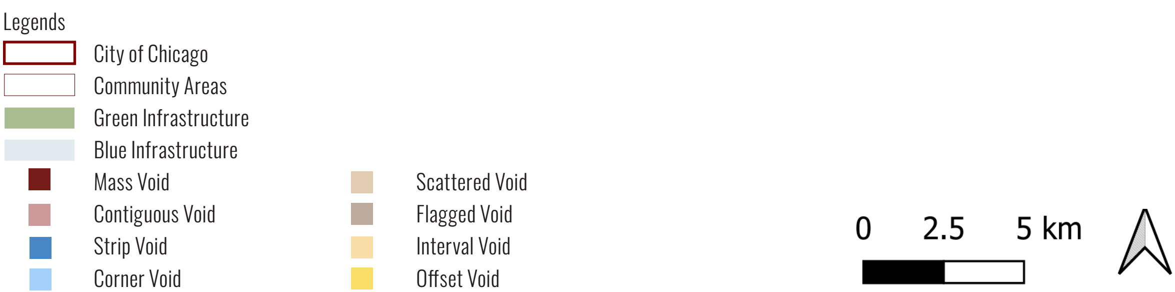
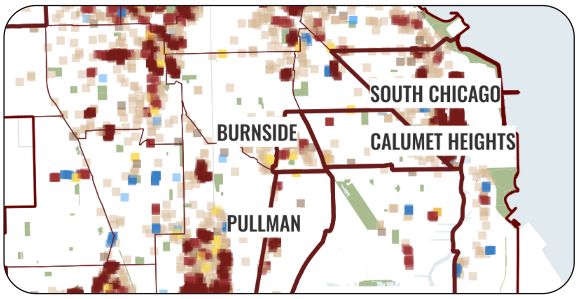


Figure 58. Void Types and interventions (Scattered, Flagged, Interval, and Offset). Source: Author



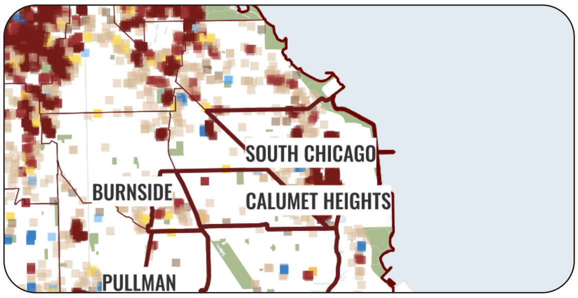
Map 38. 10 High-risk Vacant lot typologies and interventions. Source: Author





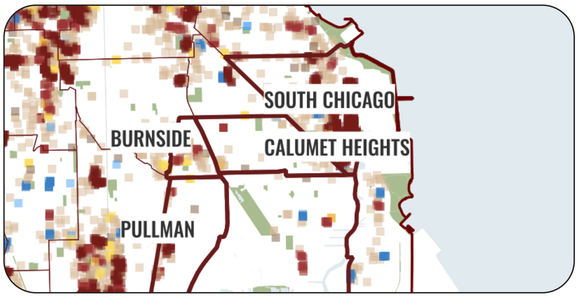
1. Burnside

0	25
17	1
0	0
0	4



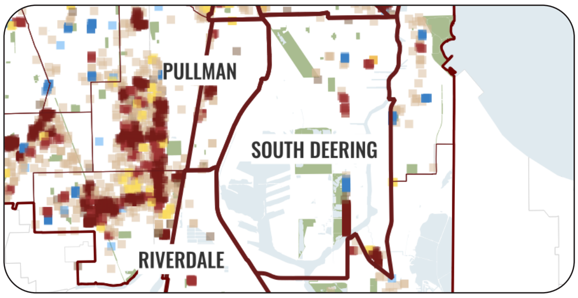
2. South Chicago

474	94
32	3
9	4
3	4



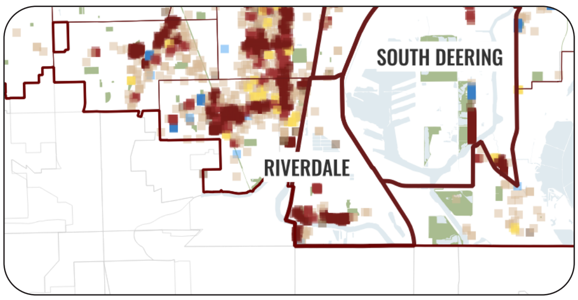
3. Calumet Heights

0	21
5	1
0	4
1	0



4. South Deering

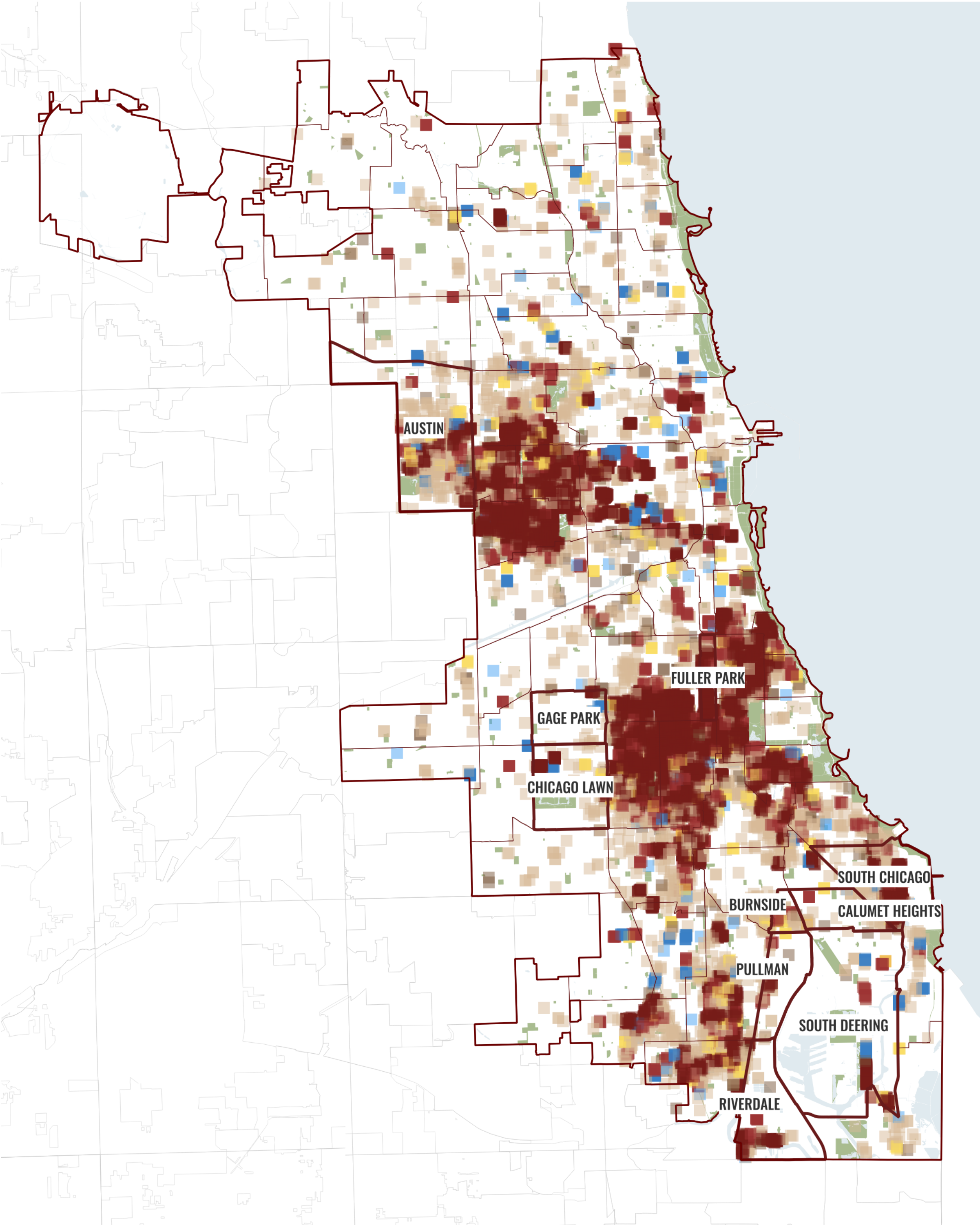
116	13
20	5
28	4
0	4



5. Riverdale

105	22
24	4
0	0
1	0

Mass Void	Scattered Void
Contiguous Void	Flagged Void
Strip Void	Interval Void
Corner Void	Offset Void

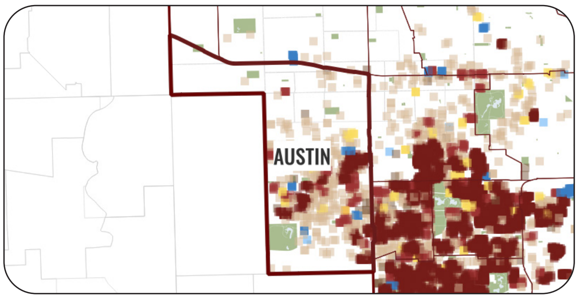


Map 39. 10 High-risk Vacant lot typologies and interventions. Source: Author

Legends

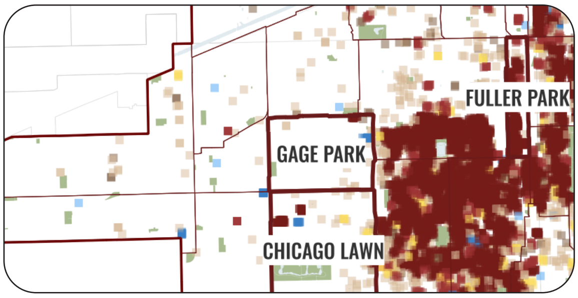
- City of Chicago
- Community Areas
- Green Infrastructure
- Blue Infrastructure
- Mass Void
- Contiguous Void
- Strip Void
- Corner Void
- Scattered Void
- Flagged Void
- Interval Void
- Offset Void

0 2.5 5 km



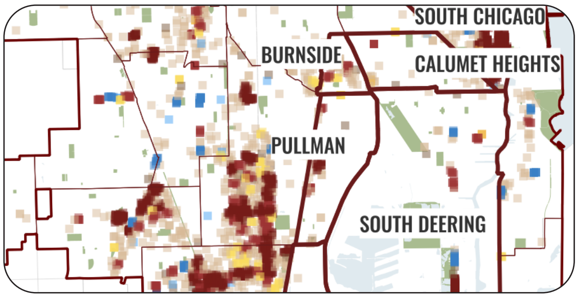
6. Austin

295	239
97	8
28	4
1	28



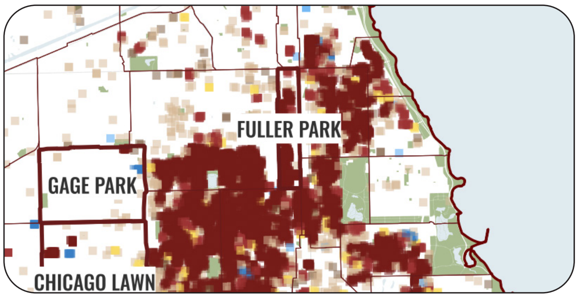
7. Gage Park

13	14
0	1
20	0
1	0



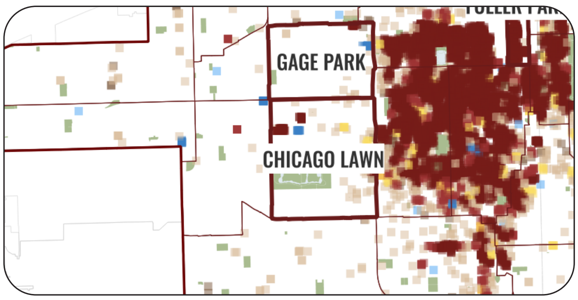
8. Pullman

14	14
15	2
0	0
0	4



9. Fuller Park

271	9
19	0
0	0
0	0



10. Chicago Lawn

67	32
0	3
8	0
0	8

Mass Void	Scattered Void
Contiguous Void	Flagged Void
Strip Void	Interval Void
Corner Void	Offset Void

4.6.2. Infrastructure for Transitions at High-Risk Community Areas

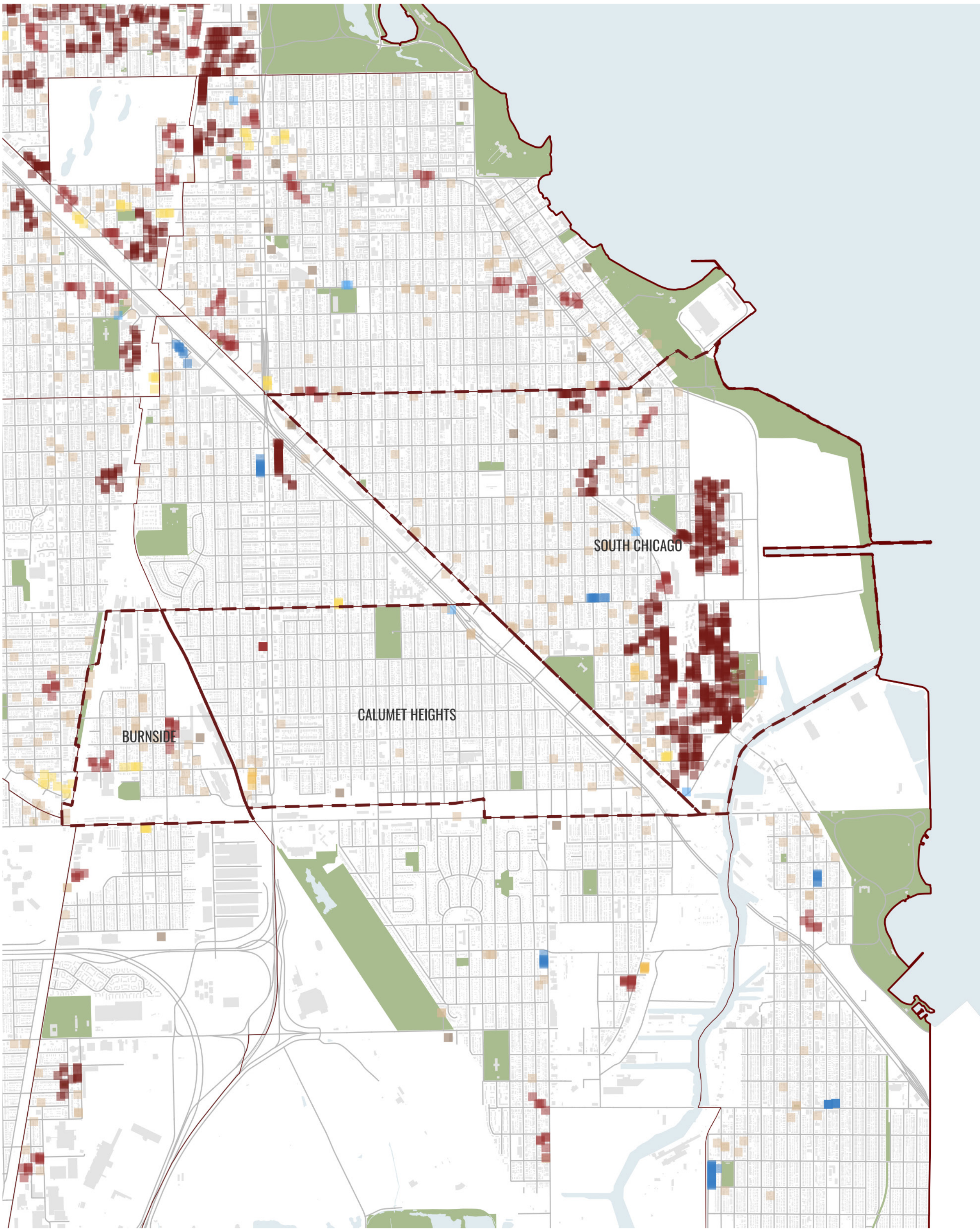
By classifying vacancy typologies, a systematic planning framework is established, converting scattered unoccupied parcels into a cohesive system of climate-responsive infrastructure. By differentiating between scattered, continuous, bulk, strip, corner, flagged, interval, and offset voids, **the typological method allows planners to match each spatial situation with an appropriate intervention scale and duration instead of treating vacancies as isolated remains of disinvestment**. At the city level, this produces a readable list of potential locations that can be arranged strategically based on pedestrian accessibility gaps, heat vulnerability, and reconstruction schedules. Reactive parcel-by-parcel management gives way to a proactive urban heat mitigation network that is integrated into the existing structure.

The collection of typologies at the metropolitan level enables the city **to spot trends in the concentration of vacancies that correspond with historically high-risk regions.** While scattered and corner voids function as dispersed micro-cooling nodes, large mass and contiguous voids especially in South and West Side community areas become anchors for mid- to long-term green infrastructure investment. By extending the "gravitational pull" of current parks and cooling areas into underserved areas, this tiered system enhances spatial redundancy. Instead of distributing scarce resources without spatial strategy, urban planning might prioritize corridors and clusters that maximize cumulative thermal impact by organizing interventions according to typology.

The typology-based approach **allows localized adaptation that takes into account the socio-spatial variables and neighborhood morphology at the community area level.** Activating contiguous or strip voids as shaded links can shorten walking distances to cooling resources and enhance internal network cohesiveness in places where access to green space is dispersed. In order to meet hyper-local demands like community gardens, shade installations, or permeable retrofits, smaller portions, such distributed or corner voids, can be strategically placed. Because of this flexibility, community-scale planning may adapt to short-term exposure hazards while still being compatible with long-term redevelopment paths.

This strategy is further strengthened by the use of temporal phasing, which synchronizes interventions with ecological maturation and land banking realities. Acute heat exposure can be promptly addressed by short-term activations, while canopy growth and infrastructure consolidation are made possible by medium- and long-term measures. The framework guarantees that intermediate uses are quantifiable contributors to thermal risk reduction rather than just short-term stand-ins by connecting classification to duration and performance monitoring. Adaptive governance is supported over time by this staged deployment, which permits modifications based on performance results and changing community goals.

In conclusion, a change in planning logic at both scales is encouraged by the system of typology, intervention matching, and temporal flexibility. It promotes fair cooling infrastructure allocation and strengthens strategic climate resilience goals at the municipal level. It integrates climate adaptation into regular mobility patterns by improving pedestrian networks' accessibility, centrality, and route redundancy at the local level. This dual-scale integration transforms unoccupied land from a sign of deterioration into a structured asset for thermally equitable, systemic urban change.



Map 40. Strategic Plan for Vacancies in High-Risk Community Areas. Source: Author

Legends

- City of Chicago
- Community Areas
- Green Infrastructure
- Blue Infrastructure
- Mass Void
- Contiguous Void
- Strip Void
- Corner Void
- Scattered Void
- Flagged Void
- Interval Void
- Offset Void

0 2.5 5 km

4.7. Urban Activation and Network Impacts

4.7.1. Betweenness

Using the Betweenness metric and a 1,000-meter network radius roughly a 15-minute walking distance the network analysis was carried out using the Urban Network Analysis (UNA) plugin created by Andres Sevtsuk. This approach categorized parks or other designated cooling areas as destinations and residential parcels as origins. Betweenness identifies corridors that structurally facilitate pedestrian access by quantifying the frequency with which each street segment is on the shortest routes between residences and key destinations. Instead of evaluating aesthetic appeal, the metric identifies which streets serve as vital linkages in the neighborhood-scale cooling system.

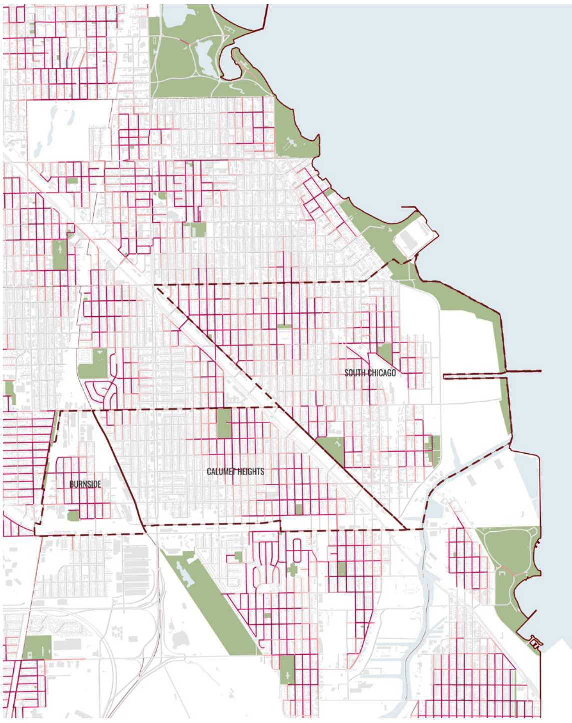
The **pre-intervention map demonstrates that access to cooling places is unevenly distributed and spatially channeled, with high-betweenness values concentrated around existing major parks and a few number of arterial routes**. Residential blocks on the outskirts show less integration, which is indicative of dispersed access in high-risk locations. **Once unoccupied parcels are activated as dispersed micro-cooling nodes, high-betweenness corridors become more widely dispersed in space.** Better route redundancy, shorter efficient travel routes, and a more continuous pedestrian network linking residences to thermally supporting areas are all suggested by this redistribution.

This structural change is **in line with Jane Jacobs' urban theories, especially her focus on connected streets, frequent attractions, and regular pedestrian traffic as the cornerstones of safe and vibrant cities**. The **initiatives strengthen informal surveillance and "eyes on the street" by increasing regular foot traffic across a wider range of streets by integrating additional cooling nodes within walking distance.** Redistributing movement improves social interaction, perceived security, and neighborhood activation in addition to mitigating heat. Thus, climate-responsive vacancy remedies enhance both the street's social vitality and environmental resilience at the same time.

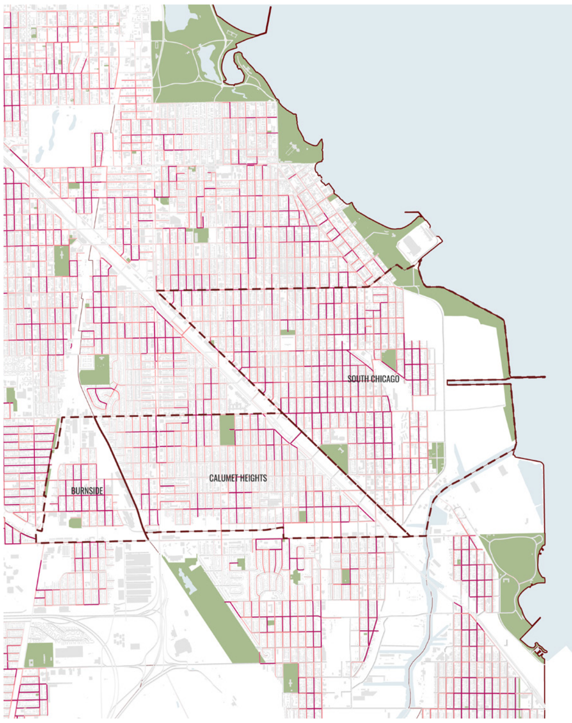
Before Interventions

After Interventions

0 750 1,500 m



Map 41. Gravity Accessibility of Existing Parks / Cooling Spaces. Source: UNA Toolkit, adapted by



Map 42. Gravity Accessibility of Existing Parks / Cooling Spaces with interventions. Source: Author

Legends

- Selected Community
- High Spatial Accessibility
- Moderate Spatial Accessibility
- Low Spatial Accessibility

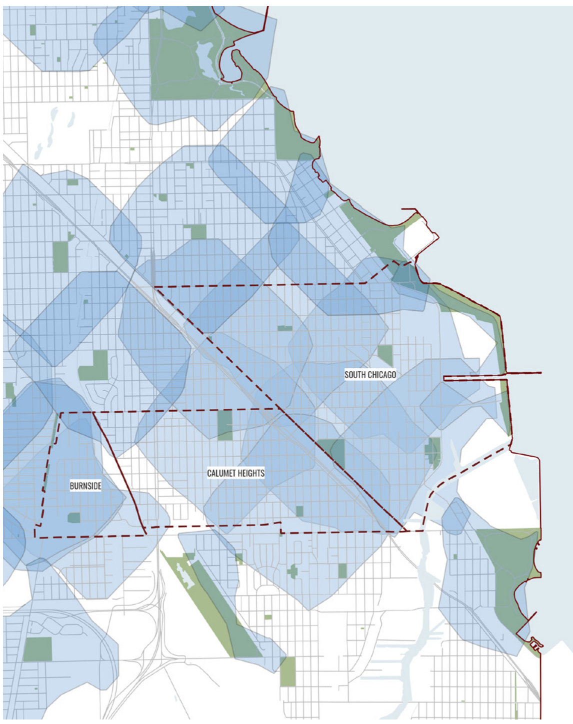
4.7.2. Catchment Areas

Existing parks and suggested improvements across classed unoccupied space typologies served as the main nodes for the catchment study, which was carried out using 15-minute walking isochrones generated from open-source routing data. To estimate a realistic 15-minute walking distance under typical pedestrian conditions, a 1,000-meter network threshold was used. The isochrones quantify the spatial extent of residential areas that have access to these cooling resources within the specified time range, with parks and activated unoccupied parcels serving as destination nodes in this framework. This method shows the cooling network's territorial reach both before and after intervention by evaluating service coverage rather than movement intensity.

Isochrone coverage in the pre-intervention state is mostly concentrated in well-established parks, resulting in an uneven spatial distribution and excluding a number of interior blocks from convenient pedestrian access. These unprotected zones line up with places where people must walk farther and are more likely to be exposed to heat. The catchment regions grow and start to overlap after adding vacancy typology-based interventions as extra cooling nodes, greatly minimizing spatial gaps. A more continuous cooling network that is woven into the neighborhood fabric is produced by integrating bulk, contiguous, and distributed voids as accessible micro-destinations.

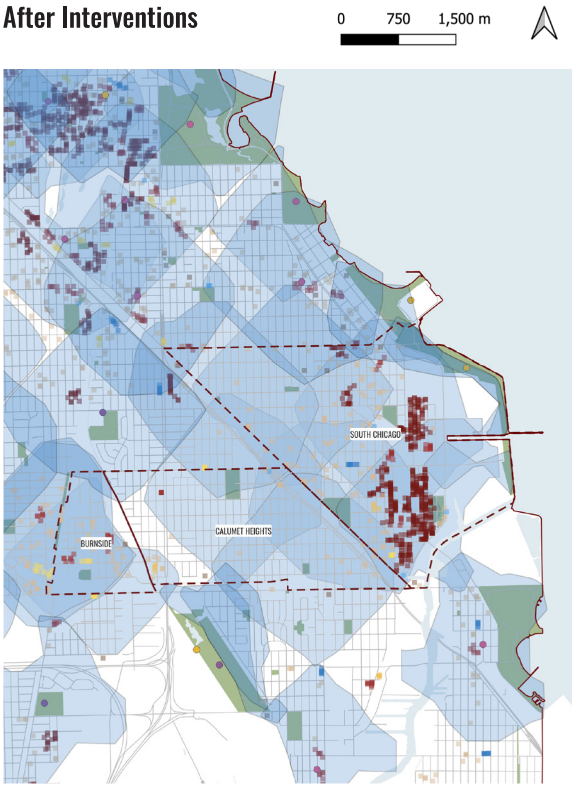
This reorganization of accessible nodes is consistent with Jane Jacobs' urban philosophy, namely her focus on closeness, dispersed destinations, and the energy created by regular pedestrian interaction. The initiatives improve daily street use and social activation by increasing the number of accessible open spaces within walking distance. By increasing foot activity, improved proximity not only lowers environmental risk but also improves perceived safety and unofficial surveillance. **As a result, both climate resilience and the improvement of neighborhood-scale urban life are reflected in the isochrone growth.**

Before Interventions



Map 43. Catchment area of Existing Parks. Source:

After Interventions



Map 44. Catchment area of Existing Parks with interventions. Source: Isochrone data, adpated by Author

Legends

Selected Community

15 Minutes isochrones

4.7.3. Limitations

Although this network and isochrone testing method offers structural insight into accessibility enhancements, it has a number of significant drawbacks. First, neither population counts nor demographic weighting at the block or parcel level are included in the analysis. Due to the universal treatment of residential parcels as origins, both high-density and low-density residential areas receive the same analytical weight. The model may therefore underrepresent regions where vulnerability is concentrated since it assesses geographical configuration rather than actual exposure levels or the size of impacted populations.

Second, the structure of origin-destination is reduced to using residences as origins and parks or interventions based on vacancies as destinations. This assumption does not take into consideration behavioral variability, trip chaining, age-related mobility disparities, or alternative destinations like libraries, transit stops, or commercial hubs. Instead, it analyzes prospective pedestrian access to cooling spaces. Therefore, rather than representing movement patterns that have been observed empirically, the framework reflects a theoretical accessibility situation. Although suitable for comparative before-and-after testing, it falls short of capturing the intricacy of pedestrian decision-making in the real world.

Lastly, the Betweenness and isochrone analyses presume that everyone has the same walking ability and are based on a fixed 1,000-meter (15-minute) walking threshold. Effective walking ranges can actually be greatly shortened by heat stress, age, handicap, and perceived safety, especially in high-risk areas. Microclimatic variation along routes, such as shaded versus unshaded streets, is also not taken into account by the model. Therefore, rather than being conclusive measurements of actual accessibility or thermal comfort outcomes, the data should be viewed as structural markers of enhanced network potential.

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CHAPTER V

Conclusion

Chapter V: Conclusion and Recommendations

Reframing Urban Heat as Structural Spatial Inequality

This thesis started with a basic assumption: Chicago's urban heat is neither a coincidental natural phenomenon or only a result of density or seasonal climatic change. Instead, **it is a spatialized expression of inequality that has been historically created and is ingrained in urban design, land policy, and infrastructure investment.** This study shows that current heat risk is patterned, cumulative, and structurally organized through the combination of redlining archives, social vulnerability indicators, land surface temperature studies, and urban network modeling. Following the geography of exclusion is the geography of heat exposure.

The findings reveal that formerly redlined neighborhoods continue to experience intensified urban heat, higher concentrations of vulnerable populations, and constrained pedestrian mobility. These trends are not accidental. They **show a long-lasting spatial logic in which past policy choices influenced not only the demographics of residents in particular regions but also the physical attributes** tree canopy distribution, impervious surface ratios, street network connectivity, and cooling resource accessibility that impact environmental risk today. Thus, Chicago's Urban Heat Island intensity functions as a political and environmental factor.

Figure 59. Spatial and Historical Inequalities. Source: Virginia Tech College of Liberal Arts and Sciences

Figure 60. Unraveling vacancy in Chicago. Source: Liang Cheng

Major Findings: Intersections of Policy, Form, and Mobility

Redlining acts as a long-term risk multiplier, according to the first significant discovery. Racialized disinvestment was institutionalized, which concentrated sociodemographic risk in particular communities. These same regions now have a higher probability of disasters due to the intersection of environmental hazards and vulnerability. Where adaptable infrastructure has historically been overlooked, heat exposure increases. Therefore, vulnerability is structurally created by policy rather than being innate to communities.

Second, Chicago's urban morphology was significantly influenced by redlining. **Historic disinvestment has resulted in geographic segregation from institutional and economic resources**, diminished tree canopy, fragmented pedestrian networks, and excessive impermeable coverage. The study demonstrates the interdependence between risk, exposure, and accessibility. Where urban architecture restricts mobility and cooling capability, heat is amplified. Thus, urban segregation manifests itself thermally.

Third, **policy becomes a spatially decisive force**. Inequitable thermal landscapes were created by historical policy; current policy has the ability to either maintain or improve these situations. Municipal climate policies, zoning frameworks, and land banking systems are not neutral tools. They influence whose environs are made safer, establish infrastructure priorities, and mold redevelopment trajectories. The study emphasizes how governance change and climate resilience are inextricably linked.

Fourth, vacancy needs to be reframed critically. **Vulnerability does not always follow from vacancy. Vulnerability instead arises when danger and low adaptation capability meet with socially at-risk people.** Underutilized and unoccupied plots serve as latent spatial infrastructure in high-risk neighborhood regions. Vacancy can promote permeability, introduce canopy or shade structures, lower localized heat intensity, and improve pedestrian network performance when it is engaged by adaptable and flexible interventions.

The last significant conclusion proves that distributed, adaptable "meta-projects" are preferable than single, long-term infrastructure megaprojects. **Design permanency may unintentionally force cities into maladaptive patterns in a period of growing climatic unpredictability.**

Mitigation, Adaptation, and the Imperative of Monitoring

An integrated trio of mitigation, adaptation, and ongoing monitoring is needed to address urban heat. Through distributed shade solutions integrated into mobility corridors, vegetation expansion, albedo augmentation, and permeability retrofits, mitigation lessens the physical drivers of Urban Heat Island intensity. By increasing thermal comfort, expanding network connectivity, and guaranteeing fair access to cooling services, adaptation enhances the lived experience of vulnerable groups.

However, **without monitoring, adaptation and mitigation are insufficient**. Urban heat is dynamic, influenced by seasonal fluctuations, policy changes, demographic shifts, and redevelopment pressures. Monitoring turns climate planning into an iterative governance process rather than a static action. Cities may monitor thermal disparities in real time using mobility models, localized sensors, and satellite analysis. Therefore, resilience needs to be ingrained as an ongoing feedback loop as opposed to a one-time infrastructure fix.

Addressing the Research Questions

In order to address the first research question, **this thesis shows how redlining's legacy still shapes contemporary patterns of urban heat exposure and environmental vulnerability at the neighborhood level.** Formerly redlined neighborhoods are confirmed by spatial overlays to have higher heat hazards, more social vulnerability, and less adaptive infrastructure. Modern thermal geographies still bear the scars of historical exclusion.

Through network-based analysis, the second research question is addressed, demonstrating that increased heat acts as a barrier to mobility. Reduced pedestrian comfort and restricted access to necessary services are caused by the intersection of high surface temperatures, fractured connectivity, and little shade. As a result, **heat acts as a restraint on infrastructure, especially for low-income households, towns with few mobility options, and senior citizens.**

By strategically redefining vacancy, the third research issue is addressed. It is possible to **use vacant land as a climate adaptation activation mechanism in areas that are susceptible to heat. Vacancy can change from a symbol of decline to a distributed climate infrastructure network** that can mitigate heat and lessen mobility disparities by working with Chicago's land banking system and municipal planning frameworks.

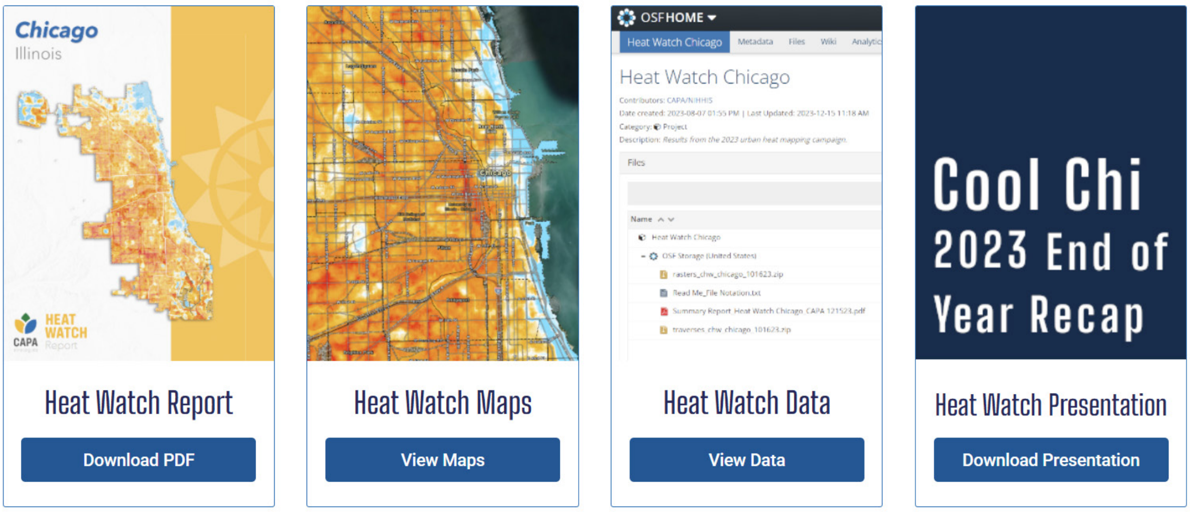

Figure 61. Heat Watch - Cool Chi platform. Source: Chicago.gov

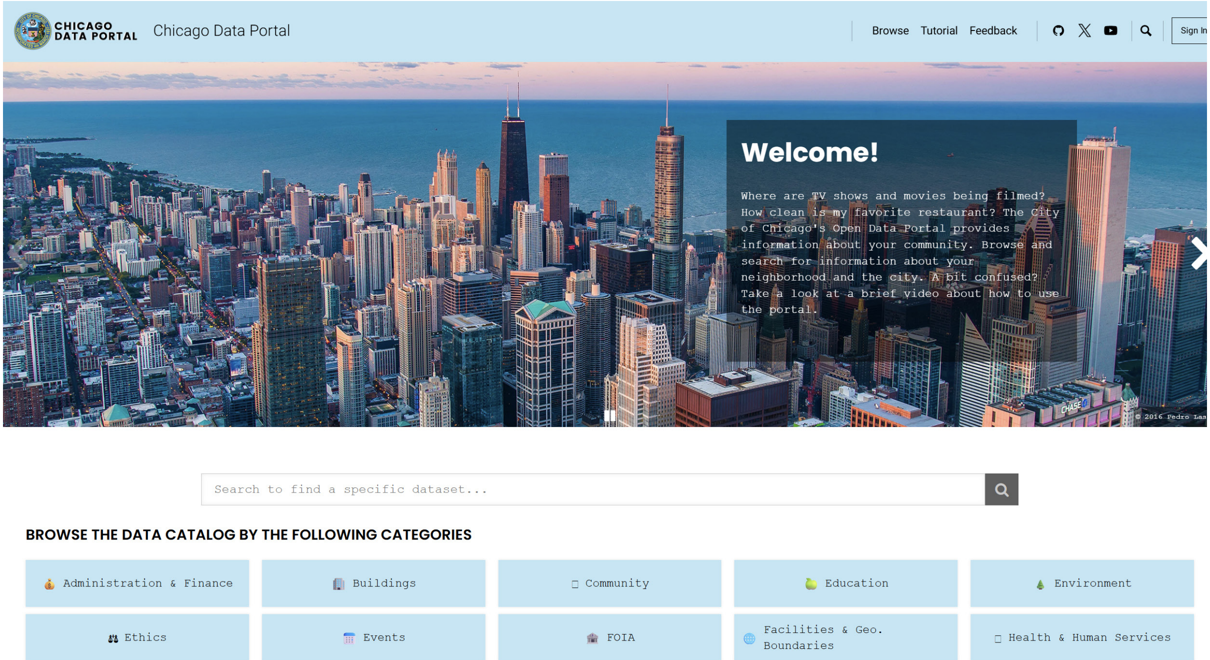

Figure 62. Chicago Data Portal. Source: Official website of Chicago Data Portal

Limitations and Future Directions

The **availability and structure of current datasets continue to limit this research despite its integrative and multi-scalar approach**. Although the study makes use of the most up-to-date and geographically complete satellite imagery and demographic data available at the time of analysis, the breadth of the analysis is unavoidably shaped by data restrictions. Although Land Surface Temperature (LST) is useful for detecting patterns of spatial heat intensity, it does not adequately represent the microclimatic conditions or variations in air temperature at the pedestrian level in shaded versus unshaded corridors. Moreover, longitudinal evaluation of changing climate patterns is limited by the analysis's time frame. While urban heat is the main hazard in this thesis, other intersecting risks like flooding, deteriorating air quality, or compound heat events could create different vulnerability landscapes that need further research. The intensity of climate-related hazards may change over time.

The **methodological horizon should be expanded in two directions by future study**. First, **to better capture embodied thermal experience**, longitudinal and sensor-based monitoring is required that combines wearable heat exposure tracking, in-situ air temperature measurements, and real-time mobility analytics. Second, and perhaps more importantly from a planning standpoint, future research should **reconsider vacancy as an active spatial mechanism for flexible transition rather than as a residual land state.** It is possible to operationalize vacant land as adaptive infrastructure that can react to changing danger intensities over time. Planning frameworks should institutionalize flexibility so that communities can move toward climate-adaptive and heat-aware futures rather than viewing redevelopment as a straight line toward permanence. In this way, vacancy becomes a spatial tool to manage uncertainty rather than a problem to be solved.

Contribution and Novelty

By developing an integrated framework that connects historical policy analysis, satellite-derived environmental data, and urban network modeling to evaluate climate risk at the neighborhood scale, this thesis adds novel knowledge to the field of urban planning. It is one of the first studies to **translate abstract resilience principles into spatially practical land typologies by placing vacancies inside typological categories** that are in line with the World Bank-informed "Plan for Heat Resilience" framework. The study provides a new paradigm of transitional infrastructure by categorizing unoccupied land based on its adaptive potential rather than its economic deficit.

Additionally, by evaluating Chicago's current risk framework using a special set of criteria derived from hazard (UHI intensity), vulnerability (demographic and socioeconomic indicators), and exposure (network-based mobility accessibility), this thesis makes a unique methodological contribution. The **city's thermal landscape can be evaluated using a hybrid quantitative–qualitative approach that combines the study of satellite imagery with qualitative spatial interpretation.** This multifaceted evaluation goes beyond traditional vulnerability mapping by integrating environmental data with urban morphology and socio-spatial history.

This work is innovative both in its philosophical reinterpretation and in its methodological synthesis. **It reinterprets heat as a mobility barrier entrenched in network systems, reframes the intensity of urban heat islands as structurally created, and views vacancy as a flexible spatial mechanism for adaptive transformation.** The thesis establishes a network-based, equity-centered approach to climate resilience by fusing geospatial modeling, historical injustice analysis, and design-oriented planning techniques.

By doing this, it takes the conversation about urban planning from static mitigation techniques to a dynamic framework that incorporates social justice, monitoring, design flexibility, and governance. The **thesis contributes to challenging traditional redevelopment paradigms and proposes an alternative model for climate-responsive urban change through this integrative viewpoint.**

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Appendices

Socio-demographic Analysis: Population Density

The geographical pattern of population density in Chicago is a highly concentrated urban core with the most densely populated areas clustered in the central and near-north sections and pockets of the South and West Sides. These neighborhoods have compact settlement patterns due to historic urban development, access to transportation, and proximity to job centers. The lakefront corridor, in particular, shows relatively higher density, reflective of its past role as a city residential and economic core.

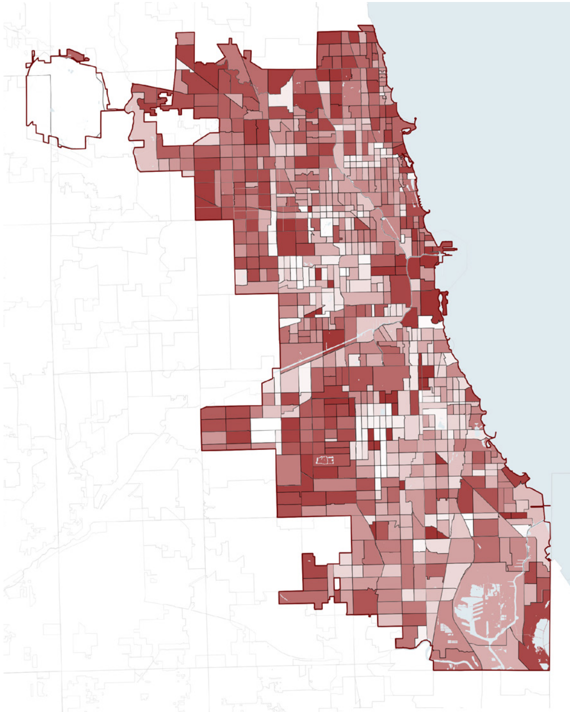
On the other hand, peripheral parts of Chicago, particularly on the far northwest and southwest edges, have much lower population density. These zones are characterized by suburban-style residential development, larger lot sizes, and industrial or infrastructural land uses that limit residential concentration. This type of spatial differentiation underscores the uneven development of Chicago, whereby older neighborhoods near the city center remain highly dense, while newer peripheries have space for more dispersed settlement patterns.

Population density is a multifaceted driver of urban equity and resilience. Neighborhoods with higher population densities have more acute problems of housing unaffordability, congestion, and exposure to environmental stressors such as the urban heat island effect. Density can also allow for greater access to public transportation, services, and green infrastructure if planned in an equitable manner. It is important for Chicago to learn about these dynamics of density to relate demographic trends to climate vulnerability, mobility, and the distribution of urban resources.

Density on the map is calculated at small geography units (census tracts/block groups) as persons per unit area and mapped so that more dense shading signifies higher density.

Table 26. Male and Female Population Count

Male	Female
1,348,930	1,415,293
Total	
2,764,223 people	



Map 45. Population density in Chicago

Legends
- City of Chicago
- Community Areas
- Census tracts
- Blue Infrastructure
- Low density
- Moderate density
- High density

Socio-demographic Analysis: Age and Sex

Chicago's population reflects a highly young and diverse urban age structure profile. The city's median age of 36.4 years is less than the Illinois state median of 39.5 years, reflecting a slightly younger population overall. The age-sex structure also has broad working-age populations between the ages of 25–44 years, with females outnumbering males in all higher age groups, again reflecting female life expectancy being longer. Just about 14.4% of the city's residents are over 65, which is less than in the state at 17.6%, highlighting a lower rate of older residents compared to the rest of Illinois. The younger median age creates an energetic workforce but means there also must be provision for aging services with the population consistently aging year by year.

Chicago is also a multicultural and multilingual city, which significantly characterizes its demography. Just about 34.7% of its residents speak a language other than English at home, headed by Spanish (22.7%), followed by other Indo-European languages (5.7%) and Asian or Pacific Islander languages (4.6%). Moreover, almost every fifth resident is foreign-born, split between naturalized citizens (48.4%) and non-citizens (51.6%). This multiculturally made city serves to underscore the imperative for inclusive urban development in light of the concerns of immigrant and multilingual populations.

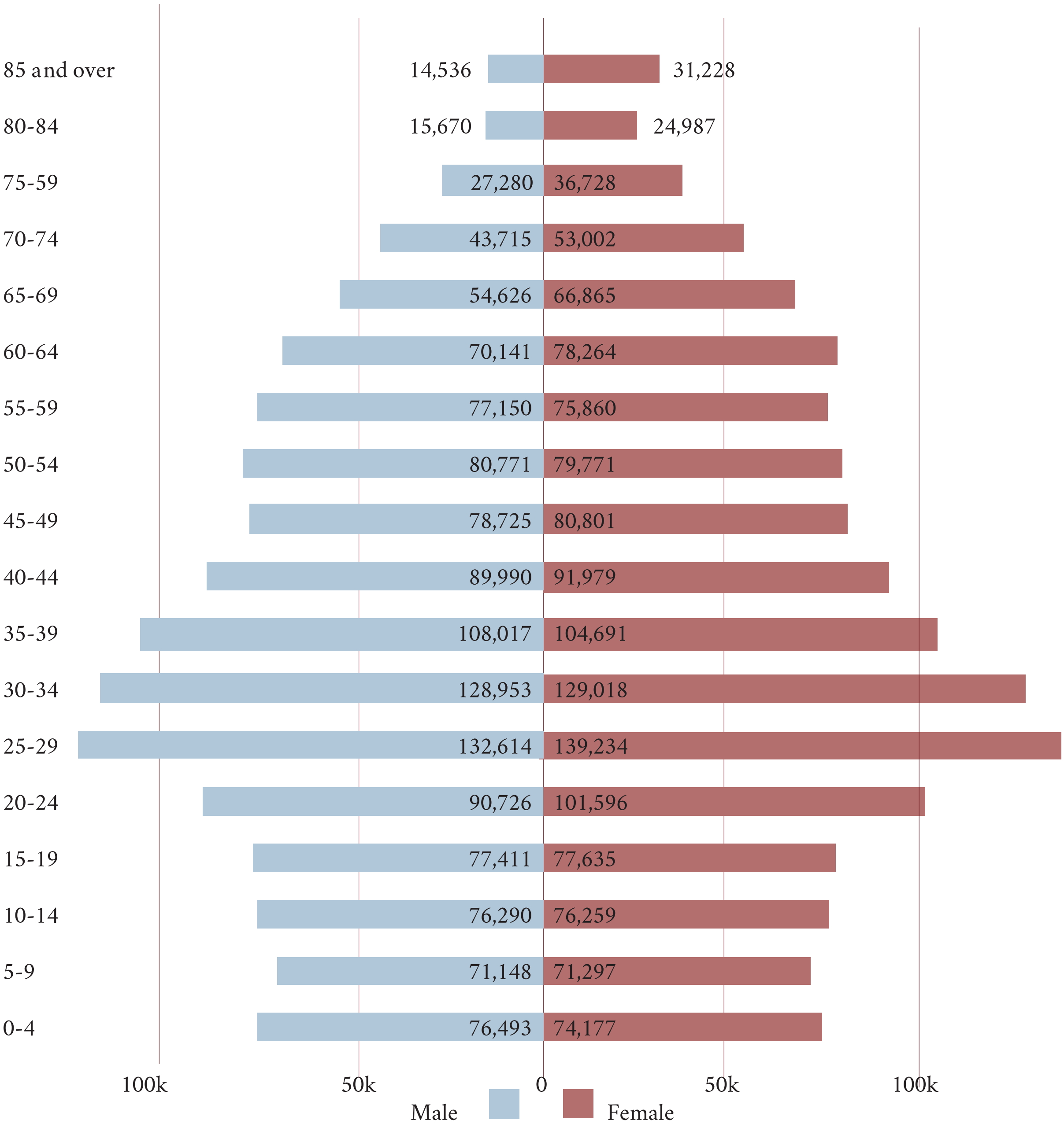


Figure 63. Population Pyramid: Population by Age and Sex

Table 27. Rail Station Events in 2024

Stations	Lines	Service Disruption	Dates
Western, Damen, Francisco, Rockwell, Kedzie, Kimball, Montrose	Brown	Western Station Project	Aug 30-31, Sep 6-7
Western, Damen, Francisco, Rockwell, Kedzie, Kimball, Montrose	Brown	Western Station Project	Oct 25-26
Dempster, Oakton	Yellow	Refresh & Renew	Nov 9-10
Racine	Blue	All Stations Accessibility Program	May 10-13, Oct 25-28
Central, Linden, Davis, Main, Noyes, Foster, Dempster, South Boulevard	Purple	Track & Structure Maintenance	Nov 24-25
Byrn Mawr	Red	Red Purple Modernization	Apr 19-22
Addison, Sheridan	Red	Red Purple Modernization	Nov 15-16
Morse, Granville, Thorndale, Jarvis, Argyle, Loyola, Bryn Mawr	Red	Red Purple Modernization	Dec 20-21
35th-Bronzville, CermakMcCormick Place	Green	Refresh & Renew	Mar 23-25
Cermak-McCormick Place	Green	Refresh & Renew	Jun 22-23
Austin	Green	All Stations Accessibility Program	Nov 2-3
54th/Cermak	Pink	Laramie Grade Crossing Project	Nov 1-4

Table 28. Annual Summary of Ridership Year 2024 (Operating days - top; Annual System totals - below)

Day Type	Last Year	This Year
Weekdays	254	256
Saturdays	52	52
Sundays	59	58

Category	Year-to-date Total (Actual)			Year-to-date Total (Cal. Adj.)		
	Last Year	Current Year	% Change	Last Year	Current Year	% Change
Bus	161,699,361	181,733,617	12.4%	162,035,586	181,254,886	11.9%
Rail	117,447,140	127,463,409	8.5%	117,669,026	127,137,450	8.0%
System Total	279,146,501	309,197,026	10.8%	279,704,612	308,392,336	10.3%

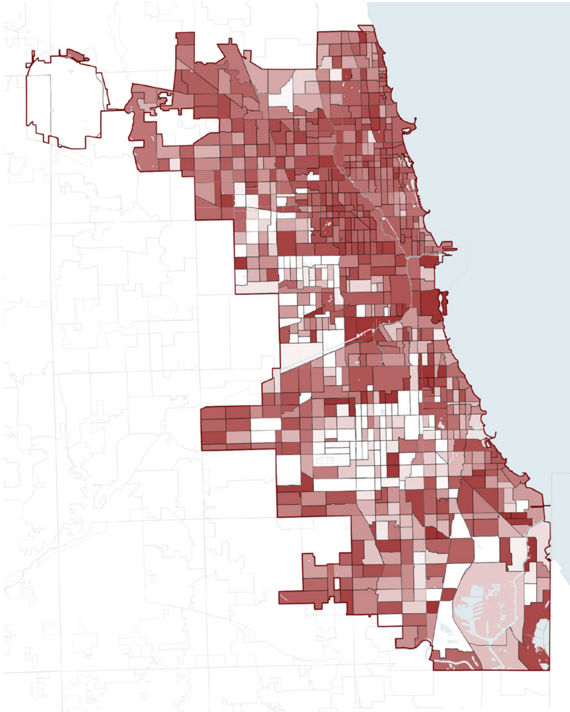
Socio-demographic Analysis: Education

Chicago's education profile shows a clear spatial disparity in educational attainment between areas. The concentration of people with bachelor's degrees or above is much higher in the city's northern and central regions, especially in the vicinity of downtown. Stronger economic performance, easier access to resources, and more well-established educational and professional institutions are common characteristics of these regions. The concentration of educated people in these areas is indicative of a long-standing urban stratification pattern in which social opportunity, wealth, and infrastructural quality are strongly correlated with educational attainment.

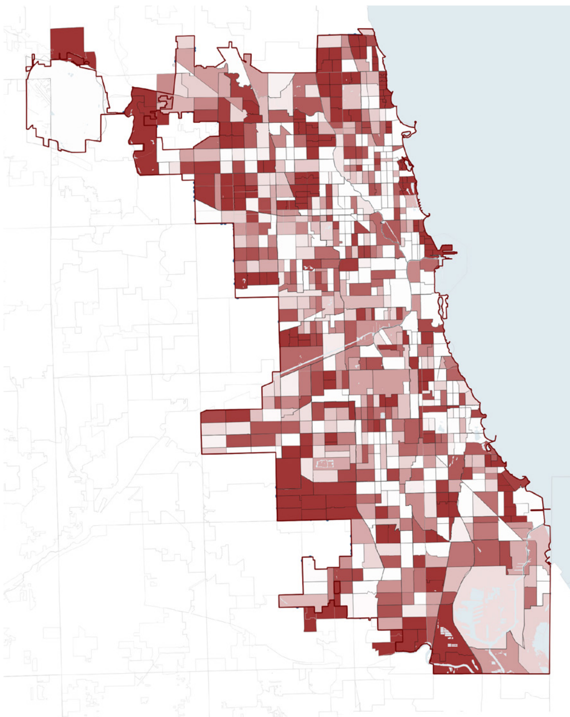
On the other hand, a greater proportion of people in Chicago's southern and western regions have less than a high school diploma, indicating much lower educational achievement. Systemic obstacles, such as underfunded schools, restricted access to higher education, and fewer local employment prospects requiring advanced qualifications, have historically plagued these regions. The structural injustices ingrained in the social and physical fabric of the city are highlighted by the continuation of these educational disparities. It also reflects the larger socioeconomic issues that still plague these communities' low-income and predominately minority neighborhoods.

Wider differences in income, employment, and quality of life are reflected in the discrepancy between high and low educational attainment throughout Chicago. greater concentrations of educated people are typically associated with better conditions, including lower unemployment rates, greater property values, and easier access to services and facilities. On the other hand, communities with lower levels of education typically face greater rates of poverty, less economic mobility, and fewer investments from the public or private sectors. As a result, the city's educational environment functions as a spatial depiction of both opportunity and inequity.

Coordinated approaches that connect education to more general urban policy objectives are needed to close these gaps. These disparities might be lessened by increasing school budget equity, expanding access to postsecondary and vocational education, and incorporating educational activities into neighborhood regeneration programs. Chicago can promote a more inclusive urban environment where education serves as a bridge toward shared prosperity and social fairness rather than a barrier by utilizing spatial data to direct focused actions.



Map 46. Bachelors graduates distribution



Map 47. Less than high school graduate

Legends
- City of Chicago
- Community Areas
- Census tracts
- Blue Infrastructure
- Low concentration
- Moderate concentration
- High concentration

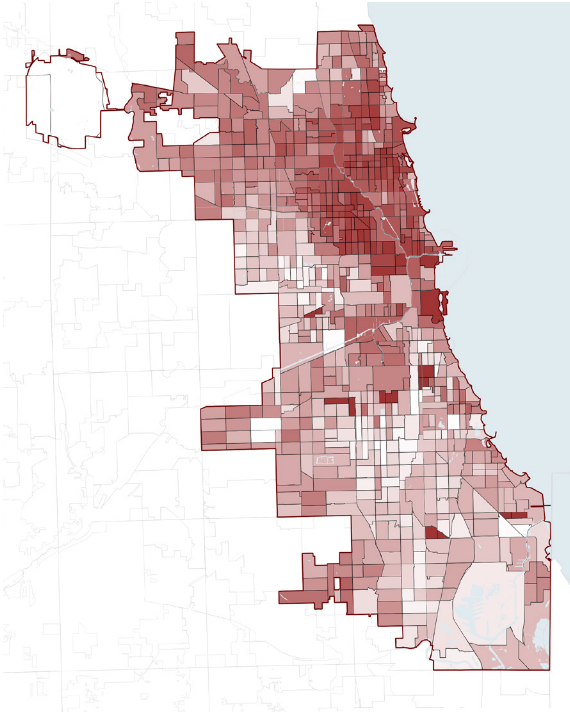
Socio-demographic Analysis: Employment and Income

Chicago's employment and income profile reveals glaring socioeconomic differences that closely resemble the city's geographic and demographic divisions. The city's central and northern regions, especially downtown and the surrounding districts, have the greatest employment rates due to the concentration of commercial infrastructure, employment options, and economic activity. These regions gain by being close to the central business center, having access to public transit, and having businesses like technology, healthcare, education, and finance grouped together. As a result of historical disinvestment, deindustrialization, and restricted access to high-quality work prospects, the southern and certain western neighborhoods exhibit noticeably lower employment concentrations.

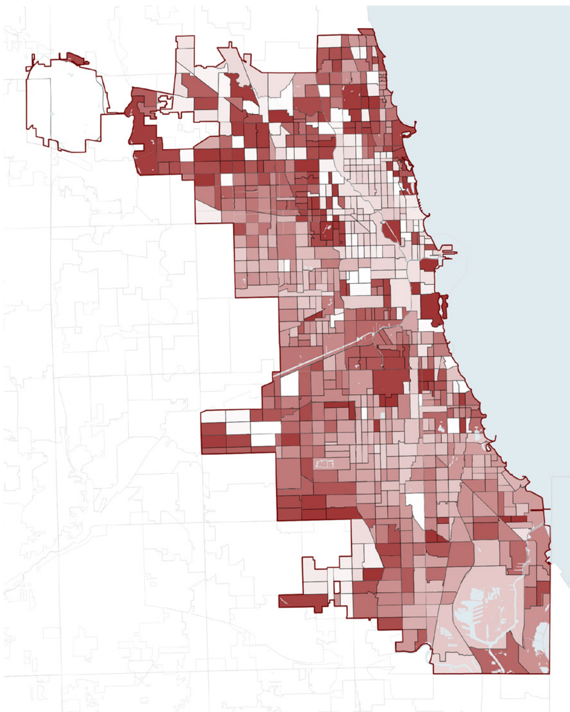
A similar gradient can be seen in the distribution of income throughout Chicago, with higher median household incomes in the northern and center regions and significantly lower income levels in the southern and western regions. While many minority-majority communities in the south and west continue to face economic marginalization, predominantly white and wealthy communities in the north have amassed wealth and resources over time. This division is consistent with long-standing racial and socioeconomic segregation. The neighborhoods impacted by systemic issues including underemployment, low educational attainment, and a lack of local economic drivers are frequently found in the lower-income zones.

These patterns of employment and income are closely linked to more general structural disparities in the urban environment of the metropolis. High-income and employment areas typically have better access to public services, top-notch schools, decent housing, and safer surroundings. Conversely, neighborhoods with low employment and income levels frequently experience compounded disadvantages, such as fewer social mobility paths, increased exposure to environmental stresses, and limited access to healthcare. Because these differences perpetuate cycles of poverty and marginalization, inclusive development requires targeted investment and fair urban planning.

Comprehensive approaches that support economic inclusion and community resilience are needed to address Chicago's unequal employment and income distribution. This entails investing in education and skill-training programs that equip locals for rising industries, promoting local job development in underprivileged areas, and enhancing transportation connections between residential zones and employment centers. Affordable housing and small business assistance must be given top priority in equitable urban policy in order to boost local economies.



Map 48. Employed 16 years old above distribution

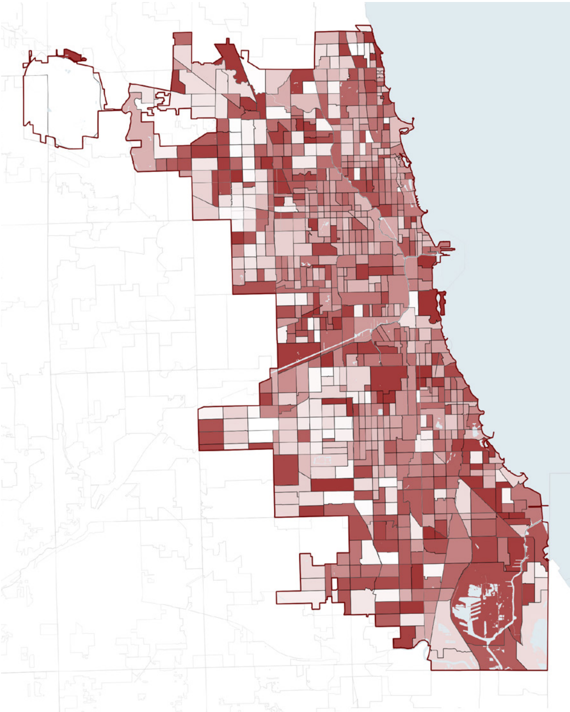


Map 49. Median Income distribution

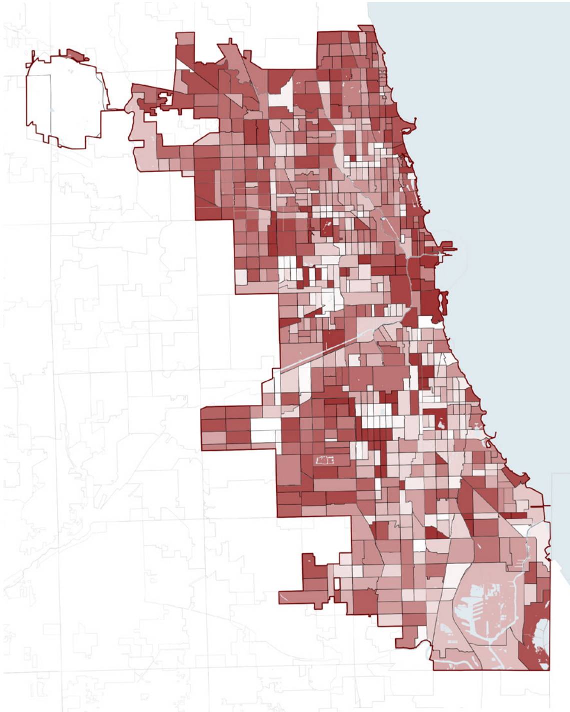
Legends

City of Chicago
Community Areas
Census tracts
Blue Infrastructure
Low density
Moderate density
High density

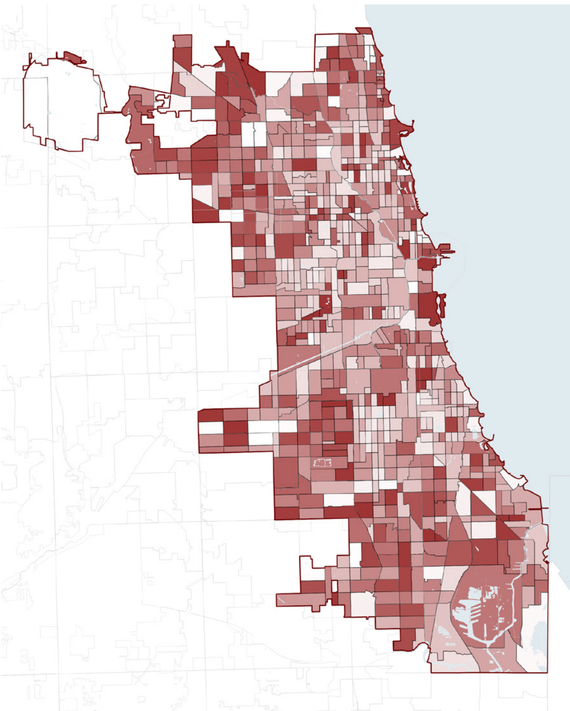
High income zone
Moderate income
Low income zone



Map 50. Age under 18 in Chicago



Map 51. Age over 18 in Chicago



Map 52. Age over 65 in Chicago

Legends

City of Chicago

Community Areas

Census tracts

Blue Infrastructure

Low concentration

Moderate concentration

High concentration

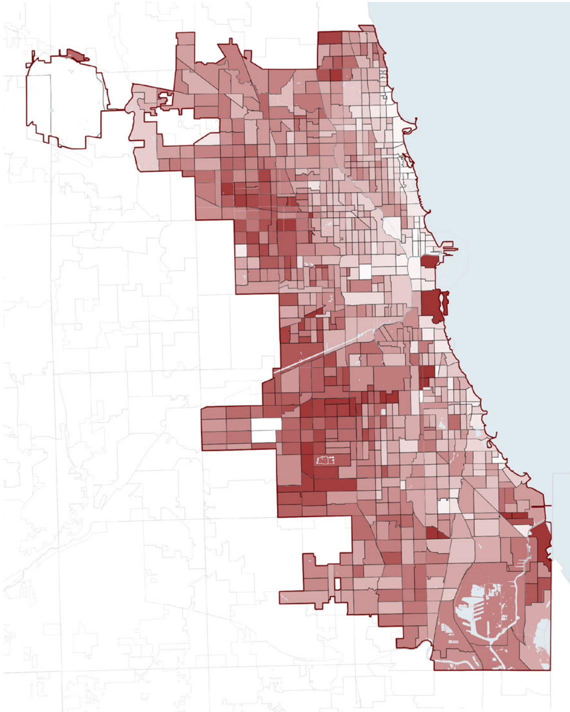
Socio-demographic Analysis: Average Household and Family size

Chicago's average household and family size spatial pattern shows substantial socioeconomic and demographic divisions around the city. Smaller households are typically found in the northern and central regions, particularly along the lakefront and close to downtown. Higher incomes, a higher percentage of single-person or dual-income households, and a high concentration of apartment or condominium living are common characteristics of these communities. Both lifestyle choices and housing typologies that serve professionals, young adults, and smaller family units are reflected in these zones' reduced household sizes.

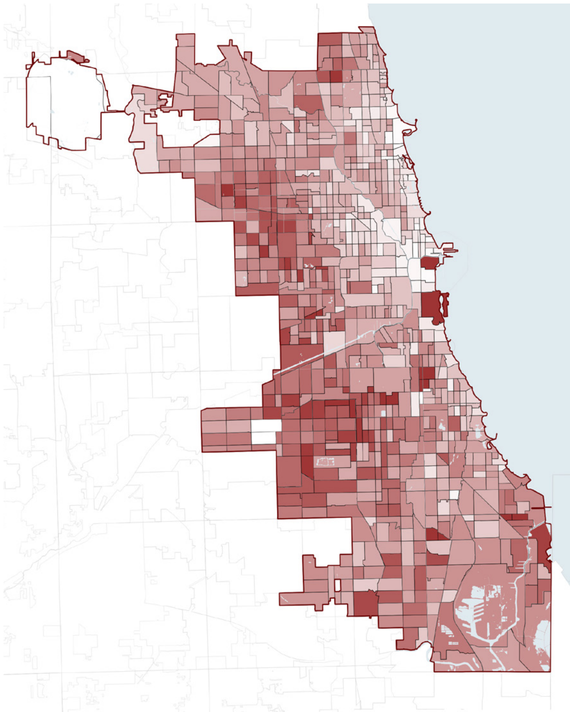
On the other hand, Chicago's western and southern regions tend to have larger households. Families and multigenerational households are more common in certain locations, which reflects both cultural norms and economic circumstances. Minority groups, especially African American and Hispanic families, who frequently have stronger household ties and broader family networks, reside in many of these areas. Economic issues also play a part; in order to lower living expenses and preserve stability in the face of financial difficulties, extended families frequently share houses due to limited housing affordability and income limits.

Chicago's differences in household and family sizes also highlight more general societal trends in housing, income, and community organization. While neighborhoods with bigger family sizes frequently show deeper social cohesion and community commitment, they may also suffer issues with overcrowding and inadequate housing. In contrast, areas with smaller families typically have higher residential mobility and a more mobile populace. These variations affect the needs for urban services, ranging from neighborhood infrastructure and healthcare access to school capacity and childcare demand.

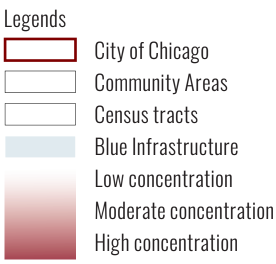
For equitable urban planning and policy-making, it is essential to comprehend the spatial distribution of household and family sizes. Larger households may need additional family-friendly services, reasonably priced housing, and public facilities like parks and schools. On the other hand, communities that encourage social contact, mixed-use projects, and improved transportation might be advantageous for places with smaller household sizes. Chicago can better accommodate the many living arrangements and requirements of its citizens by coordinating housing and community development with these demographic realities.



Map 53. Average household size in Chicago



Map 54. Average family size in Chicago



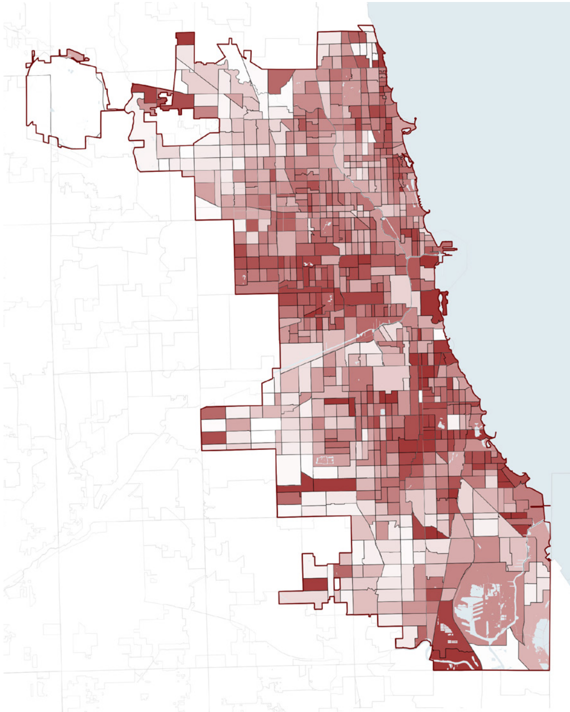
Socio-demographic Analysis: Renting and Homeownership

Chicago's rental and homeownership distribution is a reflection of long-standing racial segregation, economic inequality, and historical disinvestment. The South and West Sides, as well as other areas of the inner city, are the main locations with large renter numbers. Throughout the 20th century, discriminatory banking practices often denied mortgage access to Black, Hispanic, and immigrant populations in these neighborhoods, which frequently overlap with historically redlined zones. As a result, many locals were forced to stay in the rental market since they were denied access to property, which is a crucial route to accumulating wealth. On the other hand, the North and Northwest sides, which have historically benefited from advantageous financing practices, infrastructure investment, and higher-quality housing, are home to the majority of communities with greater homeownership rates.

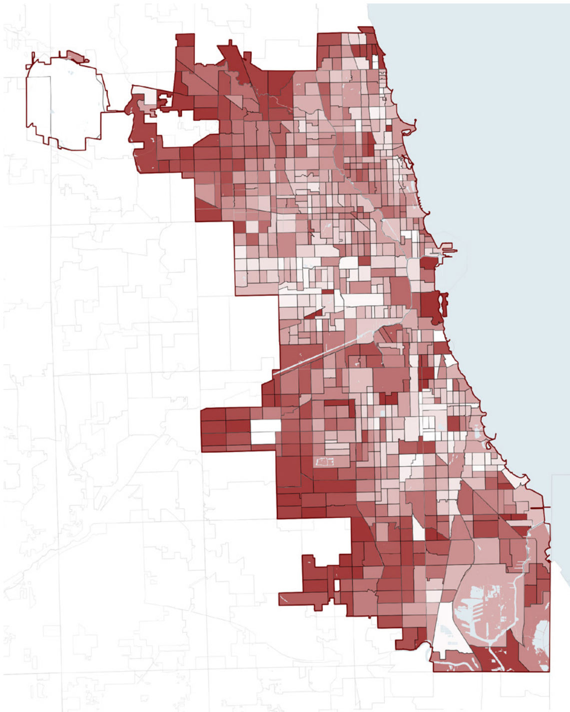
This geographical gap between renters and owners has racial and historical roots in addition to economic ones. The structural basis for today's disparities was established by redlining and urban regeneration initiatives in the past. While predominately White neighborhoods in the North were given opportunity to develop wealth across generations, Black and Hispanic communities, concentrated in redlined or "hazardous" areas, were routinely denied credit and investment. The geography of housing in Chicago is still shaped by the legacy of these policies; minority groups are still overrepresented in renting households and underrepresented in homeownership, especially in regions with older housing stock and lower incomes.

Economic marginalization and urban industrial zoning exacerbated these disparities for Hispanic and immigrant groups. Hispanic families' access to steady and reasonably priced homeownership was restricted since many of them settled in historically devalued older housing districts or areas close to industrial routes. This eventually resulted in dense rental clusters on the West and Southwest sides of the city, where despite robust community networks, housing affordability is still a problem. Similar to this, despite their lesser numbers, Asian people were spatially marginalized by exclusionary zoning or restrictive covenants, which restricted their settlement to particular enclaves and decreased their chances of acquiring property in higher-value neighborhoods.

These patterns' endurance shows how structural housing constraints continue to influence Chicago's urban environment. While owning corresponds with zones of privilege and opportunity, renting is still predominant in places that are experiencing systematic disinvestment.



Map 55. Renting population distribution



Map 56. Homeownership population distribution

Legends

City of Chicago

Community Areas

Census tracts

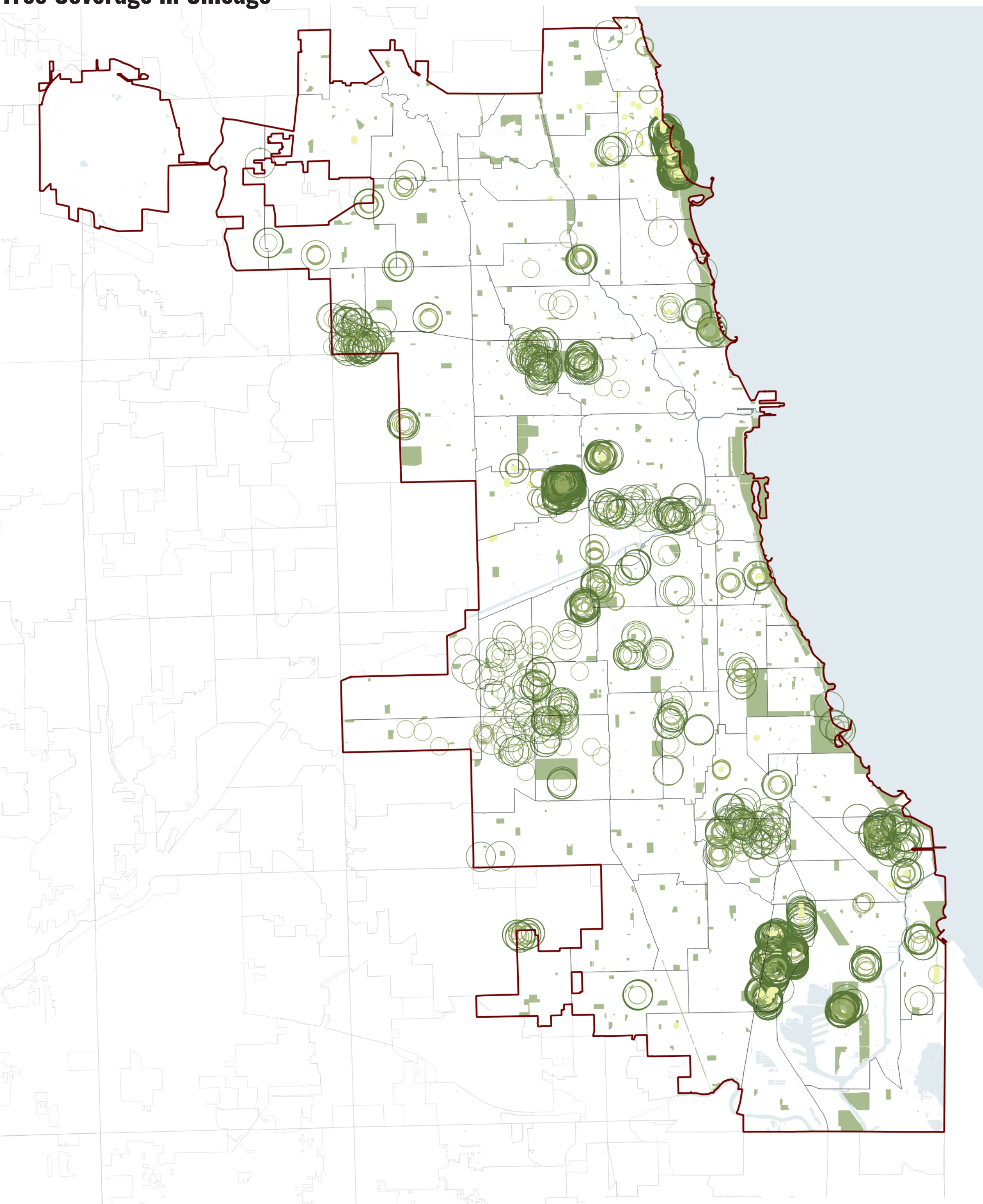
Blue Infrastructure

Low concentration

Moderate concentration

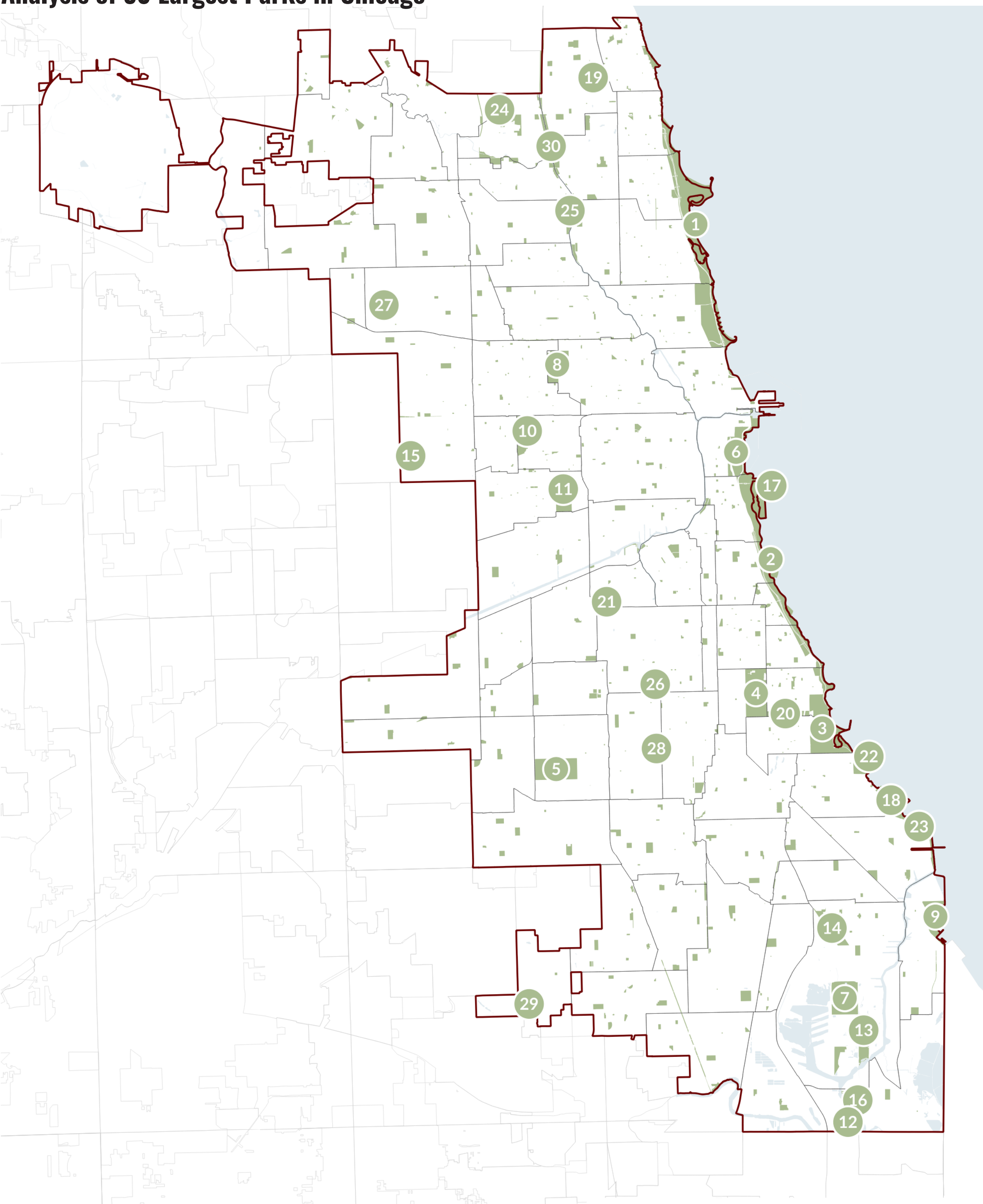
High concentration

Tree Coverage in Chicago



Map 57. Tree Coverage in Chicago

Analysis of 30 Largest Parks in Chicago



Map 58. 30 Largest Parks in Chicago

Legends

- City of Chicago
- Community Areas
- Green Infrastructure
- Blue Infrastructure
- Top 30 largest parks

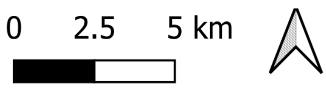


Table 29. 30 Largest Parks in Chicago and its Geophysical Attributes

#	Park Name	Size (Hectares)	Land Use	Access	Compactness	Water	Tree Cover
1	Lincoln (Abraham)	489.66	Rec, Con	O	0.0123	S, W	40
2	Burnham (Daniel)	266.21	Rec	O	0.0012	S	25
3	Jackson (Andrew)	223.19	Rec, Cul	O	0.012	S, W	35
4	Washington (George)	141.84	Rec	O	0.0351	W	20
5	Marquette (Jacques)	127.73	Rec, Res	O	0.0588	S	30
6	Grant (Ulysses)	119.56	Rec, Cul	O	0.0048	S	15
7	Big Marsh	118.05	Con, Nat	L	0.0506	W	60
8	Humboldt	85.33	Rec	O	0.0531	W	45
9	Calumet	73.37	Rec, Ind	O	0.0271	W	35
10	Garfield (James)	71.18	Rec, Edu	O	0.0224	X	50
11	Douglass (Anna & Frederick)	66.97	Rec, Com	O	0.0243	X	30
12	Park No. 565	58.66	Con, Nat	L	0.0683	S	50
13	Rainbow Beach	58.01	Rec, Be	O	0.0134	S	10
14	Byrnes (Marian)	57.22	Con, Nat	L	0.029	W	55
15	Columbus (Christo-pher)	56.95	Rec, Com	O	0.0751	X	25

Land Use:

Rec	Recreational	Ind	Industrial Buffer
Con	Conservation		
Res	Residential		
Cul	Cultural		
Edu	Educational		
Com	Community		
Be	Beachfront		
Nat	Natural		

Access:

O	Open
L	Limited
E	Exclusive
C	Closed

Compactness:

$(4\pi \times \text{Area}) / (\text{Perimeter}^2)$

X = insufficient data

Water:

W	Waterways
S	Sea
X	None within 1km distance

Tree Cover:

Reference: Chicago Park District, City of Chicago

#	Park Name	Size (Hectares)	Land Use	Access	Compactness	Water	Tree Cover
16	Hegewisch Marsh	52.79	Con, Nat	L	0.0402	W	65
17	Northerly Island	47.74	Rec, Nat	O	0.0309	S	35
18	Rainbow Beach	44.16	Rec, Be	O	0.0194	S	10
19	Warren (Laurence)	36.27	Rec, Com	O	0.0498	X	20
20	Midway Plaisance	29.34	Rec, Cul	O	0.0218	X	25
21	Mckinley (William)	29.17	Rec, Com	O	0.0634	X	30
22	South Shore Cultural Center	29.05	Rec, Cul	O	0.0437	S	20
23	Park no. 566	28.45	Con, Nat	L	0.0201	S	55
24	North Park Nature Center	23.52	Con, Nat	L	0.0211	W	70
25	Horner (Henry)	23.35	Rec, Com	O	0.0594	X	25
26	Sherman (John)	23.35	Rec, Com	O	0.07	X	20
27	Riis (Jacob)	23.27	Rec, Com	O	0.0707	X	30
28	Ogden	23.08	Rec, Com	O	0.0694	X	20
29	Mount Greenwood	21.3	Rec, Com	O	0.0197	X	35
30	Legion	19.6	Rec, Com	O	0.0074	X	20

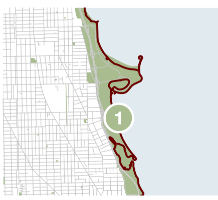
Park Access

Most parks in the dataset (24) are classified as open, while a smaller share (6) have limited accessibility.

Water Proximity

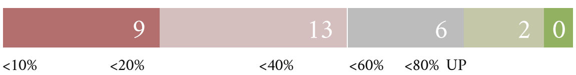
Parks are distributed across proximity to waterways (7), sea (9), both (2), or none at all (12).

Compactness



The shape and layout of parks vary, with compactness illustrating how efficiently land is utilized within the park boundary.

Tree Cover



Most parks have less than 20% tree cover, with only a few reaching higher levels.

Raw Data of Social Vulnerability Index

Table 30. Raw Data of Social Vulnerability Indeex (per CA). Source: Author

Number	Community Name	Socioeconomic	Household	Minority	Housing/ transport	RPL Over-all
1	Rogers Park	0.758	0.319	0.65	0.905	0.769
2	West Ridge	0.772	0.648	0.691	0.798	0.822
3	Uptown	0.592	0.242	0.602	0.879	0.616
4	Lincoln Square	0.439	0.157	0.5	0.597	0.368
5	North Center	0.134	0.145	0.425	0.324	0.122
6	Lake View	0.238	0.078	0.392	0.598	0.205
7	Lincoln Park	0.152	0.053	0.341	0.661	0.17
8	Near North Side	0.185	0.092	0.46	0.734	0.247
9	Edison Park	0.156	0.154	0.307	0.208	0.098
10	Norwood Park	0.301	0.542	0.425	0.436	0.383
11	Jefferson Park	0.545	0.438	0.601	0.379	0.49
12	Forest Glen	0.297	0.426	0.406	0.193	0.239
13	North Park	0.565	0.709	0.674	0.66	0.68
14	Albany Park	0.787	0.498	0.757	0.674	0.758
15	Portage Park	0.655	0.51	0.682	0.508	0.629
16	Irving Park	0.575	0.372	0.659	0.643	0.582
17	Dunning	0.594	0.462	0.586	0.396	0.517
18	Monthclare	0.698	0.859	0.756	0.72	0.806
19	Belmont Cragin	0.825	0.711	0.852	0.546	0.806
20	Hermosa	0.827	0.692	0.86	0.6	0.81
21	Avondale	0.672	0.237	0.736	0.503	0.557
22	Logan Square	0.465	0.165	0.621	0.576	0.416
23	Humboldt Park	0.843	0.719	0.857	0.664	0.832
24	West Town	0.297	0.101	0.537	0.572	0.276
25	Austin	0.912	0.826	0.93	0.675	0.915

Number	Community Name	Socioeconomic	Household	Minority	Housing/ transport	RPL Overall
26	West Garfield Park	0.936	0.74	0.947	0.582	0.888
27	East Garfield Park	0.907	0.643	0.907	0.743	0.882
28	Near West Side	0.565	0.288	0.734	0.737	0.556
29	North Lawndale	0.937	0.682	0.907	0.668	0.888
30	South Lawndale	0.929	0.713	0.914	0.518	0.855
31	Lower West Side	0.808	0.406	0.813	0.662	0.742
32	Loop	0.344	0.018	0.625	0.928	0.387
33	New South Side	0.334	0.49	0.734	0.564	0.483
34	Armour Square	0.851	0.867	0.817	0.716	0.888
35	Douglas	0.78	0.565	0.884	0.764	0.808
36	Oakland	0.838	0.701	0.922	0.619	0.834
37	Fuller Park	0.885	0.929	0.95	0.8	0.95
38	Grand Boulevard	0.788	0.485	0.921	0.509	0.717
39	Kenwood	0.668	0.674	0.824	0.68	0.737
40	Washington Park	0.881	0.61	0.941	0.665	0.854
41	Hyde Park	0.497	0.143	0.678	0.81	0.509
42	Woodlawn	0.882	0.583	0.892	0.751	0.866
43	South Shore	0.838	0.66	0.943	0.734	0.857
44	Chatham	0.854	0.596	0.962	0.444	0.772
45	Avalon Park	0.829	0.858	0.974	0.375	0.775
46	South Chicago	0.886	0.723	0.923	0.653	0.863
47	Burnside	0.868	0.721	0.942	0.802	0.9
48	Calumet Heights	0.554	0.705	0.977	0.333	0.608
49	Roseland	0.873	0.675	0.953	0.529	0.814
50	Pullman	0.765	0.48	0.865	0.237	0.584

Number	Community Name	Socioeconomic	Household	Minority	Housing/ transport	RPL Overall
51	South Deering	0.869	0.82	0.917	0.486	0.836
52	East Side	0.785	0.765	0.866	0.423	0.739
53	West Pullman	0.817	0.766	0.963	0.442	0.778
54	Riverdale	0.915	0.367	0.977	0.748	0.852
55	Hegewisch	0.72	0.746	0.745	0.498	0.706
56	Garfield Ridge	0.609	0.649	0.771	0.411	0.61
57	Archer Heights	0.798	0.531	0.844	0.469	0.72
58	Brighton Park	0.904	0.699	0.89	0.41	0.801
59	McKinley Park	0.821	0.49	0.845	0.523	0.732
60	Bridgeport	0.723	0.504	0.756	0.474	0.654
61	New City	0.929	0.779	0.893	0.615	0.881
62	West Elsdon	0.803	0.864	0.837	0.411	0.779
63	Gage Park	0.923	0.725	0.929	0.791	0.922
64	Clearing	0.681	0.52	0.751	0.386	0.611
65	West Lawn	0.863	0.683	0.863	0.562	0.82
66	Chicago Lawn	0.956	0.78	0.943	0.601	0.905
67	West Englewood	0.96	0.835	0.963	0.422	0.879
68	Englewood	0.923	0.799	0.956	0.524	0.865
69	Greater Gramd Crossing	0.86	0.75	0.962	0.648	0.874
70	Ashburn	0.763	0.679	0.89	0.432	0.731
71	Auburn Gresham	0.875	0.785	0.962	0.516	0.849
72	Beverly	0.206	0.215	0.522	0.179	0.168
73	Washington Heights	0.736	0.616	0.956	0.333	0.675
74	Mount Greenwood	0.249	0.403	0.262	0.529	0.331
75	Morgan Park	0.538	0.535	0.705	0.414	0.532
76	O’Hare	0.655	0.477	0.501	0.638	0.636
77	Edgewater	0.641	0.292	0.628	0.808	0.641

Raw Data of Urban Heat Islands (per CA)

Table 31. Raw Data of Urban Heat Islands (per CA). Source: Author

Number	Community Name	UHI Mean	UHI Score (0-1)	UHI Rank
1	Rogers Park	2.8365	0.34	55
2	West Ridge	3.6472	0.5	29
3	Uptown	1.9172	0.15	70
4	Lincoln Square	2.7144	0.31	59
5	North Center	3.4195	0.46	35
6	Lake View	2.9317	0.36	49
7	Lincoln Park	2.7824	0.33	58
8	Near North Side	2.8639	0.34	54
9	Edison Park	3.5946	0.49	30
10	Norwood Park	3.5835	0.49	31
11	Jefferson Park	3.2994	0.43	39
12	Forest Glen	1.576	0.08	74
13	North Park	2.0388	0.17	69
14	Albany Park	2.823	0.33	56
15	Portage Park	3.7754	0.53	27
16	Irving Park	2.8904	0.35	52
17	Dunning	2.3396	0.23	66
18	Monthclare	2.6603	0.3	61
19	Belmont Cragin	4.5852	0.7	14
20	Hermosa	4.597	0.7	13
21	Avondale	3.8683	0.55	24
22	Logan Square	3.4653	0.47	33
23	Humboldt Park	4.2492	0.63	19
24	West Town	3.3998	0.45	36
25	Austin	3.4445	0.46	34

Number	Community Name	UHI Mean	UHI Score (0-1)	UHI Rank
26	West Garfield Park	3.2334	0.42	42
27	East Garfield Park	3.3044	0.43	38
28	Near West Side	3.8496	0.55	25
29	North Lawndale	2.5484	0.28	62
30	South Lawndale	3.2379	0.42	41
31	Lower West Side	4.386	0.66	17
32	Loop	1.2652	0.01	76
33	New South Side	2.8659	0.34	53
34	Armour Square	3.5497	0.48	32
35	Douglas	2.4028	0.25	64
36	Oakland	1.2081	0	77
37	Fuller Park	3.0713	0.39	46
38	Grand Boulevard	3.1038	0.39	45
39	Kenwood	1.2917	0.02	75
40	Washington Park	1.828	0.13	72
41	Hyde Park	1.7347	0.11	73
42	Woodlawn	2.3759	0.24	65
43	South Shore	2.8229	0.33	57
44	Chatham	4.1098	0.6	21
45	Avalon Park	4.9847	0.78	4
46	South Chicago	3.7753	0.53	28
47	Burnside	4.4326	0.67	15
48	Calumet Heights	6.0394	1	1
49	Roseland	5.2508	0.84	3
50	Pullman	4.7722	0.74	10

Number	Community Name	UHI Mean	UHI Score (0-1)	UHI Rank
51	South Deering	2.7044	0.31	60
52	East Side	4.627	0.71	12
53	West Pullman	4.396	0.66	16
54	Riverdale	2.4265	0.25	63
55	Hegewisch	1.898	0.14	71
56	Garfield Ridge	3.9091	0.56	23
57	Archer Heights	2.9583	0.36	48
58	Brighton Park	4.0475	0.59	22
59	McKinley Park	4.3769	0.66	18
60	Bridgeport	4.8819	0.76	7
61	New City	3.8098	0.54	26
62	West Elsdon	3.1678	0.41	43
63	Gage Park	4.1479	0.61	20
64	Clearing	4.9676	0.78	5
65	West Lawn	4.7932	0.74	9
66	Chicago Lawn	3.3115	0.44	37
67	West Englewood	2.9978	0.37	47
68	Englewood	2.3286	0.23	67
69	Greater Gramd Crossing	3.1403	0.4	44
70	Ashburn	4.8713	0.76	8
71	Auburn Gresham	4.6381	0.71	11
72	Beverly	2.8922	0.35	51
73	Washington Heights	5.4536	0.88	2
74	Mount Greenwood	2.9142	0.35	50
75	Morgan Park	4.9586	0.78	6
76	O'Hare	2.17	0.2	68
77	Edgewater	3.2404	0.42	40

Raw Data of Access Deficit (Isochrones)

Table 32. Raw Data of Access Deficit (Isochrones). Source: Author

Number	Community Name	Isochrone_Count	C2 (Accessibility Deficit 0-1)
1	Rogers Park	3	0.67
2	West Ridge	3	0.67
3	Uptown	5	0.44
4	Lincoln Square	8	0.11
5	North Center	6	0.33
6	Lake View	5	0.44
7	Lincoln Park	5	0.44
8	Near North Side	5	0.44
9	Edison Park	0	1
10	Norwood Park	2	0.78
11	Jefferson Park	3	0.67
12	Forest Glen	5	0.44
13	North Park	3	0.67
14	Albany Park	7	0.22
15	Portage Park	5	0.44
16	Irving Park	7	0.22
17	Dunning	0	1
18	Monthclare	0	1
19	Belmont Cragin	0	1
20	Hermosa	0	1
21	Avondale	3	0.67
22	Logan Square	5	0.44
23	Humboldt Park	6	0.33
24	West Town	7	0.22
25	Austin	4	0.56

Number	Community Name	Isochrone_Count	C2 (Accessibility Deficit 0-1)
26	West Garfield Park	5	0.44
27	East Garfield Park	6	0.33
28	Near West Side	9	0
29	North Lawndale	7	0.22
30	South Lawndale	3	0.67
31	Lower West Side	8	0.11
32	Loop	4	0.56
33	New South Side	6	0.33
34	Armour Square	8	0.11
35	Douglas	5	0.44
36	Oakland	4	0.56
37	Fuller Park	7	0.22
38	Grand Boulevard	8	0.11
39	Kenwood	5	0.44
40	Washington Park	8	0.11
41	Hyde Park	5	0.44
42	Woodlawn	4	0.56
43	South Shore	0	1
44	Chatham	4	0.56
45	Avalon Park	0	1
46	South Chicago	0	1
47	Burnside	0	1
48	Calumet Heights	0	1
49	Roseland	4	0.56
50	Pullman	0	1

Number	Community Name	Isochrone_Count	C2 (Accessibility Deficit 0-1)
51	South Deering	0	1
52	East Side	0	1
53	West Pullman	0	1
54	Riverdale	0	1
55	Hegewisch	0	1
56	Garfield Ridge	5	0.44
57	Archer Heights	4	0.56
58	Brighton Park	6	0.33
59	McKinley Park	5	0.44
60	Bridgeport	6	0.33
61	New City	7	0.22
62	West Elsdon	7	0.22
63	Gage Park	4	0.56
64	Clearing	4	0.56
65	West Lawn	4	0.56
66	Chicago Lawn	2	0.78
67	West Englewood	3	0.67
68	Englewood	6	0.33
69	Greater Gramd Crossing	6	0.33
70	Ashburn	0	1
71	Auburn Gresham	5	0.44
72	Beverly	0	1
73	Washington Heights	3	0.67
74	Mount Greenwood	0	1
75	Morgan Park	0	1
76	O’Hare	2	0.78
77	Edgewater	5	0.44

Raw Data of Vacant typologies

Table 33. Raw Data of Vacant typologies. Source: Author

Number	Community Name	Mass	Contiguous	Corner	Flagged	Interval	Offset	Scattered	Strip
1	Rogers Park	0	18	0	0	0	4	11	0
2	West Ridge	0	0	0	0	0	0	11	0
3	Uptown	0	8	1	3	0	0	14	0
4	Lincoln Square	0	18	3	0	0	8	14	10
5	North Center	0	1	0	2	0	0	11	0
6	Lake View	0	0	0	1	0	8	10	22
7	Lincoln Park	0	0	2	4	0	0	10	6
8	Near North Side	52	40	1	1	0	0	13	6
9	Edison Park	0	0	0	0	0	0	0	0
10	Norwood Park	0	0	0	1	0	0	6	0
11	Jefferson Park	0	0	1	0	0	1	6	0
12	Forest Glen	0	5	0	0	0	0	1	0
13	North Park	0	0	0	0	0	3	1	0
14	Albany Park	33	8	1	0	0	0	13	0
15	Portage Park	0	5	0	3	0	4	15	0
16	Irving Park	0	0	0	0	0	0	4	6
17	Dunning	0	0	0	2	0	0	6	0
18	Monthclare	0	0	0	1	0	0	0	0
19	Belmont Cragin	0	5	0	1	0	0	10	13
20	Hermosa	0	0	0	0	0	0	6	0
21	Avondale	0	5	2	0	0	4	8	7
22	Logan Square	12	24	0	0	0	6	34	20
23	Humboldt Park	372	55	2	7	0	28	108	6
24	West Town	35	1	4	3	0	21	71	0
25	Austin	295	97	1	8	4	28	239	28

Number	Community Name	Mass	Contigu-ous	Corner	Flagged	Interval	Offset	Scat-tered	Strip
26	West Garfield Park	385	64	1	9	0	16	70	0
27	East Garfield Park	883	47	0	4	0	24	47	0
28	Near West Side	554	64	3	8	0	16	78	110
29	North Lawndale	1200	63	0	10	0	12	72	8
30	South Lawndale	21	32	1	6	0	4	46	7
31	Lower West Side	39	12	3	14	0	13	52	0
32	Loop	3	29	2	3	0	9	25	7
33	New South Side	52	5	0	0	0	6	5	0
34	Armour Square	0	14	2	2	0	0	10	0
35	Douglas	159	37	2	11	0	6	23	12
36	Oakland	107	20	0	0	0	5	9	0
37	Fuller Park	271	19	0	0	0	0	9	0
38	Grand Boulevard	649	80	0	6	0	19	72	0
39	Kenwood	37	25	2	4	0	11	21	0
40	Washington Park	479	25	1	7	0	12	32	0
41	Hyde Park	0	0	0	0	0	0	10	0
42	Woodlawn	383	68	0	4	0	16	55	8
43	South Shore	39	68	3	8	0	12	99	0
44	Chatham	49	7	0	1	0	12	52	0
45	Avalon Park	25	0	0	1	0	8	20	18
46	South Chicago	474	32	3	3	4	4	94	9
47	Burnside	0	17	0	1	0	4	25	0
48	Calumet Heights	0	5	1	1	4	0	21	0
49	Roseland	262	93	2	9	0	34	137	6
50	Pullman	14	15	0	2	0	4	14	0

Number	Community Name	Mass	Contigu-ous	Corner	Flagged	Interval	Offset	Scat-tered	Strip
51	South Deering	116	20	0	5	4	4	13	28
52	East Side	0	6	0	0	0	0	31	35
53	West Pullman	353	72	3	10	0	44	118	26
54	Riverdale	105	24	1	4	0	0	22	0
55	Hegewisch	0	5	1	1	0	8	27	0
56	Garfield Ridge	0	5	0	5	0	4	18	0
57	Archer Heights	1	0	1	0	0	0	4	0
58	Brighton Park	0	0	1	1	0	0	17	0
59	McKinley Park	0	13	0	8	0	4	14	0
60	Bridgeport	1	20	2	1	0	12	23	0
61	New City	1157	85	1	16	0	20	95	0
62	West Elsdon	0	0	1	0	0	0	1	0
63	Gage Park	13	0	1	1	0	0	14	20
64	Clearing	0	0	1	0	0	0	5	8
65	West Lawn	0	5	0	0	0	0	3	11
66	Chicago Lawn	67	0	0	3	0	8	32	8
67	West Englewood	1063	119	1	16	8	47	101	0
68	Englewood	1718	106	2	3	0	31	96	22
69	Greater Gramd Crossing	218	79	3	6	0	32	126	0
70	Ashburn	0	0	0	3	0	0	20	0
71	Auburn Gresham	146	62	2	4	12	8	106	0
72	Beverly	0	19	2	1	0	4	3	14
73	Washington Heights	29	5	3	1	0	6	36	28
74	Mount Greenwood	0	0	0	0	0	0	4	0
75	Morgan Park	123	30	1	1	0	8	83	9
76	O'Hare	0	0	0	0	0	0	0	0
77	Edgewater	0	9	1	2	0	4	15	0

```
// ==========================================================================
// UHI — Chicago, Aug 2024 (°C) @ ~30 m | Wider AOI via buffered city
// Buffers tested: 20, 30, 50 km (rural baseline sensitivity)
// Landsat 8/9 C2 L2 ST_B10, WorldCover for urban/water
// ==========================================================================

// ---------- AOI (choose ONE) ----------
// Option A: Use your city boundary asset and buffer it (RECOMMENDED)
var city = ee.FeatureCollection('projects/urban-heat-island-milano/assets/chicago').geometry();
var cityBufferKm = 40;          // <<< adjust coverage radius (km)
var aoi = city.buffer(cityBufferKm * 1000);

// Option B (fallback): Larger manual rectangle around Chicago
// var aoi = ee.Geometry.Polygon([
//   [[-88.45, 42.60], [-88.45, 41.20], [-87.00, 41.20], [-87.00, 42.60]]
// ]);

Map.centerObject(aoi, 9);

// ---------- Settings ----------
var year = 2024;
var month = 8;          // August
var testBuffersKm = [20, 30, 50]; // rural baseline sensitivity
var displayScale = 30;      // Landsat L2 ST grid
var exportSelectedBufferKm = 30; // which buffer to export as GeoTIFF
var useMedianComposite = true; // set false to use mosaic() fallback

// ---------- Helpers ----------
function monthRange(y, m) {
var start = ee.Date.fromYMD(y, m, 1);
return { start: start, end: start.advance(1, 'month') };
}

function maskL2Clouds(img) {
// QA bits: 2=Cirrus, 3=Cloud, 4=Cloud Shadow, 5=Snow (mask these)
var qa = img.select('QA_PIXEL');
var cirrus = qa.bitwiseAnd(1 << 2).eq(0);
var cloud  = qa.bitwiseAnd(1 << 3).eq(0);
var shadow = qa.bitwiseAnd(1 << 4).eq(0);
var snow   = qa.bitwiseAnd(1 << 5).eq(0);
var mask = cirrus.and(cloud).and(shadow).and(snow);
return img.updateMask(mask);
}

function addLST_C(img) {
// ST_B10: *0.00341802 + 149.0 (Kelvin) → °C
var lstK = img.select('ST_B10').multiply(0.00341802).add(149.0);
var lstC = lstK.subtract(273.15).rename('LST_C');
return img.addBands(lstC);
}

function composeMonthlyLST(mr, region) {
var l8 = ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
.filterDate(mr.start, mr.end)
.filterBounds(region)
.map(maskL2Clouds)
.map(addLST_C)
.select('LST_C');

var l9 = ee.ImageCollection('LANDSAT/LC09/C02/T1_L2')
.filterDate(mr.start, mr.end)
.filterBounds(region)
.map(maskL2Clouds)
.map(addLST_C)
.select('LST_C');

var merged = l8.merge(l9);
var composite = useMedianComposite ? merged.median() : merged.mosaic();
return composite.clip(region);
}

// ---------- Data ----------
var mr = monthRange(year, month);
var lst30 = composeMonthlyLST(mr, aoi);

// WorldCover (urban=50, water=80)
var wc = ee.Image('ESA/WorldCover/v200/2021').select('Map');
var URBAN = 50;
var WATER = 80;
var urban = wc.eq(URBAN);
var water = wc.eq(WATER);

// ---------- Core function: compute UHI for a given rural buffer ----------
function computeUHIforBuffer(bufferKm) {
var searchRegion = aoi.buffer(bufferKm * 1000);   // ring around the BIGGER AOI
var ruralMask = urban.neq(1).and(water.neq(1));   // not urban & not water

var ruralMean = lst30.updateMask(ruralMask).reduceRegion({
reducer: ee.Reducer.mean(),
```

```
geometry: searchRegion,
scale: displayScale,
maxPixels: 1e13
}).getNumber('LST_C');

var UHI = lst30.subtract(ee.Image.constant(ruralMean))
.rename('UHI_C')
.clip(aoi);

var stats = UHI.reduceRegion({
reducer: ee.Reducer.mean()
.combine({reducer2: ee.Reducer.minMax(), sharedInputs: true})
.combine({reducer2: ee.Reducer.stdDev(), sharedInputs: true})
.combine({reducer2: ee.Reducer.count(), sharedInputs: true}),
geometry: aoi,
scale: displayScale,
maxPixels: 1e13
});

var row = ee.Feature(null, {
buffer_km: bufferKm,
rural_mean_c: ruralMean,
uhi_mean_c: stats.get('UHI_C_mean'),
uhi_min_c: stats.get('UHI_C_min'),
uhi_max_c: stats.get('UHI_C_max'),
uhi_std_c: stats.get('UHI_C_stdDev'),
uhi_count: stats.get('UHI_C_count')
});

return {UHI: UHI, ruralMean: ruralMean, row: row};
}

// ---------- Run sensitivity ----------
var results = testBuffersKm.map(function(b) { return computeUHIforBuffer(b); });

// Collect stats into a table
var rows = results.map(function(obj){ return ee.Dictionary(obj).get('row'); });
var statsFC = ee.FeatureCollection(ee.List(rows));
print('UHI Stats by Rural Buffer (°C):', statsFC);

// ---------- Map preview ----------
var uhiVis = {min: -5, max: 8, palette: ['#2c7bb6','#abd9e9','#ffffbf','#fdae61','#d7191c']};
testBuffersKm.forEach(function(b){
var obj = results[testBuffersKm.indexOf(b)];
var uhiDisp = ee.Image(ee.Dictionary(obj).get('UHI'))
.resample('bilinear')
.reproject({crs: 'EPSG:3857', scale: displayScale});
var name = 'UHI (°C) — Aug 2024 — Rural buffer ' + b + ' km';
var shown = (b === exportSelectedBufferKm);
Map.addLayer(uhiDisp, uhiVis, name, shown);
});
Map.addLayer(ee.Image().paint(aoi, 1, 2), {palette: 'white'}, 'AOI outline', false);

// ---------- Export the stats as CSV ----------
Export.table.toDrive({
collection: statsFC,
description: 'UHI_Chicago_Aug2024_BufferSensitivity_Stats',
fileNamePrefix: 'UHI_Chicago_Aug2024_BufferSensitivity_Stats',
fileFormat: 'CSV'
});

// ---------- Export GeoTIFF for the selected buffer ----------
var selectedIdx = testBuffersKm.indexOf(exportSelectedBufferKm);
var selectedUHI = ee.Image(ee.Dictionary(results[selectedIdx]).get('UHI'));

Export.image.toDrive({
image: selectedUHI.toFloat(),
description: 'UHI_Chicago_Aug2024_Landsat30m_UTM16N_buffer' + exportSelectedBufferKm + 'km_AOI+' + cityBufferKm + 'km',
fileNamePrefix: 'UHI_Chicago_Aug2024_Landsat30m_UTM16N_buffer' + exportSelectedBufferKm + 'km_AOI+' + cityBufferKm + 'km',
region: aoi,
scale: displayScale,
crs: 'EPSG:32616', // UTM Zone 16N (Chicago), north-up metric
maxPixels: 1e13
});
```

```
// ====================================================
// NDVI + LST monthly (2024) with clean QA masking
// Landsat 8/9 C2 L2 | 30 m | AOI-clipped
// Exports monthly GeoTIFFs + preview in GEE
// ====================================================

// 1) AOI
var aoi = ee.FeatureCollection("projects/urban-heat-island-milano/assets/chicago").geometry();
Map.setOptions('HYBRID');
Map.centerObject(aoi, 9);
Map.addLayer(ee.Image().paint(aoi, 1, 2), {palette: ['#000000']}, 'AOI', false);

// 2) Year + months list
var year = 2024;
var months = ee.List.sequence(1, 12);

// 3) Helpers — QA mask, band scaling, NDVI & LST
function maskL2(img) {
// QA_PIXEL: bits — 3 shadow, 4 snow, 5 cloud, 9 cirrus => must be 0
var qa = img.select('QA_PIXEL');
var qaMask = qa.bitwiseAnd(1 << 3).eq(0)
.and(qa.bitwiseAnd(1 << 4).eq(0))
.and(qa.bitwiseAnd(1 << 5).eq(0))
.and(qa.bitwiseAnd(1 << 9).eq(0));

// QA_RADSAT: 0 means no saturation flags set
var satMask = img.select('QA_RADSAT').eq(0);

return img.updateMask(qaMask).updateMask(satMask);
}

function addScaledBands(img) {
// Surface reflectance scaling (C2 L2): reflectance = DN*0.0000275 - 0.2
var red = img.select('SR_B4').multiply(0.0000275).subtract(0.2).rename('red');
var nir = img.select('SR_B5').multiply(0.0000275).subtract(0.2).rename('nir');
var ndvi = nir.subtract(red).divide(nir.add(red)).rename('NDVI');

// LST scaling to Kelvin, then Celsius
var lstK = img.select('ST_B10').multiply(0.00341802).add(149.0).rename('LST_K');
var lstC = lstK.subtract(273.15).rename('LST_C');

return img.addBands([red, nir, ndvi, lstK, lstC], null, true)
.copyProperties(img, ['system:time_start']);
}

// 4) Collection builder for a given month with ±15-day buffer
function getMonthlyComposite(y, m) {
var start = ee.Date.fromYMD(y, m, 1).advance(-15, 'day');
var end   = ee.Date.fromYMD(y, m, 1).advance(1, 'month').advance(15, 'day');

var l8 = ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
.filterBounds(aoi).filterDate(start, end);
var l9 = ee.ImageCollection('LANDSAT/LC09/C02/T1_L2')
.filterBounds(aoi).filterDate(start, end);

var col = l8.merge(l9)
.map(maskL2)
.map(addScaledBands)
.select(['NDVI', 'LST_C', 'LST_K']);

// Prefer median; if empty, fall back to mosaic (rare with Landsat)
var has = col.size().gt(0);
var comp = ee.Image(ee.Algorithms.If(
has, col.median(), col.mosaic()
))
.clip(aoi)
.set({year: y, month: m, composite: 'median_if_available'});

return comp;
}

// 5) Exports + stats loop (client-side)
var allStats = [];
months.getInfo().forEach(function(m) {
var month = ee.Number(m);
var monthStr = (m < 10 ? '0' : '') + m;
var comp = getMonthlyComposite(year, month);

// Split out NDVI / LST bands
var ndvi = comp.select('NDVI');
var lstC = comp.select('LST_C');
var lstK = comp.select('LST_K');

// ---- Exports (GeoTIFFs) ----
Export.image.toDrive({
image: ndvi.toFloat(),
description: 'NDVI_'+year+'_Month_'+monthStr,
folder: 'EarthEngine_Exports',
fileNamePrefix: 'NDVI_'+year+'_Month_'+monthStr,
region: aoi, scale: 30, crs: 'EPSG:32616', maxPixels: 1e13,
```

```
formatOptions: {cloudOptimized: true}
});

Export.image.toDrive({
image: lstC.toFloat(),
description: 'LST_C_'+year+'_Month_'+monthStr,
folder: 'EarthEngine_Exports',
fileNamePrefix: 'LST_C_'+year+'_Month_'+monthStr,
region: aoi, scale: 30, crs: 'EPSG:32616', maxPixels: 1e13,
formatOptions: {cloudOptimized: true}
});

Export.image.toDrive({
image: lstK.toFloat(),
description: 'LST_K_'+year+'_Month_'+monthStr,
folder: 'EarthEngine_Exports',
fileNamePrefix: 'LST_K_'+year+'_Month_'+monthStr,
region: aoi, scale: 30, crs: 'EPSG:32616', maxPixels: 1e13,
formatOptions: {cloudOptimized: true}
});

// ---- Monthly stats over AOI ----
var ndviStats = ndvi.reduceRegion({
reducer: ee.Reducer.mean()
.combine({reducer2: ee.Reducer.min(), sharedInputs: true})
.combine({reducer2: ee.Reducer.max(), sharedInputs: true})
.combine({reducer2: ee.Reducer.stdDev(), sharedInputs: true}),
geometry: aoi, scale: 30, maxPixels: 1e13, bestEffort: true
});

var lstStats = lstC.reduceRegion({
reducer: ee.Reducer.mean()
.combine({reducer2: ee.Reducer.min(), sharedInputs: true})
.combine({reducer2: ee.Reducer.max(), sharedInputs: true})
.combine({reducer2: ee.Reducer.stdDev(), sharedInputs: true}),
geometry: aoi, scale: 30, maxPixels: 1e13, bestEffort: true
});

var row = ee.Feature(null, ndviStats.combine(lstStats))
.set('year', year)
.set('month', m);

allStats.push(row);
});

// 6) Export one CSV with all monthly stats
var summary = ee.FeatureCollection(allStats);
Export.table.toDrive({
collection: summary,
description: 'NDVI_LST_Monthly_Stats_'+year,
folder: 'EarthEngine_Exports',
fileNamePrefix: 'NDVI_LST_Monthly_Stats_'+year,
fileFormat: 'CSV'
});

// 7) Preview in GEE — choose a month to visualize
var previewMonth = 8; // <- set the month you want to preview (e.g., 8 for August)
var compPrev = getMonthlyComposite(year, previewMonth);

// Dynamic 5–95% stretch for NDVI and LST_C (evaluate client-side for safe UI)
function addPreview(image, band, name, palette, fallbackMin, fallbackMax) {
var percs = image.select(band).reduceRegion({
reducer: ee.Reducer.percentile([5, 95]),
geometry: aoi, scale: 60, bestEffort: true, maxPixels: 1e13
});
percs.evaluate(function(p) {
var min = (p && p[band + '_p5'] != null) ? p[band + '_p5'] : fallbackMin;
var max = (p && p[band + '_p95'] != null) ? p[band + '_p95'] : fallbackMax;
Map.addLayer(image.select(band), {min: min, max: max, palette: palette}, name);
});
}

addPreview(
compPrev, 'NDVI', 'Preview — NDVI (month ' + previewMonth + ')',
['#8b0000','#b22222','#d2691e','#f0e68c','#c7e9b4',
#7fcdbb','#41b6c4','#1d91c0','#238b45','#006d2c','#00441b'],
-0.2, 0.9
);

addPreview(
compPrev, 'LST_C', 'Preview — LST °C (month ' + previewMonth + ')',
['#313695','#4575b4','#74add1','#abd9e9','#e0f3f8',
#ffffbf','#fee090','#fdae61','#f46d43','#d73027','
#a50026'],
15, 45
);
```

```
// =====================================================
// Chicago NDVI (~1 m) with gap-filling
// - Uses NAIP 4-band (newest→oldest) to cover entire city
// - Optional final fill with Sentinel-2 NDVI (upsampled)
// - Preview + 1 m GeoTIFF export (+ optional 3 m)
// =====================================================

// ---------------------------
// 0) AOI: City of Chicago
// ---------------------------
var aoiFc = ee.FeatureCollection('projects/urban-heat-island-milano/assets/chicago'); // <-- your asset
var chicago = aoiFc.geometry();
Map.centerObject(chicago, 11);
Map.addLayer(chicago, {color:'#ff9800'}, 'AOI: City of Chicago', false);

// ---------------------------
// 1) Params
// ---------------------------
var CRS = 'EPSG:26916';          // UTM16N (meters), stable 1 m grid
var YEARS_TO_TRY = ee.List.sequence(2015, 2025); // try many years (newest wins)
var USE_S2_FILL = true;          // set to false if you want NAIP-only
var EXPORT_3M = true;            // optional 3 m smoothed export

// ---------------------------
// 2) Build NAIP newest→oldest mosaic (4-band only)
// ---------------------------
var naip4All = ee.ImageCollection('USDA/NAIP/DOQQ')
.filterBounds(chicago)
.filter(ee.Filter.listContains('system:band_names', 'N')) // require NIR
.filter(ee.Filter.listContains('system:band_names', 'R')) // ensure R is present
.filter(ee.Filter.listContains('system:band_names', 'G'))
.filter(ee.Filter.listContains('system:band_names', 'B'));

// Keep only the years we want
var naipByYears = ee.ImageCollection(
YEARS_TO_TRY.iterate(function(y, col){
y = ee.Number(y);
var yrCol = naip4All.filter(ee.Filter.calendarRange(y, y, 'year'));
return ee.ImageCollection(col).merge(yrCol);
}, ee.ImageCollection([]))
);

// Sort by time desc so newer pixels overwrite older in mosaic
var naipMosaicAllYears = naipByYears.sort('system:time_start', false).mosaic().clip(chicago);

// For info: what is the newest NAIP year in AOI?
var latestMillis = naip4All.aggregate_max('system:time_start');
var latestYear = ee.Date(latestMillis).format('YYYY');
print('Newest NAIP year present:', latestYear);

// ---------------------------
// 3) NDVI from NAIP (N & R)
// ---------------------------
var ndvi_naip = naipMosaicAllYears
.normalizedDifference(['N','R'])
.rename('NDVI');

// ---------------------------
// 4) Optional final fill with Sentinel-2 NDVI
//    (to guarantee wall-to-wall coverage)
// ---------------------------
var ndvi_full = ndvi_naip;

if (USE_S2_FILL) {
// Date window around warm months for better greenness; adjust if needed
var s2 = ee.ImageCollection('COPERNICUS/S2_SR_HARMONIZED')
.filterBounds(chicago)
.filterDate('2024-05-01','2024-10-31')
.filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 60));

// Simple QA60 mask
function maskS2(img){
var qa = img.select('QA60');
var mask = qa.bitwiseAnd(1<<10).eq(0).and(qa.bitwiseAnd(1<<11).eq(0));
return img.updateMask(mask).copyProperties(img, img.propertyNames());
}
var s2Clean = s2.map(maskS2);
var s2Med = s2Clean.median().clip(chicago);

// S2 NDVI @10 m
var ndvi_s2 = s2Med.normalizedDifference(['B8','B4']).rename('NDVI');

// Upsample S2 to 1 m and use to fill any remaining NAIP gaps
var ndvi_s2_1m = ndvi_s2
.resample('bilinear')
```

```
.reproject({crs: CRS, scale: 1});

// Fill gaps where NAIP is masked
ndvi_full = ndvi_naip
.reproject({crs: CRS, scale: 1})
.unmask(ndvi_s2_1m)
.clip(chicago);
}

// ---------------------------
// 5) Optional 3 m smoothed NDVI (mean of 1 m)
// ---------------------------
var ndvi_3m = ndvi_full
.reproject({crs: CRS, scale: 1})
.reduceResolution({reducer: ee.Reducer.mean(), max-
Pixels: 1024})
.reproject({crs: CRS, scale: 3})
.clip(chicago);

// ---------------------------
// 6) Previews
// ---------------------------
Map.addLayer(
naipMosaicAllYears.visualize({bands:['R','G','B'],
min:0, max:255}),
{}, 'NAIP RGB (~1 m, newest→oldest)'
);

Map.addLayer(
ndvi_full,
{min: -0.2, max: 0.9, palette:
['#8c510a','#d8b365','#f6e8c3','#c7e-
ae5','#5ab4ac','#01665e']},
NDVI ~1 m (gap-filled, Chicago only)'
);

Map.addLayer(
ndvi_3m,
{min: -0.2, max: 0.9, palette: ['white','#a1d99b','#31a3
54','#006d2c']},
NDVI 3 m (smoothed, Chicago only)', false
);

// ---------------------------
// 7) Exports — GeoTIFFs
// ---------------------------
// 7a) 1 m NDVI (gap-filled)
Export.image.toDrive({
image: ndvi_full,
description: 'Chicago_NDVI_1m_gapfilled',
folder: 'GEE_Exports',
fileNamePrefix: 'chicago_ndvi_1m_gapfilled',
region: chicago,
crs: CRS,
scale: 1,
maxPixels: 1e13
```

```
// =====================================================
// City of Chicago — NDBI from Sentinel-2 (10 m)
// Preview + GeoTIFF export (Chicago-only)
// =====================================================

// --- 0) AOI: City of Chicago boundary (FeatureCollection) ---
var aoiFc = ee.FeatureCollection('projects/urban-heat-island-milano/assets/chicago'); // <-- your asset
var chicago = aoiFc.geometry();
Map.centerObject(chicago, 11);
Map.addLayer(chicago, {color:'#ff9800'}, 'AOI: City of Chicago', false);

// --- 1) Parameters ---
var start = '2024-06-01';   // set your window (e.g., warm season)
var end   = '2024-09-30';   // adjust as needed
var CRS   = 'EPSG:26916';   // UTM 16N (stable 10 m grid for Chicago)

// --- 2) Sentinel-2 SR (harmonized) + simple cloud mask (QA60) ---
function maskS2srQA60(img) {
var qa = img.select('QA60');
var cloudBitMask = 1 << 10;  // clouds
var cirrusBitMask = 1 << 11; // cirrus
var mask = qa.bitwiseAnd(cloudBitMask).eq(0)
.and(qa.bitwiseAnd(cirrusBitMask).eq(0));
// Keep reflectance bands + QA for safety
return img.updateMask(mask)
.select(['B8','B11','B4','B3','B2','QA60'])
.copyProperties(img, img.propertyNames());
}

var s2 = ee.ImageCollection('COPERNICUS/S2_SR_HARMONIZED')
.filterBounds(chicago)
.filterDate(start, end)
.filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 60))
.map(maskS2srQA60);

// Safety printouts
print('S2 images used:', s2.size());
print('Date range:', start, '→', end);

// Median composite
var s2Med = s2.median().clip(chicago);

// --- 3) NDBI computation ---
// NDBI = (SWIR - NIR) / (SWIR + NIR) = (B11 - B8) / (B11 + B8)
var ndbi = s2Med.normalizedDifference(['B11','B8']).rename('NDBI').clip(chicago);

// --- 4) Preview layers ---
Map.addLayer(
s2Med.select(['B4','B3','B2']).divide(10000),
{min:0.0, max:0.3},
Sentinel-2 True Color (median)'
);

Map.addLayer(
ndbi,
{
min: -0.5, max: 0.5,
palette: [
#2166ac','#67a9cf','#d1e5f0','#f7f7f7',
#fddbc7','#ef8a62','#b2182b'
]
},
NDBI (10 m, Chicago-only)'
);

// --- 5) Export GeoTIFF ---
Export.image.toDrive({
image: ndbi.reproject({crs: CRS, scale: 10}),
description: 'Chicago_NDBI_10m_S2_'+ start + '_to_' + end,
folder: 'GEE_Exports',
fileNamePrefix: 'chicago_ndbi_10m_s2_' + start + '_to_' + end,
region: chicago,
crs: CRS,
scale: 10,
maxPixels: 1e13
});
```

Classifiying Vacancy Typologies

1. Data Standardization:
- Reprojected vacant lot points and road centerlines into projected CRS (meters).
- Removed null geometries and ensured valid spatial features.

2. Density-Based Clustering (DBSCAN):
- Distance threshold ≈ 75 meters.
- Minimum cluster size ≈ 4 points.
- Cluster size used to classify:
  >=12 points → Mass Void
  5–11 points → Contiguous Void
  2–4 points → Interval Void
  1 point → Scattered Void

3. Strip Void Detection:
- Calculated bounding box elongation ratio for clusters (length/width).
- If elongated and aligned with road corridor → Strip Void.

4. Corner Void Detection:
- Extracted road intersections.
- Points within ~15m of intersection → Corner Void.

5. Offset / Flagged Logic:
- Evaluated distance to road and irregular spacing within cluster.
- Applied hierarchical classification to avoid overlaps.

6. Hierarchical Assignment Order:
Corner > Strip > Mass > Contiguous > Interval > Offset > Flagged > Scattered

This workflow ensures reproducibility, spatial rigor, and thesis-level defensibility.

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